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U. S. COMMISSION OF FISH AND FISHERIES,

Washington, March 6, 1896.

The Bulletin of the United States Fish Commission for 1895 was completed during the early part of the year 1896, and subsequent to the death of Commissioner Marshall McDonald, which occurred in Washington on September 1, 1895. As the investigations covered by the papers appearing in this volume were mostly made under the administration of Mr. McDonald, and during his occupancy of the Commissionership, it is deemed right that he should be credited with the same by the retention of his name on the title page of the volume, although none of the papers included was issued prior to his death.

HERBERT A. GILL,

Acting Commissioner.

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THE AMERICAN LOBSTER:

A STUDY OF ITS HABITS AND DEVELOPMENT.

BY

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"Ἴδε καλᾶν κουρίδων, ἴδε καμάρων, ἴδε φίλα.
Θᾶσαι μὰν ὡς ἐρυθραί τ'ἐντὶ καὶ λειοτριχιῶσαι."

"Behold the dainty courides, my friend,
And see these lobsters; see how red they are,
How smooth and glossy are their hair and coats."
Sophron, quoted by Athenæus.

"La Nature a toûjours de quoi payer les soins de ceux qui l'examinent; il n'est point de si petit côté où elle ne soit inépuisable."
Réaumur.

"Wir finden zwar bey allen Scribenten der natürlichen Historie eine Beschreibung des Fluskrebses, wenn man aber alles was sie von selbigem gesaget zusammnimmt, so kommt so wenig heraus, dass auch hier das Sprichwort, *Quotidiana vilescunt*, **was wir täglich vor Augen haben, achten wir nicht**, allerdings einzutreffen scheinet."
Roesel von Rosenhof.

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1.—THE AMERICAN LOBSTER: A STUDY OF ITS HABITS AND DEVELOPMENT.

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INTRODUCTION.

I.

While working on the embryology of Alpheus several years ago, I decided to study the development of the lobster for the purpose of comparison. An opportunity was offered in the summer of 1889, which I spent at the laboratory of the United States Fish Commission at Woods Hole, Massachusetts. In the spring of that year I had also received, through the kindness of Dr. G. H. Parker, a considerable quantity of embryological material of the lobster, representing particularly its later stages of development.

In the spring of 1890 I was invited by Hon. Marshall McDonald, United States Commissioner of Fisheries, to prepare as complete a work as possible upon the habits and development or general biology of the lobster. Accordingly during the past five years I have devoted all the time which could be spared from professional duties to this research. For a part of each summer, from June to the latter part of August, I have enjoyed the excellent facilities for study which the laboratory of the Fish Commission at Woods Hole affords, and in the autumn of 1893 I was enabled to carry my observations into the field by a journey along the coasts of Massachusetts and Maine and into the Province of New Brunswick.

The materials, therefore, upon which this work is based have been gathered from a large number of different points, although the most systematic and prolonged observations have been made at Woods Hole. In this pleasant task I have been aided by the friendly efforts of many who have made collections, particularly of eggs, at widely separated parts of the coast and at different times of the year. These I have gratefully acknowledged in the pages of this work.

To everyone at the Woods Hole station I am indebted for many kindnesses, but particularly to Hon. Marshall McDonald, whose aid and encouragement I have constantly received, and to Mr. Richard Rathbun, of the United States Fish Commission, who has forwarded my plans in every possible way.

II.

During the course of this study I have published several papers embodying the results of my researches (*91–93*, *96–101*),[1] but these should not be consulted without reference to this final revision of my work. Whatever errors this may contain I must leave for other naturalists to rectify.

[1] Italic figures in parentheses refer to the numbers of publications in the Bibliography at the end of this paper.

The lobster, though it may be rightfully called the King of the Crustacea, in consideration of both its size and strength, its abundance and economic value, had, until recently, been singularly neglected by naturalists. Even its breeding habits were not understood, and so little was our knowledge of many phases of its general biology that I determined from the first to devote ample time to this important subject.

Rathbun, who brought together what was known concerning the habits of the lobster in a contribution to the Natural History of Useful Aquatic Animals, published in 1887 (*155*), spoke as follows:

> Although the lobster is one of the most important of our food invertebrates, careful observations regarding its natural history, and especially its breeding habits, rate of growth, etc., have been strangely neglected. This fact is greatly to be deplored, considering that the lobster has recently become the subject of important legislation by the several States which it inhabits and that its cultivation by artificial means has been frequently attempted. * * * The success attending the artificial breeding of several of our food-fishes has inspired the hope that similar methods might succeed with regard to the lobster, and many persons are now awaiting with interest the results of experiment in that direction. It is very certain, however, that the breeding of lobsters can never be successfully carried on until we have become acquainted with at least the main features of their natural history. The artificial cultivation of animals can only progress through the fulfillment of natural laws, which must be thoroughly understood before they can be properly applied. As it is, however, the would-be experimenters in the matter of lobster breeding must still follow a very uncertain pathway, meeting with numerous failures which previous studies might have arrested (p. 781).

Many facts relating more particularly to the larval development and reproduction have important economic bearings, and for the benefit of those who have neither the time nor inclination to read the details of this paper I have added a careful summary of the principal observations and conclusions at the end (Chapter XIV).

Under the subjects discussed in the various chapters I have given all the important historical references, and have added a full bibliography. There has grown up around every well-known animal like the lobster a considerable mass of popular pseudo-scientific literature, which is of no value either as literature or science, and may well be ignored.

III.

The lobster is singularly free from common names, in this country at least. It is rarely confused with any other animal unless it be with the Palinurus of the Pacific Coast and the West Indies, and with some of the larger species of crayfish, all of which, however, are very distinct, the latter being inhabitants of fresh water.

Patrick Brown tells us in his "History of Jamaica," published in 1789, that the Palinurus was then commonly called the "horned lobster or great crayfish." The terms rock lobster and spiny lobster are still applied to it in this country and in Europe, but the entire lack of large claws—one of the most striking characteristics of the lobster—its spines, brilliant coloring, and enormous antennæ, should prevent the most inobservant person from confusing it with so distinct a form.

The lobster, as I have explained in Chapters II and III (pp. 55, 82), has acquired numerous epithets while carrying eggs or passing through the various phases of the molt.

The old generic name Astacus (ἄσταχυς or ὄσταχος) was used by Aristotle and the older naturalists down to the present century to embrace the crayfishes and the lobsters proper. Aristotle thus speaks in the fourth book of his History of Animals

of "the small astaci, which are bred in the rivers"[1] showing that the reference is undoubtedly to the crayfish.

Athenæus frequently mentions the Astacus in the third book of The Deipnosophists, where, as in the passage quoted below, he undoubtedly had in mind the lobster. This is from a famous poem of Archestratus, wherein, as Athenæus remarks, he never once mentions the crab by the name of *κάραβος*, yet does speak of the *ἄσταχος*.

> But passing our trifles, buy an astacus,
> Which has long hands and heavy, too, but feet
> Of delicate smallness, and which slowly walks
> Over the earth's face. A goodly troop there are
> Of such, and those of finest flavor where
> The isles of Lipara do gem the ocean:
> And many lie deep in the broad Hellespont.
>
> (The Deipnosophists; Bk. III, tr. by C. D. Yonge, 1854.)

Athenæus then quotes from another author, Epicharmus, to show that the *ἄσταχος* mentioned by Archestratus is the same as the *κάραβος*:

> There are astaci and colybdænæ, both equipped
> With little feet and long hands, both coming under
> The name of *κάραβος*.

The English word lobster is from the old English *lopystre*,[2] which is probably a corruption of the Latin *locusta*—English, locust—a name used by Pliny in speaking of the lobster in his Natural History. Thus, in the ninth book, he says: "The lobsters, being of that kind which want blood, are protected by a weak shell."[3] In the next section of the same chapter there is a sentence,[4] in which the astaci are mentioned as one of the genera of crabs. It is possible that lobsters are here referred to, but the meaning is doubtful.

Gesner, whose remarkable History of Animals was published at Zürich between 1551 and 1587, speaks of the lobster under the Aristotlean name of Astacus, and adds a very interesting synonymy. He says:

> The English call the Astacus a *creuyse of the sea*,[5] for the lopstar of the English is the locust, not the astacus; although Eliot in different places has translated *astacus*, locust, and leo as a lopster.[6]

---

[1] *Τοῖς ἀστακοῖς μικροῖς, οἱ γίγνονται καὶ ἐν τοῖς ποταμοῖς. A. H.* 4. 4.

[2] *Longusta* or langusta, *la langouste* of the French, the Palinurus, probably has the same origin. This was corrupted to "long oyster" in the West Indies. (See The Natural History of Jamaica, by Hans Sloane, vol. II, p. 271.)

[3] Locustæ crusta fragile muniuntur in eo genere quod caret sanguine. Latent mensibus quinis, similiter cancri qui eodem tempore occultantur, et ambo veris principio senectutem anguium more exuerunt renovatione tergorum. Lib. IX, Cap. XXX, sec. 50.

[4] Cancrorum genera carabi, astaci maeae, paguri, heracleotici, leones et alia ignobiliora. Ibid., sec. 51.

[5] *Creuyse* according to Skeat, is probably a variation in the spelling of the Middle English for crayfish (crayf-ish), —— *crevis, creves, crevise*, or *crevcys;* Old French, *crevisse*, or *escrevisse;* Modern French, *écrevisse;* Old High German, *crebez;* Middle High German, *krebez;* German, *Krebs*, allied to *Krabbe.*

[6] Anglis astacus est a *creuyse of the sea*, nam lopstar Anglorum, locusta est, non astacus; quamquam Eliota diversis locis astacum locustam et leonem interpretatus *a Lopster* (*75, De Astaco*, pp. 113–121). [Eliota is Sir Thomas Elyot, who published a Latin-English dictionary in 1538.]

Some light is thrown upon this passage by the German translation of Gesner's Historia Animalium, published at Frankfort in 1598, where the lobster is spoken of as *Humer oder grossen Meerkrebs.* The Latin name *Astacus* is also given to it. A paragraph, which I did not find in the original, is as follows:

> These sea-crabs mentioned above, are called by Pliny sea-elephants, on account of their size and strength. They are also regarded by some as sea-lions, and by such names are commonly known at Montpelier.[1]

The lobster was also called by the Greeks *κάμμαρος*, Latin *gammarus*, probably from its arched back, from which Spanish, *camaron*, and the Italian *gambaro* are derived. Gesner tells us that the crayfish, was often called simply *gambaro*, to distinguish it from the lobster *gambaro di mari;* that to the French and Normans the lobster was known as *Homar;* to the Germans as *Humer.* In Norway, Sweden, Denmark, and Germany it is now called *Hummer.*[2] This in French became *Homard* (Homar, Latinized form *Homarus*). It has been suggested by Boeck that the name may possibly have come from the Norse verb *homa*, meaning to go backward.

Gesner adds that the lobster was called by the Venetians *astase vecari andio;* by the Illyrians, *larantola* (or *caranthola*), and by the Swiss, *langroit* or *escrevice de mer.* The Dutch call the lobster *Zeekruft* or sea-crayfish, while it is known to the Turks of Constantinople as *liczuda* or *lichuda.*

According to Boeck there are numerous poetical allusions to the lobster in the Eddas and Sagas. Thus the sea is described as "the path of the lobster" in Olaf der Heilige's Saga, and in Olaf Tryggvason's Saga it is said that "the wave-horses run over the fields of the lobster," meaning the ships that sail on the waves. "To be at the bottom with the lobster" is to drown, as in the song of Snigly Holle. "In the Selkolle Songs of Einar Gilson, in Bishop Gudmund's Saga, the term "the light of the lobster," equivalent to the fire of the sea or gold, is used. In the same place the expression, "the horse of the lobster mountain," meaning the ship, is used. Finally there is found in the poem Liknar-braut, the expression "land lobster," meaning a serpent or dragon. (*20*, p. 224.)

IV.

Excluding from our consideration the Palinurus or langouste and the Norwegian lobster, ***Nephrops*** *norvegicus*, two species belonging to this genus are now known, namely:

HOMARUS, Milne Edwards.

(1) *Homarus gammarus* (Linn.); = *Cancer gammarus* (Linn.);
= *Homarus vulgaris* (M. Edw.) European Lobster.

(2) *Homarus americanus* (M. Edw.) American Lobster.

A third form, *H. capensis*, has been imperfectly described from the Cape of Good Hope, but it is doubtful if it belongs in this genus. (See *102*, p. 754, note 4.)

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[1] Diese obgenandte Meerkrebsz nennet Plinius Meerhelffant von wegen irer grösse und stärcke werden sonst auch von etlichen Meerlöwen geachtet sind mit solchem Namen von menniglichen zu Mompelier genennt worden . . . . . *Fischbuch; translated from the original of Conrad Gesner into German by Conrad Forer; p. 125; Franckfurt, 1598.*

The animal described and figured on the next page of this work and called the Small Lobster or Small Sea-crab—*Astacus marinus parvus*—is probably a species of Galatea. Palinurus is described as the *Meerstöffel.* Synonyms are: A Species of Lobster; A Kind of Large Sea-crab; Locusta; Carabus.

[2] The old Norwegian and Danish writers, Pantoppidans (1752, *152*), Ström (1762), Bomares (1767), and Leems (1767) speak of the lobster as *Hummer*, while by Olafssens and Povelsens (1772) it is called *Humar*, according to Fabricius. These dates refer to works. For bibliography see Otho and J. C. Fabricius (*63–64*).

I will now add a fuller synonymy of the technical names which have been applied to the European and American lobsters.

EUROPEAN SPECIES.

Astacus .....1551. Rondelet (*167*).
Astacus verus.....1618. Aldrovandus (*2*).
Astacus marinus communis.1657. Jonston (*107*).
Astacus marinus .....1553. Belon (*15*).
1758. Seba (*179*).
1762. Baster (*8*).
1777. Pennant (*151*).
1792. Fabricius (*64*).
1811. Olivier (*143*).
1838. Lamarck (*113*) [3d ed.].
1825. Desmarest (*52*).
1826. Risso (*166*).
1842. Rathke (*160*).

Cancer gammarus.....1761. Linné (*123*).
1776. Müller (*139*).
1795. Herbst (*88*) [2d ed.].
1829. Latreille(*115*)[2d ed.].
Astacus europeus.....1837. Couch (*45*).
Homarus vulgaris.....1837. Milne Edwards (*58*).
1853. Bell (*14*).
1863. Heller (*87*).
Homarus marinus.....1868. Bate (*10*).
Astacus gammarus....1819. Leach (*117*).
1857. White (*203*).
1893. Stebbing (*186*).

AMERICAN SPECIES.

Astacus marinus americanus.....1758. Seba (*179*).
Astacus marinus.....1817. Latreille (*115*) [1st ed.].
1817. Say (*177*).

Homarus americanus..1837. Milne Edwards (*58*) and most subsequent writers.
Astacus americanus...1893. Stebbing (*186*).

Latreille,[1] in 1810, designated as the type of the old genus *Astacus* the species *A. fluviatilis* Fabricius (=*Cancer astacus* Linné), which is the European crayfish. In 1815 Leach began to dismember this genus by giving to the Norwegian lobster the name *Nephrops*. Later, in 1819 (*117*),[2] he proposed the generic term *Potamobius* to embrace the true crayfishes, leaving the lobsters alone in possession of the Aristotelian name. This division would transfer the type species of *Astacus* (*A. fluviatilis*) to the genus *Potamobius*, which is contrary to the rules of zoological nomenclature, and can not be accepted. In 1837 the lobsters were placed by Milne Edwards in a distinct genus, *Homarus*, while the elder name was retained for the crayfishes. Spence Bate was in favor of uniting the generic name of Milne Edwards to the specific name of Fabricius, calling the European species *Homarus marinus* (Fabr.). The proposal of Leach "to use *Astacus* for the lobsters and to give a new generic name (*Potamobius*) to the fresh-water crayfishes," would, in the opinion of Huxley, "have had the advantage of retaining the primitive signification of ἄστακός. But *Potamobius* had already been used in another sense, and the change introduced by Milne Edwards is so generally adopted that it would be confusing to attempt any further alteration" (*102*). Previous to 1819 the name *Potamobie* had been used by Leach[3] in a list of the known genera of Crustacea. It was, however, a *nomen nudum*, which would have permitted the use of the name *Potamobius* for the crayfishes had the genus been correctly formed. Stebbing (*186*), apparently unaware of Latreille's restriction, proposed to restore the old terminology of Leach.

According to Milne Edwards's classification, which I have adopted, the common European crayfish should be called *Astacus astacus* (Linn.), the European lobster *Homarus gammarus* (Linn.), and the American lobster *Homarus americanus* (M. Edw.).

[1] *Considérations Générales sur l'Ordre Naturel des Animaux composant les Classes des Crustacés, des Arachnides, et des Insectes*, p. 422. Paris, 1810.

[2] *George Samouelle's Entomologist's Useful Compendium*, p. 95. London, 1819.

[3] *Dictionnaire des Sciences Naturelles*, XII, p. 75, 1818.

For the preceding references I am indebted to the kindness of Dr. Walter Faxon and Miss Mary J. Rathbun, and I desire to acknowledge the aid I have received from them on the nomenclature discussed in the last two paragraphs of this page.

V.

Although the lobster has a place in the literature of the Old World, it is seldom mentioned by American writers. Rathbun, who was the first to give a history of the American lobster fisheries, says that the great abundance and rare flavor of the lobster "are not infrequently mentioned in the early annals of New England, and it probably formed an important element in the food-supply of the seacoast inhabitants of colonial times. As a separate industry, however, the lobster fishery does not date back much, if any, beyond the beginning of the present century, and it appears to have been first developed on the Massachusetts coast, in the region of Cape Cod and Boston, although some fishing was done as early as 1810 among the Elizabeth Islands and on the coast of Connecticut. Strangely enough this industry was not extended to the coast of Maine, where it subsequently attained its greatest proportions, until about 1840." (*156.*)

In an account of marketing in Boston in 1740, among various kinds of meats and game, "oysters and lobsters" are mentioned "in course, the latter in large size at 3 half-pence each." (*200*, vol. II, p. 540.)

Kalm, the Swedish traveler, writing in 1771, thus speaks of the abundance of sea food on the shores of Long Island:

> The soil of the southern part of the island is very poor; but this deficiency is made up by a vast quantity of oysters, lobsters, crabs, several kinds of fish, and numbers of water fowl, all of which are there far more abundant than on the northern shores of the island. Therefore the Indians formerly chose the southern part to live in, because they subsisted on oysters and other productions of the sea. (*108*, vol. 2, pp. 226–227.)

The older writers had little to say of the sea and its products in New England, yet many interesting facts could probably be gathered by a careful examination of all available sources.

VI.

Lobsters are caught in pots or traps made of laths, nailed to a wooden frame, with a funnel-shaped opening at each end. The traps are commonly 4 feet long, 2 feet wide, and 18 inches high. The funnels are usually netted out of manila twine. The pots are weighted with stones or bricks, and set either in single warps or in trawls of from 8 to 40 pots each. Each pot has a buoy line to which a wooden spindle-shaped buoy is attached. The latter bears the owner's mark or stamp, and shows the position of the trap. The traps are baited with fish, such as herrings, sculpins, or flounders, and the lobster, when once induced to come inside the pot, seldom escapes, unless small enough to crawl between the slats. It has been estimated that half a million lobster traps have been in use in the Maritime Provinces during a single year.

The old-fashioned hoop nets formerly in use consisted of a single iron ring or hoop to which a net with cord was attached. When baited they had to be closely watched and pulled up from time to time, in order to secure the lobster before he could get out of the net.

The lobster fishery is conducted chiefly in the spring and summer months. The pots are tended from small boats, and the catch is kept in floating cars moored in some protected spot near the shore. Welled fishing smacks, or more rarely welled steamers, gather up the lobsters from the fishermen and carry them to the canneries and to the markets in the large distributing centers, such as Portland, Boston, and New York. Lobsters are shipped alive in barrels, with ice in summer, to many parts of

the country. The winter shipment is also very considerable. Large numbers are immediately boiled for home consumption, while many are kept alive in floating cars at the market until required. The impounding of lobsters, or placing them in large inclosures of salt water, called pounds, where they can be kept during the winter, is now successfully practiced on a large scale.

VII.

We have witnessed in the lobster fishery for many years past the anomaly of a declining industry with a yearly increasing yield, but with the gradual diminution in the size of the lobsters caught and an undue increase in the number of traps and fishermen. "How much longer," writes the inspector of fisheries of New Brunswick, "an increased catch can be made out of a diminishing supply is a problem of some interest to those who have watched the rise, progress, and decay of this industry."[1]

In 1886 fully 90,000,000 lobsters were captured in Canada,[2] principally in Nova Scotia, New Brunswick, Prince Edward Island, and Quebec. Out of this vast number nearly 34,000,000 were taken in New Brunswick alone, and 22,000,000 in Prince Edward Island. These numbers are extraordinary, when we consider, as in the last instance, the small extent of the coast and the narrow limits of the fishing season.

In regard to the catch of lobsters in New Brunswick for 1886, the inspector of fisheries says in his report[3] that the average size is diminishing, and "to fill a pound can now requires rather more than an average of six lobsters—about 2½ ounces of meat per fish. The returns show 4,661,812 cans preserved, and 4,290 tons of fresh lobsters. In order to fill these cans, 28,000,000 lobsters were killed. If to these we add the number exported fresh, allowing 1½ pounds to each, which is a large average, the number killed during the season will be 33,720,000."[4]

In 1887 about 70,000,000 lobsters were taken in Canada, and in 1892 upward of 68,000,000 lobsters (estimated as above) were captured, valued at nearly $2,000,000.[5]

In 1884 the catch of lobsters in New Brunswick amounted to 5,662,072 cans and 1,709 tons, valued at $900,580, the number of traps in use being 105,984. In 1892 the number of traps had increased to 172,022, an increase of over 60 per cent, while the product had decreased by nearly the same amount, being 3,204,320 cans and 1,132 tons, valued at only $493,804.[6]

The average annual yield of the Norwegian lobster fishery from 1879 to 1884 is estimated to have been 1,175,000 lobsters, valued at $107,468, the greater number

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[1] W. H. Venning, inspector of fisheries of New Brunswick. (Annual Report of the Department of Fisheries, Dominion of Canada, 1886, p. 146.)

[2] This estimate is based upon the official statistical return of the lobster fishery, allowing five lobsters to a pound can of meat, and a trifle over 2 pounds in weight to each lobster. The yield in 1892 was 16,434,431 pounds in cans, and 8,662 tons of fresh lobsters, valued at $2,638,394. (Report on the Lobster Industry of Canada for 1892. Supplement to the Twenty-fifth Annual Report of the Department of Marine and Fisheries, No. 10*d*, Ottawa, 1893.)

[3] Annual Report of the Department of Fisheries of the Dominion of Canada, 1886.

[4] Ibid.

[5] It should be remembered that these estimates, large as they seem, are based upon statistics which are generally reliable, and probably fall far below the number of animals annually killed; for they do not include the number of undersized lobsters illegally used for canning, nor those used as food by fishermen and their families. Then there is, besides, the vast number of lobsters which annually fall a prey to other enemies than man.

[6] Report on the Lobster Industry of Canada, 1892, Supplement to the Twenty-fifth Annual Report of the Department of Marine and Fisheries, No. 10*d*, Ottawa, 1893.

being shipped to England.[1] About 3,000,000 lobsters are said to be taken in the British Isles in a year, while the total number captured on the North Atlantic coast of America has undoubtedly in some years reached close to 100,000,000.

The total quantity of lobsters taken in the United States in 1880 was 20,238,683 pounds, valued at $488,432; of this quantity, 19,946,733 pounds, worth $477,484, were taken in the New England States, and 291,950 pounds, valued at $10,948, in the Middle Atlantic States. In 1887 the United States lobster catch was 28,882,180 pounds, with a market value of $799,717, of which 28,627,600 pounds, worth $784,238, were caught in New England and 254,580 pounds, valued at $15,479, in the Middle Atlantic region. The output of the New England lobster fishery in 1889 was 30,449,603 pounds, valued at $833,736; of this catch, 25,001,351 pounds, worth $574,165, were taken in Maine.

The division of the United States Fish Commission concerned with statistics and methods of fisheries took a complete census of the lobster fishery of New York, New Jersey, and Delaware in 1892,[2] and in 1893 canvassed the lobster fishery of the New England States. Through the courtesy of Dr. H. M. Smith, the assistant in charge of the division, I am able to present in the following table the results of these inquiries.

The total number of persons engaged in the lobster fishery of the United States in 1892 was 3,766; of these, 2,628 were in Maine and 616 in Massachusetts. The vessels employed in lobster fishing numbered 58, valued at nearly $75,000. The number of boats used was 3,976, having a value of $325,000. Over 200,000 traps, worth $221,000, were operated. The total investment in the fishery, including the value of live cars ($25,835), was $648,065, distributed among the different States as shown in the table. The quantity of lobsters taken and sold by United States fishermen in 1892 was 23,724,525 pounds, for which $1,062,392 was received. Of this output, 17,642,677 pounds, valued at $663,043. were caught in Maine and 3,182,270 pounds, worth $205,638, in Massachusetts.

Table showing the extent of the lobster fishery of the United States in 1892.

States.	Number of fishermen employed.	Vessels, boats, and traps used.						Lobsters taken.	
		Vessels.		Boats.		Traps or pots.			
		No.	Value.	No.	Value.	No.	Value.	Pounds.	Value.
Maine	2,628	7	$7,050	2,888	$242,629	153,043	$143,709	17,642,677	$663,043
New Hampshire	26	.....	.....	29	594	1,393	2,786	196,350	11,790
Massachusetts	616	2	1,710	739	47,162	26,192	38,479	3,182,270	205,638
Rhode Island	145	12	8,455	86	15,320	6,341	10,090	774,100	53,762
Connecticut	258	34	46,265	183	17,585	10,105	22,178	1,614,530	101,358
New York	55	2	9,880	34	1,140	2,240	3,469	165,093	15,655
New Jersey	36	1	1,475	16	1,062	678	1,099	143,905	10,861
Delaware	2	.....	.....	1	40	21	53	5,600	285
Total	3,766	58	74,835	3,976	325,532	200,013	221,863	23,724,525	1,062,392

Between 1887 and 1892 the decline in the lobster fishery of the United States was over 5,000,000 pounds, although the value of the catch was more than $260,000 greater in the latter year. When the yield and value of the fishery in the New England States in 1892 are compared with the results of the fishery in 1889, we find a falling

[1] Bulletin of the United States Fish Commission, vol. VI; also Report of the United States Fish Commissioner for 1889.

[2] See a Statistical Report on the Fisheries of the Middle Atlantic States, by Hugh M. Smith, M. D., Bulletin of the United States Fish Commission for 1894, page 455.

off of more than 7,000,000 pounds, or over 23 per cent, but an increase in the market value of the output of over $200,000, or nearly 25 per cent. These figures illustrate very forcibly the decline which, unless speedily checked, threatens to destroy this valuable fishery.

Five attempts to transport lobsters alive across the continent and plant them in the Pacific Ocean have been made by the United States Fish Commission (*157*), in 1875–1889, and all but the first have proved successful. No evidence has, however, yet appeared to show that the lobster has multiplied and thriven in its new environment. More recently attempts have been made, with some degree of success, to ship lobsters across the Atlantic, and deliver them alive in the markets of London and Paris.

England, France, and Germany are the principal markets for the export trade outside of the United States, but, like other preserved meats, the canned lobster is shipped to all parts of the world.

VIII.

Civilized man is sweeping off the face of the earth one after another some of its most interesting and valuable animals, by a lack of foresight and selfish zeal unworthy of the savage. If man had as ready access to the submarine fields as to the forests and plains, it is easy to imagine how much havoc he would spread. The ocean indeed seems to be as inexhaustible in its animal life as it is apparently limitless in extent and fathomless in depth, but we are apt to forget that marine animals may be as restricted in their distribution as terrestrial forms, and as nicely adjusted to their environment. Thus, as we shall see, the American lobster occupies only a narrow strip along a part of the North Atlantic coast, and while it is probably not possible to exterminate such an animal, it is possible to so reduce its numbers that its fishing becomes unprofitable, as has already been done in many places.

The only ways open to secure an increase in the lobster are to protect the spawn-lobsters, or to protect the immature until they are able to reproduce, or to take the eggs from the lobsters themselves and hatch them artificially. The latter is the method which has been adopted and is now in use in the British Maritime Provinces, and less extensively in the United States.

In an earlier paper, published in the United States Fish Commission Bulletin for 1893 (pp. 75–86), I have discussed the question of the artificial propagation of the lobster, and have called attention to what seem to me the weakest points in the present method and what the most promising field for future experiments.

ADELBERT COLLEGE, CLEVELAND, OHIO,
June, 1895.

Chapter I.—HABITS AND ENVIRONMENT.

DISTRIBUTION OF THE LOBSTER.

The American lobster inhabits the coastal waters of the Atlantic Ocean from Labrador to Delaware, and occurs in depths of from less than 1 to more than 100 fathoms. It is thus confined to a strip of the Atlantic Ocean about 1,300 miles long, and at some points (as on the coast of Maine, where there is an extensive fishery in the outward islands) from 30 to upward of 50 miles wide. Its geographical range covers about 20 degrees of north latitude, from the thirty-fifth to the fifty-second parallel; but owing to the extreme irregularity of the coast the actual area of distribution is much greater. At present the lobster is most abundant and attains the largest size in the northern half of its range, that is upon the coasts of Maine and the British Maritime Provinces.

The lobster was recorded from Labrador by Packard in 1863. "The rocky shores," he says, "exposed to surf from the gulf, did not seem to harbor any animal life, but a narrow, interrupted belt of sand and mud flats in Salmon Bay" (near Caribou Island) supports a feeble assemblage of littoral forms (*144*). Under the rocks and seaweed the lobster was occasionally seen. At Henley Harbor, a little above the Straits of Belle Isle, it is mentioned as "rare." This seems to be the northern limit of the lobster. At Hopedale, 200 miles above this point, he showed a picture of the lobster to one of the native Eskimos, who signified that it was not found there (*148*).

The lobster was common at Anticosti and Mingan islands (*145*), where collections were made by Verrill, Hyatt, and Shaler in 1861. Stearns (*185*), who asserts that "lobsters were found everywhere along the coast of Labrador," is doubtless in error. He probably had in mind the "Gulf coast," or "Inner Labrador," as the territory of the Province of Quebec which stretches southwesterly from the Straits of Belle Isle is often erroneously called.

In speaking of the habits of lobsters in "Labrador," Stearns says:

> Very often the beach is covered with rocks, large and small, interspersed with holes and pits filled with water at low tide. The seaweed grows over these places, thus affording capital hiding-places. One can often procure 100 lobsters in an afternoon from a strip of the beach hardly as many yards long. The small boys hunt them with long poles on the ends of which are tied large cod hooks. With these the boys reach in and feel about in the holes and under the rocks until they feel the shell of a lobster, when a smart or careful haul, as the case may require, generally brings the animal out of its snug quarters. [These lobsters] are seldom very large, while the very young ones appear not to come inshore among the rocks to any great extent (*185*).

Dr. W. Wakeham, to whose kindness I am indebted for much interesting information on the northerly range of the lobster, writes as follows:

> My own experience of the Labrador coast does not go beyond Chateau Bay at the northeastern entrance to the straits of Belle Isle. From this point west along the Labrador and north shore of Quebec, I have found the lobster everywhere fairly abundant up to Manicouagan in the river St.

Lawrence. I have inquired of Gaspé whalers who are in the habit of going as far as Cape Harrison, on the coast of Labrador, but they all tell me that they have never taken a lobster below St. Charles—that is, a few miles north of Chateau Bay. West of Chateau Bay, as I have said, they are found all along the coast, but not in paying quantities. Several attempts have been made to operate canneries on this coast, but they have one after another been abandoned. The lobsters seem to give out suddenly. They are all caught up when the traps are first set. Of course the water is too deep for any general fishery, and it is only in shoal bays and harbors that traps can be used.

In reply to a letter of inquiry from Dr. Wakeham, Mr. P. M. McKenzie, one of the chief factors of the Hudson Bay Company, says that he has been on the Labrador coast and entrance of Hudson Straits for fourteen years, and has "never seen a lobster or heard of any being caught between Grady Harbor (longitude W. 56° 25′, latitude 53° 46′) and Cape Chudleigh." He says further, that he does not think they occur between Grady Harbor and the straits of Belle Isle, but "all along the Gulf from Seven Islands to St. Augustine there are a great many at certain points."

Mr. W. H. Whitely, overseer of fisheries at the straits, writes to the same effect:

> Lobsters are not found below [i. e., east of] the narrows of the straits of Belle Isle [the lowest point, a place called Brodore Bay]. Some are found on the southern or Newfoundland side of the straits. They are not plenty at any place within 100 miles west of the north side of the straits of Belle Isle, but a few are found in places sheltered from rough water and drifting ice. I have never heard of any lobsters being seen at any point on the Labrador east of the straits.

From the character and abundance of this testimony we may safely conclude that the lobster is not found on the coast of Labrador very far beyond the straits of Belle Isle, or not many miles north of Henley Harbor (about 52° north latitude). From the straits northward the temperature is said to fall rapidly, owing to the arctic current which flows south, and the presence of ice, which is carried along with it close to the land. We should not, therefore, expect to meet with the lobster, except as a very rare straggler, north of the straits.

It is interesting to find, on the other hand, that Fabricius (*63*) includes the lobster (*Cancer gammarus* L.) in his Fauna Grœnlandica. He is particular to state, however, that he does so upon the authority of others, as he had never seen the lobster in Greenland himself. He says that the lobster is found under the name of Pekkuk in the Greenlandish dictionary. He had heard the natives distinguish the smaller Squillas by the name of Pekkungoit, from a much larger form (*Cancris*), called Pekkuit or Pekkurksoit, and very similar to the "Gammari." This name may have been derived from the Esquimaux of the southern Labrador coast or from Iceland, where, according to Mohr's "Islandske Naturhistorie," the European lobster "has been found by Dr. Poulsen in Gröndevig, but it does not extend to Greenland or Spitzbergen" (*20*).

De Kay, writing in 1844, remarks that while the lobster was taken in comparatively small quantities on the New Jersey coast, "two years after building the breakwater in Delaware Bay, lobsters made their appearance there in great quantities." He also says that in about the year 1814 General Pinckney "caused a car full of lobsters to be emptied into the harbor of Charleston, South Carolina. A few of their survivors, or their descendants, were captured about ten years since, but, as I am informed, they were the last." (*51*, p. 25.)

The stonework of Delaware Breakwater, says Rathbun (*155*), may be considered the southern boundary of the lobster, although he has recorded several instances of its occurrence south of this point. Thus it has been said that lobsters have been seen along the beach in the surf near Indian River Inlet, Delaware. Two or three have

been recorded at Johnstown, in the northeastern corner of Virginia, "and in October 1884, the United States Fish Commission steamer *Albatross* obtained a single specimen of good size off Cape Hatteras, North Carolina, from a depth of about 30 fathoms, by means of the beam trawl" (*155*). Coues (*49*) also records the capture of a single lobster at Beaufort, North Carolina, in the summer of 1870.

Dr. Wakeham writes that lobsters are abundant around the island of Anticosti and that a large number of canneries have been in operation on this island for some years. He says that lobsters are more abundant on the southern side of the island, and concludes that this is "due to the fact that the water deepens gradually on the southern side, while on the north side of the island you go abruptly into deep water. The lobsters taken at Anticosti and on the north shore of the Gulf are of large size. This may be explained by the fact that they have not been overfished to the same extent there as elsewhere. At any rate we do not find any small lobsters in the traps. The largest lobster that I have seen taken on the north shore weighed 18 pounds."

Sars (*176*) considers it remarkable that lobsters on the southern coast of Norway never become as large as those farther north. It seems to me that the explanation of this fact is simple, and applies to both European and American species. The northern parts of the range of the lobster have been the last to be fished, and consequently the average size is greater than in the south, where the fishery began.

The bathymetrical range varies with the season and is influenced largely by the temperature of the water. It may be also governed in some measure by the abundance of food and by the reproductive and molting periods.

Lobsters are occasionally seen close to the shore in very shallow water and they are sometimes even stranded on the beach. This was the case with the large lobster, weighing upward of 20 pounds, the mutilated shell of which is now preserved in the land office of Boothbay Harbor Village, Maine (see p. 114). This great lobster was discovered on the beach of Boothbay Harbor, at low tide, about twenty-five years ago.

Professor Verrill related to me his experience with a large lobster at Grand Manan, Maine, in 1859. This lobster, which he thinks must have weighed at least 20 pounds, had established himself so securely under the projecting side of a large bowlder that it was not an easy matter to dislodge him, even at low tide; but with the aid of a boat-hook this giant was at last drawn out and captured. When it was finally taken to the settlement it attracted very little interest, the fishermen saying that it was worth only a penny, 2 cents being then the regular price of lobsters, whether of 5 or 20 pounds weight. In those days lobsters were never weighed and sold by the pound.

Lobsters, on the other hand, stray out to great distances from the shore, and have been recorded on the fishing-banks of Nova Scotia "from the fishing-banks and ledges of the Gulf of Maine, such as Jeffrey's Ledge and Cashe's Ledge, and from the more southern offshore banks. They have also been taken from the stomachs of cod caught on George's Banks." (Rathbun, *155*, p. 787.)

Lobsters are also sometimes driven by severe storms on the beach, where they perish in great numbers. In March, 1888, thousands of lobsters were washed ashore on the south side of Marthas Vineyard during a south and southwest gale.

CHARACTER OF THE ENVIRONMENT.

Where there is great diversity of natural conditions throughout the geographical range of an animal we may expect to find its habits varying in a proportionate degree. From Labrador to Maine the Atlantic coast is rocky, and often precipitous, with deep bays and harbors, and with large islands, some like Grand Manan presenting sheer perpendicular walls to the sea. The coast of Maine, in its middle and eastern sections, is essentially bold and rocky, and diversified to an extraordinary degree by channels cut by large fresh-water rivers, by long deep inlets, studded with islands large and small, by bold rocky promontories, and by groups of larger islands farther from shore, such as the Vinal Haven or Fox islands. These are masses of gray granite, scarred and cut up by glacial forces into an archipelago of smaller islands, abounding in long granite basins and inlets, into which pure sea water is driven with every tide. Thus are formed the most admirable breeding-grounds for the lobster, for fish, and other marine animals. In the region of Cape Cod we meet with extensive shoals, which resemble on a smaller scale those of North Carolina. The northern part of the Massachusetts coast is rocky, while the southern section is greatly diversified, abounding in submerged ledges, sandy and weedy bottom, and a great variety of bays and channels in the vicinity of the Elizabeth Islands, where lobsters used to abound until their numbers were depleted by overfishing.

Under the variety of conditions which I have hinted at, we should not only expect to find lobsters larger and more abundant in some localities than elsewhere, a condition greatly influenced by the number and persistence of fishermen, but also to meet with variations in the time of laying and hatching of the eggs, in the season of molting, in the time when the semiannual movements are undertaken, in color, and in a variety of other details.

The habits of the lobster as affected by the changes of season and other causes in the various stages of its life will be described, as we have been able to interpret them, in different parts of this work. Certain habits, however, are often so closely interrelated that the mere mention of one requires a consideration of others also.

INTELLIGENCE OF THE LOBSTER.

Since the lobster belongs to a less specialized class than the crab, it is not surprising to find that its intelligence is of a lower order. Sluggish as it often appears when out of water and partially exhausted, it is quite a different animal when free to move at will in its natural environment on the sea bottom. It is very cautious and cunning, capturing its prey by stealth, and with weapons which it knows how to conceal. Lying hidden in a bunch of seaweed, in a crevice among the rocks or in its burrow in the mud, it waits until its victim is within reach of its claws, before striking the fatal blow. The senses of sight and hearing are probably far from acute, but it possesses a keen sense of touch, and of smell, and probably also a sense of taste. We have, moreover, seen that it is quite sensitive to changes in temperature.

All animals which play the part of scavengers have strong powers of scent, and the lobster is no exception to the rule. This is illustrated by the way in which it can be enticed into the traps. Thus it is asserted that where traps are set on a trawl placed across the tide, the catch is greater than when the trawl is set in the direction

of the current, since in the former case the scent, or fine particles coming from the bait, is more widely diffused. Lobsters are sometimes wary and shy of entering the trap, and have been seen to crawl about it several times and examine it cautiously on all sides before, too weak or too hungry to resist temptation, they finally enter. When the pots are hauled, lobsters sometimes escape by darting backward through the narrow opening of one of the funnels, but this seldom happens and may be set down to accident.

Many facts will be given in the course of this work which illustrate either directly or indirectly the intelligence of the lobster. I will add here only the following account of a lobster which was kept at the Rothsay aquarium, in England (Nature, XV, p. 415, March 8, 1877). A flounder was unintentionally left in one of the aquaria, in which three lobsters were placed. The largest lobster immediately appropriated the fish, which was then dead, and buried it beneath a heap of shingle, on which he mounted guard. Five times within two hours was the fish unearthed, and as often did the lobster shovel the gravel over it with his huge claws, each time ascending the pile and turning his bold, defensive front to his companions.

THE LOBSTER'S POWERS OF MOVEMENT.

The adult lobster lives and feeds exclusively upon the sea bottom, which it never leaves of its own accord in any considerable degree. In traveling over the bottom in search of its prey, the lobster walks nimbly upon the tips of its slender legs. The large claws are extended forward in front of the head, a position which offers the least resistance to the water, while the two hinder pairs of walking legs, which end in hard spur-like joints, serve as picks to steady the movements of the animal. In thus going about it has the constant aid of the delicate swimmerets, attached vertically to the under surface of the "tail," each of which consists of a short stalk and two very flexible blades. By the movements of the swimmerets the lobster is impelled slowly forward without the aid of the walking legs. The branches of the swimming feet are garnished with long, chitinous setæ or hairs, to which, as is well known, the eggs in the female are attached. Thus these appendages are not only natatory, but play an important part in reproduction, and by their almost incessant beating movements serve to keep the developing eggs well aerated and clean.

When taken out of the water the lobster can only crawl, in its vain attempts to walk, owing to the heavy weight of the body and claws, which the slender walking legs are now unable to sustain. If turned over on its back the animal is usually able to right itself when out of the water, but not without great effort. If placed near the salt water and left to its own devices, it will almost immediately strike out by the nearest path for the sea with as keen a sense of direction as the sea turtle will show when upon land. Its power of crawling on land is, however, limited to short distances, and the lobster never forsakes the salt water of its own accord and, as has been said, never willingly leaves the sea bottom.

In exploring its feeding-grounds, where an enemy is likely to be encountered, the legs which carry the long claws are extended forward in front of the head, or carried somewhat obliquely, their tips resting on the bottom, and the long sensitive "feelers" are waved constantly back and forth to give warning of any foe or other objects which the eye may fail to detect. These are exclusively organs of touch. If the anticipated

enemy makes his appearance or if the animal is surprised, as when it is suddenly touched with the blade of an oar or cornered, it will immediately strike an attitude of defense. It now raises itself on the tips of its walking legs, and lifts its powerful claws over the head after the manner of a boxer, and strikes with one of its claws at the offending object, trying to crush it or tear it in pieces. I have several times pulled lobsters partially or completely out of their burrows with an oar. You have only to thrust the oar-blade into their holes, when, if a lobster is present, it will immediately seize it with a firm grip; but it often shows its intelligence by relaxing its hold before becoming completely exposed. By far the most powerful organ of locomotion in the lobster is its "tail." By the flexion of this, aided by the extended tail-fan, the animal is able to shoot backward through the water with astonishing rapidity, sometimes going, according to one observer, 25 feet in less than a second. If tossed into the water back or head first, the animal, unless exhausted, immediately rights itself and, with one or two vigorous flexions of the tail, shoots off obliquely toward the bottom, as if sliding down an inclined plane.

The lobster, though less active and keen-witted than the higher crabs, can not be regarded as a sluggish animal in any sense. In the water its movements are graceful; it is wary, resourceful, pugnacious, capable of defending itself against enemies which are often larger than itself, and, if the occasion requires it, of running about with the greatest agility and speed.

On calm evenings in summer at about sundown I have seen lobsters very close to shore lying on little patches of sand, surrounded by eelgrass, probably waiting their opportunity to seize a passing fish or crab. If approached in a boat on such an occasion, they soon become aware of your presence and put themselves in an attitude of defense, but press them too close, or attempt to pin them down with an oar, they immediately dart backward into deeper water among the seaweed. If still pursued, the lobster rises and flies in another direction, thus zigzagging its way over the bottom until it finds safety in some denser tangle or rocky crevice.

Of the English lobster, Travis remarks:

> In the water they can run nimbly upon their legs or small claws and, if alarmed, can spring tail forward to a surprising distance as swift as a bird can fly. The fishermen see them pass about 30 feet, and by the swiftness of their motion suppose that they go much farther. Athenæus remarks this circumstance, and says that incurvated lobsters will spring with the activity of dolphins. When frightened they will spring from a considerable distance to their hole in the rock, and, what is not less surprising than true, will throw themselves into their hole in that manner, through an entrance barely sufficient for their bodies to pass; as is frequently seen by the people who endeavor to take them at Filey-bridge (*191*).

When a lobster is surprised it seems to disappear with a single leap or bound as a locust or grasshopper might do. This habit, added to their appearance, explains why lobsters were called by Pliny and the ancient writers *locustæ*, or "locusts of the sea." The lobster, however, never rises more than a few inches or at most a few feet above the bottom, and it is evident that swimming at the surface would be impossible on account of the great weight of the body. The "traveling lobsters," or *færd-hummer*, which Norwegian fishermen, as Sars tells us (*176*), have described as swimming at the surface of the ocean in large schools, often many miles from the coast, were, without doubt, some large species of surface-feeding shrimp.

Lobsters kept in an aquarium often thrive well, and will live for a long period if they are properly cared for. In the hatchery of the United States Fish Commission

at Woods Hole, Massachusetts, sea water is kept running through the tanks, in the larger of which we have kept lobsters and watched their habits for several months at a time. If the tank is provided with a pile of stones the lobster very soon investigates this with care, seeking out the most attractive holes. If several individuals are placed in the same aquarium, each will select its own hole or corner over which it establishes a sort of proprietary right. In these they lie during the greater part of the day with their antennæ and a part of the body and large claws projecting, ready when a good chance offers to strike at a fish, or if an enemy should approach, to retire at a safer distance into their retreats. If the occupants of the same aquarium are of about equal size, and if they show no weakness, they usually live in peace; but if one has been disabled in any way, as by the loss of a claw, he is attacked by the strong and forthwith destroyed.

As the lobster lies in its corner of the aquarium—always with its tail folded, if a female "in berry"—it slowly sweeps the water with its long, sensitive antennæ, which it now holds erect, now lowers until they lie horizontal and extend almost directly in front of the body. The smaller pair of antennæ are elevated, while the larger outer branch of each is constantly beating with a slight up-and-down movement; this branch supports the delicate filaments which have been regarded as the terminal organs of the sense of smell. If one watches this lobster he may see it deliberately lower the branches of the first pair of antennæ and clean them by drawing them through the bunches of stiff bristles of the third pair of maxillipeds, the large prominent appendages which project forward at the sides of the mouth immediately in front of the chelipeds. The large claws are held in readiness for use, their tips resting close together on the bottom and their opposite ends raised obliquely upward.

PERIODICAL MIGRATIONS AND THEIR RELATION TO CHANGES IN THE ENVIRONMENT.

The adult lobster never moves up and down the coast like the migratory fishes, but is of a far more sedentary disposition. In the spring months of April and May, however, large numbers appear to move from deeper water toward the shore. In the fall they retire to deeper water again.

The movements of such anadromous fish as the mackerel and the menhaden are influenced by the spawning period, by the temperature conditions, and by the abundance of food. The mackerel is said to thrive in a water-temperature as low as 40° F. or even less. The same causes, of which the influence of temperature may sometimes be the most potent, probably determine the migration of both fish and crustacean.

When the question of food is paramount, the lobster will remain in considerable numbers in the relatively shallow water of harbors, but only on a rocky bottom, where food is most abundant. The extent of the migration is also naturally influenced by the depth of the water and the general character of the bottom, being more extended on a gradually sloping bottom where deep water is less readily accessible. The exact period at which the semiannual migrations of the lobster occur varies at different points on the coast and also at the same point for different seasons.

In the vicinity of Rockland, Maine, and to the eastward as far as Eastport, the summer fishery begins in the latter part of May and lasts until the first of November.

During this time, lobsters are caught in from 3 to 10 fathoms of water. For the rest of the year the winter fishing is conducted in 35 to 40 fathoms. In general, the spring migration along the entire coast of Maine and in the Maritime Provinces is accomplished in April and May, and the fall movement into deeper water in October and November.

When the spring is late and the water cold, the lobster keeps away from the shore. Thus the spring of 1884 was a month later than usual in Prince Edward Island, says the inspector of fisheries in his annual report (*56*), "and the ice hung long about the coast." The first lobster was caught on the 3d of June. "The hands about the factories had been idle for fully four weeks, but the first batch or run of lobsters came in quite as fast as they could be utilized. I have noticed this to have been the case in previous years, as if when ice remained long the lobster congregated in large bodies on the outer edge of the frozen belt ready to run for the shore as soon as it was clear and the temperature suited. Subsequently the batches fell off to a little less than the average." Ice is said to remain so long on this coast that few lobster fishermen begin work until the first or second week in May. In 1892 the ice left early, and some lobsters were landed on the north side of the island the 29th of April. Packing was begun as early as the 10th of May. (Fishery Statements, 1891, p. 97.)

At Cape Breton, in late seasons, very little lobster fishing is done before the 1st of June, or even later. Lobsters probably do not, as a rule, move in schools, but approach and leave the shores gradually with the change of temperature, yet a sudden cold snap seems to cause them to disappear promptly from any locality. It is probable that their disappearance under such circumstances may be explained by their burrowing in the mud. (See pp. 26 and 29.) Mr. M. B. Spinney, of Cliffstone, Maine, informed me that in May or June in 1869, at Prince Edward Island, while sailing in a small boat from Georgetown into Grand River, lobsters were seen for the distance of several miles crawling over the bottom in very large numbers and often very close together, the water being 10 or 12 feet deep.

Mr. Adolph Nielsen writes, in reply to certain questions, that as the coast of Newfoundland is affected by the polar current, a spurt of northeast and easterly winds often brings down the temperature of the water, and this causes the lobsters to move off into deeper water or bury themselves in the sand or mud in the midst of the season. At such times the fishermen can not take them in their traps.

The sudden appearance of lobsters in the spring in relatively shallow water lends color to the supposition that they sometimes move in large numbers together. Thus, Mr. A. C. Smith says that in 1884 the proprietor of a lobster factory in New Brunswick "set his traps on the 20th of April, keeping them baited, but caught nothing till the night of the 5th of May, when the lobsters suddenly 'struck in' as plentiful as at any time of the season."

It is certain that lobsters do not indulge in any considerable northward or southward migrations. This is proved, as Rathbun has pointed out (*158*), by the depletion of the lobster fishery at certain points on the coast, as at Provincetown, Cape Cod, Massachusetts. He states that the fishery was begun here in 1800, and that between 1845 and 1850 New York City received nearly its entire supply of these crustaceans from the Provincetown region. A marked decrease in their abundance was noticed in 1865, and this was followed by a gradual annual diminution, until in 1880 there were but eight men engaged in the business. If there were any considerable coastwise

migration, it is evident that regions once depleted would in time be restored naturally by accessions from neighboring sections. This does not appear to be the case, and we may look upon each geographical region on the coast as inhabited by a distinct school of lobsters, which hold their ground fairly constantly, so that if their numbers are depleted by overfishing they would under natural conditions be stocked but slowly. If this argument is sound, and it certainly looks as if the Cape Cod region were a case in point, it must follow that the young are not widely distributed, but I can hardly accept this as probable. It would seem as if the young, which, to be sure, have little powers of locomotion, would always tend to find an extra local distribution by tides, winds, and currents. Furthermore, if this were the case, it would follow that restocking under natural conditions is a slow process at best. Writing in December, 1885, Rathbun says (*158*):

> The Cape Cod lobster fishery has been at a low standing for many years and, although but few men have engaged in the fishery of that region for a long time, there are, as yet, no signs of improvement.

That lobsters move up and down the coast to some extent is inevitable, although such a migration may be regarded as accidental rather than deliberate or instinctive. They may also return suddenly, as some believe, to places where they have not been seen for years. Thus a correspondent wrote to the United States Fish Commission from South Amboy, New Jersey, February 15, 1886, that lobsters had made an appearance there after an absence of about twelve years. "I discovered them late in October, and captured a hundred before the cold weather set in, after which I could not catch any." (Bull. U. S. F. C., vol. VI, p. 407.) Statements of this kind must, however, be received with much caution, since what appears to be a sudden arrival may be due to desultory observations.

The subject of the schooling of lobsters is one about which it is very difficult to get accurate information, and we need to use much caution in drawing conclusions from too slender data. The only region which I have been able to study for a number of consecutive seasons is that about Woods Hole, Massachusetts, including Marthas Vineyard, No Man's Land, and the Elizabeth Islands, and I will give in some detail the observations which I have been able to make in this limited area, believing that they will shed some light upon this interesting and perplexing question.

The fishermen of a part of this region set their traps from the last of April to the middle or last of June on rocky bottom in the vicinity of Gay Head and No Man's Land, while from the middle or last of June until September they generally fish upon the sandy bottom of the Sound in much shallower water. A few lobstermen fish during September upon the rocks. They distinguish "rock lobsters" from what they call "school lobsters." The latter are also called "sand" or "June lobsters," and are considered more migratory than the "rock lobsters" or "ground-holders." "School lobsters" are most abundant in summer from the middle of June to the middle or last of July on a sandy bottom in Vineyard Sound in 5 to 10 fathoms of water.

On June 28, 1890, I found the fishermen at Menemsha[1] setting their traps both off Gay Head on a rock bottom and on the sandy bottom of the Sound. The difference

[1] Menemsha is a small fishing settlement in the town of Chilmark, Marthas Vineyard, about 2 miles due east from Gay Head, on Vineyard Sound. Gay Head, the remarkable promontory forming the western extremity of Marthas Vineyard, is 14 miles southwest of Woods Hole Harbor and 6 miles north of No Man's Land.

in the lobsters caught at the same time under these conditions was sufficiently marked to attract attention. The lobsters captured on the rocks had hard shells and frequently bore old eggs, while those taken in the Sound had in no single instance, up to this time during the season, borne external eggs, either old or new, and a large number of them had soft shells. These are often called "paper shells," or "buckle shells," the shell being relatively soft, so that it is easily compressible with the thumb and finger, and the colors are very bright, showing that they have molted within four or five weeks. Special care was taken to save all egg lobsters caught, since the United States Fish Commission purchased them for use in its hatchery. These "buckle shells" or "school lobsters" were said to appear rather suddenly about the middle of June or first of July, and to retreat into deeper water during the first half of September.

On the 9th of July I again visited Menemsha, and found that since the first of the month only six lobsters with old eggs had been obtained. These were caught in the Sound, where the majority of all lobsters now taken had soft shells. On the 16th and 28th of July, when I made further visits to the locality, the fishery was conducted almost wholly in the Sound. At the later period the fishermen had begun to shift their traps to slightly deeper water, following up the lobsters in their retreat from the shore. On the 11th of August they were fishing both in Vineyard Sound and off Gay Head in 8 to 15 fathoms. A large proportion of these lobsters taken in the Sound had soft shells, but an examination of the ovaries of the soft-shell females proved beyond a doubt that they had hatched their old eggs and molted during the present season.

Some very interesting facts have been brought out by the record of the fishery at No Man's Land during the months of May and June, 1894. Mr. Vinal Edwards found that egg-lobsters of large size could be taken there in abundance, and accordingly the Fish Commission drew the supply of eggs for its hatchery from that place. Mr. Edwards carefully recorded the catches of the smackmen, examining nearly every lobster himself. The result is given in table 1. The traps were set on ledges of rock, 15 miles from land, in about 15 fathoms of water. Besides the extraordinary disproportion of the sexes—only 6.4 per cent of males being obtained out of a total of 1,318 lobsters captured in May—we notice the equally remarkable and probably correlated fact that 63.7 per cent of the total number are females with eggs soon to be hatched.

TABLE 1.—*Record of lobsters caught off No Man's Land in May, 1894.*

Total catch	1,318	Per cent of females with eggs	63.7
Females with eggs	840	Per cent of females without eggs	29.8
Females without eggs	394	Per cent of males	6.4
Males	84	Per cent of females	93.5

Another striking fact which the fishermen noticed was the persistence with which the lobsters at this time of the year clung to the rocky areas. When set on a rock bottom the traps were certain to catch lobsters in abundance, but when sunk upon a sandy or muddy bottom, though but a few feet away, not a lobster was trapped. In fishing on trawls, where a long line of traps was put out, it sometimes happened that some of these would strike a sand bottom, often not more than a narrow streak or bar, but they were always found empty. Mr. Edwards systematically fished for lobsters in Woods Hole Harbor from December, 1893, to the June following. He found them

in the winter months abundant on the rocks, but when the traps were placed on the mud not a lobster was taken.[1]

The disproportion of the sexes noticed at No Man's Land is due, I believe, to the fact that the females find it more advantageous to remain on a rocky bottom while they are encumbered with their old eggs. As soon as these hatch, the female lobsters press on in large numbers toward the shore, coming up into the sounds and bays and on to sandy bottoms during the summer. The lobster can probably protect herself and eggs better while on the rocks, but almost immediately after the hatching of the eggs the molt occurs, for some time after which the female is helpless. Now the molting lobster seems to prefer the sandy bottom while in this critical state, probably because it can shield itself better from its enemies. On the sand the molting lobster may hide in tangles of seaweed, or scratch a hole and partially bury itself, as it often does, and remain tolerably secure, but let the soft lobster try to conceal itself among the rocks, and what is the result? There are hosts of bottom-feeding fish which haunt the rock-piles, none of which are probably more troublesome than the cunner, which can go almost anywhere, and would soon surround the soft lobster in its retreat and nibble at its legs, or snip off its eyes, which means death. The cunners, eels, and other fish may attempt to pick off the eggs, but these are on the under side of the body and except in extraordinary cases, where the ova are excessively numerous, the lobster can fold them between the segments of its tail and thus rest tolerably secure (see p. 34). This theory is supported by the fact that the "school lobsters" caught on the sand bottom of Vineyard Sound rarely have old eggs and very commonly possess soft shells. Rocky bottoms furnish food in greater abundance, at certain seasons, which explains their preference for these areas in winter. Where on the other hand, as in the region about Provincetown, Cape Cod, the bottom is uniformly sandy, the lobster has little or no choice of environment.

To sum up the preceding observations, what seems to take place at the western end of Vineyard Sound during the season of migration is as follows: The general movement of lobsters toward the shore is here modified by the fact that lobsters with old eggs find it advantageous to remain on the rocky ledges until the young are hatched, while the males press on in their inward movement. After the hatching period the females make their appearance in large numbers in the Sound toward the last of June or first of July, and form a large part of what fishermen call "school lobsters" or "buckle shells." Their appearance is probably not as sudden as it often seems. Fishermen, as a rule, work only one set of traps, putting them down now here, now there. In order to follow the movements of these animals systematically, it would be necessary to set traps simultaneously in different places and on different bottoms, and to keep them there for a considerable time.

Some females with old eggs come into the Sound before the young are hatched, but the majority do not. It must be borne in mind also that many lobsters remain in the Sound and harbors the year round, and that these observations refer only to the movements of the larger number. Toward the latter part of August the pendulum begins

[1] Speaking of the lobsters captured in February, Mr. Edwards says: "The lobsters taken this month have been caught on rocky bottom in five lobster pots. I have set five others in deep water on sandy bottom, and also on the mud, but find none. I have tried in shoal water in eelgrass, but there are none there. I also tried for them in the middle of Vineyard Sound and in Buzzards Bay, but found none."

to swing the other way, and the lobsters move into deeper water or to a rocky bottom. This outbound movement is continued during the months of September and October, but, as already pointed out, it is by no means general and is probably more pronounced in cold than in mild seasons.

TABLE 2.—*Showing the monthly mean temperature of the ocean at Woods Hole, Massachusetts.*

{ Computed from daily observations of temperature of bottom, taken at high water, at United States Fish Commission Station, by Vinal N. Edwards. }

Time.	1889.	1890.	1891.	1892.	1893.	Means 1889–93.
	°F.	°F.	°F.	°F.	°F.	°F.
January	36.9	38.8	33.0	36.8	29.5	35.0
February	32.1	39.9	34.7	31.2	29.7	33.5
March	35.6	36.6	35.3	33.2	32.5	34.6
April	42.7	43.2	44.3	42.6	40.0	42.5
May	55.6	53.2	52.4	51.0	51.2	52.7
June	63.3	62.0	61.1	62.1	61.2	62.1
July	68.7	69.3	64.8	68.0	69.5	68.1
August	70.6	71.1	70.9	73.3	70.9	71.4
September	67.1	68.5	61.1	66.9	67.5	66.6
October	55.3	59.0	59.6	58.6	60.5	58.6
November	49.9	48.0	47.4	48.3	52.4	49.2
December	43.0	36.7	43.5	37.2	40.9	40.2
Yearly mean	51.7	52.2	50.6	50.8	50.5	.....

The mean temperature of the water at Woods Hole, Massachusetts, was 52.68° F. for May, from 1889 to 1893 (v. table 2), the extremes of monthly averages varying from 51° in May, 1892, to 55.6° in May, 1889, and the range was similar for the latter part of October during the same period. The greatest heat is reached in August (70.6°, 1889, to 73.3°, 1892), while the temperature of the water in September is but little lower than that of July. In the latter part of October the water becomes cooled to about the same degree it had reached during the latter half of May. We may therefore conclude that the optimum temperature for the lobster lies between 50° and 60° F. When the temperature of the sea water marks 50° to 55° in spring large numbers of these animals have already begun to creep nearer the shores into shallower and warmer places, and again in the fall, when the temperature has fallen to this point, many have already been impelled to recede to greater depths. Many lobsters, however, remain in the relatively shallow water of harbors all winter, a fact which has already been emphasized; so it is certain that temperature is not the only influence at work in directing these semiannual movements. The question of food may be of equal or even greater importance.

The winter catch of lobsters in relatively shallow water is often considerable. Thus, on December 13, 1888, Mr. Edwards set two lobster pots[1] in the harbor of Woods Hole, in about 25 feet of water, and hauled them fifteen times during the month, taking an average of 15 lobsters to a haul, or 223 in all. In December, 1889, 54 lobsters were taken in a fyke net at the head of the harbor, 36 were captured in January, while none were caught in February.

In December, 1893, Mr. Edwards began to collect more systematically facts relating to the winter habits of the lobster, the results of which are discussed in another place (see pp. 30, 31, 44, 45, 79, 80). Five traps were set in the harbor of Woods Hole in 25 to 29 feet of water on rocky bottom (it being impossible to get any lobsters on the mud); 224 were taken in December, 501 in January, 246 in February, and 348 in

[1] In these and all other traps used, the space between the laths varied from 1 to 1¼ inches.

March. Only 6.1 per cent of the total catch were egg lobsters, and while this number would have been increased if the traps had been scattered instead of kept in definite spots, it would contrast markedly with the results at No Man's Land, where more than half of the total catch were lobsters with external eggs (table 1).

In severe winters lobsters are driven into deeper water or forced to protect themselves by burrowing in the mud. The effect of sudden or extreme cold upon these animals may be witnessed in lobster pounds, where they are kept in large numbers to supply the winter market. On the Vinal Haven Islands, near Rockland, Maine, there is a large pound belonging to Messrs. Johnson and Young, of Boston, of 12 to 15 acres in area. It is said to have an average depth of 18 feet at low water. In January, 1893, during a cold snap, ice was formed over this pool to the thickness of 31 inches. At this time many of the lobsters died. All the pollock also, which had been placed in the pond, were killed, some of them being 2½ feet long, and large numbers of hake at the same time succumbed.[1]

Lieut. W. M. Wood (*207*), while transporting live lobsters from New York City to Chesapeake Bay, tried some experiments upon the effect of reducing the temperature of the water. Lobsters placed in water at the freezing-point were just alive after one hour's immersion. He was of the opinion that lobsters could be kept alive for a number of days in a cold chest, with a temperature of from 40° to 50° F. The practice of transporting lobsters by the aid of ice is now generally adopted.

The annual range of temperature throughout the stretch of coast inhabited by the lobster is less than might be supposed. The temperature of the surface water of Winter Quarter Shoal, Virginia, ranges from 35° to 76° F.; at Five Fathom Bank, New Jersey, the range is 37° to 76°. Delaware Breakwater, which is practically the southern limit of the lobster, is situated between the light-ships anchored upon these two shoals. At Sandy Hook light-ship, north of the Five Fathom Bank, New Jersey, we have an annual range of 33° to 74°; at Bartlett Reef and Hartford Shoal light-ships, on Long Island Sound, it is 33° to 70°. The middle portion of Vineyard Sound, farther east, has a similar range, while at the Brenton Reef and Vineyard Sound light-ships, the region of Block Island, the Elizabeth Islands, and Marthas Vineyard, the temperature varies from about 32° to 69°. The range at Woods Hole (see table 2) is about 29° to 73°, taking the means for each month, while the actual extremes are greater. At Pollock Rip light-ship, at the southern end of Cape Cod, the mean range is 32° to 62°; in the Gulf of Maine the same range is obtained by combining the results of observations at all stations. In some places the maximum is only 54°. The preceding data are extracted from a paper by Mr. Rathbun (*157*).

Mr. J. H. Duvar says that from 1878 to 1880 the average temperature on the north shore of Prince Edward Island was 56.56° in June, 63.40° in July, and 62.27° in August. The temperature of the water at bottom in 6 to 8 fathoms he estimated roughly at 55°. Lobsters spawn in July on the north shore; in August on the south

[1] The inspector of fisheries of Prince Edward Island has an interesting note on the capture of lobsters through the ice in his annual report for 1882 (*210*). He says that on March 10 of that year there were brought to him "a number of lobsters of a uniform length of body [probably meaning carapace or shell of the back] of 4 inches, and one weighing 3 pounds that had been taken through the ice by the scoop of a mud-digging machine in a creek off Cascumpeque Bay. They seemed rather sluggish, but not torpid." It is evident that these lobsters preferred to burrow in the mud rather than migrate into deeper water.

shore. This is explained, he thinks, by the current and by the rise of the tides in the straits of Northumberland, which make the southern water cooler, and hence delay the spawning (*209*, p. 233).

Nielsen finds that the temperature of the water along the coast of Labrador ranges very low and does not exceed 46.05° F. on the warmest summer days. The lobster is thus debarred from this coast north of Henley Harbor, where it comes more directly under the influence of ice and the arctic current (see p. 15).

SENSIBILITY TO LIGHT.

The lobster is essentially a nocturnal animal, exploring the bottom in the quest of food mainly in the night, when it is far more active than during the day. This can be proved by anyone who watches their habits in aquaria or in lobster ponds or cars. It is true that they show some activity in the daytime, especially if they are fed, but at night they become very restless. Moving nimbly about, they explore every part of the car or investigate anew the resources of the aquarium. I believe that the eggs are laid and that the pairing takes place at that time, and this inference is strengthened by the fact that this is the common habit of shrimp and many other crustacea. The crayfish, according to Chantran (*37*), usually lays its eggs in the night.

According to Forel, light can not penetrate in the ocean below a depth of 400 meters of tolerably clear water, but even in 50 fathoms off the Atlantic coast the difference between day and night can not be very considerable. This is not the case in shallow bays or sounds with sandy bottom, which lobsters frequent in summer, and where we may expect to find the greatest difference between their diurnal and nocturnal habits. The lobster, like many other marine invertebrates, is very sensitive to the extremes of heat and cold. If exposed to direct sunlight out of the water, or to the nipping air of a winter's day, it weakens and succumbs in a short time.

The large floating cars in which lobsters are generally stored alive, in readiness for market, are always kept closed. When they are particularly shallow and the lobsters are exposed to the glare of the sun they always suffer and sometimes die in consequence. The majority of lobsters probably spend the greater part of the year in depths where the effect of sunlight is but very slight, and during the course of its evolution the eye of this animal has become sensitive to a minimum quantity of light For this reason alone we should expect that the adults would avoid intense sunlight The effect of light upon the colors of the shell is considered in another place. (See pp. 135, 136.)

DIGGING AND BURROWING HABITS OF THE LOBSTER.

The lobster not only digs up the sea bottom in its search for shellfish and covers itself with mud in cold weather, but burrows, under some conditions at least, as extensively as the muskrat. I have observed this interesting habit only in lobsters confined in pounds where they are obliged to adapt themselves to new conditions, it is true, but since they burrow while in these inclosures in summer as well as in winter, we may infer that the habit is one which is often practiced when the animal is free to roam at will. This has been observed, moreover, by fishermen who have frequently taken lobsters from their holes.

The lobster pound at the Vinal Haven Islands is a granite basin with a clay or mud bottom, and with low mud banks in certain parts of the shore. At low tide it has an average depth of 3 fathoms, while the difference between tides is 10 feet. On the 26th of August, 1893, I explored this pound in a boat, in company with Mr. Thomas Barton, an intelligent lobster fisherman, and had an excellent opportunity to observe how lobsters behave under such conditions on a bright summer afternoon. It was quite common to see these animals partially buried in the mud in shallow water, their antennæ, eyes, and part of the shell projecting from the muddy surface. We could rely upon finding lobsters in the holes which they excavate beneath stones, and rarely failed to discover one or more individuals in every good-sized chink among the rocks. Others lay at the mouths of burrows which they had dug straight into the banks. Comparatively few lobsters were seen lying upon the bottom or crawling actively over it. Occasionally two or three lobsters could be dislodged from a common place of retreat, and Mr. Barton said that in the spring, when the ice was breaking up, he had taken five lobsters from a single hole in the mud. Some years ago the lobsters made their way out of this pound, as I was told by an old fisherman formerly employed there, by excavating a submarine passage beneath the dam. In order to effect their escape, they had dug down beneath the stones to a depth of from 2 to 3 feet.

At one of the pounds in Southport, Maine, I had a still better opportunity to study the burrowing habits of the lobster. The larger pound at this island is under the charge of Mr. A. P. Greenleaf, a man of much experience in fishing the lobster and a very intelligent observer of its habits.[1] He finds that the lobster burrows most extensively in winter, when it is far less active in the pounds than at other times. When the water is drawn off from the pound in winter the lobsters often remain in their holes, the mouths of which are then exposed along the banks, but in summer they are more careful under these conditions to forsake their burrows and crawl into deeper water.

In digging, lobsters probably make use of their large claws and walking legs, and possibly the tail-fan may be brought into service as a scoop or shovel, but I have no observation in support of this latter supposition. In some cases, however, I have noticed the under side of the tail-fan to be scratched and scarified and the marginal fringe of hairs worn down in such a way as to suggest the probability of such a use.[2]

That lobsters transport stones with their large claws, Mr. Greenleaf had the opportunity to observe, while watching a lobster one day in the pound. The animal was maneuvering about a hole, in 3 feet of water. It was seen to crawl up to the burrow, possibly one which had been dug by another lobster, and cautiously put in first one claw and then the other. Finally it went in so as to conceal about half the length of

[1] Mr. Greenleaf is the only fisherman whom I have met who has independently determined the period during which the female lobster regularly carries her eggs.

[2] The process by which the hole is said to be excavated solely by means of the tail has been described by a writer on the habits of the lobster (*181*). This paper abounds in errors, and leads one to suspect that the author has drawn too largely upon the accounts of others; still, this fact need not discredit this particular observation. He says: "The tail is slowly drawn up at first, taking as much of the mud as possible on its under side; then, when well under the body, a final powerful jerk sends the mud or sand from out in front, and at the same time draws the lobster farther back into the cavity thus made, enabling him to get a better grasp for repeating the process over and over again, till by degrees he disappears from sight." The statement that "these holes are for the shelter of the lobster during the period of exuviation," however plausible it may be, is contrary to observed facts.

its body and brought out in its large "club claw" a small stone, which it deposited near the mouth of the burrow. Having thus removed this obstruction, it faced about and "backed," tail first, into its newly acquired shelter.

The east pound at this place has 18 feet of water at half tide and an average depth of about 8 feet. On one side are low rocky cliffs, the talus of which gives shelter to many lobsters, while the low clay banks of the opposite shore are so completely undermined by their burrows as to afford, in some places, a very insecure foothold. I examined these banks carefully from a boat, and had the opportunity of satisfying myself of the extent to which the tunneling operations had been carried on. The holes were driven horizontally into the mud bank to a distance of from 1 to 5 feet, and in each a lobster could either be seen, the tips of its large claws and its antennæ standing out, or could be felt by inserting the end of an oar, the lobster fixing its large claws on the blade and sometimes allowing itself to be dragged out clear.

The holes had sometimes a relatively large opening of 8 to 10 inches in diameter, which allowed of their being readily probed and measured with an oar blade. I did not observe that they ever had an upward or downward curve, but they sometimes swerve to the right or left, which is explained, perhaps, by the presence of some obstacle in the path. In some cases the holes were made beneath rocks, and the entrance was often much larger than that described, owing, perhaps, to the union of the mouths of two originally distinct burrows. The pile of dirt and the broken clam shells which are sometimes seen near the hole of the lobster recall the excavations of the muskrat. It is exceptional to see a lobster with its tail projecting from the burrow. I saw one or two under these circumstances, and when touched they immediately disappeared. I thought that possibly they might be engaged in digging while in this position, but this was evidently not the case, as the water about the hole was very clear. These pounds are often much roiled, so energetically do the lobsters turn over the bottom and dig into the banks. On this account it is not easy to watch the process of excavation, which in all probability is carried on at night.

I was informed by one fisherman, who had hunted lobsters quite extensively along the north Atlantic coast, that he had frequently taken lobsters out of holes in the mud and eelgrass, while wading in shallow water. It has been observed in pounds that a cold snap in winter will cause the lobsters to burrow suddenly in the mud, so that they can not be taken in traps for several days. We have already noticed the probable occurrence of the same thing in Newfoundland, when the temperature of the water is abruptly lowered. (See pp. 21, and 26, note 1.)

The burrowing habits of certain species of crayfish are well known, while those of the Stomatopods, which have been described by Professor Brooks, (26½) are equally characteristic. We meet with the same habit in many shrimp, such as Alpheus, expressed in a greater or less degree; in crabs, and in a great number of the lower crustacea.

THE FOOD OF THE LOBSTER AND HOW IT IS PROCURED.

The food of the lobster consists principally of fish, alive or dead, and of invertebrates which inhabit the bottom and come within its reach. It is not unusual to find bits of algæ, such as the common eelgrass, in its stomach, and sometimes in such quantities as to show that it is not an accidental occurrence. Vegetable matter, however, forms, at most, but a small part of its diet. Fragments of dead shells are

frequently met with, and in lobsters from 3 to 4 inches long, under very peculiar circumstances. (See pp. 89 and 90.) Coarse sand and gravel-stones, occasionally as large as duck shot, may also be found in the stomach, but with no marked regularity. These are not necessary for grinding the food, as in the gizzards of fowls, since the walls of the lobster's stomach are furnished with an admirable masticatory apparatus; still, whether of accidental occurrence or not, they can hardly fail to serve a useful purpose.

In the course of this investigation of the habits of the lobster, the stomachs of large numbers of these animals were carefully preserved during a period of seven months (December to June). They were all captured in the harbor of Woods Hole, Massachusetts, under the conditions described on p. 25. A considerable number of these stomachs were empty; more than half contained remnants of recently devoured fish, a mass of scales and bones, mixed with fragments of the indigestible parts of other organisms. In many cases it was quite evident that the bait of the traps formed the only food found in their stomachs.

The lobster undoubtedly regurgitates the insoluble and indigestible parts of its food. That the crayfish possesses this power was shown by the experiments of Lemoine (*118*). When the buccal cavity was stimulated by electricity, antiperistaltic movements were set up in the remaining parts, until the contents of the stomach escaped by the mouth. It was thus proved that the œsophagus was capable of two kinds of movements—peristaltic and antiperistaltic. Some such outlet for waste matter is absolutely necessary in an animal where the fluid or finely divided and digestible parts of the food only can pass into the delicate intestine. The hard parts of fish, mollusks, and crustacea appear to be retained until they have given up a good deal of their lime, thus contributing to the calcareous supply of the exoskeleton.

The stomachs examined contained remnants of the following organisms placed in the order of their relative abundance: fish (procured independently of the traps); crustacea, embracing chiefly isopods and decapods; mollusca, consisting largely of small univalves; algæ; echinoderms and hydroids. The bones of fish showed them to belong, as a rule, to small individuals or species. Among the crustacean remains parts of the small mud-crab, Panopæus (*P. sayi* and *P. depressus*, the common species in Vineyard Sound) were almost invariably recognized, and it was not unusual to find parts of the skeletons of small lobsters. The isopod, *Civolana concharum*, is frequently eaten by the lobster, often in large numbers. This species is a scavenger, and devours the bait used in the traps, which explains its common occurrence in the stomachs of lobsters recently caught. In one case, that of a female captured in January, the stomach was filled with fresh lobster eggs in an advanced stage of development. These were not taken from any lobsters in the trap, but under what circumstances they were obtained one can easily conjecture. The egg-lobster is undoubtedly a shining mark, not only for outside enemies, but even for members of its own species. The larger mollusks are eaten by crushing the shells and picking out the soft parts, while many of the smaller species are swallowed entire, and afterwards pulverized in the gastric mill. Echinoderms probably enter largely into the diet of the lobster, wherever they abound. Parts of the common starfish (*Asterias forbesii*) and rarely a few spines of the sea-urchin (*Arbacia punctulata*) were detected, but it might be that the latter were swallowed together with other calcareous fragments. Very little change

in the food was noticed during the winter and spring months, and there was little evidence that the appetites of these animals sensibly abated during the cold weather, yet it is probable that food is less abundant and less necessary in winter. (See pp. 24, note 1, and 25.)

That lobsters catch fish alive there is no doubt, but few have ever seen this feat performed. Fish which inhabit the bottom, like the flounder, would naturally fall an easy prey to their powerful claws. They are said to catch the sculpin, and I have known a lobster which was confined in an aquarium at the United States Fish Commission station in the summer to seize and devour the sea-robin (*Prionotus evolans*).

The common blue crab (*Callinectes hastatus*) is said to capture fish, and fishermen report having taken haddock on trawls with the heads almost nipped off, as if cut by the claws of the lobster.

The smaller of the large claws is essentially a pair of toothed nippers, the hard tips of which are incurved so as to enable the animal to secure and hold every object which it can fairly seize. This is sometimes called the "fish claw" or the "quick claw" by fishermen in Maine, while the heavy crushing-claw is called the "club claw," and according to Travis (*191*) it was known in England in the last century as the "knobbed" or "numb claw."

While lobsters are great scavengers, it is probable that they always prefer fresh food to stale. Some fishermen maintain that there is no better bait than fresh herring.[1] Fresh codfish-heads, flatfish, sculpins, sea-robins, menhaden, and haddock are also used, as well as salted fish. The flesh of the shark is occasionally utilized by the Gay Head fishermen on account of its firmness and lasting qualities.

In the lobster pound at Southport, Maine, the lobsters are fed chiefly upon herring and sculpin. The fish are scattered around the shore and over the pond. They stop feeding them after the 1st of December, and the fall stock is taken out for the winter market in January, February, and March.

In the large lobster pound at the Vinal Haven Islands I have seen the muddy bottom scored in all directions—the work of lobsters in their search for clams. One is there reminded of a pasture in which the soil has been rooted up by pigs. As a fisherman remarked, if you put lobsters in a pound and do not feed them, they will soon turn over the bottom as effectively as it could be done with a plow. Some of the holes which the lobsters had made in digging clams were 2 feet in diameter and 6 inches or more in depth. Here they had dug up the eelgrass, or loosened it so that it had floated to the surface, and cartloads of it had been cast ashore. We have already seen that lobsters sometimes eat parts of this plant,[2] but they had plainly rooted it up in this case with another object in view. The broken and often comminuted shells of the long-necked clam (*Mya arenaria*) could be seen strewn everywhere about their excavations.

The lobster probably attacks such large and powerful mollusks as the conchs, which live upon hard bottom, in deep water, and devours their soft parts. An illustra-

[1] I am told by Mr. M. B. Spinney, of Cliffstone, Maine, that many years ago, when lobsters were very abundant, he and his father used "wash bait" in taking them. Fish, such as the mackerel, were minced up and put overboard. Then, as lobsters came flocking from all directions about the boat, they would gaff them.

[2] The grass-wrack, or eelgrass (*Zostera marina*), belonging to the pond-weed family (*Naiadaceæ*), is, with one or two exceptions, the only flowering plant found growing submerged in salt water on the New England coast.

tion of this was afforded in an aquarium at Woods Hole in the summer of 1892, when a conch (*Sycotypus canaliculatus*) was placed in the same tank with a female lobster which was nearly 10 inches long and which had been in captivity about eight weeks. The conch, which was of the average size, was not molested for several days, but at last, when hard pressed by hunger, the lobster attacked it, broke off its shell, piece by piece, and made quick work of the soft meat.

On many parts of the coast the lobster does not find any lack of dead fish for food. This is notoriously the case where seining is conducted on a large scale, as on the coast of Maine. One of the great evils attending this method of taking fish is the destruction wrought upon the young. In seining mackerel the catch is hoisted upon deck, where the fish are sorted, the larger, which are marketable, being saved while the smaller fry are thrown overboard. Owing to the rough treatment which they receive, and especially the exposure to the sun, the smaller fish are thus said to be destroyed by thousands. The lobsters in the vicinity profit by this evil, playing the part of scavengers.

If a lobster which has fasted for a number of hours is fed with a little fresh meat, such as a piece of clam or fish, the process of feeding will be found to be one of no little interest. The lobster eagerly seizes a piece of food with the chelæ of the third and fourth pairs of walking legs, and passes it up to the third pair of maxillipeds, which are held close together, each being bent at the fourth joint and folded on itself. With the third maxillipeds thus pressing against the mouth, the food is kept in contact with the other mouth parts, all of which are in motion, and their action is thus brought to bear upon it. By means of the cutting spines of the appendages external to the mandibles—maxillæ and first and second pairs of maxillipeds—the meat is as finely divided as in a sausage machine, and a stream of fine particles is passed constantly into the mouth, being previously submitted to the action of the mandibles.

If one wishes to watch the movements of the complicated mouth parts more closely, he has only to take a lobster out of the water, place the animal upon its back, and when it has become sufficiently quiet stimulate the mandibles or the broad plate of the large maxillipeds with the juice of a clam or the vapor of ammonia, which can be squirted with a pipette. Masticatory movements are immediately set up in the appendages, those belonging to the side stimulated usually working independently. The two small chelate legs are also drawn up rapidly to the mouth, as if to hand up pieces of food.

When stimulated in this way the plates of the first pair of maxillæ come together over the lower posterior half of the mandibles. The movements of the masticatory parts of the second maxillæ are synchronous with the beating of the scaphognathite. These project somewhat obliquely over the convex surfaces of the appendages in front, inward, and slightly upward. The large plates of the first maxillipeds work up and down, and at the same time inward toward the middle line, describing an ellipse. The second pair of maxillipeds move alternately or together, inward and outward, with slight up-and-down movement. The large maxillipeds move together, the toothed margins meeting like the edges of a nutcracker (compare fig. 68, pl. 30), while the three terminal joints are bent inward and somewhat downward, as in the case of the second maxillipeds, so as to meet on the middle line below and hold the food up to the mouth.

Chapter II.—REPRODUCTION.

THE REPRODUCTIVE ORGANS.

The breeding habits of an animal are not only of great scientific interest, but of the utmost practical importance, in view of any experiments which we may undertake in its artificial propagation. When this work was begun the breeding habits of the lobster were very imperfectly understood, and until now no exhaustive study of the subject has been attempted. In questions of this kind, one may be led to draw conclusions from too slender data, since an abundance of carefully attested facts gathered from a sufficiently wide area can be attained only with great difficulty.

In the summer of 1891 I made as full a study as the time would allow of the reproductive organs and habits of the lobster at Woods Hole, Massachusetts, and in the summer and fall of 1893 I was able to add to my knowledge of this subject by materials gathered at different points along the northern Atlantic coast.

The reproductive organs will now be briefly considered, reserving a description of their structure and development for another part of this paper. (See Chapter X.)

The ovaries, or "coral" as they are sometimes called, consist of two cylindrical rods of tissue united by a transverse bridge in the upper part of the body, and are immediately exposed upon opening the dorsal body wall. The uniting bridge of tissue probably represents the first trace of a fusion, which is expressed in various degrees in different Decapods. The ovarian lobes extend over about two-thirds the length of the animal, from behind the head to the third, fourth, or fifth segments of the "tail," and when approaching maturity are of a rich, dark-green color (plate 36, fig. 123; see also plate 38). The ripe ovaries are so much swollen that they fill all the available space in the upper parts of the body-cavity. The bead-like eggs are clearly seen through the thin ovarian wall, and when this is cut they flow out, if perfectly ripe, in an uninterrupted stream. When the congested ovary is not mature the loosened eggs stick together and can not be easily disengaged without injury. A female with eggs approaching maturity can be readily distinguished by extending the translucent membrane between the "tail" and carapace, through which the deep-green color of the ovary is at once apparent, but since the eggs can not be pressed from the unyielding body of the animal, there is no way of telling when these are ripe short of actual dissection.

The secondary organs of reproduction in the female are: (*a*) The oviducts, two short membranous tubes, which lead from the ovaries to the exterior, and open, one on each side, upon the basal segments of the second pair of walking legs; (*b*) the copulatory pouch or seminal receptacle, for storage of spermatozoa (plate 7, and plate 38, fig. 130), situated between the bases of the third pair of walking legs; (*c*) cement glands, which secrete the material by which the eggs are fixed to the swimming legs (plate 40, fig. 144, and plate 49, figs. 211, 212); (*d*) the first pair of abdominal appendages, which are so reduced in size and modified as to be useless for swimming.

The male reproductive organs are the testes (plate 36, fig. 120), the ducts of which open at the base of the last pair of walking legs. The sperm which is inclosed in gelatinous capsules or spermatophores, the secretion of the seminal ducts, is thus ejected in packets. There is no penis or tubular extension of the integument from the opening of the duct, as is the case with the Brachyura.

The first pair of legs of the tail are also modified in a peculiar way in the male, as if they served for conducting the spermatophores through the elastic, slit-like orifice of the seminal receptacle.

There are numerous secondary sexual distinctions, the most striking of which is seen in the abdomen. The latter is conspicuously broader in the female, a variation which is correlated with the greater size of the ovary as compared with the testis; its lateral plates are deeper and it is more conspicuously hollowed below to form an incubatory pouch for the ova. A discriminative fisherman can thus distinguish the sex at a glance. (Compare plates 4 and 6.) The large claws are more voluminous in the male than in the female, and the male attains the greatest size. This would imply that the male molts oftener than the female, which, according to the observations of Brook (*26*), is actually the case.

In addition to these distinctions Gouriet (*82*) found that in the crayfish the antennæ were longer in the males than in the females; that while the length of the abdomen of the male was relatively shorter, it was heavier than in the female. He found the length of the abdomen, compared with that of the carapace, to be in the proportion of 7 to 6 in the female, while in the male this difference in length did not exceed $\frac{1}{15}$ inch.

In the male lobster the second pair of swimmerets carries a small spur on its inner blade, the function of which is obscure. The reduction of the first pair of abdominal appendages in the female is in all probability correlated with their use in reproduction. If they were of the normal size they would catch so many eggs at the time of oviposition that it would be next to impossible for the female to completely flex the abdomen. Locomotion would thus be interfered with, and the eggs would be constantly exposed. As it is, it sometimes happens in very large females, where the ova are excessively abundant, that it is impossible to completely fold the abdomen. (See p. 54.)

Each testis consists of a slender, grayish-white, sacculated tube filled with developing sperm cells (fig. 120, plate 36), and its coiled duct usually contains sperm in abundance. The spermatophore can be easily pressed from the duct, when the latter is dissected out. The sperm cells have a characteristic shape (fig. 129, plate 37) and are absolutely immobile in the conditions under which they are ordinarily observed, but it is impossible to suppose that this is always the case. Their complicated form, recalling that of the bell-shaped medusa, leads one to suspect that under the influence of some subtle and unknown stimulus, possibly of a chemical nature and coming from the cement glands or some other organ, they are able to execute independent and rapid movements through the water.[1]

[1] Cano states that he once detected amœboid movements in the rayed sperm-cells of the crab Maia. See observations quoted on p. 49.

THE PAIRING OF THE LOBSTER AND OF OTHER CRUSTACEA.

The copulation of the lobster has never been seen, as far as I am aware, in any of the species, but we know that it takes place in spring and summer at least, if not at other times of the year. If ripe females, or females even with newly laid eggs, are examined in June or July at Woods Hole, the seminal receptacle is found to be almost invariably charged with spermatozoa, and it is evident that copulation takes place, certainly in many cases, without immediate reference to the condition of the animal. Thus on August 19 I examined a female lobster which was 9 inches long and found her seminal receptacle loaded with sperm. The ovaries were of a light, greenish-yellow color, and in a very immature condition. This lobster had been impregnated at least two years before her eggs would be ripe.

I was surprised to find the seminal pouch of another lobster, which was examined about the same time, to be charged with freshly deposited sperm, *although it had just hatched a brood and was preparing to molt.* It therefore seems probable that the male lobster has no means of discriminating the sexual condition of the female. This lobster, in the ordinary course of nature, would soon have lost in the molt the sperm with which she had been so recently supplied. The first copulation, which had occurred either before or shortly after the hatching of the brood, must have been followed by a second union in order to secure the fertilization of the next batch of eggs. These would not be due, moreover, until one year from this time. It is thus evident that the female lobster is not impregnated once for all and compelled to take the chances of fertilizing her eggs, but is approached more than once by the male. The molting of these animals, although subject to less variation in the adult female than in the male, renders this necessary. Females usually molt shortly after the hatching of a brood. Where the molting is accomplished just before the eggs are laid, which happens very rarely—I have noticed only two cases in the lobster—(see p. 80), copulation can precede the act of extrusion by a few days at the most.

A lobster which had been kept in an aquarium for upward of two months in the summer, without access to the male, laid eggs which were normally fertilized. This and other facts which have just been mentioned show that the female lobster must in some cases be impregnated more than once before each reproductive period, and also that the spermatozoa retain their vital activities for a long time, perhaps, as Bumpus suggests (*30*), from one to two years. This is not so remarkable, when we consider the longevity of spermatozoa recorded by Sir John Lubbock (Weismann's Essays; vol. 1, p. 52), who succeeded in keeping a queen ant until she was 15 years old, during which time she continued to lay fertile eggs. Fertilization must have taken place at the latest in the season when the insect was captured. "There has been no male in the nest since then," writes Lubbock, "and, moreover, it is, I believe, well established that queen ants and queen bees are fertilized once for all. Hence, the spermatozoa of 1874 must have retained their life and energy for thirteen years, a fact, I believe, unparalleled in physiology."

Observations on the copulation of the crayfish (*Potamobius fluviatilis*) have been made by Gerbe (*43*), Chantran, and other naturalists. The latest and most detailed account of Chantran, published in 1872 (*39*), is as follows:[1]

[1] In quotations from works in foreign languages, I shall give, for convenience, the English translation. The extract can be verified by reference to the original.

The male crayfish deposits its fertilizing matter in the form of spermatophores upon the plates of the tail-fan and upon the plastron of the female. The time of egg-laying varies from two to forty-five days after copulation. When the time comes for the extrusion of the eggs, the female raises herself upon her feet, and then the abdominal appendages secrete for a number of hours a grayish, somewhat viscous mucus. She thereupon lies upon her back, bends her "tail" toward the opening of the oviducts, so as to form a kind of cistern or chamber, as described by Lereboullet, into which during the following night the eggs are received as fast as they are expelled from the genital organs. This expulsion lasts from one to several hours. These eggs, which are always turned so as to present their whitish spot or cicatricula uppermost, in order to be fertilized the more readily, are thus found engulfed in the grayish mucus which fastens, in some degree, the swimmerets and the borders and extremity of the "tail" to the thorax. This also helps to bound the pocket or chamber, in which there is a certain amount of water inclosed with eggs and mucus. Immediately after egg-laying we can find in the water and mucus spermatozoids exactly like those contained in the spermatophores which are attached to the plastron, and from which, in fact, the sperm-cells proceed. The spermatozoids are thus in direct contact with the eggs and are in the presence of a vehicle which assists them to penetrate the ova. Fecundation is effected in this chamber, that is, outside of the genital organs of the female.

The spermatozoids found mixed with the eggs and mucus in the egg-chamber are like those found in the spermatophores and male sexual organs. In the course of the first three days after egg-laying these spermatozoids become spherical, pale, and continue immobile. After this they wither and become smaller, darker, and more irregular. Finally, when, after the fixation of the eggs, the excess of mucus has completely disappeared by means of pressure exerted by the incessant contractions of the abdomen, which takes place in from six to eight days after egg-extrusion, those spermatophores which still remain attached to the plastron consist of small white coriaceous filaments. The latter are either isolated or composed of several adhering together. They have nothing to show but a central cavity, in which the microscope can detect nothing but a few spermatozoids, more or less withered. The wall of the spermatophores preserves its thickness and remains, as before, composed of a hard, striated, tenacious mucus.

On the 10th of October a small species of Cambarus copulated in an aquarium, in the following manner: The animals lay on their sides, and the sternal surface of the thorax of the male was pressed closely against that of the female. The abdomen of the female was folded beneath that of the male. The male grasped with his great claws the large pincers of the female, and thus held her securely, bringing also into service the walking legs. According to Andrews (Johns Hopkins Univ. Circ., vol. XIV, p. 74), the spermatophores, which I did not observe, are deposited in the annulus of the female, and the animals are firmly adherent by means of definite hooks and ridges on the appendages of the male and female respectively.

The following notes are interesting as showing how popular errors in regard to the breeding habits of lobsters have arisen. Some of these statements, mixed with a minimum of accurate observation, have been repeated so many times that they have almost assumed the semblance of truth.

Travis (*191*) writes to Thomas Pennant, in a letter on the habits of *Homarus gammarus*, published in 1777, that lobsters "begin to breed in the spring and continue breeding most of the summer; they propagate *more humano* and are extremely prolific. Dr. Baster says he counted 12,444 eggs under the tail, besides those that remained in the body unprotruded. They deposit these eggs in the sand, where they are soon hatched." This curious contradictory statement is repeated by Herbst (*88*), who says that "they lay their eggs in the sand, where they are hatched by the sun."[1]

[1] The same notion existed in regard to the breeding habits of crabs. Thus, Herbst says: "The sea crabs do not show so much care for their young as the crayfish. They try to deposit their eggs either on the shore in the sand or they commit them to the sea, which washes these eggs thus extruded in on the beach, where they are soon hatched by the sun, and the young seek again their proper element." Of the land crabs, he says: "They carry their eggs to the sea, where the females wash them off from their tails. They are then cast up by the sea on the beach, where they are hatched by the sun."

Boeck asserts (*20*) in his history of the Norwegian lobster fishery, that a real act of copulation takes place, the male placing its double male member (modified appendages of the first abdominal somite) into the outer genital openings of the female, and that the eggs are impregnated while they are yet in the ovary.

Fraiche (*70*) says that the union of the sexes takes place in the fall of the year (October and November) for the common and Norwegian lobsters, and in the case of the former species extends into winter:

> As with the crayfish, the sexual act is accomplished belly to belly, and so closely and firmly do they clasp each other, that, if taken from the water at this period, it is with difficulty that they can be separated.

He thinks that the seminal fluid is introduced directly into the oviducts, and says that the sides of the abdomen secrete a viscous substance which incloses the eggs and attaches them to the body of the female.

The question, How is the fertilization of the eggs effected in crustacea? is one which has been asked by naturalists from the days of Aristotle down to the present century, and it has received the most varied and contradictory answers. A brief account of the history of opinion on this subject has been given by Brocchi in his thesis on the male organs of the decapod crustacea, published in 1875 (*25*). One source of difficulty lay, as recent studies have proved, in supposing that the process was essentially the same in both Macrura and Brachyura.

Porzio[1] and Cavolini (*36*),[1] among the older writers, as Brocchi shows, had clearer ideas upon this question than their immediate successors. Thus the Neapolitan physician, Porzio, says, in his study on the lobster:

> Organa autem propagationis et generationis sic constructa sunt, ut facilem non inveniam rationem qua maris semen, in feminæ corpus ejaculari, infundi, vel introiri possit.

Cavolini also remarks in his memoir on generation, published in 1787, that—

> The crustacea copulate face to face, with the penis on the outside of the body; there is no intromission, for the papilla which we have shown to be present on the base of the last pair of legs can scarcely serve to make a passage for the semen; the eggs are glued to the hairs of the female and are bathed in the semen (*36*).

Milne Edwards (*58*) in his Histoire Naturelle des Crustacés, published in 1834, expressed some true ideas upon the reproductive processes in the crustacea which were not comprehended by many subsequent writers. At the same time he falls into errors in regard to certain organs and their functions. He says that the first two pairs of abdominal appendages in the male, which are often so different from the following pairs, seem to serve as exciting organs in the act of reproduction, but that naturalists have been mistaken in regarding them as representing the penis. In many cases, as in Gegarcinus, their size would make it impossible for them to penetrate into the vulva, and he says "we have proved, by direct observation, that in others it is the lower end of the efferent canal which is alone introduced into the body of the female." These appendages apparently assist in directing the penis toward the vulva, and possibly in exciting the latter. (See note 1, p. 39.) He calls attention to the important fact that in the Anomura and Macrura there is no copulatory pouch such as he had discovered

[1] I have been unable to consult the original works of these writers, and give the quotations from them on the authority of Brocchi and Cano.

in the Brachyura. In the Brachyura he found that a true copulation took place: "The wands of the male penetrate into the copulatory pouches situated below the vulvæ of the female, and deposit there the semen, which is so held and preserved in that part that it may be turned over the eggs as fast as they pass out." On the coasts of Brittany Milne Edwards found a female *Cancer pagurus*, which was fertilized, "and in which the extremities of the wands of the male were broken off after copulation, as happens in many insects; these organs remained inclosed in the copulatory pouches." As Brocchi (*25*) observes, Milne Edwards seems to have foreseen the presence of spermatophores, for in a subsequent work (*59*) he says, in reference to this observation, that since his attention has been directed to spermatophores it has seemed possible "that the sort of stopper in question left in the vulva may have been a body of that nature rather than a fragment of the penis."

In regard to the reproduction of the Macrura, where there is no internal seminal receptacle, the fecundation of the eggs, says Milne Edwards (*58*), is less easily understood:

> It is generally admitted that in all these animals there is a true copulation, in consequence of which the seminal fluid is introduced into the interior of the generative organs of the female. If it were not so, it would be difficult to understand how the eggs, which fill the entire ovary, the first of which are laid a long time before the last are developed, come in contact with this fluid, as a necessary condition of their fertilization. But there is not, so far as I know, any direct observation which proves the existence of such a copulation, and the absence of a copulatory pouch leads us to suppose that in these animals the eggs are fertilized as in the cricket, or very shortly after they have left the body of the mother. After being received into the cavity of the ovary, the egg is directed little by little toward the external orifice of one of the oviducts, the walls of which secrete in spring a rather thick, albuminous liquid, which, hardening after the eggs are laid, forms a second external envelope.

This error of attributing the viscous secretion to the oviducts has been repeated by subsequent writers, notwithstanding the fact that it was corrected by Milne Edwards (*60*) in a subsequent work. He says in a note following a recapitulation of the observations of Lereboullet, that the glue by which the eggs are attached does not come from the walls of the oviduct, but is secreted by subcutaneous glands situated on the under side of the abdomen, between the bases of the appendages. A membranous penis is said to be formed by the subdermal portion of the seminal tube, which is here enlarged and has thickened walls. This dilated portion of the canal, the "vecteur" of the sperm, "is capable of evaginating and passing outside beyond the genital opening, to the borders of which it is inserted. It thus forms a tubular appendix, having the function of a penis."

Milne Edwards was undoubtedly mistaken in supposing that the large glandular segment of the vas deferens of the Macrura was evaginated in copulation. This, as Grobben remarked, would be mechanically impossible (*83*).

Duvernoy (*57*) in 1850 again raised the question whether fertilization in Decapod Crustacea took place at the moment the eggs were laid, and comes to the conclusion that in Macrura and some Brachyura, where there is no seminal reservoir, fecundation takes place without a true copulation. He says:

> The way in which the oviducts are stuffed like sausages with large numbers of eggs arranged in line, when they have reached maturity, would not admit of an internal fertilization, except for those eggs which were brought near the orifice, unless there was a copulatory pouch or a seminal reservoir, before the mouth of which they must successively pass at the time of egg-extrusion, in order to be fertilized, as is the case with insects.

He supposed that in all cases where internal fecundation was impossible, the eggs were fertilized at the moment they were laid, as occurs in the tailless Batrachians; he

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had also the notion that the male helped the female to place her eggs under the abdomen and glue them to the swimmerets.

Apart from the physical impossibility of an internal copulation and fertilization, in the way which many have conjectured, the absence in the Macrura of two important accessory reproductive organs, the *vagina* and *internal seminal receptacle*, points at once to the fact that the eggs are fertilized outside of the body. With the discovery of an external seminal pouch in the lobster, the function of which had been curiously overlooked or misunderstood until Bumpus called attention to it in 1891 (*30*), this is still further emphasized.

As Brocchi and, more recently, Cano (*32*) have pointed out, the vagina and internal seminal receptacle always occur in the Brachyura in relation to the presence of a male penis (the terminal portion of the efferent duct which is said to be capable of evagination), and imply a different method of copulation.

The common green crab (*Carcinus mœnas*), the pairing of which has been repeatedly observed, illustrates this process among the Brachyura. A pair of these crabs was brought into the laboratory at the United States Fish Commission at Woods Hole on the 27th of July. They were adherent solely by the intromittent organs[1] of the male, which were introduced into the orifices of the oviducts of the female. The male had a hard shell; the female, which was smaller, a soft shell, conditions which seem to be necessary for copulation, as Cavolini (*36*) long ago showed, and as Bouchard-Chantraux (*21*) and Lafresnaye (*111*) independently observed (*25*).

Cano gives the following account of the copulation of Maia (*33*):

> The male crab runs to meet the female, lifts her up and places her beneath him, embraces her closely with his feet, and his claws hold her by the margin of the orbits or in the region of the antennæ. In other cases the male turns upon its back, catches hold of the female and draws her upon his belly. The whole action lasts about an hour.

It is undoubtedly true, as Cano has remarked, that in all the Macrura and Anomura, which have no internal receptaculum seminis, penis or vagina, there is no internal copulation and the sperm is never found in the ovary or its ducts.

THE LAYING OF EGGS.

In order to determine the time and limits of the breeding season of the lobster, it is necessary to collect and examine a large number of their eggs at different places and at different times of the year. The examination of the winter or summer eggs alone will not suffice to solve the problem, as I have learned by my own experience, and this explains why the question has been the subject of so many conflicting statements and has remained unsettled down to the present day. (For a review of this question see Nos. *98* and *101* of Bibliography.)

The following quotations illustrate the confusion which has surrounded this important subject. Verrill (*196*) remarks:

> There is a great difference in the breeding season on different parts of the coast. The lobsters from New London and Stonington often lay their eggs as early as the last of April or first of May; while at Halifax Mr. Smith found females with recently laid eggs in September. At Eastport, Maine, the females carry their eggs in midsummer.

[1] The only intromittent organs noticed in this case were the slender wand-like appendages of the first abdominal somite. The penis is probably introduced after the former have been withdrawn. (Compare p. 37.)

At the time this was written it was not known that the lobster usually carries her eggs for a period of ten or eleven months. It was, therefore, quite natural that Verrill should misconstrue the discriminative statement of Smith (*182*), who says:

> The season at which the female lobsters carry eggs varies very much on different parts of the coast. Lobsters from New London and Stonington, Connecticut, are with eggs in April and May, while at Halifax, Nova Scotia, I found them with eggs, in which the embryos were just beginning to develop, early in September. A corresponding variation is noticed in the lobster of the European coast.

Verrill further says (*196*, p. 745):

> Subsequent observations have shown that the breeding season of the lobster extends over a large part of the year. * * * Mr. Vinal N. Edwards has forwarded two living females, of medium size, taken in Vineyard Sound, December 12, both carrying an abundance of freshly laid eggs. He states that he finds about one in twenty carrying eggs at that season.

Wheildon says, in a paper published in 1875 (*202*), that the assumption that the lobster has a definite annual spawning season is an error, and that in February of that year he had obtained "spawn in several stages of development from newly laid eggs to the swimming larvæ."

The following statement of a member of the local government of Prince Edward Island expresses an opinion upon the breeding habits of the lobster, which is as misleading as it is common:

> I feel certain that the close season has not and can not accomplish anything toward the first object [protection for lobsters while spawning], as it is now admitted by everyone who has had any experience in packing, that lobsters in spawn are caught at all seasons of the year and that they have no particular season for spawning.

Bumpus concludes that—

> The eggs are *normally* deposited during the months of July and August, and develop rapidly so long as the water is relatively warm. * * * Large numbers of eggs collected during the winter months, both from the colder waters of Nahant as well as from the warmer waters of Woods Hole, were almost invariably in the same advanced stage of development—the eyes large and bright, the appendages well outlined, and the yolk occupying but a fraction, perhaps one-third of the surface exposure.

Out of hundreds of lobsters found "in berry" in May, 1890, at Woods Hole, "not a single one had eggs in early stages of development." (*30*)

After fluctuating from one view to another, I came to the conclusion that the breeding season was limited as defined in the paragraph just quoted, but as my observations had been restricted to the summer months and to the region about Woods Hole, I determined to extend them to other points of the coast and to other seasons of the year. The results of these inquiries I will now give in detail. They may be summarized as follows:

For the majority of lobsters there is a definite breeding season, which is the summer, July and August being the months in which the greatest number of eggs are laid. A minority, on the other hand, perhaps 20 to 25 per cent of the entire number of spawners, lay their eggs at other times of the year, in the fall and winter at least, if not also in the spring. The fall and winter eggs are normally extruded, and do not appear to be necessarily the product of the first reproductive period. A glance at table 12 shows that while the average size of the females is small, it is fully up to the average of all females captured during the same time.

I received an "egg-lobster," which is not recorded in the following tables, from Woods Hole early in December. It was 12½ inches long, and its eggs were just past the egg-nauplius stage. If laid in July or August, they would have reached this stage in about 18 days.

SUMMER EGGS IN VINEYARD SOUND.

The following tables illustrate the time of spawning of the lobster in the vicinity of Woods Hole, in Vineyard Sound, and about Gay Head. The date of the extrusion of the eggs is, of course, only approximately determinable. It is estimated from observations on the rate of development of embryos at Woods Hole. The parent lobsters were confined in floating latticed boxes, which were exposed to the wash of the waves, in one instance, for nearly a year. (See table 18, p. 56.)

TABLE 3.—*Time of spawning of the lobster in Vineyard Sound and vicinity in 1889.*

No.	Locality.	Date of capture.	Stage of development.	Age of embryo.	Date of extrusion of eggs.
1	Woods Hole Harbor	July 10	Thoracic abdominal plate well marked	8 to 9 days	July 1
2	Menemsha	July 11	At least four pairs of appendages behind mandibles.	20 to 21 days	June 20
3	do	do	Egg nauplius: second antennæ bilobed	14 to 15 days	June 26
4	do	do	do	do	Do.
5	Woods Hole Harbor	do	do	do	Do.
6	do	do	Close of yolk segmentation	3 days	July 8
7	Menemsha	do	Yolk segmentation: 60 to 100 segments	1½ days	July 9
8	do	do	do	do	Do.
9	do	do	do	do	Do.
10	Woods Hole Harbor	do	do	do	Do.
11	do	do	do	do	Do.
12	do	do	Early egg nauplius: second antennæ not bilobed.	10 days	July 1
13	do	July 16	Egg nauplius, later stage: second antennæ bilobed.	14 to 15 days	Do.
14	do	do	Close of yolk segmentation	3 days	July 13
15	do	do	Thoracic abdominal plate becoming prominent.	6 days	July 10
16	do	do	Yolk segmentation: 50 to 100 segments	1⅓ days	July 14
17	do	July 18	Large thoracic abdominal plate. Pit obscured.	8 to 9 days	July 9
18	do	July 20	Very slight invagination: nuclei close to surface.	4 days	July 16
19	do	July 28	Eye pigment developed	27 days	July 1
20	do	Aug. 3	do	do	July 7

TABLE 4.—*Time of spawning of the lobster in Vineyard Sound and vicinity in 1890.*

No.	Locality.	Date of capture.	Stage of development	Age of embryo.	Date of extrusion of eggs.
1	Menemsha	July 7	Yolk segmentation probably not begun	24 hours	July 6
2	do	July 9	Yolk unsegmented	Few hours	July 9
3, 4	do	July 28	Post-nauplius stage	21 days	July 7
5	do	do	Eye pigment just visible	27 days	July 1
6–14	do	do	Close of yolk segmentation	3 days	July 25
15–17	do	do	Invagination stage, small pit	4 to 5 days	July 24
18	do	do	Yolk segmentation: 16 to 60 segments	24 to 30 hours	July 27
19	do	July 30	Yolk unsegmented	A few hours	July 30
20	do	July 30, 1.45 p.m.	do	About 8 hours	Do.
21–26	do	July 30	Early segmentation of yolk	24 to 30 hours	July 29
27–45	do	do	Close of yolk segmentation	3 days	July 27
46–51	do	do	Invagination stage	5 days	July 25
52, 53	do	do	Egg nauplius	15 days	July 15
54	do	do	Eye pigment formed	27 days	July 3
55	do	Aug. 1	Egg nauplius	15 days	July 17
56–60	do	do	Close of yolk segmentation	3 days	July 29
61	do	do	Yolk segmentation: 16 to 60 segments	24 to 30 hours	July 31
62	do	do	Thoracic abdominal plate formed	8 to 9 days	July 23
63	Woods Hole Harbor	Aug. 5	Invagination	5 days	July 31
64	do	Aug. 11	Egg nauplius	15 days	July 27
65	Gay Head	do	Eye pigment formed	27 days	July 15
66–68	do	do	Invagination	5 days	Aug. 6
69, 70	do	do	Thoracic abdominal plate formed	8 to 9 days	Aug. 2
71–73	do	do	Egg nauplius	15 days	July 27
74	Woods Hole Harbor	Aug. 14	Invagination	5 days	Aug. 9
75	do	do	Post-nauplius stage	20 days	July 25
76, 77	do	Aug. 18	Invagination(?)	5 days	Aug. 13?
78–81	Menemsha	Aug. 20	Egg nauplius	15 days	Aug 5
82–84	do	do	Post-nauplius stage	21 days	July 31
85, 86	do	Aug. 21	Early egg nauplius	10 days	Aug. 11

TABLE 5.—*Time of spawning of the lobster in Vineyard Sound and vicinity in 1891.*

No.	Locality.	Date of capture.	Stage of development.	Age of embryo.	Date of extrusion of eggs.
1	Gay Head	July 19	Yolk segmentation	1½ days	July 17
2	do	July 23	Close of yolk segmentation	3 days	July 20
3	Menemsha	July 28	Invagination	4 days	July 24
4	do	do	Late stage with eye pigment	29 days	June 29
5	do	do	*Close of yolk segmentation*	3 days	July 25
6	Gay Head	July 29	do	3 days	July 26
7	do	do	Eye pigment formed	27 days	July 2
8	do	do	Egg nauplius	15 days	July 14
9, 10	Menemsha	Aug. 5	Invagination (?)	4 days	Aug. 1
11–13	do	do	do	4 days	Do.
14–16	do	do	Close of yolk segmentation	3 days	Aug. 2
17–21	do	do	Egg nauplius	15 days	July 21
22	do	do	Late stage, eye pigment conspicuous	30 days	July 6
23	Woods Hole Harbor	Aug. 8	Before formation of eye pigment	25 days	July 14
24	Gay Head	Aug. 11	Invagination	4 days	Aug. 7
25, 26	do	do	Thoracic abdominal plate	8 days	Aug. 3
27	do	do	Egg nauplius	15 days	July 27
28	do	do	Post-nauplius stage	20 days	July 22
29, 30	Menemsha	Aug. 12	Early egg nauplius	10 days	Aug. 2
31	Woods Hole Harbor	Aug. 12	Invagination	4 days	Aug. 8
32	do	*Aug. 18*	*Egg nauplius, late stage*	16 days	Aug. 2
33	Gay Head	Aug. 19	Eggs free in ripe ovary		
34	do	Aug. 21	Egg nauplius, late stage	18 days	Aug. 3
35, 36	do	do	Eye pigment forms large, nearly oval spot	42 days	July 10
37, 38	do	do	Egg nauplius	15 days	Aug. 6

TABLE 6.—*Time of spawning of the lobster in Vineyard Sound in 1892 and 1893.*

No.	Locality.	Date of capture.	Stage of development.	Age of embryo.	Date of extrusion of eggs.
		1892.			
1	Woods Hole Harbor	July 29	Invagination	4 days	July 25
2	do	July 30	Egg nauplius	15 days	July 15
3	do	Aug. 1	Beginning of yolk segmentation	1½ days	July 31
4	do	do	Invagination	4 days	July 28
5	do	Aug. 3	Close of yolk segmentation	3 days	July 31
6	do	do	Post-nauplius stage	20 days	July 14
7	do	do	Before eye pigment is formed	26 days	July 8
8	do	Aug. 6	Yolk unsegmented	About 1 day	Aug. 5
		1893.			
1–3	Menemsha	July 25	New eggs: stage not determined		
4	Woods Hole Harbor	Aug. 11	Eggs laid in aquarium at United States Fish Commission station.		About Aug. 10
5	do	Aug. 15	Close of yolk segmentation	3 days	Aug. 12
6	do	do	Five pairs of appendages behind mandibles; no eye pigment.	23 days	July 23

TABLE 7.—*Variation in time of spawning of lobsters in Vineyard Sound and vicinity in the years 1889–93.*

Period of spawning.	1889.	1890.	1891.	1892.	1893.	Total.
June 1–15						
16–30	5		1			6
July 1–15	14	11	6	3		34
16–31	1	62	12	4	1	80
August 1–15		13	18	1	2	34
16–31			1			1
Number of individuals examined	20	86	38	8	3	155

The data afforded by the preceding tables lead us to conclude that the summer eggs are produced in this region during a period of about nine weeks, extending from the middle of June to the middle or last of August, the largest number being laid

during the latter half of July and the first two weeks of August. The summer spawning of each year lasts about six weeks, but may fluctuate from year to year, backward or forward through an interval of a fortnight.

The observations for the years 1890 and 1891 only, are large enough to make a comparison of much value. Of the 86 lobsters with new eggs examined in July and August, 1890, 85 per cent extruded eggs in July and 15 per cent in August, while in the following year, out of 38 females, one-half had laid in July and half in August. In 1890, however, 72 per cent of the eggs were laid in the latter half of July and 15 per cent in the first half of August, while in 1891 47 per cent were extruded in the first part of August and 31 per cent in the latter half of July. The season of 1891 thus appears to have been somewhat later than that of the former year.

The record of ocean temperatures given in table 2 (p. 25) shows that the water was cooler in 1891 than in the preceding year, the difference of the mean annual temperatures being 1.6°. This difference is slightly raised by eliminating the month of June, when the smallest number of lobsters carry eggs. It is possible that so small a variation as is here recorded in the mean annual temperature of the sea water would sensibly affect the rate of development, yet a larger number of observations would be required before this could be satisfactorily shown.

There are undoubtedly other causes than the temperature changes which influence the growth of the ovarian eggs, which it must be remembered require at least two years to reach maturity. Anything which affects the individual during this interval may affect also the time of spawning, and this affords a partial explanation of the fact that eggs are sometimes produced at other seasons of the year than the summer.

SUMMER EGGS ON THE COAST OF MAINE.

Tables 8, 9, and 10 throw more light on the time of spawning upon the coast of Maine, where the water is somewhat cooler than at Woods Hole. The range of temperature in the Gulf of Maine is about the same as that obtained at Pollock Rip light-ship, off the southern end of Cape Cod, namely, 32° to 62° F.

TABLE 8.—*Time of spawning at Southport, Maine.*

[Many of the lobsters were captured in Nova Scotia and brought to Southport before laying their eggs.]

No.	Place of spawning.	Date of examination of eggs.	Stage of development.	Age of embryo.	Date of extrusion of eggs.
		1893.		*Days.*	
1	Southport, Me	Sept. 7	Telson in front of optic lobes: Eye-spots oval	61	July 8
2–3	do	do	Eye-spots lenticular or nearly semicircular	35	Aug. 3
4–8	do	do	Eye-spot narrower than in Nos. 2–3	33	Aug. 5
9–10	do	do	Eye-spot, small crescent	30	Aug. 8
11–16	do	do	do	29	Aug. 9
17–21	do	do	Eye-spot, linear	27	Aug. 11
22–23	do	do	Before formation of eye pigment	25	Aug. 13
24–25	do	do	Egg nauplius, late stage	18	Aug. 20

TABLE 9.—*Time of spawning of the lobster at different points on the coast of Maine.*[1]

No.	Locality.	Date of examination of eggs.	Stage of development.	Age of embryo.	Date of extrusion of eggs.
		1893.		*Days.*	
1–2	Vinal Haven	Aug. 26	Eye-spot, small crescent	29	July 28
3	do	Aug. 28	Late segmentation of yolk	3	Aug. 25
4–7	do	Aug. 31		33	July 30
8	North Haven	Aug. 28	Eye-spot a small crescent	29	July 31
9	Vinal Haven	Aug. 26	do	29	July 29
10	do	Aug. 31	do	29	Aug. 2
11	do	do	do	28	Aug. 3
12–13	do	do	do	29	Aug. 2
14–17	do	Sept. 2	do	29	Aug. 4
18	do	Aug. 26	Post-nauplius stage	21	Aug. 5
19–20	do	Aug. 6	Eye-spot linear	27	July 10
21	do	Aug. 31	Post-nauplius stage	21	Aug. 10
22	do	Sept. 1	do	21	Aug. 11
23	Millbridge	Aug. 26	Egg nauplius	15	Do.
24	Vinal Haven	Sept. 2	do	15	Aug. 18
25–26	do	Aug. 31	Segmentation of the yolk	1½	Aug. 29

The results given in tables 8 and 9 are combined in table 10, which may be compared with table 7. In the first column, taken from table 8 (in which some of the lobsters were brought from Nova Scotia to Southport, Maine), all but three individuals extruded eggs during the first half of August. In the second column 46 per cent laid eggs during the same period. Combining the results of the observations at Woods Hole for five years, 1889–1893 (table 7), we find that 52 per cent of egg-bearing lobsters, in all cases observed, laid in the latter half of July, while about 21 per cent spawned during the first half of July and an equal number in the first half of August. We find that 66 per cent of the individuals recorded in table 10 laid eggs during the *first half of August.* These results tend to show that the summer spawning season in the middle and eastern districts of Maine is *about two weeks later* than in Vineyard Sound.

TABLE 10.—*Time of spawning of the lobster on the coast of Maine for the summer of 1893.*

Spawning period.	Data from table 8.	Data from table 9.	Totals.
July 1–15	1	2	3
July 16–31	0	8	8
August 1–15	22	12	34
August 16–31	2	4	6
Number examined	25	26	51

FALL AND WINTER EGGS AT WOODS HOLE.

The catch of egg-bearing lobsters in the harbor of Woods Hole for seven consecutive months is given in table 11. Out of a total of 168 captured, 21 per cent were taken in January, 6 per cent in February, and 20 per cent in April. Of the entire number, 25.5 per cent bore eggs which had been laid during the fall and winter months. This fact was determined in the following way. Some of the eggs of every lobster captured were preserved and carefully examined. Where no eye pigment was present it was at once evident that the eggs had been laid at a comparatively recent date. In all other cases the pigmented areas of the eyes were drawn to scale and compared with

[1] For the collection of eggs at various points on the coast and islands north of Massachusetts I am particularly indebted to Messrs. F. W. Collins of Rockland, M. B. Spinney of Cliffstone, J. W. Fisher of Eastport, and also to Mr. Greenleaf of Vinal Haven, Maine.

a series of similar drawings of embryos developing under normal conditions from summer eggs.

The eye pigment furnishes the most convenient scale for the measurement of the rate of development of the embryo as a whole, since it appears early, is clearly defined, and since the development of the eye is correlated with that of the other organs of the body. Where the ocular pigment forms a thin crescent in eggs taken in January, the embryo will be found in a stage of development similar to that reached in the summer eggs four weeks after fertilization. In such a case, it is a safe inference that the ova have been laid in the fall. Again, when in May or early June the area of ocular pigment is not greater or is less than that observed in summer eggs by the first of September (cut 36, pl. J), we may be confident that such eggs were extruded later than the previous summer.

TABLE 11.—*Number of egg-lobsters taken at Woods Hole.* (*See table 21.*)

Time.	Females with eggs. (*b*)	Females with eggs laid in July and August.	Females with eggs laid out of season. (*a*)	Percentage of *a* to *b*.
1893.				
December	22	17	5	22.7
1894.				
January	36	24	12	33⅓
February	11	9	2	18
March	12	9	3	25
April	33	26	7	21
May	34	26	8	23.5
June	20	13	7	35
Total	168	124	44	25.5

Table 12 shows the stage of development of the eggs of 44 lobsters taken under the conditions described (p. 25) and compared with the normal condition of summer eggs shown in table 18, lobster No. 3 (1) to (20). These comparisons are rendered clearer by a series of drawings (cuts 23–38) made from the eggs of this lobster.

TABLE 12.—*Stage of development of eggs laid in fall and winter at Woods Hole.*

No.	Date.	Length in inches.	Stage of development.	No.	Date.	Length in inches.	Stage of development.
	1893.				1894.		
1	Dec. 20	10¼	No eye pigment. Like stage 3 (7), table 18.	22	Mar. 15	9⅛	Like 3 (11), table 18.
2	Dec. 23	9½	Forked telson overlaps brain. Like preceding.	23	Apr. 16	10	Little earlier than 3 (10), table 18.
3	Dec. 25	8	Like 3 (11), table 18.	24	Apr. 17	10	Like 3 (9), table 18.
4	Dec. 26	10¼	Like 3 (7), table 18.	25	Apr. 17	10	Little earlier than 3 (10), table 18.
5	Dec. 27	8	Trifle later than 3 (9), table 18.	26	Apr. 18	11	Little earlier than 3 (9), table 18.
	1894.			27	Apr. 19	8½	Like 3 (9), table 18.
6	Jan. 1	11½	Like 3 (9), table 18.	28	Apr. 20	10⅛	Like 3 (10), table 18.
7	Jan. 2	9½	Like 3 (10), table 18.	29	Apr. 21	9	Little earlier than 3 (9), table 18.
8	Jan. 3	11½	Like 3 (9), table 18.	30	May 1	10½	Little earlier than 3 (10), table 18.
9	Jan. 3	9⅛	Like 3 (11), table 18.	31	May 1	7⅛	Like 3 (10), table 18.
10	Jan. 4	9	Eye pigment just visible.	32	May 3	10¼	Little earlier than 3 (9), table 18.
11	Jan. 9	10	Like 3 (6), table 18.	33	May 8	9½	Like 3 (9), table 18.
12	Jan. 11	10¼	Like 3 (10), table 18.	34	May 9	10	Like 3 (9), table 18.
13	Jan. 12	10	Like 3 (10), table 18.	35	May 10	10	Little later than 3 (9), table 18.
14	Jan. 13	10	Like 3 (9), table 18.	36	May 11	7	Little later than 3 (9), table 18.
15	Jan. 20	9	Like 3 (10), table 18.	37	May 12	9	Little earlier than 3 (9), table 18.
16	Jan. 27	10	Like 3 (10), table 18.	38	June 7	9	Like 3 (11), table 18.
17	Jan. 31	10	Like 3 (9), table 18.	39	June 7	11	Like 3 (11), table 18.
18	Feb. 19	9¼	Like 3 (11), table 18.	40	June 9	8⅛	Like 3 (11), table 18.
19	Feb. 5	9	Like 3 (9), table 18.	41	June 8	11	Little earlier than (11), table 18.
20	Mar. 10	10¼	Like 3 (11), table 18.	42	June 11	10½	Like 3 (11), table 18.
21	Mar. 13	10⅛	Like 3 (11), table 18.	43	June 12	10	Like 3 (11), table 18.
				44	June 14	9½	Like 3 (11), table 18.

FALL AND WINTER EGGS IN OTHER PLACES.

The conclusion that the production of eggs in the fall and winter is of general occurrence throughout the entire range of the lobster is supported by the observations recorded in table 13. Here are eggs, none of them laid during the summer months, coming from a wide area from the middle and eastern parts of the Maine coast, from the outward islands, and from the province of New Brunswick. They are compared, as before, with the rate of development of summer eggs observed at Woods Hole [lobster No. 3 (1) to (20), table 18]. In one instance, No. 20, the yolk is unsegmented, though taken in February; in others the egg nauplius, which in summer appears at about the fourteenth day, is barely outlined.

TABLE 13.—*Stage of development of eggs laid in fall and winter on the coasts of Maine and Province of New Brunswick.*

No.	Date.	Locality.	Stage of development.	No.	Date.	Locality.	Stage of development.
	1893.				1894.		
1	Nov. 10	Isle au Haute	Like 3 (9).	21	Feb. 5	Matinicus Island	Like 3 (10).
2	Nov. 15	York Island	Late segmentation of yolk (?).	22	Feb. 8	Ragged Island	Like 3 (8).
				23	Feb. 10	Isle au Haute	Like 3 (10).
3	Nov. 25	Cranberry Isle	Egg nauplius. Earlier than 4 (3).	24	Feb. 10	Isle au Haute	Like 3 (9).
				25	Feb. 14	Long Island	Like 3 (4).
				26	Feb. 17	Matinicus Island	Like 3 (10).
				27	Feb. 21	Mount Desert	Like 3 (8).
4	Dec. 11 1894.	Matinicus Island	Like 3 (9).	28	Feb. 22	Cranberry Isle	Like 3 (9).
				29	Mar. 1	Cranberry Isle	Like 3 (10).
5	Jan. 11	Beaver Harbor, Bay of Fundy.	Like 3 (10).	30	Mar. 1	North Haven	Like 3 (5).
				31	Mar. 10	Isle au Haute	Like 3 (10).
6	Jan. 13	Mount Desert	Like 3 (9).	32	Mar. 13	Matinicus Island	Like 3 (9).
7	Jan. 15	Cranberry Isle	Like 3 (10).	33	Mar. 15	York Island	Like 3 (9).
8	Jan. 17	Isle au Haute	Like 3 (9).	34	Mar. 20	Cranberry Isle	Like 3 (9).
9	Jan. 18	Eastport	Like 3 (10).	35	Mar. 22	Ragged Island	Like 3 (9).
10	Jan. 18	Musquash Bay, 35 m. east of Eastport.	Like 3 (9).	36	Mar. 27	Fox Island	Like 3 (9).
				37	Mar. 29	Matinicus Island	Like 3 (9).
11	Jan. 19	Seeley Basin, 24 m. from Eastport.	Like 3 (10).	38	Mar. 30	Brimstone Island	Like 3 (11).
				39	Apr. 1	Swan Island	Like 3 (9).
12	Jan. 20	Baker Island	Like 3 (10).	40	Apr. 5	Fox Island	Like 3 (10).
13	Jan. 20	Otter Creek	Like 3 (9).	41	Apr. 10	Eastport	Like 3 (10).
14	Jan. 21	Eastport	Eye pigment just visible.	42	Apr. 15	Baker Island	Like 3 (10).
				43	Apr. 24	Eastport	Like 3 (10).
15	Jan. 22	10 miles from St. John, N. B.	Like 3 (10).	44	Apr. 26	Deer Island, 4 miles from Eastport.	Like 3 (11).
16	Jan. 24	18 miles from St. John, N. B.	Like 3 (10).	45	Apr. 30	Eastport	Like 3 (11).
				46	Apr. 30	Islesboro	Like 3 (11).
17	Jan. 27	Brimstone Isle	Like 3(4). Late egg nauplius.	47	May 1	Green Island	Like 3 (11).
				48	June 10	Matinicus Island	Like 3 (9).
18	Jan. 29	Isle au Haute	Like 3 (6).	49	June 8	York Island	Like 3 (9).
19	Jan. 17	Spoon Island	Like 3 (9).	50	June 13	Vinal Haven	Like 3 (10).
20	Feb. 4	Matinicus Island	Yolk unsegmented.	51	June 20	High Island	Like 3 (11).

Mr. N. F. Trefethen, of Portland, who deals extensively in lobsters, and who has a lobster pound in South Bristol, 35 miles east of Portland, believes that some lobsters in that vicinity spawn in June. In support of this view he cited the following case: In the latter part of May, 1893, he placed 20,000 lobsters in his pound and took them all out at intervals in the month of July, beginning the first of the month. All the lobsters had been examined before they were placed in the pound, and none of them were known to be with spawn. At the most only a relatively few egg-lobsters could have been put into the pound by accident. When taken out about one-third of the lobsters had spawn attached to the body. It is thus evident that some of these females must have laid their eggs in June or in the first part of July. No tally was kept of the proportion of egg-lobsters taken out during the first part, the middle, and the latter part of July, and it is possible that the great number of egg-lobsters, which

caused surprise, may have laid their eggs during the last half of July, and that very few in reality extruded their eggs during the first part of this month. It is not probable that any eggs were laid in June.

In the second week of August, 1893, a vessel came into Portland, Maine, bringing lobsters from Seguin Island and Georgetown. Very few lobsters were at this time (August 13 to 20) with spawn.

I have been told by fishermen and others that lobsters are sometimes taken out of the wells of smacks in winter with very dark, external eggs, when it had been the rule to carefully exclude every egg-lobster in loading the boat, the inference being that lobsters had laid while in the well. Allowing a wide loophole for error in such cases, it is very evident from the facts already recorded that this is quite likely to happen.

Mr. Nielsen gives the spawning period for lobsters in Newfoundland as extending from the 20th of July to the 20th of August (Annual Report of the Newfoundland Fisheries Commission, 1892), but also states, in reply to certain questions which I endeavored to have answered, that lobsters were taken with newly laid eggs up to the latter part of September.

The spawning months for the lobster in Prince Edward Island are said to be July and August. We have no data whatever upon the spawning habits of the lobster on the coast of Labrador, or in the extreme southern parts of its range.

Considering the fact that the lobster is distributed through 20 degrees of latitude, there is less variation in the time of spawning than might be expected.

THE LAYING OF THE EGGS AND THE ABSORPTION OF OVARIAN OVA.

I have not seen the process of egg extrusion and consequently have no direct observations to record. It has, however, been witnessed in other crustacea where it is undoubtedly similar. In two instances lobsters have laid eggs while kept in small aquaria in the laboratory of the United States Fish Commission. Since these animals were under constant surveillance during the day, it is almost certain that the eggs were deposited in the night or early morning, as is the well-known habit of many decapods. In each case the mother lobster scratched off nearly all of her eggs in the course of a few days.[1] In other attempts to observe this process, where the eggs seemed to be overdue, I dissected the animals and found that the ova were retained and partially absorbed. This led to other attempts with similar results.

Two "ripe" female lobsters, measuring 11.5 and 9 inches, respectively, were captured July 30 in Woods Hole Harbor, and placed in a large floating car, which was kept covered so that the lobsters were not exposed to direct sunlight. Fifteen days later, August 14, their ovaries were examined. In the smaller individual more than half the ovarian eggs, which were overdue, were in various stages of degeneration, thus giving the ovary a remarkable appearance. Instead of the uniform dark green hue, it was of a light yellow or straw color flecked with darker green areas, where

[1] Ehrenbaum (*61*, p. 287), who mentions a single case of a female lobster which was found lying on its back shortly after the eggs had been extruded from the body, says: "The mass of eggs lay in the mold formed by the folded abdomen without being fixed, since the cement had not as yet hardened. When the animal, in consequence of a disturbance, soon made movements and tried to get upon its feet, most of the eggs were left at the bottom of the aquarium, and only a small number were already so firmly fixed that they clung to the swimming feet."

the eggs had not yet broken down. The ovary of the larger lobster was similar to this, but the process of histolysis had not advanced quite so far.

The eggs are sometimes absorbed under natural conditions, but why this happens is not understood. A very interesting illustration of this fact came to hand on July 16, 1894, when, on account of its very dark color, my attention was directed to a hard-shell female lobster, about 11 inches long. The membranes of the joints of the limbs and under surface of the body were of a dull-green color, very unlike the appearance which these parts assume in a molting lobster. Examination showed that the ovarian eggs were almost completely absorbed and that the blood of the animal had a very distinct greenish tinge. The ovary was of a bright lemon-yellow tint, the color of the degenerated eggs, flecked lightly with green, where an egg had not lost its normal appearance. The ovarian lobe had shrunken to less than one-half its former size. The green pigment which was dissolved in the blood had undoubtedly come from the eggs, and had been taken up into the blood faster than it could be eliminated from it. I was told by Professor Ryder that the ovarian eggs of the sturgeon are sometimes absorbed in a similar way, and the same phenomenon is probably met with throughout the animal series.

In the lobster there are always a few ripe ovarian eggs which fail of extrusion at the proper time, which are invariably absorbed and give to the mature ovary at the next reproductive period a characteristic appearance. (See p. 69 and plate 38, fig. 136.)

One of the females which laid eggs had been kept by herself for several weeks. When discovered, on August 24, the ova were in an advanced stage of yolk segmentation. They were somewhat undersized and of a peculiar light-grayish color. The eggs were fertile, although the segmentation was generally abnormal. The lobster, which was placed in an aquarium on July 30, was found to have external eggs on the 11th of August, in a very early stage of development. They had probably been extruded during the previous night. These eggs were rapidly attacked by fungi and their development was retarded in consequence. Long fungoid filaments grew over the surface of the eggs, and diatoms attached themselves in great numbers to the egg-capsule. The eggs of lobsters taken under natural conditions are always clean and, so far as I have observed, free from vegetable growths of every kind.

The eggs are fertilized after ejection from the oviducts by the spermatozoa, a supply of which is always stored up in the seminal receptacle of the female. There is no internal copulation, and no possibility of an internal fertilization in either the ovaries or their ducts, as already explained (p. 39). The ova are probably immersed as soon as they are extruded, in a liquid cement substance, which is secreted in special glands situated in the swimmerets of the female. The "tail" is folded so as to form a closed pouch or chamber, as has been observed in the crayfish and other decapods (see note 1, p. 47), and the eggs received within it are mixed with the liquid cement and sea water. Fixation to the hairs of the swimmerets is finally effected by means of the cement, which gradually hardens. How the sperm cells are conveyed from their receptacle to the eggs, whether through the medium of the sea water or the glue, or whether or not by a motion of their own, is not definitely known. (Page 34, note 1.)

That the cement is incapable of fixing and holding the eggs until after exposure to sea water for some time (perhaps a few hours) was shown in the case of a lobster

taken from the well of a fishing smack, after extrusion had been partially accomplished, at Rockland, Maine, August 6, 1893. The lobster, I was told, was taken out and laid on the deck, when the soft, dark-green mass of eggs began to flow away from the body from their own weight. (Compare note 1, p. 47.)

Cano (*32*) gives the following detailed account of the laying of the eggs in the crab Maia:

> The time that intervenes between copulation and the deposit of the eggs may be eight, ten, fifteen days, or even longer, and can not be fixed, since copulation happens before the eggs mature in the ovary. The eggs, at the time of ovulation, pass the opening of the receptaculum seminis, and are here invested with a coat of cement, which is secreted and held in the receptacle. The eggs then revolve on their axes in the vaginal canal, and are expelled, one at a time, by means of the valvular apparatus. This is formed by a prolapsus of the vaginal canal. * * * Besides the proper muscles of this canal there exist special muscles which, by lowering the membranous covering, provoke the expulsion of the eggs through the valvular orifice. The eggs thus ejected fall into the abdominal chamber. The female beats them about with repeated blows of the tail, while the pleopods, keeping them in continued agitation, make them converge toward the center of the abdominal pouch. The deposition of eggs is effected in Maia in the course of twenty-four hours, but sometimes in Lissa it takes a longer time. On the next day all the eggs adhere in groups, by means of one or two peduncles, to the hairs of the internal branches of the pleopods, while the external branch agitates them continuously. This movement, besides renewing the surrounding water, probably assists in rupturing the egg shell, when the embryos are ready to hatch. Fixation could not be explained without the interaction of the sea water. The cement at first becomes more viscous, then hardens and forms a very thin pellicle, which, with the growth of the embryo, becomes quite hard and resistant. It would seem that the sea water might explain the chemical change which the cement undergoes, a change analogous to that which is observed in the exoskeleton after the molt. The cement may be regarded as a substance very like chitin, both being of ectodermic origin. The cement serves not only for fixation, but unquestionably as the vehicle of the seminal elements toward the eggs.
>
> If we examine the zone of cement which invests the eggs at the moment the latter traverse the short vaginal canal, there is seen a large quantity of seminal corpuscles, some of these still in the spermatophoral envelope, others free and swimming in the homogeneous mucus. These vary both in shape and dimensions. All the elements are immobile, but once I noticed that some of these cells, especially those with radial prolongations, were endowed with amœboid movements. Whether these movements are the same as those which impel the sperm into the egg I can not say from direct observation. The question then remains open as to when and how the spermatozoa pass into the eggs, which are unprovided with a micropyle. If they are able to penetrate through the poral canals of the chorion, and if this penetration can happen during the very brief passage of the egg through the vaginal canal or at the moment of deposition of the eggs, as in the Macrura, then the sea water must exert unknown physico-chemical actions on the cement, which makes the egg itself adhere later to the hairs of the pleopods.
>
> The typical phenomena of fecundation—the expulsion of the polar bodies and formation of pronuclei—I have not been able to observe directly.
>
> When the eggs have reached the receptaculum seminis the nucleus has become invisible. The first segmentation nuclei are found in the central part of the eggs and move toward the periphery. Segmentation begins almost as soon as the eggs are fixed.

Cano (*33*) observed cases in Carcinus and Portunus where the eggs were laid at different periods, one-third of the eggs being in the morula stage and the rest ready to hatch. Again, it was rarely found that the eggs were laid just before the molt, in which case they were cast off and destroyed. This anomalous condition was first noticed by Lo Bianco in Palinurus (*18*).

NUMBER OF EGGS LAID AND THE LAW OF PRODUCTION.

The production of ova among animals is directly correlated with the condition of the young at the time of hatching. Where eggs are very small and present in large numbers, as in some of the crabs, we may look for a long larval period; when the ova attain a much greater size and are at the same time very abundant, as in the lobster, we find the larval period abbreviated; in other cases, as in some shrimps, where eggs are relatively very large and few, the young hatch with the external characteristics of the adult.

The production of a large number of eggs always means great destruction under natural conditions. In such cases, however, the opportunity is afforded of increasing the supply of adults, provided we are able to tide the larvæ over their earlier stages of development. The number of eggs produced by the lobster is thus a subject which deserves careful attention in view of its economic bearings alone.

The numbers here recorded are based upon the records kept at the United States Fish Commission station. The eggs of each individual were carefully removed from the "tail" of the female lobster and measured in a graduate (having sloping sides), and the whole number of ova was estimated on the basis of the number contained in a fluid ounce. Mr. Edwards found the number of new eggs in one fluid ounce to be about 6,440 (in one ounce 6,461, in another 6,419), and the number of old or well-developed eggs in an ounce to be 6,090. This is a relatively rough method of determination, and the results are of course only approximately accurate.

I estimated by weight the number of fresh eggs carried by a lobster 13 inches long to be 17,623; total weight of eggs, 54.9 grams; number of living eggs to the gram, 321. These eggs were in an early stage of development.

The number of eggs borne by a large and a small lobster, carefully determined both by the wet and dry methods by my assistant, Mr. F. C. Waite, is given in the following table:

TABLE 14.—*The production of eggs determined by different methods.*

Observations.	Lobster No. 51, table 20; from Gay Head.	Lobster No. 69, table 20; from Woods Hole Harbor.
Stage of development of eggs	Late segmentation.	Post-nauplius; about three weeks old.
Length of lobster in inches	15½	9½
Number of eggs to the gram (*a*)	815	1,009
Weight of 1,000 eggs in grams (*b*)	1.2255	0.9893
Total weight of eggs in grams	68.8092	10.4029
Number of eggs to the c. c. (*c*)	220	211
Number of eggs to the fluid ounce	6,248	5,992
Number of eggs determined by the dry method (*a*)	56,079	10,507
Number of eggs determined by the dry method (*b*)	56,148	10,514
Number of eggs determined by the wet method (*c*)	58,500	10,919

Mr. Waite estimated the number of eggs in a fluid ounce (on the basis of 2,110 to 10 c.c., the number obtained by count) to be 5,992. These eggs had been in strong alcohol for upwards of three years. They were about three weeks old when preserved, and in alcohol had an average diameter of 1.625 mm. (1.56, 1.69 mm.)

In the wet method (*c*) employed, the number of eggs was estimated upon the actual number, obtained by counting, in 10 c. c. In the dry method the number was

determined either (*a*) on the basis of the number of eggs to the gram, or (*b*) by the weight of 1,000 eggs. The numbers obtained by the last two methods agree very closely, and it is plain that the dry method is the most reliable. The wet method gives a number which is from 3 to 4 per cent greater than that obtained by the dry method. There is probably a constant error of this amount in the wet method,[1] and this slight error is due to the presence of the stalk of the secondary egg membrane, which has a tendency to keep the wet eggs apart, but which shrivels and cracks off when dry. It increases the buoyancy of the fresh eggs and is the cause of the bunching commonly observed. The excess due to the bunching of the eggs is about 0.3 per cent. This source of error was eliminated in No. 69 of the table, where the eggs were separated with needles before measuring.

THE LAW OF PRODUCTION.

In table 15 I have reduced the results of a very large number of observations made upon lobsters varying from 8 to 19 inches in length. The total number examined is 4,645. Of these, 1,678 were taken on the ledges 15 miles southwest of No Man's Land Island from April 20 to June 16, 1894. The remaining 2,967 were captured in Vineyard Sound and in the vicinity of the Elizabeth Islands from April to June, 1889–94. A smaller number were taken in February during the same years. The eggs went to supply the hatchery of the United States Fish Commission.

TABLE 15.—*Production of eggs.*

Length of lobster.	Smallest number of eggs.	Largest number of eggs.	Average number of eggs.	Number of lobsters examined.	Length of lobster.	Smallest number of eggs.	Largest number of eggs.	Average number of eggs.	Number of lobsters examined.
8 inches....	3,045	9,135	4,822	6	13 inches.....	6,090	48,720	28,610	321
8½ inches....	6,090	7,612	6,851	2	13¼ inches.....	24,360	48,720	33,495	5
8½ inches....	3,045	12,180	6,935	9	13½ inches.....	6,090	54,810	32,858	146
8¾ inches....	6,090	9,135	7,105	3	13¾ inches.....	42,630	42,630	42,630	2
9 inches....	3,045	18,270	7,902	143	14 inches.....	6,090	85,260	36,960	426
9¼ inches....	6,090	12,180	9,083	35	14¼ inches.....	21,315	60,900	42,968	90
9½ inches....	3,045	20,792	9,297	241	15 inches.....	12,180	97,440	46,524	280
9¾ inches....	3,045	15,225	9,947	55	15¼ inches.....	.....	.....	54,810	1
10 inches....	3,045	24,360	10,555	514	15½ inches.....	24,360	97,440	53,795	45
10¼ inches....	6,090	22,838	11,622	61	15¾ inches.....	48,720	54,810	50,750	3
10½ inches....	3,045	36,540	12,905	532	16 inches.....	24,360	97,440	57,146	103
10¾ inches....	6,090	24,360	14,067	45	16¼ inches.....	.....	.....	66,990	1
11 inches....	3,045	48,720	15,410	568	16½ inches.....	36,540	85,260	66,053	13
11¼ inches....	6,090	25,882	17,102	43	17 inches.....	12,180	85,260	63,336	30
11½ inches....	3,045	42,630	18,668	307	17½ inches.....	60,900	73,080	64,960	3
11¾ inches....	12,180	24,360	17,993	11	18 inches.....	60,900	91,350	77,430	7
12 inches....	3,045	54,810	21,351	414	19 inches.....	54,810	91,350	77,647	4
12¼ inches....	18,270	27,405	23,396	8					
12½ inches....	9,135	42,630	24,812	156	Total number examined.....				4,645
12¾ inches....	18,270	42,630	26,390	12					

The average number of eggs of a lobster of a given length has little value unless obtained from a large number of individuals. While the small number of eggs occasionally recorded for lobsters over 12 inches long may be the result of loss, in lobsters under this size it is probably more often due to belated sexual maturity.

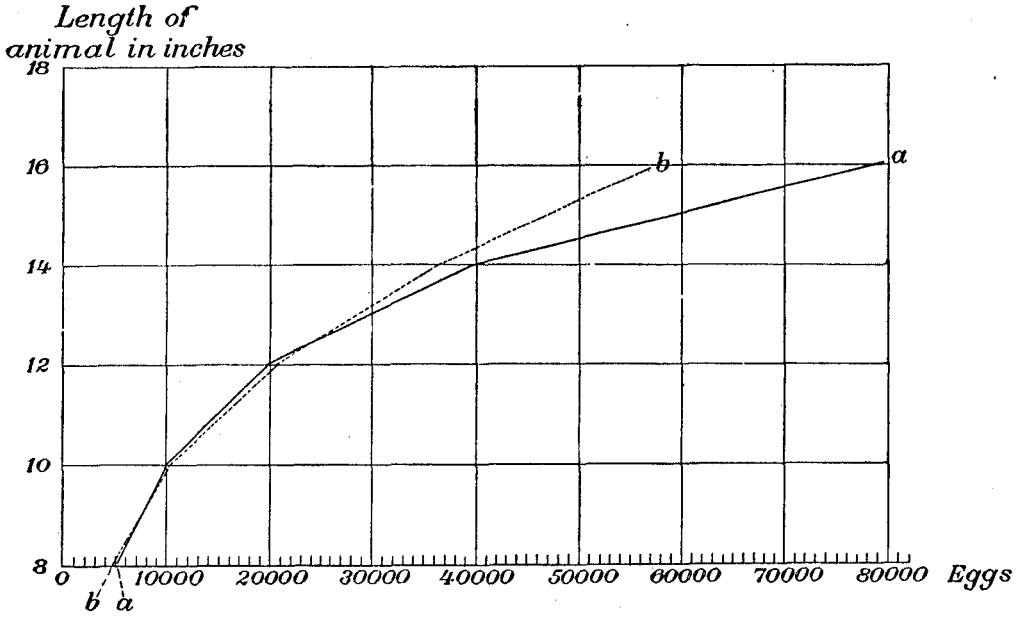
[1] This excess will probably about offset the slight loss of eggs which must always occur. The numbers given in table 15 do not therefore require correction on this account.

In casting the eye down the column of averages[1] in table 15, we are immediately struck by the fact that a 10-inch lobster bears about twice as many eggs as one 8 inches long, and that a 12-inch lobster has double the number borne by one which measures 10 inches.

It is therefore suggested that in the early years of sexual vigor there is a general law of fecundity or production which may be formulated in this way: *The numbers of eggs produced by female lobsters at each reproductive period vary in a geometrical series, while the lengths of the lobsters producing these eggs vary in an arithmetical series.* It is safe to assume that the avearge number of eggs laid by a lobster 8 inches long is not above 5,000. If such a law prevails we would have the following:

Terms.	(1)	(2)	(3)	(4)	(5)	(6)
Series of lengths in inches..	8	10	12	14	16	18
Series of eggs	5,000	10,000	20,000	40,000	80,000	160,000

An examination of table 15 shows how closely the first four terms of this series are represented in nature, and that when the 14 to 16 inch limit is reached, there is a decline in sexual vigor. Yet the largest number of eggs recorded for lobsters of



CUT 1.—*Curve of fecundity of the lobster.*

1 division on ordinate corresponds to 2 inches in length of lobster. 1 smaller division on abscissa represents 1,000 eggs.
aa, curve deduced from law of production as theoretically stated.
bb, curve of fecundity deduced from observations recorded in table 15, for lobsters 8, 10, 12, 14, and 16 inches long.

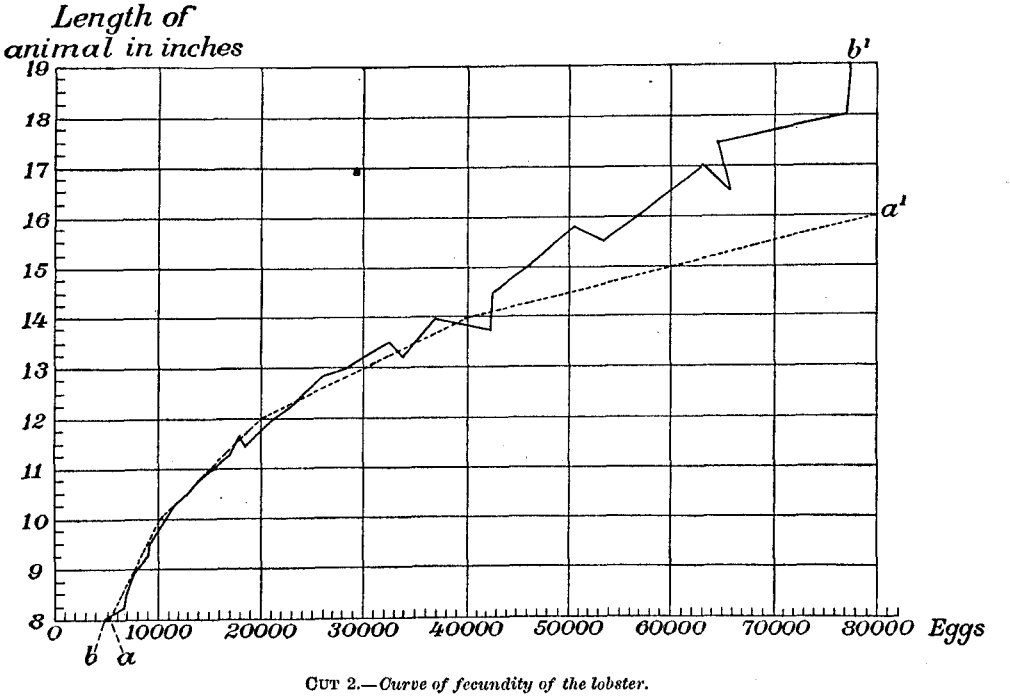
this size shows that there is a tendency to maintain this high standard of production even at an advanced stage of sexual life.

[1] It is a conspicuous fact that in the fifth column of table 15 the largest numbers refer to individuals whose length is expressed in even inches or half inches. This is of course the result of inaccuracy in taking measurements: the quarters have been somewhat neglected.

A graphic representation of the fecundity of the lobster tells more forcibly than words or figures can how closely it is in conformity with the law just enunciated. If a curve is constructed in accordance with the latter, we obtain, as in cut 1, the curve *aa*, which is the wing of a parabola. Neglecting for the present all data in table 15 but those corresponding to the arithmetical series of lengths, 8, 10, 12, 14, 16 inches, we obtain the curve of fecundity represented by the dotted line *bb*, cut 1. This curve is parabolic and follows the curve *aa* with remarkable uniformity up to the region of the fourth term, where the ratio of production is distinctly lessened. This becomes still more marked in the fifth and sixth terms.

In cut 2 the details of the curve *bb* are given, including all the data of the table. We see in the line bb^1 the same remarkable conformity to the parabolic curve required by the law. Beyond the fourth term (length 14 inches) the irregularities in the curve become greatest, owing to the small number of individuals represented.

I believe the law above formulated expresses the propagative powers of the lobster during the height of its sexual activity, although it must not be supposed that the latter conforms uniformly to any arithmetical standard.



CUT 2.—*Curve of fecundity of the lobster.*

4 smaller divisions on ordinate correspond to 1 inch in length of lobster. 1 smaller division on abscissa represents 1,000 eggs.

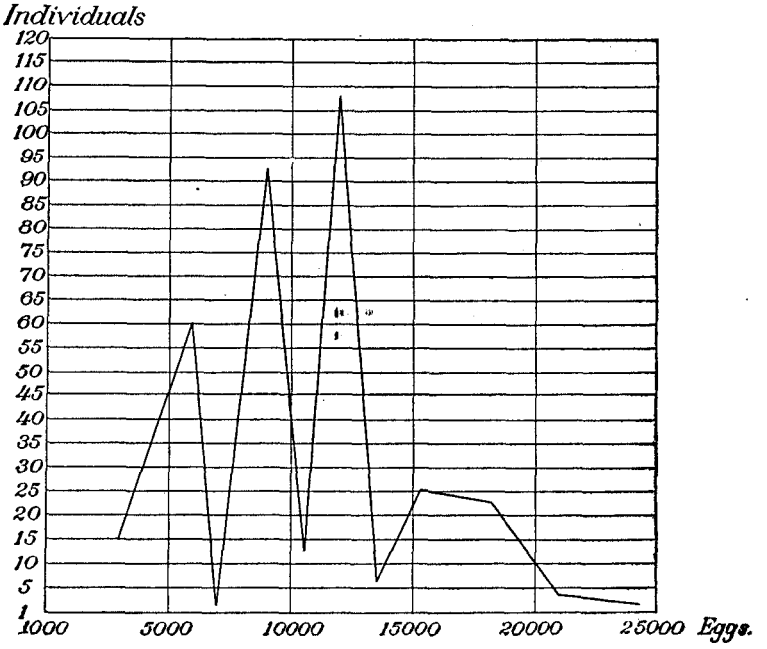
aa^1, curve deduced from law of production as theoretically stated.

bb^1, curve of fecundity deduced from all the data contained in table 15, or from number of eggs produced by 4,645 lobsters.

After the lobster has reached a certain age, determined by its early or late sexual maturity, its reproductive energy tends to decline, as is the case with the higher animals, and the ratio of increase, maintained at an earlier period, begins to fall. Whether the highest point of production is ever reached at 14 or 16 inches it is

difficult to say, and whether the sexual decline is gradual or not it is impossible to decide from the data at hand. In this connection, however, it is interesting to recall the fact that the male lobster attains greater size than the female. The large lobsters, weighing upward of 20 pounds and measuring upward of 20 inches in length, are invariably males, so far as my observation extends.

The largest egg-bearing lobsters of which I have any record were taken 15 miles southwest of No Man's Land, June 9, 1894, and examined by Vinal N. Edwards. One 19 inches long, carried 91,350 eggs, which weighed 15 ounces; another, 16 inches in length, bore 97,440 eggs, which measured 16 fluid ounces and weighed nearly a pound. Mr. Edwards said that the mass of eggs was in these cases so great that the animals were unable to completely fold their "tails." (See p. 34.) A lobster with external eggs was taken at Green Island, Maine, in November, 1892, which, according to Mr. F. W. Collins, weighed 18½ pounds.



CUT 3.—*Curve showing the relative fecundity of 352 lobsters, each 10 inches long.*

Number of individuals laid off on ordinate.
Number of eggs laid off on abscissa.

The No Man's Land lobsters seemed to carry rather more eggs than those of the same length captured elsewhere. Thus 234 lobsters, 13 inches long, from No Man's Land produced on the average 29,526 eggs (extremes 6,090–48,720), while for 79 lobsters caught elsewhere the average production was 26,518 (extremes as above). The small number examined in the last instance shows, however, that the comparison has little or no value.

The variation in the number of eggs borne by lobsters of the same length is often very great, and is as marked in large as in small individuals. Thus in 152 cases the average production of 10½-inch lobsters was about 11,000 eggs (the average in 532 cases, table 15, is nearly 13,000); 32 per cent of this number bore from 12,000 to 13,000

eggs; 15 per cent carried from 15,000 to 16,000; 6 per cent had 18,000 to 19,000; one individual carried upward of 21,000, while 4.6 per cent bore only 3,000 to 4,000. This is further illustrated by cut 3, which shows the variation in fecundity of 352 lobsters each 10 inches long. In this case 26 per cent laid 9,000 eggs, 30 per cent 12,000, not quite 1 per cent 18,000. The curve drops and keeps well down after the 12,000 limit is reached, which possibly implies a loss of eggs in those lobsters having more than the average number.

TABLE 16.—*Production of eggs by volume.*

Length of lobster.	Smallest number of fluid ounces.	Largest number of fluid ounces.	Average number of fluid ounces.	Number of lobsters examined.	Length of lobster.	Smallest number of fluid ounces.	Largest number of fluid ounces.	Average number of fluid ounces.	Number of lobsters examined.
8 inches.....	½	1½	.78	6	13 inches.....	1	8	4.70	321
8½ inches.....	1	1½	1.12	2	13½ inches.....	4	8	5.50	5
8½ inches.....	½	2	1.14	9	13½ inches.....	1	9	5.39	146
8¾ inches	1	1½	1.17	3	13¾ inches.....	7	7	7.00	2
9 inches.....	½	3	1.30	143	14 inches.....	1	14	6.07	426
9¼ inches.....	1	2	1.50	35	14½ inches.....	3½	10	7.05	90
9½ inches.....	½	3¼	1.53	241	15 inches.....	2	16	7.64	280
9¾ inches.....	½	2½	1.63	55	15¼ inches.....	.....	.....	9.00	1
10 inches.....	½	4	1.73	514	15½ inches.....	4	16	8.83	45
10¼ inches.....	1	3¾	1.91	61	15¾ inches.....	8	9	8.41	3
10½ inches.....	½	6	2.12	532	16 inches.....	4	16	9.38	103
10¾ inches.....	1	4	2.31	45	16½ inches.....	.....	.....	11.00	1
11 inches.....	½	8	2.53	568	16⅝ inches.....	6	14	10.85	13
11¼ inches.....	1	4½	2.79	43	17 inches.....	2	14	10.40	30
11½ inches.....	½	7	3.06	307	17½ inches.....	10	12	10.67	3
11¾ inches.....	2	4	2.95	11	18 inches.....	10	15	12.71	7
12 inches.....	½	9	3.51	414	19 inches.....	9	15	12.75	4
12¼ inches.....	3	4½	3.84	8					
12½ inches.....	1½	7	4.07	156	Total number examined.....				4,645
12¾ inches.....	3	7	4.34	12					

The data collected in table 16 will show in still another way the variation in the quantity of eggs produced by lobsters of different sizes. The average weight of a 10½-inch female lobster with eggs is 1¾ pounds (table 31), the eggs weighing about 2 ounces. A 15-inch lobster which weighs upward of 4 pounds (table 31), sometimes carries a burden of a pound of eggs. As already remarked, a fluid ounce of fresh eggs weighs about 1 ounce avoirdupois.

PERIOD OF INCUBATION AT WOODS HOLE AND RATE OF DEVELOPMENT.

The freshly laid eggs are somewhat irregular in shape, but soon plump out and become nearly spherical. Some, however, have the form of elongated spheroids (plate 17, fig. 24). They measure approximately $\frac{1}{16}$ inch in diameter, or 1.5 to 1.7 mm. In color they are dark olive-green,[1] sometimes almost black, hence the use of the term "black egg-lobster," common among fishermen, to distinguish the "new egg-lobster" from the "old" or the "light egg-lobster," in which the dark-green food yolk has been more or less absorbed by the growing embryo. In England the female lobster with external eggs is spoken of as being "in berry," or is sometimes called a "berried hen."

The rate of development of the summer eggs at Woods Hole is illustrated by tables 17 and 18, and by cuts 23–38 (plates G to J).

[1] For variation in the color of the egg, see p. 137, and plate 17, figs. 23 and 24.

TABLE 17.—*The rate of development of the embryo at Woods Hole.*

No.	Day.	Hour.	Temperature of water.	Age of egg.	Stage of development.	Remarks.
	1890.		°F.	*Hours.*		
1 (1)	July 30	1.45 p. m.	72	8 (?)	Yolk unsegmented....	2 to 4 cells present.
1 (2)	...do ...	6.00 p. m.	72	12¼	.....do	
1 (3)	...do	10.00 p. m.	72	16½	.....do	
1 (4)	July 31	10.00 a. m.	72	28½	Segmentation of yolk.	Few eggs only, with yolk unsegmented.
1 (5)	...do	2.00 p. m.	72	32¾	.....do	Very few eggs still with yolk unsegmented.
1 (6)	...do	6.00 p. m.	72	36¾	.....do	Several stages of yolk segmentation, some eggs with about 30 segments; others with very small and numerous cells; in a few eggs yolk still unsegmented.
1 (7)	Aug. 1	9.30 a. m.	72	51¾	.....do	Majority of eggs with at least 160 segments; some with irregular segmentation; some with yolk non-segmented.
1 (8)	Aug. 2	12.00 m.	72	77¾	.....do	Majority of eggs with periphered layer of very small cells; rarely an egg with unsegmented yolk.
1 (9)	Aug. 3	11.00 a. m.	72	100¾	Invagination	Majority of eggs in this stage.
	1889.					
2 (1)	July 11	5.30 p. m.	68	.....	Segmentation of yolk.	Late stage, about equivalent to 1 (7) above; *cells not quite superficial.*
2 (2)	July 12	9.30 a. m.	68	16 +	.....do	Protoplasm generally at surface, and cells most numerous on one side of egg.
2 (3)	July 13	1.00 p. m.	69	43½ +	Invagination	
2 (4)	July 14	5.45 p. m.	69	72½ +	.....do	Pit at surface.
2 (5)	July 18	9.50 a. m.	68	160½ +	.....do	Depression on surface very marked.
2 (6)	July 19	12.20 p. m.	68	174¾ +	.....do	Nauplius embryo not yet outlined.

TABLE 18.—*Rate of development of the embryo at Woods Hole.*

No.	Day.	Hour.	Temperature of water.	Age of egg.		Stage of development.	Remarks.
	1890.		°F.	*Days.*	*Hrs.*		
3 (1)	July 9	3.45 p. m.	71	8	3 (?)	Invagination	Pit at surface very conspicuous. See cut 25.
3 (2)	July 11	12.45 p. m.	69	10		Egg-nauplius	In some eggs, second antennæ not budded.
3 (3)	July 15	10.30 a. m.	69	14	2¼	.....do	*Second antennæ* bifid; thoracic abdominal fold formed. See cut 31.
3 (4)	July 17	12 m.	70	16	3¾	.....do	Late egg-nauplius. See cut 32.
3 (5)	July 22	12 m.	70	21	3¾	Post-nauplius	4 to 5 pairs of post-mandibular appendages; tip of "tail" conspicuously forked; optic disks lobular. Cut 34.
3 (6)	...do	10.30 a. m.	69	24	2¼	.....	Optic lobes very large; telson overlaps brain; 6 or 7 pairs of post-mandibular appendages; antennæ and telson tipped with rudimentary setæ.
3 (7)	July 27	.....	70	26	2¼	.....	Telson reaches base of optic lobes.
3 (8)	July 29	5 p. m.	71	28	8¾	.....	*Eye pigment present for about 24 hours.* Cut 35.
3 (9)	Aug. 3	10.30 a. m.	72	33	2½	.....	Eye-spots crescentic or semicircular; telson overlaps bases of optic lobes.
3 (10)	Aug. 12	12.30 p. m.	72	42	16¼	.....	Eye-spots oval; telson considerably behind optic lobes.
3 (11)	Sept. 1	.....	.....	61		.....	See drawing, cut 36.
3 (12)	Oct. 1	.....	.....	91		.....	
3 (13)	Nov. 1	.....	.....	122		.....	See drawing, cut 37.
3 (14)	Dec. 1	.....	.....	152		.....	
	1891.						
3 (15)	Jan. 1	.....	.....	183		.....	
3 (16)	Feb. 1	.....	.....	211		.....	See drawing, cut 38.
3 (17)	Mar. 1	.....	.....	242		.....	
3 (18)	Apr. 1	.....	.....	273		.....	
3 (19)	May 1	.....	.....	303		.....	
3 (20)	June 1	.....	.....	334		.....	Larvæ hatching out.

The lobster (No. 3, table 18) which laid eggs about July 1, 1890, was kept under observation at the Fish Commission station at Woods Hole for a period of 11 months or 334 days, until June, 1891, when, as we see, the eggs had begun to hatch. Under natural conditions the period of incubation of the summer eggs at Woods Hole is nearer 10 months—(from July 16th–August 15 to May 15–June 15).

The very fresh eggs can be usually detected by examination with a hand lens. The transparent egg capsule closely invests the yolk, which then presents a uniform, finely granular texture. The external segmentation of the yolk follows in twenty to twenty-five hours after oviposition, and the large yolk-segments can be easily distinguished by the naked eye. At the close of this process, or after the invagination has begun, the living egg, when examined with a low power, resembles the fresh egg, excepting that the yolk has now a coarser and more irregular texture. The embryo is distinctly marked off in the egg-nauplius stage in about ten days, and when from twenty-six to twenty-eight days old the eye pigment can be seen at the surface.

THE HATCHING OF THE EGGS.

THE HATCHING OF LOBSTERS AT WOODS HOLE.

We have seen that the period of incubation or fosterage lasts from ten to eleven months in the case of the summer eggs. As yet nothing is known about the hatching of the fall and winter eggs. The bulk of the eggs which are taken for the Woods Hole hatchery complete their development in the McDonald jars in June, as shown in the following table:

TABLE 19.—*Time of collection and hatching of the eggs of the lobster at the United States Fish Commission station, Woods Hole, Massachusetts; compiled from records of the station.*

Time of collection of the eggs.	Hatching begun.	Hatching ended.	Time of hatching of majority of eggs.
1890. Apr. 16 to June 13; majority taken in May.	May 17	June 23	June.
1891. Apr. 28 to June 29	May 25 (eggs taken Apr. 28)	June 15	June.
1891–1892. Dec. 1, 1891, to Apr. 28, 1892	May 30 (eggs taken Apr. 25)	June 29	June.
1893. Apr. 19 to June 26	June 15	July 15	June 15 to 30.

These results agree with what takes place in nature when the lobster is permitted to keep her eggs for the full time. The eggs from several lobsters are usually placed in a single jar, and the jars are replenished while the hatching goes on.[1] The dates in the second and third columns of table 19 therefore indicate the general range of the hatching period, not that of the hatching of a single brood.

Lobsters with light eggs, or eggs of the previous summer, were last caught in Vineyard Sound and vicinity in the summers of 1890 to 1893, at the following dates:

1890, July 9. One female lobster taken in Woods Hole Harbor with eggs hatching; several hundred eggs not yet hatched.

1891, July 16. Six female lobsters, with nine-tenths of the eggs hatched, taken at Menemsha. On July 11 a lobster was taken at that place with eggs in process of hatching, and on June 30 two lobsters with old eggs were caught in Woods Hole Harbor. In one of these the eggs had begun to hatch; in the eggs of the other there was still considerable unabsorbed yolk.

1892, June 28. Four lobsters with old eggs were taken.

1893, June 30. No lobsters with old eggs were taken at Menemsha after June 30. At this time they had in the past few days obtained 16 lobsters with old eggs, and in half of these the eggs had meantime hatched.

1894, July 14. A lobster was brought from Menemsha, having been caught some time before, with eggs about four-fifths hatched out.

[1] The temperature of the water in the hatching jars in summer is about one degree higher than that of the water outside.

The last lobsters with light eggs were taken by the Gay Head lobstermen in 1890, July 7. This was also the date of the capture, at that point, of the first lobster with new eggs.

The time occupied by the hatching of a single brood was upward of a week, in the following case: On June 30, 1891, a lobster with old eggs, taken in Woods Hole Harbor, was stripped, and the spawn was placed in a "McDonald" jar. On July 3 one larva had appeared; by July 5 a dozen larvæ had been hatched; on the 13th of the month hatching was still progressing slowly, and some of the young had molted and were in the second stage.

In another lobster taken at Menemsha, July 11, 1891, with young just hatching out, the eggs, treated in the same way, were nearly all hatched in one week's time. On July 12 a large number of the first larvæ were swimming about the jar, and on July 18 the eggs were mostly hatched and many of the young were in the second larval stage.

In July and August, 1892, Mr. A. P. Greenleaf placed 300 egg-lobsters from Nova Scotia with newly laid eggs in one of the lobster pounds at Southport, Maine. In April, 1893, he seined, and found the females still bearing eggs. He seined the pond again in June, when it was evident that the larger part of the eggs had hatched.

Mr. Thomas Garrett, who began to fish for lobsters in the Vinal Haven Islands over forty years ago, caught in July a large, old egg-lobster, which weighed about 6 pounds, in the "Basin" near the present lobster park. He returned it to the water, caught it a second time, liberated it again, and about the 1st of August caught it for the third time, when the eggs had all hatched out

THE DISPERSAL OF THE YOUNG.

With the hatching of the young the period of fosterage comes to an end.[1] By the fanning movements of her swimmerets the young are driven away from the body of the mother as soon as the egg-membranes have burst and are immediately dispersed; thenceforth they lead a free and independent existence.

The hatching of the eggs of the lobster has been often witnessed by smackmen and keepers of lobster pounds. In May, June, and July "the surface of the water in the wells of the smacks often becomes perfectly alive with the young, and they may be

[1] Nothing very definite seems to be known about the ovulation and hatching of the young in the European lobster, *Astacus gammarus*. Rathke's observations in 1840 did not settle the question (see p. 167), and Sars's paper (*175*), published over thirty years later, left it still in doubt. Sars says that "the reproduction of the lobster does not appear, as is generally held, to be confined to any definite period of the year, yet the young are mostly hatched in summer. It is not unusual, however, to find the lobster with external eggs at other times of the year." Mayer (*138*) remarks that there is no definite breeding season, but that Homarus (*Astacus gammarus*) and Palinurus extrude their eggs mostly in November and December. These conflicting statements show that the European lobster carries her external eggs for a long period, and I have no doubt that when this subject is carefully investigated it will be found that the breeding habits of *Astacus gammarus* are very similar to those of the American species.

When this work was in press and after the preceding note was written I received Dr. Ehrenbaum's paper, to which I have already referred (*61*). He says that the eggs are laid and the young are hatched from about the middle of July to the middle of September. In one of two cases observed the eggs were laid August 1, 1893, and the first larvæ hatched July 20, 1894; in the other, the eggs were extruded August 28, 1893, and the larvæ hatched July 21, 1894. The period of incubation is thus about 11 months, as in the American form, and the times of the laying and hatching of the eggs in the two species very nearly agree.

scooped up by the hundreds of thousands," and, as Rathbun says (*158*, p. 32), "a sort of transplanting of young lobsters has been going on along the New England coast, and especially the southern portion of it, ever since the well-smack lobster trade began." As the vessels sail along, the newly hatched lobsters "work out through the holes in the bottom of the well, and are thus constantly adding to the supply of the regions through which the smacks pass."

Peter Kalm relates in his Travels, under date of October, 1748, the following interesting anecdote of the transplanting of lobsters around New York by the New England fishing boats, which it seems carried wells:

> Lobsters are likewise plentifully caught hereabouts, pickled much in the same way as oysters, and sent to several places. I was told a very remarkable circumstance about these lobsters, and I have afterwards frequently heard it mentioned. The coast of New York had already European inhabitants for a considerable time, yet no lobsters were to be met with on that coast; and though the people fished ever so often, they could never find any signs of lobsters being in this part of the sea. They were, therefore, continually brought in great well boats from New England, where they are plentiful; but it happened that one of these well boats broke in pieces near Hell Gate, about 10 English miles from New York, and all the lobsters in it got off. Since that time they have so multiplied in this part of the sea that they are now caught in the greatest abundance. (*108*, vol. 1, pp. 240–241.)

It is well known that the crayfish protects her young after they are hatched and carries them about under her tail, as Roesel so well described over a hundred years ago. He says:

> If the mother of these little crayfish, after they begin to stir about, becomes quiet with her food at any time, or for some other reason sits still, they begin to move away from her somewhat and to crawl about her, but if they spy out the slightest danger, or there is any unusual movement in the water, it seems as if the mother called them back by a signal, for they all at once quickly return under her tail and gather into a cluster again, and the mother hurries off with them to a place of safety as fast as she can. After a few days, however, they gradually leave her. (*169*, p. 336.)

Huxley was the first to observe that the ends of the forceps or large claws of the young crayfish are bent into "abruptly incurved hooks," by means of which the young cling to the mother. He says:

> Immediately after the young are set free, they must instinctively bury the ends of their forceps in the hardened egg glue which is smeared over the swimmerets, for they are all found to be holding on in this manner. They exhibit very little movement, and they bear rough shaking or handling without becoming detached, in consequence, I suppose, of the interlocking of the hooked ends of the chelæ embedded in the egg glue. Even after the female has been plunged into alcohol the young remain attached. I have had a female, with young affixed in this manner, under observation for five days, but none of them showed any signs of detaching themselves; and I am inclined to think that they are set free only at the first molt. After this it would appear that the adhesion to the parent is only temporary. (*103*, pp. 43–44.)

The young lobster has no organs for attaching itself to the mother. Its large claws do not end in sharp hooks (fig. 33, plate 20), as in the crayfish, and when once set free, it never again finds shelter under the body of the parent. I have noticed that the young of *Pontonia domestica* (a delicate West Indian prawn, which lives as a commensal in the shell of the Pinna), when hatched in an aquarium, usually keep together in a ball or cluster, like a swarm of gnats, a habit which is doubtless shared by many of the prawns, but they never seek protection from the mother, who lives in the mantle chamber of the mollusk. Young lobsters which are hatched and kept in the aquarium swarm up to the surface or go to the bottom of the jar when closely confined, but if given greater liberty they tend to scatter. A swarming or gregarious habit would be fatal to this species, on account of its inborn pugnacity and cannibalism.

Bell (*14*, pp. 248–249) has given the following account, furnished him by Mr. Peach, of the way in which lobsters were supposed by fishermen to protect their young. Hardly a word of it is true, but it is a good example of the pseudo-scientific literature to which I have referred, and on this account is worth quoting:

> I have heard the fishermen of Goram Haven say that they have seen in the summer, *frequently*, the old lobsters with their young ones around them. Some of the young have been noticed *six inches long*. One man noticed the old lobster with her head peeping from under a rock, the young ones playing around her: she appeared to rattle her claws on the approach of the fisherman, and herself and young took shelter under the rock; this rattling, no doubt, was to give the alarm. I have heard this from several, some very old men, who all speak to this *without concert*, and as a matter of course; and they are men I can readily believe.

Young lobsters 6 inches long hardly require protection; smaller ones (an inch long) are rarely seen by fishermen, and old and young separate as soon as the latter are hatched.

The writer of a popular magazine article, in quoting a fisherman, thus speaks of the habits of young lobsters:

> The mother is often seen surrounded by baby lobsters a few inches in length, who take refuge under her tail in case of danger. (The Lobster at Home, by William R. Bishop, Scribner's Monthly, vol. XXII, 1881, p. 212.)

Erdl (*62*) says of the green crab (*Carcinus mœnas*), that it often appears to play with small, round stones and with empty snail shells, just as cats play with balls. ("Manchmal scheint mit kleinen runden steinen, mit leeren Schneckenhäusen wie die Katzen mit den kugeln zu spielen.") Here, doubtless, the writer was misled by his imagination: in the former instance we have a popular error which seems to have crossed the Atlantic Ocean with emigrants to the New World.

Of the hatching of the eggs of the European lobster, which were thought to be laid in the sand by some of the older naturalists (see p. 36), Travis (*191*) curiously remarks:

> Though the ova are cast at all times of the year, they seem only to come to life during the warm summer months of July and August. Great numbers of them may then be found, under the appearance of tadpoles, swimming about the little pools left by the tides among the rocks, and many also under their proper form, from half an inch to 4 inches in length.

VARIATIONS IN THE TIME OF HATCHING.

According to Mr. Nielsen, the hatching period of the lobster in Newfoundland begins about the first week in July and continues until the 15th or 20th of August, the majority of the eggs hatching from the 15th or 20th of July to the 20th of August. It is thus from three to six weeks later than at Woods Hole, which is what we might expect from the difference in the temperature of the ocean at these points. It is not yet known to what extent the time of hatching and period of embryonic development varies from the normal course at the most divergent points on the coast; but it would not be surprising if young were hatched at almost any time from late summer until spring, owing to the irregularity in the production of eggs already pointed out.

Mr. Nielsen hatched a number of lobsters in floating incubators during November in Newfoundland, and Mr. Rathbun (*158*) gives the following account of the hatching of some lobsters at the Woods Hole station by Capt. H. C. Chester, in November, 1885:

> The eggs were detached from the lobster and placed in the "McDonald" jar November 5. They began to hatch November 8, three days afterwards, and continued hatching for a few days longer, but

only about 50 young ones were observed. The remainder of the eggs are still in jars in good condition. A few of the embryos were transferred to an aquarium with running water, and others to a small vessel in which there was no change of water. The former lived about 24 hours, the latter about 36 hours. The temperature of the water in the hatching jar November 5 was 54.3° F.; on the 6th, 55°; and on the 7th and 8th, 56°. * * * The conditions under which the eggs were kept were perfectly normal, the water being of about the same temperature as that of the harbor outside.

I have learned of another very interesting case of the artificial hatching of the eggs of the lobster out of the regular season. This happened during the latter part of January and the first ten days of February, 1889, at the hatchery of the United States Fish Commission at Ten Pound Island, Gloucester, Massachusetts. Mr. E. M. Robinson, to whom I am indebted for these facts, was at that time superintendent of the station. He says that the eggs were clipped from the lobster at about Christmas time, and suspended in aquaria through which sea water was constantly running. The temperature of the water was very low, at least as low as 36° F., and as many as 10,000 lobsters were hatched under these conditions.

Mr. Nielsen, who visited the station at that time, corroborates this account, so far as the actual hatching of young lobsters is concerned. He writes that he examined with the microscope a young lobster which had been hatched on the day of his visit. The larva had perished in breaking out of the egg and in passing its first molt, but was perfectly developed in every way.

These facts clearly show that the hatching period varies in the same way that the time of egg-laying varies. The one must be correlated with the other.

William H. Wheildon gives some interesting facts about the lobster in a short paper published in 1875 (*202*), already referred to. He says:

> In February of the present year we exhibited spawn in several stages of development from newly laid eggs to the swimming larvæ.

The fact that the lobsters are with eggs in every month of the year, and that young sometimes make their appearance in winter and fall, does not prove, however, as this writer, like so many others, inferred, that the animal has no particular breeding season, but from these facts alone it would never have been possible to have arrived at a clear understanding of the reproductive habits. To the circumstance that egg-lobsters are taken at all seasons and often with eggs in very different stages of development is due, more than to anything else, the confusion which had settled down upon this most important phase in the life-history of this animal.

In the case of the lobsters hatched at Woods Hole in early November, 1885, the eggs were probably laid in the late winter or spring of the same year. I have the record of a lobster which had in all probability spawned as early as June 20 (table 3, No. 2). Supposing these ova to have been extruded by the first week in June, they would have had five months, including the warmest period of the year, for their development. For five months, from the first of December to the first of May, the eggs are subjected under natural conditions to a relatively low temperature, and their development is greatly retarded. Consequently a batch of eggs which is extruded at the first or middle of August and hatched in May or June following is not, in all probability, subjected to a greater number of heat units than eggs which are laid in June and hatched in November. The embryos grow very slowly during the winter months, but the advancement may be sufficient, when development has already proceeded far enough in the fall, to bring the embryo to the point of hatching under favorable circumstances in winter.

DESTRUCTION OF THE EGG-LOBSTER AND ITS SPAWN.

The berried lobster has many enemies, of which man is the chief, but if we except the latter, she seems to avoid them with remarkable skill. At least it is true that during the long period in which the ova are carried the losses are relatively slight. You detect but rarely a bad egg in the whole lot, and when, after ten months, the mother's fostering care is about to end, one is surprised to see how healthy every egg appears and how few seem to have been torn off. I have found that lobsters will scratch off and devour their own eggs when confined in aquaria; and we often see the spider crab (*Libinia canaliculata*) industriously picking off its eggs, as if for its own amusement, when it seems to have no lack of other food. The eel has a decided partiality for the eggs of the lobster, but the cautious way in which she keeps her tail folded up when crawling over the bottom, and the lightning-like speed with which she can dart about when disturbed, must often circumvent her most wily adversary. On July 5, 1890, I placed three egg-lobsters, from which I wished to obtain embryos in progressive stages of development, in a small floating car. One of these was a large perfect female, a second was a small perfect female, and a third was disabled by the loss of its claws. The next morning I found that the smaller female lobster had been killed and eaten. The large one had cut its body in two, at the junction of the "back" and "tail," and eels had eaten out the flesh and picked off nearly every egg, only two or three being left. I afterwards found that lobsters kept in a similar way were liable to lose their eggs while still active, and the aggressor was undoubtedly the eel.

Fishermen have maintained (*28*, p. 11) that egg-lobsters, if put together, devour each other's eggs, but this is not true. At least I am certain that this never occurs unless the lobster is first killed by its companions.

At Small Point, Maine, "berry" lobsters used to be considered the best kind of bait for certain fish. The "tail" of the lobster was cut off, a part of the upper shell removed, and the eggs left clinging to the under side. This practice was probably not confined to a single locality.

The pernicious destruction of the egg or spawn-lobsters is wisely prohibited in most of the States, and it is to be regretted that an attempt to enforce such a law has not been made in the Maritime Provinces and in Europe. This should certainly be done even if the law is often evaded, owing to the ease with which the eggs can be scraped off with a mitten or brush.

Ignorance of the fact that the lobster carries her eggs for a long period has been an element of confusion in the establishment of close seasons. Thus in Connecticut the law of 1878 forbade the destruction of females with spawn from July 1 to July 15. In Massachusetts, in 1880, the sale of females with eggs was prohibited during July. In 1883 the Maine legislature made a close time for egg-bearing females from April 1 to August 1; this was changed in 1885 to from October 1 to August 15. In both Maine and Massachusetts it is now, as it should be, illegal to take spawn-lobsters at any time.

The destruction of the spawn of lobsters is a terrible waste of life, and this is of itself sufficient reason for the adoption of any measure which may tend to lessen the evil. In certain parts of England lobsters in berry have been considered as in the very best condition for eating, and the eggs are highly prized for salad. On this account and because it was thought too great a hardship to compel the fishermen to throw back the "berried hens," the commissioners were not inclined to recommend

any legislation on this point. The following extracts from the testimony relating to this subject is interesting. A witness from London says (*28*):

There is a difficulty in throwing back the berried hens. They are generally worth twice as much as any other lobsters. The spawn is bruised and put into sauce, and makes better sauce than the lobster itself. In salads it is boiled, and sprinkled over the salad. It is a capital article of food. The spawning hens are of value to the cooks, who won't have lobsters without spawn. The sale of berried hens must not be prohibited, as it would be preventing the fishermen from taking the most fish. The production of the lobster is so enormous that if a gauge were fixed the taking of a few berried hens would make no appreciable difference. Berried hens are in the best possible condition as food. They form fresh spawn immediately after they have cast their spawn. If they have no spawn outside, they are full of red coral inside.

In his Report on the Fisheries of Norfolk, Buckland (*29*) says:

The lobster is never so good as when in the condition of a berried hen. Berried hens occur most frequently in April, May, and June. They begin to lose their berries about July, but still many berried hens occur in July. The use of the berries is almost entirely devoted to cooking; they are used in many preparations by the West End chefs, especially for coloring and enriching sauces. The "chefs" are also fond of coral out of the body of the lobster.

The evidence of a manager of a shellfish factory in the Haymarket is quoted as follows (*29*):

Mr. Sheppard, who boils lobsters for Scotts', at the top of the Haymarket, informs me that he has taken from one lobster (weighing 3 to 3½ pounds) 6 ounces of berries in the month of May. In August, out of 100 lobsters he would not be able to get 6 ounces of eggs from the whole. On the 5th of August he had 26 crabs, not one of which carried any spawn. In the month of May a great proportion of these 26 hen crabs would be full of spawn. The eggs from the berried hens are used for coloring various sauces; the berries are often mashed up in the sauce, a little anchovy added, and then it is called "lobster sauce." In order to supply these eggs for sauce to the cooks, Mr. Sheppard has collected in April and May from 14 to 18 pounds of lobster spawn. I find that there are 6,720 [eggs] in an ounce of lobster spawn. Here, then, we have destroyed eggs which might have represented, say, in 16 pounds of eggs, no less than 1,720,320 lobsters. A very good substitute for lobster spawn could be made by boiling logwood (!). He considers that all berried hens should be returned to the water all the year round.

The number of eggs borne by the female lobster is considered on pp. 50–55. A 15-inch lobster sometimes carries nearly 100,000 eggs, which weigh a pound.

The reasons urged by the commissioners for not indorsing the recommendation to prohibit the sale of berried lobsters are remarkable as examples of logic. Thus, they said "if it were illegal to take berried lobsters it would not pay the fishermen in many cases to pursue the lobster fishery. In the next place, the lobster, when berried, is in the very best possible condition for food; and it would be as illogical, therefore, to prohibit its capture as to prohibit the taking of full herrings." Furthermore, it is said that if the sale of berried lobsters were made illegal "the fishermen would probably remove the berries. The berries would no longer be seen in the market, but berried lobsters would be killed as much as ever." Berried lobsters are, it must be remembered, especially valuable; the berries are in great demand for sauce and for garnish for fish and salad." (*28*, p. XVI.) "Accordingly," says a writer in the Quarterly Review (*213*), "we must run the risk of exterminating a valuable animal to please our cooks."

Mr. Buckland says again, in his Report on the Fisheries of Norfolk:

There are, I regret to say, many difficulties in the way of preventing berried hens being destroyed, the principal one being that, unlike the salmon, lobsters when carrying eggs are at their very best for human food. Notwithstanding this, it must be evident that the destruction of so many lobsters in the form of eggs must of necessity greatly tend to produce that scarcity of lobsters which is now being felt in the London and other markets.

The concession to the cooks contained in the previous extracts is no more defensible than the idea that the lobster when in berry is necessarily at its best as an article of food. The reviewer just referred to, thus speaks upon the latter point:

> We were under the impression—a common one, we believe—that as the spawning season began to come on all the food eaten went chiefly to aid the growth of the innumerable eggs in the female or of the soft roe in the male.

Travis (*191*), writing in 1768 from Scarborough—a place which still abounds in lobsters—says:

> It is a common mistake that a berried hen is always in perfection for the table. When her berries appear large and brownish she will always be found exhausted, watery, and poor. * * * Cock lobsters are in general better than hens in winter.

It should be borne in mind that there is no organic connection between the external eggs, which are carried under the "tail," of the lobster, any more than there is between a plaster and the skin to which it is made to adhere by an adhesive substance.

The case of the berried lobster and of the roe-herring are not strictly analogous, since the lobster is carrying her eggs which have been extruded, perhaps months before, while the herring is yet in the active process of producing the spawn within the body.

One would suppose that the only time when the lobster could be compared as to the effects of spawning with fish like the salmon would be for a short period after the eggs were laid. But this is not exactly the case, and Travis was nearer right than his successors, when he maintained that the egg-lobster was an inferior article of food. The fact is that the egg-lobster is in poorer condition or weighs relatively less than the female of the same length without eggs. This point is illustrated more fully in another part of this work (see p. 119).

The lobster at the time of egg-laying is not in as poor condition, however, as the shotted herring or the salmon, which at this period is worthless as food, and the reason is plain. The ovary of the lobster ripens slowly during a period of at least two years, and the production and emission of the eggs is not so severe a drain upon its vitality as in the case of the fish. After the eggs have been laid for some time, the lobster gains in flesh; the ovary resumes its slow growth, but it is a year before the "coral" becomes very conspicuous. The testes, corresponding to the "soft roe" of fishes, are always very small, and produce sperm, not at a particular period, as is the case with many species of fish, but probably throughout the entire year. The time when the adult lobster is in the poorest condition for food is when the animal is getting ready to cast its shell, and for a few weeks after the molt while the new shell is still soft.

The destruction of a few hundred thousand eggs, or even a few millions, would have no appreciable effect upon the supply of lobsters at any point on the coast; but where the practice of taking lobsters with eggs is general throughout the range of the fishery, the total amount of ova or embryos which are thus killed is prodigious, and can not fail to lessen the number of adults.

PERIOD OF SEXUAL MATURITY.

To determine the size which is usually attained by the sexually mature lobster is of the first importance in studying the economy of this animal. If the female lobster is not allowed to reproduce at least once before she is caught and destroyed, a depletion of the fishery must inevitably result.

In some of the States and in the Maritime Provinces of Great Britain, where lobsters still abound, or were abundant in the past, protective laws have been enacted, prescribing a definite limit to the length of marketable lobsters. In Newfoundland this limit is set at 9 inches. (The Royal Gazette, May 27, 1893.) In Maine the limit is placed at 9 inches for the months of May and June, and 10½ inches for the remainder of the year.[1] In Massachusetts, New Hampshire, and New York the limit is fixed at 10½ inches; in Rhode Island at 10, and in Connecticut at 6 inches. It is thus evident that very uncertain and contrary opinions have been entertained in regard to the size which is reached by the sexually mature lobster. In order to settle this question upon the solid ground of anatomy, and at the same time work out a number of other problems relating to the reproductive organs, I made in the summer of 1890 a large number of dissections, and have embodied some of the results in table 20.

TABLE 20.—*General condition of the sexual organs, of the external and internal eggs, and of the shell in lobsters, chiefly females, ranging from 2 to 16 inches in length, in June, July, and August.*

No.	Sex.	Length.	Date of capture.	Locality.	Condition of sexual organs.	Condition of swimmerets.	Remarks.
		Inches.	1890.				
1	Female	10 1/16	June 28	Gay Head, rock bottom.	Ovary pea-green color; extends nearly to end of third abdominal segment.	With old eggs, now hatching.	Shell hard. Compare fig. 138, pl. 38.
2	...do....	11½	...do....	.....do.....	Ovary nearly ripe; extends to end of third abdominal segment.	.....	Oviducts not distended with eggs.
3	Male...	8 1/16	...do....	.....do.....	Ducts of testes charged with ripe sperm.	.....	
4–10	Female.	.....	...do....	.....do.....	Ovaries pea-green color. Compare fig. 138, pl 38.	All with old eggs, hatched this year.	The gluey threads still attached to the hairs of the swimmerets show conclusively that young have been hatched this season.
11–17	...do....	.....	...do....	.....do.....	Ovaries approaching maturity.	Clean.....	All about to extrude eggs this season. In one case eggs nearly ripe. Size of internal egg, 1.33 mm.
18–21	Male....	8 1/16	...do....	.....do.....	Testes filled with solid masses of ripe spermatozoa, which are surrounded by a gelatinous secretion.	.....	Spermatophores—or packages of sperm, wrapped in a gelatinous substance—can be pressed out of the ducts.
22	Female.	11¾	July 9	Menemsha, sand bottom.	Ovaries dirty, yellow color; very immature.	Clean.....	Apparent'y no young hatched this year. Probably never sexually mature.
23	.. do....	12	..do....	.....do.....	Ovaries dark green; nearly ripe.	.....do.....	Hard shell.
24	...do....	11	...do....	.....do.....	Ovaries immature; very light green.	.....do.....	Do.
25	...do....	10½	...do....	.....do.....	Ovaries dark green; like No. 23.	.....do.....	Do.
26	.. do....	10	. do....	.... do	Ovary straw color; very immature.	.....do.....	Animal not reached sexual maturity.

[1] The legislature amended this law in 1895, so that it is now illegal to destroy lobsters measuring less than 10½ inches in length at any time of the year.

TABLE 20.—*General condition of the sexual organs, of the external and internal eggs, etc.*—Continued.

No.	Sex.	Length.	Date of capture.	Locality.	Condition of sexual organs.	Condition of swimmerets.	Remarks.
		Inches.	1890.				
27	Female	11½	July 9	Menemsha, sand bottom.	Ovary nearly mature		Soft shell.
28	...do	10½	...do	...do	Ovary straw color; like No. 26.	Clean	Has probably molted this season.
29	...do	11½	...do	...do	Ovary very light green	Old eggs, hatched this year.	Do.
30	...do	10½	...do	...do	...do	Clean	Soft shell. Hatched young before molting.
31–32	...do	10⅝, 10⅜	...do	...do	...do	...do	Do.
33	...do	10	...do	...do		Gluey	Shell hard. Hatched young, but has not yet molted.
34	...do	9½	...do	...do	Ovary nearly ripe	Clean	Hard shell.
35	...do	10½	...do	...do	Ovary light green; immature.	Old eggs, just hatched.	Do.
36	...do	10½	...do	...do	Ovary straw color; very immature.	Clean	Fairly hard shell. Animal never sexually mature.
37	...do	11½	...do	...do	Ovary pea-green color	Old eggs, hatched this year.	Fairly hard shell.
38	...do	10⅜	...do	...do	Ovary light green; immature.	Clean	Soft shell; probably hatched old eggs and molted this season.
39	...do	16	July 22	Gay Head, rock bottom.	Ovary nearly ripe; extends to end of third abdominal segment.	...do	Hard shell. Ovary flecked with yellow spots, the remains of degenerated eggs belonging to last sexual period.
40	...do	15	...do	...do	Ovary pea-green color	Gluey; old eggs, hatched this year.	Hard shell. Degenerated old eggs in ovary and oviduct.
41	Male	10¾	...do	...do			Soft shell. Molted in car June 22.
42	Female	4 3/16	...do	...do	Ovary very small; opaque white.	Smooth	Hard shell.
43	Male	3⅜	...do	...do	Testes not found in gross dissection.		
44	...do	9¾	...do				See drawing of reproductive organs, fig. 120, pl. 36.
45	Female	7 5/16	...do	...do	Ovary light yellowish white; extends to middle of second abdominal segment.		Hard shell; immature. Ovarian lobe, 3 mm. in diameter.
46	...do	4¼	...do	...do	Ovary opaque white; extends into third abdominal segment.		Hard shell. Ovarian lobe 0.8 mm. in diameter.
47	...do	9 5/16	...do	...do	Ovary light flesh color; extends to end of third abdominal segment.		Hard shell.
48	...do	5⅞	...do	...do	Ovary opaque white; very immature; extends to end of third abdominal segment.		
49	...do	7⅜	...do	...do	...do		
50	...do	12⅝	July 29	...do	Ovary light greenish white, flecked with orange.	External eggs; embryos with eye pigment.	Hard shell. Degenerated old eggs in ovary and oviduct.
51	...do	15½	...do	...do	Ovary opaque whitish, with many mature unextruded eggs.	External eggs in late segmentation stage; laid about 3 days.	Oviducts filled up to external opening with ripe, unextruded eggs. For number of eggs see table 14.
52	...do	12	...do	...do	Ovary soft, jelly-like; opaque dirty-white color, flecked with yellow and orange.	External eggs in early segmentation; about 36 hours old.	Hard shell. A few unextruded eggs, with remains of degenerated ova of last sexual period. Figs. 134, 136, pl. 38, and fig. 139, pl. 39.
53	...do	11½	Aug. 11	...do	Ovary light pea green, flecked with yellow.	Smooth	Soft shell. Has probably hatched and molted this year.
54	...do	10 7/16	...do	...do	Ovary very light pea green. Ova very small.	...do	Soft shell. Has probably hatched external eggs and molted.

TABLE 20.—*General condition of the sexual organs, of the external and internal eggs, etc.*—Continued.

No.	Sex.	Length.	Date of capture.	Locality.	Condition of sexual organs.	Condition of swimmerets.	Remarks.
		Inches.	1890.				
55	Female	10¼	Aug. 11	Gay Head, rock bottom.	Ovary olive green; diameter of ovarian egg more than half of that of mature ovum.	Smooth	Soft shell. Probably has not hatched eggs this year; would probably have laid eggs for first time the next summer.
56	...do	12½	...do	...do	Ovary rather dark green, flecked with yellow; about half its size at maturity.	...do	Soft shell. Has probably hatched eggs and molted this season.
57	...do	10	...do	...do	Ovary light pea green; small.	...do	Shell fairly hard. Has possibly shed this season; may or may not have hatched external eggs.
58	...do	10¼	...do	...do	Ovary cream color; small.	Clean	Fairly hard shell. Animal not mature.
59	...do	9 15/16	...do	...do	...do		Do.
60	...do	10⅞	...do	...do	Ovary light pea green.	Clean	Soft shell. External eggs due in following year; not certain that young have been hatched this year.
61	...do	11¼	...do	...do	Ovary soft, grayish white.	With external eggs.	Soft shell.
62	...do	12 15/16	...do	...do	Ovary green; diameter about one-half inch.	Smooth, clean	Soft shell. Probably hatched brood this year.
63	...do	12½	...do	...do	Ovary soft, whitish	External eggs in egg-nauplius stage.	Shell fairly hard.
64	...do	12⅝	...do	...do	...do	External eggs; invagination stage.	Soft shell.
65	...do	11½	...do	...do	...do	...do	Hard shell.
66	...do	10	...do	...do	Ovary small; cream color.	Clean	Animal not mature.
67	...do	10	...do	...do	Ovary small; light orange yellow.	...do	Shell fairly hard.
68	...do	11¼	...do	...do	Ovary light pea green.	...do	Soft shell. May or may not have had young this year.
69	...do	9½	Aug. 14	...do		External eggs about 3 weeks old.	For number of eggs, see table 14.
70	...do	12 5/16	Aug. 19	...do	Ovary light pea-green color; very immature.	Clean	Shell very hard.
71	...do	12⅜	...do	...do	Ovary deep green; immature.	...do	Soft shell.
72–73	...do	11⅛, 10⅞	...do	...do	Ovaries flesh color; very immature.	...do	Have probably molted this season; never mature.
74	...do	10⅜	...do	...do	Ovary bright yellow	...do	Do.
75	...do	12	...do	...do	Ovary dark green; swollen, ripe, eggs flow out when ovary is cut; diameter of lobe, one-half inch.		Shell colors bright; has probably molted this season. Degenerated eggs of former sexual period present. Fig. 141, pl. 39.
76	...do	12 13/16	Aug. 21	...do	Ovary light green	External eggs in egg-nauplius stage.	Hard shell. Ova light green about nucleus. Figs. 150 and 151, pl. 41.
77	...do	10⅜	...do	...do	Ovary dark green, nearly ripe; largest ova, 1.3 mm. in diamter.		Hard shell. See drawing, fig. 123, pl. 36.
78	...do	11	...do	...do	Ovary nearly ripe	Clean	Shell moderately hard.
79	...do	10½	...do	...do	Ovary light pea green; diameter of ovum about one-third that of mature egg.	...do	Shell moderately hard; probably not mature.
80	...do	10¾	...do	...do	Ovary light yellow. Ov. lobe 7 mm. in diameter.	...do	Shell moderately hard; immature.
81	...do	11⅜	...do	...do	Ovary light pea green.	...do	Soft shell.
82	...do	10⅜	...do	...do	Ovary yellow	...do	Molted this season. Immature.
83	...do	9⅞	...do	...do	...do	...do	Shell hard.
84	...do	10¼	...do	...do	Ovary yellowish, small.	...do	Probably molted this season. Immature.
85	...do	10½	...do	...do	Ovary pea green	...do	Probably molted this year. May have had young.

TABLE 20.—*General condition of the sexual organs, of the external and internal eggs, etc.*—Continued.

No.	Sex.	Length.	Date of capture.	Locality.	Condition of sexual organs.	Condition of swimmerets.	Remarks.
		Inches.	1890.				
86	Female	11	Aug. 21	Gay Head, rock bottom.	Ovary cream color	Clean	Immature.
87	do	9⅜	do	do	Ovary light green, flecked with yellow (degenerating eggs) and white (young eggs).	External eggs about six weeks old, extruded about July 10.	Very hard shell. See drawing of ovary and ova, figs. 137 and 135, plate 38.
88	do	12	do	do	Ovary whitish, flecked with yellow spots, and dark green unextruded eggs.	External eggs in egg-nauplius stage, laid about August 6.	Soft shell.
89	do		do	do	do	do	Shell fairly hard.
90	do	10¼	do	do	Ovary same as in No. 87		Do.
			1891				
91	do	5⅝	July 22	Woods Hole Harbor.	Ovary white, 15mm. in diameter.		Hard shell.
92	do	7 1/16	do	do	Ovary whitish, with tinge of pink, 3 mm. in diameter.		Do.
93	do	7 15/16	July 24	do	Ovary white, about 3mm. in diameter.		Do.
94	do	9½	July 30	do	Ovaries nearly ripe; seminal receptacle charged with sperm.		Hard shell. For section of ovary, see fig. 140.
95	do	9½	July 30	do	Light green. Ova light yellowish green. No sperm in seminal receptacle.		Shell hard; to molt soon; eggs hatched this season. See drawing of ovary and ovum, figs. 138 and 133, pl. 38.
96	do	9¾	Aug. 4	do	Ovary nearly ripe. Female impregnated.		
97	do	12	Aug. 5	Menemsha	Ovary light pea green. Female impregnated.	Clean	
98	do	2 15/16	June 30	Woods Hole Harbor.	Ovary white; length 1⅛ in.; diameter 3/32 in.		Hard shell. See drawing of ovary, fig. 132, pl. 38.
99	do	2 7/16					
100	do	11¼	July 18	Menemsha		External eggs in late segmentation.	Eggs laid about July 25.

These results, with those given in table 15, show very clearly that on the coast of Massachusetts female lobsters become sexually mature and produce eggs for the first time when they have attained the length of from 8 to 12 inches. Very few lobsters under 9 inches in length have external eggs, while only few have attained the length of 10½ inches without having them. The limits of 9 and 10 inches, which have been variously adopted, are therefore too small, and should be increased if the lobster is to receive the benefit which is intended by this form of legislation. It is clearly illogical to protect the very small lobster and not to extend protection to the lobster which is about to spawn, in view of the natural increase of the species, since the latter has the greater chance of survival. It is highly probable that the majority of female lobsters 10½ inches long are sexually mature. It is possible that the limit is sometimes extended at both extremes and that very rarely a lobster produces eggs before it is 8 or even 7½ inches long or fails to produce them until it is over 12 inches in length. Out of over a thousand egg-bearing lobsters which have been examined at the Woods Hole station during the past four years there have been found only 20 lobsters measuring from 8 to 8¾ inches, or less than 2 per cent of the total number with external eggs. (For statistics of the majority of these, see table 15.) The hundred lobsters, the dissections of which are tabulated above, were not, however, taken at haphazard, but were selected in many cases to illustrate the development of the ovary and its growth between two successive sexual periods.

Culling from table 20 all lobsters 9 inches long and upward which are immature or have not as yet spawned, the record is as follows:

Number in table 20.	Length in inches.
47	$9\frac{5}{16}$
83	$9\frac{7}{16}$
59	$9\frac{15}{16}$
26, 66, 67	10
58, 84	$10\frac{1}{4}$
74, 82	$10\frac{3}{8}$
28, 36	$10\frac{1}{2}$
80	$10\frac{3}{4}$
73	$10\frac{7}{8}$
86	11
72	$11\frac{1}{2}$
22	$11\frac{3}{4}$

Total number, 17.

The following would have laid eggs during the current season—that is, they were within a few days or a few weeks of their first spawning:

Number in table 20.	Length in inches.
34, 94	$9\frac{1}{2}$
96	$9\frac{3}{4}$
77	$10\frac{3}{8}$
25	$10\frac{1}{2}$
78	11
27	$11\frac{1}{2}$
23	12

Total number, 8.

We thus find that 25 females, a large number out of the entire list, varying from $9\frac{5}{16}$ to 12 inches in length, had either never reached maturity or were mature for the first time. Of the 17 immature females, 6 are $10\frac{1}{2}$ inches or upward in length, and the ovaries in most cases would not have matured for at least two years. In order to be on the safe side I have purposely omitted from the enumeration all doubtful cases.

It may be asked, How can you be certain that a lobster has never spawned? The answer to this question is easily found by examining the ovary. If the surface or interior of the ovaries or their ducts are flecked with small yellow or yellowish orange spots, in however slight a degree (see fig. 136), it is an infallible sign that external eggs have already been carried. If these specks are examined under the microscope (fig. 150, plate 41), it will be seen that they are the remnants of old eggs which failed of extrusion at the last sexual period. At every such season of egg-laying there are always, as we have already seen, a few residual eggs, out of the thousands which are laid, which stick fast in the ovary or in its ducts, or for some cause are not driven outside of the body. These remain in the organs and undergo degeneration *in situ*. It is, perhaps, not surprising that traces of these eggs persist in the ovary for upward of two years without being completely absorbed, when it is remembered that the semi-fluid contents of the egg are surrounded by a tough bag of chitin, the primary egg membrane.

Another means of determining the sexual condition of the female, which, I consider to be also infallible, is the *color* of the ovaries. The ovary immediately after egg-laying

is always of an opaque grayish-white tint (plate 38, fig. 136). The ovary of a lobster taken at the time of the hatching of the brood (plate 38, fig. 138), or several weeks after it, is invariably, so far as my observation goes, of a light pea-green color, and possesses definite histological characteristics which will be considered in another place.

The ovary of a female which is approaching maturity for the first time (see Nos. 22, 26, 47, 58, 67, 74, 83, etc., table 20), on the other hand, is variable in color. It may have a flesh or almost salmon tint, a cream color, a dirty yellow, bright light-yellow, light olive-green color, or one of many intermediate tints.

The interesting fact has already been pointed out that the percentage variation in the numbers of eggs produced by lobsters from 8 to 12 inches is excessively great. This points to the conclusion, which is confirmed by anatomical evidence, that the period at which lobsters reach sexual maturity is a variable one, extending over several years, over a period, at least, in which lobsters vary from 8 inches, or slightly under, to 12 inches, or slightly over, in length.

THE FREQUENCY OF SPAWNING.

Is the lobster an annual spawner, or, to put the question in another way, what percentage of mature female lobsters produce external eggs each year? These questions, although of much importance, have generally received erroneous answers.

In the summer of 1890 I first demonstrated, upon the ground of anatomy, that the lobster did not and could not breed annually, as had been commonly supposed. This is proved, first, by the growth of the ovarian eggs, and confirmed by the relatively small percentage of females with external eggs captured during the winter and spring.

The growth of the ovarian eggs was followed from the time of hatching of the brood until the ova of the next generation were ripe and ready for extrusion. (See note, p. 152.) These results are embodied in table 20. In some notes published in May, 1891, I pointed out that three-fourths of the whole number of egg-lobsters examined in the summer of 1890 in Vineyard Sound had extruded eggs during the latter part of July (see table 7). It was also shown that the eggs which are then laid are "carried by the female throughout the fall, winter, and spring, and are not hatched under natural conditions until the following summer" (*92*). The hatching period was given as extending over a period of about eight weeks, from May 15 to July 15. This agrees, for the most part, with the experience of recent years.

Bumpus (*30*) gives correctly the periods of spawning—with the exceptions I have noted—of incubation, and hatching of the young. Garman (*72*), in a report upon the lobster to the fishery commissioner of Massachusetts, summarizes his results as follows:

(1) The female lobster lays eggs but once in two years, the laying periods being two years apart.

(2) The normal time of laying is when the water has reached its summer temperature, varying in different seasons and places, the period extending from about the middle of June till about the 1st of September.

(3) The eggs do not hatch before the summer following that in which they were laid, the time of hatching varying with the temperature, and the period extending from the middle of May till about the 1st of August.

These conclusions—subject to the corrections which I have pointed out—are essentially a repetition and confirmation of facts which were already known.

Mather emphasizes (*135*, *136*) the facts that the lobster carries its summer eggs all winter and that it breeds once in two years.

In order to prove with certainty that the lobster can not breed every year, we have only to dissect a female which has recently produced a brood, or has external eggs nearly ready to hatch, in June, July, or August. In table 20 records of over

twenty-one such dissections are given (Nos. 1, 4 to 10, 29 to 33, 35, 37, 38, 40, 53, 56, 62, 95) which illustrate the condition of the ovary before the eggs hatch, up to about the middle of August, or from six to eight weeks after hatching. The ovarian eggs have had, in all these cases, from ten months' to a year's growth, this interval having elapsed since the last sexual period, when eggs were extruded.

The colored drawing, fig. 138, plate 38, represents, in natural size, the ovary of a lobster (No. 95, table 20) four to six weeks after the hatching of its eggs. In figs. 136, 137, and 138 I have given representations of the ovaries of the lobster as they appear thirty-six hours, six weeks, and one year after egg-laying. Figs. 134, 135, and 133 show the average size and form of the ovarian eggs, drawn to the same scale, at these various periods. The ovarian eggs are in about the same condition of immaturity in figs. 133 and 135, and it would seem that immediately after egg-laying the ovary grows very rapidly, and then enters upon a long period of rest. In the following summer, when the external eggs have hatched, another period of rapid growth is experienced in the ovary, and at the beginning of the third summer after ovulation there is a third period of active growth which continues until the new ova of the next generation are ripe. That the spawning periods are thus two years apart is a valid inference drawn from the study of the anatomy of the reproductive organs. (See note, p. 152, and in particular the description of fig. 138, p. 246.)

If the spawning period of the lobster is a biennial one, and if the sexes are equally divided, we should expect to find half of the adult females carrying eggs each year. In other words, one in every four mature lobsters (of both sexes) captured would carry external eggs. Since lobsters do *not mature at a uniform period*, or when of a uniform size, it is impossible to get perfectly accurate data upon this point. It would be impossible, furthermore, to trust any data, unless we could be certain that the egg-bearing lobsters were uniformly distributed. The facts which we have, relating to this point, are however, worth considering.

In April, 1889, a number of lobster pots were set in the harbor of Woods Hole by Vinal N. Edwards, and a daily record of the catch was made. A total of 3,230 lobsters were captured, as described in table 21. About one in every seven bore eggs. The percentage of females with external eggs to the whole number of females taken was 40 in April, while it dropped to 36 in May. This slight fall might or might not be owing to the hatching of some of the eggs, while it is evident that the drop to 9 per cent in June is due to this cause, by far the larger part of the eggs being hatched in this month.

It is seen that in the total catch of 2,657 lobsters, from December 1, 1893, to June 30, 1894, the sexes are very nearly equally divided, and that about one in every fifteen lobsters captured bore external eggs. Neither this nor the percentage of females with eggs to the whole number of females has any special significance, since both mature and immature are included. Striking out the months of May and June, when the eggs are mostly hatched, and eliminating the smaller lobsters, we find the percentage of egg-bearing lobsters 10 inches long or over to the whole number of females of the same length with or without eggs (that is, mature female lobsters), to be 21.79. If the limit is taken at 9 inches, we find the percentage to be 19.81. In other words, about one-fifth of the females 9 inches or more in length bore eggs.

The catch off No Man's Land in May, 1894 (table 1), illustrates very well how the conditions are affected by the locality. Out of 1,318 lobsters taken 93.5 per cent were females, and 63.7 per cent carried eggs; moreover, 68 per cent of the total number of females bore eggs.

TABLE 21.—*Percentage of male to female lobsters and the percentage of egg-bearing females taken in Woods Hole Harbor.*

	Time of capture.										For whole period.
	1889, Apr. 24 to 30.	1889, May.	1889, June.	1893, Dec.	1894, Jan.	1894, Feb.	1894, March.	1894, April.	1894, May.	1894, June.	
Total catch	104	942	2,184	224	501	246	348	457	434	447	5,887
Males	49	440	1,009	123	250	116	161	247	197	219	2,811
Females	55	502	1,175	101	251	130	187	210	237	228	3,076
Males under 10 inches	49										49
Males under 10½ inches		418	976	97	215	107	137	210	173	196	2,529
Males over 10½ inches		22	33	26	35	9	24	37	24	23	233
Females under 10 inches	55										55
Females under 10½ inches		439	1,099	78	194	106	147	163	207	192	2,625
Females over 10½ inches		63	76	23	57	24	40	47	30	36	396
Females with eggs	22	185	108	22	36	11	12	33	34	20	483
Females without eggs	33	317	1,067	79	215	119	175	177	203	208	2,593
Females under 10 inches with eggs	22										
Females under 10½ inches with eggs		131	63								
Females over 10½ inches with eggs		54	45								
Percentage of females with eggs to total number of females	40	36	9	21.78	14.34	8.46	6.42	15.71	14.35	8.77	17.48
Percentage of females with eggs to whole catch	21	19.6	4.9	9.82	7.18	4.47	3.45	7.22	7.83	4.47	8.99
Percentage of females to males	112.2	114.3	116.4	82.1	100.4	112.07	116.15	85.02	120.30	104.11	106.30

The inspector of fisheries for the Province of Prince Edward Island says:

In 1879 returns from almost all the factories then in operation gave, for the whole catch, only from 3 to 10 per cent in spawn, much the larger portion being in July.

This agrees closely with the results obtained at Woods Hole, but it does not follow, as Mr. Duvar supposes, "that one-fifth of the females carry ova each year," or that "there are four times as many young breeders coming forward as there are egg-bearers," and "that one-fourth of the number come into breeding year after year" (*209*, p. 234), since the adult lobster does not breed annually, as he erroneously supposes.

From December 1, 1893, to May 1, 1894, 358 female lobsters measuring 10 inches or more in length were taken in the harbor of Woods Hole, and 1,234 were captured during the same period at No Man's Land, in all 1,592 lobsters, 57 per cent of which bore external eggs. If we include the 9-inch lobsters, we find that the total number of females taken at both places is 1,779, and that 53 per cent carried eggs. This supports the conclusion already reached from the study of anatomy, that the lobster breeds once in two years, in which case 50 per cent, or fully one-half, of all sexually mature female lobsters spawn in some part of each year. It also shows very forcibly that valid inferences respecting the breeding habits can not be drawn from observations made in a restricted area. Thus, had our attention been confined to Woods Hole it would have appeared that only one-fifth of adult females bore eggs (from December to May), or that the lobster spawned only once in five years.[1]

[1] Ehrenbaum (*61*) found that only 25.4 per cent of females supposed to be of adult age caught at Heligoland carry eggs, and hence concluded that the European lobster becomes productive only once in four years. Besides the objection that the data are derived from one locality, which, as table 21 shows, is a serious one, there is the further difficulty that over 10 per cent of these female lobsters were captured during the months of July, August, and September, when, according to Ehrenbaum, both the laying and the hatching of the eggs occur. This alone might vitiate the result. The best way to test this question by experiment would be to take a female which had recently hatched a brood and keep her alive until the following summer, when the next batch of eggs would be due, in case the spawning period is a biennial one. So far as I know, this has never been done.

It should be borne in mind that, as we have already seen, a certain number of lobsters from 9 to 12 inches long have never borne eggs. Thus the chances for error in making estimates of this kind are further increased.

The percentages given in table 21 must therefore be greatly increased to express the ratio between the actual spawners of the current year and those which have reached the spawning age, since in the total number of females there were undoubtedly included many which were not mature. While the percentage of egg-lobsters taken in the same locality may vary considerably from year to year or from month to month it seems probable that if we could average the results taken from many different localities along the coast we should find that the number of spawners each year represents about half the total number of mature females.

RELATIVE ABUNDANCE OF THE SEXES.

Some species of crustacea are strictly monogamous, such as the beautiful tropical shrimp, *Stenopus hispidus*, which is always seen swimming in pairs, the male and female being rarely separated. This is also true of another delicate shrimp, *Pontonia domestica*, which lives in the mantle chamber of the mollusk Pinna. In such cases the sexes are of necessity about equally divided. But in the lobster there seems to be no attachment of this kind. It is probable that a given male fecundates more than one female, and it is certain that the sexes are distributed with great irregularity, at certain seasons of the year at least, as I shall presently show. Nevertheless, if an extended census could be taken, at different points on the coast, it is very probable that but little difference would be found in the numbers of the sexes.

The following table shows the relative abundance of male and female lobsters found in Woods Hole Harbor and at No Man's Land:

TABLE 22.—*Relative abundance of male and female lobsters at Woods Hole and No Man's Land.*

Date.	Total catch.	Male.	Female.	Per cent of females to males.
Woods Hole:				
1889. April 24–30	104	49	55	112.2
May	942	440	502	114.3
June	2,184	1,009	1,175	116.6
1893. December	224	123	101	82.1
1894. January	501	250	251	100.4
February	246	116	130	112.07
March	348	161	187	116.15
April	457	247	210	85.02
May	434	197	237	120.30
June	447	219	228	104.11
Totals	5,887	2,811	3,076	106.30
No Man's Land:				
1894. May	1,318	84	1,234	1,469

In the monthly catches at Woods Hole in 1889 the females preponderated by 12 to 16 per cent, while in the total catch for 1893–1894 the sexes are very nearly evenly divided. During this period the percentage of females to males fluctuated from 82.1 minus to 120.30 plus, a variation of about 38 per cent. The traps were stationary, but the lobsters were constantly moving about over the bottom; yet there was no segregation of the sexes, and such variation as we find in the monthly catches has no special significance.

When, however, we glance at the data from No Man's Land, it is evident that something besides chance has caused the overwhelming preponderance of females, 1,469 per cent. It seems almost certain that this condition of things is only temporary, and it may be explained, as I have suggested in another place (see pp. 23,24), in relation with the inshore migration and the hatching of the eggs.

Regarding the relative abundance of the sexes of the lobster, Verrill (*196*) remarks:

> Among those which I have examined from New London, Waterford, and Stonington, Connecticut, in our markets, I have not noticed any marked inequality in the number of the sexes. Mr. Smith examined the lobsters in the market at Provincetown on two occasions, in August and September, without finding any decided differences in the number of males and females. He also repeatedly examined those in the fish-markets at Eastport, Maine, in summer, with the same result.

Capt. N. E. Atwood published in 1866 a paper on the habits of the lobster in the proceedings of the Boston Society of Natural History (*5*), in which he makes the following remarks:

> From Plymouth northward and eastward [lobsters] are caught in deep water in the months of February and March, but not in large quantities; as the season advances they come near the shore and remain through the spring, summer, and autumn, and are very plentiful. Along this range of coast three-quarters at least are males at all seasons of the year. At Cape Cod (Provincetown) their habits differ very much from the habits of the lobsters on the north shore. They do not come there until June and remain until October, when they disappear and go to parts unknown. One very singular fact I have noticed is, that the lobsters which visit Cape Cod are nearly all females; they appear to come near the shore for the purpose of depositing their young, after which they pass away and others in turn take their places, as is indicated by the change that is constantly taking place, for when the fishermen are catching great quantities of large, good hard-shelled lobsters—and they are unusually abundant—perhaps the next day there will be a new kind, smaller and not of so good quality, the former ones having passed away and others come to take their places.
>
> In Boston the number of lobsters sold annually can not be much short of a million. The male lobster is preferred and is the most salable, as this city has always been supplied from the northern shore of Massachusetts and coast of Maine, where the males are most plentiful. It is a great advantage to the fishermen that the people prefer males. In New York it is very different in this particular, the city being supplied from Cape Cod after June, and the female lobsters thus considered much the best. I have sold many lobsters in New York, and males sell at only about half price. The male is much poorer than the female in meat.

I have quoted the foregoing passages at some length, not because they are free from error, but because they were written by an intelligent fisherman at a time when scarcely anything was known of the habits and general biology of the American lobster. If such a preponderance of females actually occurred on the shores of Cape Cod it may have been a seasonal phenomenon, similar to that observed at No Man's Land. It did not exist in August and September, when the observations of Professor Smith were made at a later period.

The statement that males are more plentiful than females on the northern shore of Massachusetts and the coast of Maine is without doubt an unsupported generalization. Conflicting statements in regard to this subject are often given by fishermen, who, as Verrill suggests, probably do not often discriminate the sexes when the females are without eggs. The only detailed facts which we possess on this subject are those recorded in tables 21 and 22, and they seem to point to the conclusions already drawn.

Chapter III.—MOLTING AND GROWTH.

EARLIER OBSERVATIONS.

The process of molting, which makes growth possible to the arthropod, is of such interest and importance that it deserves very careful attention. There is much to be added to our knowledge of this subject in the lobster, and I shall deal with it at full length. Aristotle knew very well that crabs and lobsters shed their shells (The History of Animals, Book VIII, c. XIX), although his observations were not accurate; but the fact was forgotten and finally denied altogether.

It is only necessary to go back to the beginning of the last century (in 1712) to find Réaumur (*161*) demonstrating that the river crayfish periodically cast its shell, yet in the early part of the seventeenth century, a hundred years before, Olaus Wormius, according to Couch (*47*), speaks of the molting of crabs as a thing not to be doubted.

The regeneration of the lining of the stomach of the crayfish was reported by Van Helmont, but this writer's reputation did not lend much weight to the statement until it was confirmed in 1709 by Geoffroy (*74*).

To that marvelously acute observer, Réaumur, we are indebted for the best account of the exuviation of the crayfish. He took crayfishes which appeared to be ready to molt and placed them in jars of water in his museum and watched them carefully. Others he put into boxes, the bottoms of which were pierced with holes, and moored them in the river Marne, which flowed past his garden. The crayfishes in the river were under more favorable conditions than those kept in the house, and molted more frequently in consequence. He gives a very circumstantial account of the external process of molting in the crayfish, which took place in June, July, and August. The time occupied in the final act of casting the shell by crayfishes kept in the river was from seven to fifteen minutes, while those in the house often struggled for several hours before they were free. Sometimes they died in the operation, especially the young ones. Some would lie on their sides, some on their bellies or backs, and in the latter case he observed that they frequently died.

However, as Couch remarked, Réaumur's paper produced so little effect that when, many years later (1756), Peter Collinson communicated some cursory remarks on this subject to the Royal Society, his account of the molting of the crab was received with so much doubt that his second paper was chiefly employed in furnishing evidence of the fact.

Observations on the molting of the higher crustacea have since been made by Couch (*45*, *46*, *47*), Gosse (*81*), Chantran (*37*), Max Braun (*22*), Vitzou (*197*), Sars (*176*), Hyatt (*104*), Brook (*26*), and others. The histological changes involved in the molting

process have been studied by Max Braun (*22*), and more recently by Vitzou (*197*). As so often happens, there are many observations on this subject which either ignore the earlier and often better ones, or add nothing of value to our knowledge of the process. Hyatt, in remarking that, while the molting of the lobster had been previously described several times, "no professional naturalist" had "actually seen the process and recorded his observations," appears to have overlooked the account of Sars (*176*), which, however, is not particularly circumstantial.

Sars saw a lobster in the act of molting in July near Tananger, in Norway. He says:

> It had just been taken out of a lobster box, and could be handled without its offering the slightest resistance. The shell on its back was burst in the middle, and the tail and the feet were nearly out of the old shell, while the largest claw stuck out only half its length. This latter portion of the change is evidently very dangerous, and, although I observed it for quite a while, I could see little or no progress.

This lobster was not a good exponent of the molting process. As soon as the larger claws begin to be withdrawn from the old shell the exuviation, under normal conditions, is speedily brought to a close. Nor is it true that the lobster "only reaches its former size after a considerable time has elapsed." According to Sars, the lobster on the Norwegian coast molts chiefly in July.

Both Couch (*45*) and Salter (*174*) have given accounts, at secondhand, of the molting of the European lobster. Couch, writing in 1837, says that the newly molted lobster shows great activity in effecting its escape, which is undoubtedly true in some cases, but not in all. The lobster whose cast shell is described escaped "through an aperture too narrow to have allowed it to pass if its new covering had possessed a very moderate degree of firmness." He supposed that escape was effected by the cracking open of the shell, in the middle line, where he noticed that in life a faint stripe was perceptible. He observed in a lobster preparing to molt that absorption took place along this area, and inferred that the two halves of the shell were completely separated when the critical moment came. Of the molting, he further says that "it is not improbable that the general opinion is correct which limits the exuviation of the adult animals to once in the year," and "general opinion" does not seem to have made much progress in clearing up this matter during the last fifty years.

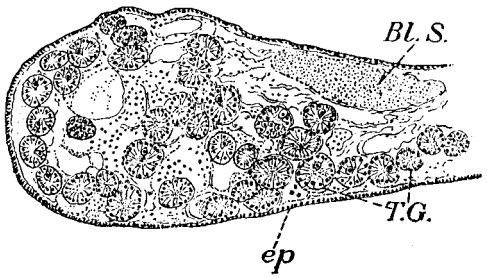
Salter's account, published in 1860, is interesting on account of some extraordinary statements, such as that in molting the legs are extracted pair by pair, which of course is a physical impossibility, as Hyatt pointed out, and that the abdomen is the part first withdrawn from the old shell. This latter statement expresses exactly the reverse of what has since been found to occur.

Wheildon (*202*) published in 1875 a short paper containing some interesting facts on the molting habits of the American lobster, which will be referred to again.

The work of Vitzou, which appeared in 1882, is the best yet done on this subject. He treats of the histology of the old and new shell, and of the organic and "inorganic reserves," which are supposed to be laid down in certain tissues with reference to the molting period.

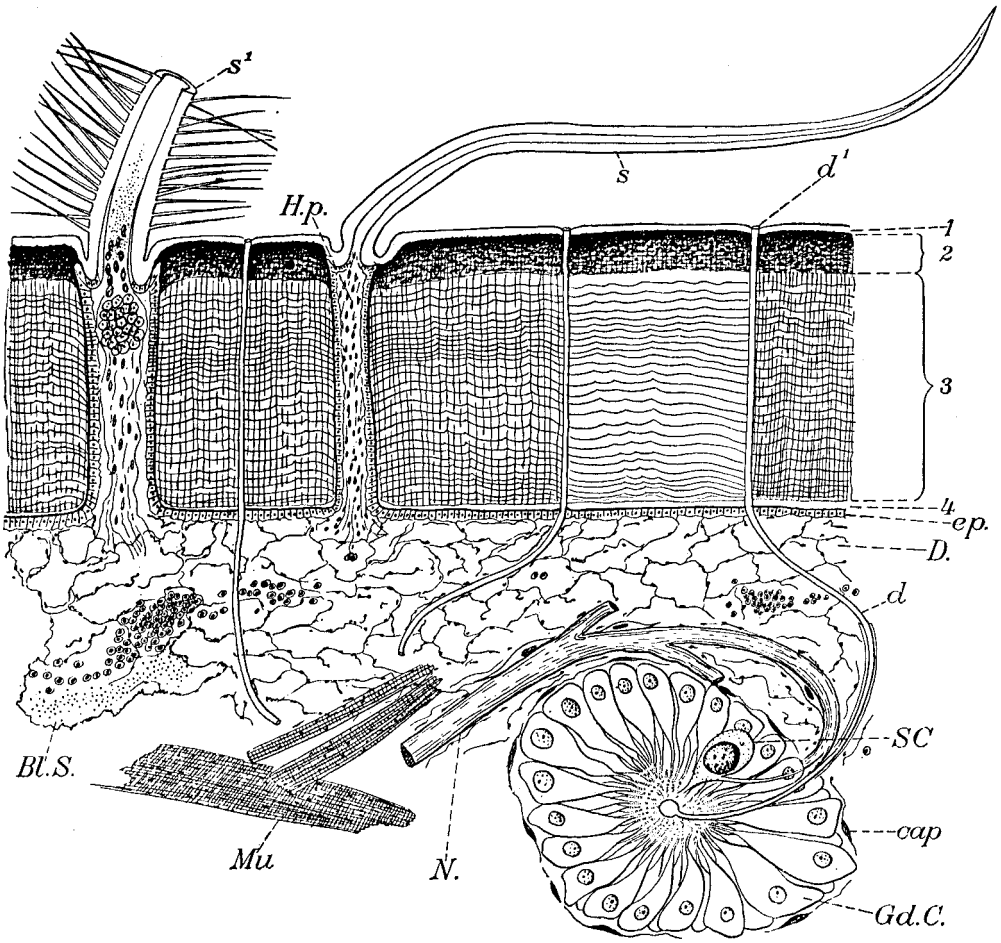
Hyatt's paper (*104*), appearing in 1883, gave an accurate account of some of the phenomena of exuviation in this species.

Packard in 1886 published some notes (*147*) in which very little is added to our knowledge of the subject. He says that "the integument of the legs is molted last, and when, owing to rough handling, the process is delayed, the extremities of the legs



CUT 4.—Part of transverse section of exopodite of pleopod of female lobster (the cuticle removed), showing the distribution of the cement glands. July 19, 1891.

Bl. S, blood sinus. *ep*, chitinogenous epithelium. *T. G*, tegumental gland.



CUT 5.—Diagram of vertical section through skin, showing a tegumental gland (relatively much smaller than represented) in section and its duct opening to the exterior, also hair pores perforating the cuticle, with the superimposed hairs or setæ. The structure of the cuticle or shell is diagrammatically shown.

Bl. S, blood sinus. *cap*, capsule of tegumental gland. *D*, dermis. *d*, duct of gland. *d*¹, mouth of duct. *ep*, chitinogenous epithelium. *Gd. C*, gland cell. *H. p*, hair pore. *Mu*, muscle. *N*, nerve, supplying gland. *SC*, central nerve cell. *s*¹, plumose hair. *s*, simple hair. *1*, enamel layer of shell. *2*, calcified pigmental layer of shell. 3, calcified non-pigmented layer. *4*, inner non-calcified layer of shell.

Drawn by F. H. Herrick.

slough off." The remarkable statement that "the abdominal legs are molted before the thoracic ones" would imply that the hinder part of the body is first withdrawn from the old shell, which is not true.

The statement that the lobster "remains inactive for nearly or quite a week, until the new crust becomes hard," can not be accepted without modification, since the soft lobster is frequently caught in traps, and the newly molted lobster often displays surprising agility, and besides it requires more than one week for the shell to become hard.

Brook (*26*), writing in 1887 on the reproduction of the lost parts of the lobster, has some interesting notes on the growth of the European lobster which he kept and observed in an aquarium for nearly a year and a half in one instance, during which period the animal molted four times. The ecdysis usually occurred at night, and the exuvium was buried.

No one, strange to say, has ever examined the cast-off shell and observed with sufficient care the areas of absorption. This has resulted in much useless discussion as to whether the carapace splits along the middle line when it is cast off. I shall refer to this hereafter.

We are now concerned with the adult animal only. The molting of the embryo and larva will be considered in Chapter XII.

THE STRUCTURE AND GROWTH OF THE SHELL.

The phenomena of the molt are unintelligible without a knowledge of the structure of the skin or integument. The histology of the shell in the crustacea has been studied with varying degrees of success by a number of naturalists—by Carpenter (*34*), Lavalle (*116*), Williamson (*205*), and Tullberg (*191½*). The most accurate statement is in the paper by Vitzou (*197*), on which I shall mainly rely in giving the following account.

The skin as a whole is composed of dermis and epidermis, and consists of the various parts shown in the diagram (cut 5). The epidermis is made up of a single layer of chitinogenous epithelial cells, and of the shell which they secrete; the dermis is composed of connective tissue, blood vessels, nerves, pigment cells, and glands. The shell consists of four layers, namely: (1) the thin outermost layer, which I shall call the *enamel layer*, apparently structureless; (2) the *pigment layer*, composed of parallel lamellæ, traversed by canaliculi and filled with pigment and lime salts; (3) the *calcified layer*, devoid of pigment but otherwise like the last, forming the greater part of the carapace; (4) a noncalcified inner layer, composed of very thin lamellæ.

The chitinogenous epithelium corresponds to the Malpighian layer of the epidermis of the vertebrate, while the layers of chitin represent its horny cuticle.

The vertical canaliculi correspond, as Vitzou has shown, in certain decapods, to the boundaries of the chitinogenous cells; but this is not the case in the lobster, where they are close together and very numerous.

During the molting period the cells of the chitinogenous epithelium undergo a great change. They grow out, vertical to the surface, into very slender and exceedingly long rods. (Compare Cut 11, and figs. 171, 173, plate 43.) The epithelium formed over the surface of a budding limb is of the same character. The chitinous layers of the new shell are formed by discontinuous thickenings of what, according to Vitzou, may be regarded as the upper wall of the epithelial cell. Thus are formed parallel lamellæ of varying density, which fuse with those of adjoining cells and make a continuous shelly crust.

At the time the shell is ready to be cast the tegumentary covering consists of (1) the old shell; (2) the new shell; (3) an intermediate structureless membrane, besides the chitinogenous epithelium, and (4) the dermis. The new carapace, according to Vitzou, is composed of the enamel and pigment layers only. The calcified layer is not formed until after the molt.

The connective-tissue cells are now of large size and contain granules of glycogen. Claude Bernard first demonstrated the presence of glycogen below the carapace in crustacea. Glycogen was extracted by Vitzou from the connective tissue, liver, lymph, and ovaries, during the molting period. Besides acting as a pancreas, the liver was found to be a great producer of glycogen during the molt. Glycogen is thus an organic reserve, which furnishes material for the growth of the new shell and tissues. According to Vitzou, Schmidt and Berthelot have shown that the chitin of the crustacea contains a principle belonging to the same group as cellulose and lignin. This substance, under the influence of sulphuric acid, may be transformed into a body analogous to glucose. Hence the remark of Claude Bernard, that "without forcing the metaphor one may say that the crustacea are enveloped in a carapace of wood." (Leçons sur les phénomènes de la vie, 1879, t. 2, p. 113.—*197.*)

The enamel is plainly the first product of the secretions of the skin which goes into the new shell, and when once laid down can not be competely removed except by a molt. The enamel is often partially removed by friction, as is seen in the abrasions on the shells of old lobsters or those about to molt.

The surface of the shell, particularly that of the carapace, has a decided punctate appearance, due to the hair pores. These mark the points where setæ either penetrate the shell now or did so at an earlier stage of development. In the adult lobster the setæ of the carapace have disappeared or are worn down except upon its margins and in the orbital regions. In the fourth larva, however, the whole carapace is seen to be studded with hairs (fig. 113, 115, plate 35).

If the carapace—better one without pigment—is examined with a hand lens, the surface is seen to have a beautiful though somewhat irregular mosaic appearance. It is divided into polygonal areas which inclose the hair pores. These markings are probably due, as Professor Patten has shown to be the case in Limulus, to shallow depressions in the enamel, dependent upon a peculiar bending together or clustering of the outer ends of the canaliculi. The hair pores open on the inner side of the shell in small blister-like elevations.

A very minute pore of another character is scattered among the hair pores on the inner side of the shell. It has the appearance of a symmetrical crater with a minute tube issuing from it. This is the duct and opening of the tegumental gland. The distribution of these two kinds of pores would probably repay careful study. But few parts of the carapace, such as the white tendon marks (see p. 135), are wholly free from them. Toward the lateral margins of the carapace they become exceedingly small and numerous. Some of the superficial pits in the dorsal region, on the other hand, are very large.

We thus see that the dense shell is a veritable strainer, being perforated by hundreds of thousands of minute passages, which lead from the surface to the parts below it, to the tegumental glands on the one hand, or to the sensory cells which lie at the roots of the hairs, on the other. The bearing of these facts will be better appreciated when we discuss hereafter the function of the tegumental glands themselves.

THE SHEDDING OF THE SHELL IN THE LOBSTER.

THE MOLTING PERIOD.

The hard-shell lobster is heaviest, has the firmest flesh, is hardiest, standing transportation best, and therefore most valuable for the market. A large percentage of all lobsters taken during the fall and winter months are of this character, and all or nearly all lobsters caught in March, April, and May belong also to this class. Shedders and soft-shell lobsters are taken in greater or less abundance from June to October, varying somewhat with the season and locality and surrounding conditions, such as the nature of the sea bottom and the temperature of the water. By far the greater number of lobsters in all seasons, and in all places, cast their shells during the months of July, August, and September. However, the time of shedding varies considerably on different parts of the coast, being from four to six weeks earlier in some seasons in western Maine than in the extreme eastern section. Shedders are not fit for the market, being lean and watery, and soft lobsters are in a similar condition and will not bear much handling or transportation. Until the shell becomes tolerably hard the soft lobster is in constant danger of attack from its companions, and is easily wounded and killed. Lobsters with very soft shells and those which have been mutilated are often kept in the lobster preserves or pounds until the shell is hardened or the injury repaired.

No systematic data have hitherto been gathered at any point along our coast upon the molting habits of the lobster. I am therefore glad to be able to give the results of a series of daily observations made at Woods Hole, Massachusetts, during the space of seven months, from December 1 to June 30, 1894. During this interval 2,657 lobsters were captured in traps set at fixed points in the harbor. As shown in table 23,[1] there was no month in which either shedders or soft lobsters were not caught.

TABLE 23.—*The molting of the lobster.*

Months.	Temperature of water in harbor.	No. of days for which average temperature is given.	Nature of bottom.	Catch.			Shell hard and bright.		Shell hard and dull.		Shell soft.	
				Male.	Fem.	Total.	Male.	Fem.	Male.	Fem.	Male.	Fem.
	F.											
December ...	37.71	14	Rocky	123	101	224	117	101	2	0	4	0
January	35.48	27	....do	250	251	501	239	250	7	0	4	1
February	32.54	24	....do	116	130	246	115	130	0	0	1	0
March	37.40	27	....do	161	187	348	154	186	7	0	0	1
April.....	42.52	25	....do	247	210	457	232	206	14	4	1	0
May	53.65	26	....do	197	237	434	194	236	3	1	0	0
June.....	62.20	25	....do	219	228	447	185	202	0	2	34	24

Only one soft-shell lobster was taken in February out of a total catch of 246, and no "shedders" (shell hard and dull) were captured during this month. Again, one soft-shell lobster only was observed in March and April, and none in May. In June,

[1] Lobsters with shells "hard and dull" are nearing the molting period; those with "soft shells" have recently shed, and in those with "hard and bright" shells the molting time is most distant. See p. 82.

on the other hand, the number of lobsters which have recently shed jumps suddenly to 58. These observations may be summed up for the whole period as follows:

Total catch.		Shell hard and dull.	Shell soft.	Total.
2,657	1,313 males	33	44	77
	1,344 females	7	26	33

Of the entire catch, 110 have either recently molted or are preparing to molt; 77 of them are males, 33 females. The total number of males is smaller, yet the number of soft shells among them is nearly twice as great as in the other sex. This fact implies that the males molt oftener than the females, which would be an *a priori* deduction from the greater size which the male attains (see p. 34), or that they molt more frequently during those months. It is interesting to recall in this connection the observation of Chantran (*37*) that the male crayfish molts twice in the year, while the female molts but once. Females molt, as a rule, shortly after the young are hatched, and very rarely just before the eggs are laid (see p. 35).

When I was in Portland, Maine, on the 24th of August, 1893, soft-shelled lobsters were being caught in that region, while fishing smacks were bringing hard-shelled lobsters from Jonesport, near the eastern border of the State. Soft-shelled lobsters are still taken in the Portland district, as I was informed by Mr. N. F. Trefethen, for four or five weeks before they are received in large numbers from Jonesport.

Mr. F. W. Collins, of Rockland, thinks that lobsters shed earlier in the shoal mud coves, which are full of eelgrass, than on rocky bottoms. The shedding commonly occurs there on muddy bottoms in the latter part of July and the first part of August.

Shedders in small numbers are occasionally taken in Rockland in January and February, and sometimes shed in cars at this time. In deep water outside, as at Seal Island, Matinicus, Green, and Ragged islands, where lobsters are caught in winter in 40 to 50 fathoms, and in shoal places in summer in 3 to 10 fathoms, very few soft-shell lobsters or shedders were taken in the summer of 1893, up to the 26th of August, not more than a dozen among thousands examined each week. The majority of the soft-shell lobsters from these localities come later in the season, from the last of September to the middle of October.

Mr. A. P. Greenleaf said he had rarely seen soft-shell lobsters at Southport, Maine, but that in the winter of 1893 (in January and February) he had taken dozens of them.

At West Jonesport, Maine, on September 4, 1893, I was told by a fisherman at Beal Island that hard-shell lobsters had prevailed up to that time, but that soft-shells were becoming common. He thought that the shedding was rather later than usual. This confirms the reports made at Rockland and Portland.

Molting lobsters were very common at Woods Hole in October and November, 1890, particularly in the latter month, when Mr. Vinal N. Edwards says that more were caught than during the earlier part of the season. In December, 1891, Mr. Edwards found lobsters in all stages of shedding, some that appeared as if they would be ready to molt in a few weeks, and others as if they might shed in a few days. Thus it was probable that the lobsters continued to molt to some extent in winter, which is shown by table 23 to be the case.

The abundance of shedders which was noticed in the late fall of 1890 at Woods Hole has not since been observed, and it seems clear that there is considerable variation in the molting of lobsters in a single locality at this season of the year.

It is stated in the annual report of the inspector of fisheries of Prince Edward Island (*209*, p. 236) for 1880 that soft-shell lobsters "are seldom seen on the north side of the island, while on the south side almost all that are caught in the month of July are soft and unfit for canning." A canner in Queens County says that scarcely a lobster can be caught before the 20th of May. Soft-shell lobsters begin to abound by the 1st of August and continue abundant during this month. One-third of the lobsters caught during August are said to be soft-shelled. The fishery officer for Cape Breton states in his report for 1888 (*210*) that no soft-shell lobsters were captured during the fishing season which closed July 28.

THE MOLTING PROCESS.

Next to reproducing its kind, the act of molting is the most important in the life of this animal. The whole body is covered, as we have seen, by a chitinous shell, in which salts of lime are deposited, giving to parts of it the hardness of stone. Molting consists of two distinct phenomena: (1) the formation of a new shell and (2) the rejection of the old. When once formed the shell admits of no increase in size, since it is a dead structure, excreted by the skin below it, and when it is outgrown it must be cast off and replaced by a new and larger shell. The new shell is gradually excreted under the old one, and when the latter is discarded the new shell is soft and flexible and is easily distended to meet the requirements of growth. The growth of the lobster, and of every arthropod, thus apparently takes place, from infancy to old age, by a series of stages characterized by the growth of a new shell under the old, by the shedding of the outgrown old shell, a sudden increase in size, and the gradual hardening of the shell newly formed. Not only is the external skeleton cast off in the molt and the linings of the masticatory stomach, the œsophagus and intestine, but also the internal skeleton, which consists for the most part of a complicated linkwork of hard tendons. This is rendered possible from the fact that these structures are derived from infolded portions of the skin, and in molting they are simply drawn out of their original folds or pockets. It is thus easy to see why the molting process is critical.

The frequency of the molting period depends directly upon the physiological condition of the animal, which varies with its environment. The molting process is both an expensive and dangerous operation, and calls for a considerable excess of energy. Since it is largely dependent upon the condition of the individual, which is subject to wide variation, the molt does not take place at any stated time, but may occur in any month of the year, though but rarely in the spring. Warmer weather, a more active life, and a more vigorous appetite, which are characteristic of the lobster during the warmest part of the year, are most favorable, as we have seen, to the renewal of the shell. The lobster, though a carnivorous and voracious animal, feeds less in winter, when its habits are relatively sluggish. Broken limbs and injuries to the shell are then but slowly repaired, and there is less energy to be drawn upon in molting.

The growth of the crustacean takes place during the period of the molt, while the new shell is being formed, and not immediately after the ecdysis, as is commonly believed. It was clearly shown by Vitzou that the old shell is gradually thrown off in consequence of the growth during the molting period, when the animal tends to become larger than its envelope. The rapid swelling out of the body after the old shell is gotten rid of is due to the absorption of water through the new shell into the blood and tissues, not to cellular growth.

Before the molt takes place the lobster has been for a long time preparing for it, while growth has been going on. After molting, it is several weeks before the new shell is as hard as the old one, so that the lobster is, for a large part of its life, either preparing for a molt or recovering from one. It is therefore not remarkable that lobsters have acquired many popular names among fishermen, such as "hard shell" or "old shell" lobster; "shedder," "black shell," or "crack back" (lobsters preparing to molt); "soft shell," "new shell," "shadow," "rubber shell," "paper shell," "buckle shell" lobster, etc. (lobsters which have recently molted).

HABITS OF MOLTING LOBSTERS.

Shedders can be readily distinguished by the dark, dull colors of the old shell hence the common name of "black lobster," and by the deep reddish tint of the membranes at the joints, where the flesh is now seen through the old and new cuticle. The lobster is now naturally sluggish, though not too inactive to enter a trap. When in this condition they very commonly haunt shallow water with a sandy, muddy, or weedy bottom, and at low tide have been taken out of bunches of eelgrass in a few inches of water. When in this condition they frequently dig a shallow hole in the mud under stones, where they can await the coming change with greater security from enemies. Fishermen frequently see a shed shell lying on the bottom and a soft lobster close by under a rock or bunch of kelp.

It is well known that many prawns habitually molt in the early morning while it is yet dark. The lobster when kept in an aquarium molts either by day or night, and it probably does the same in nature. In those which Brook observed (*26*) the shells were cast off in the night and partially buried.

Shedders and soft lobsters used to be a favorite bait with fishermen who knew where to look for them and could then find them in abundance. The shell of the black lobster was peeled off, and the soft, pulpy flesh formed a tempting bait which fish found difficult to resist. Mr. Vinal N. Edwards says that in 1869 or 1870 he used to take molting lobsters for bait at Menemsha, in Vineyard Sound, in October, sometimes a barrel of them at a time. He says that he never found a molting lobster buried in the sand, but they were usually under bunches of seaweed, such as the common kelp (*Fucus vesiculosus*) with their bodies only partially surrounded by the sand, and in 5 to 9 feet of water. It was not uncommon formerly to catch shedders in fyke nets, but he has taken none in recent years. He used to take them occasionally with hook and line. The lobster probably requires greater freedom in getting free from its old shell than could be found in the most carefully constructed burrow.

While at the Vinal Haven Islands, August 26, 1893, I saw in the pound at that place a number of soft lobsters which had molted but a few hours before. One was found lying in the eelgrass; another, a male, was exposed on the mud bottom in 2 feet of water. A shedder, weighing upward of 10 pounds, was caught by Mr. M. B. Spinney in Seal Cove, Small Point, Maine, in the month of August, in very shallow water; and in Sagadahoc Bay, near the mouth of the Kennebec River, a large soft lobster was once found and close beside it its cast-off shell. The lobster lay buried under roots of eelgrass and was out of water, when discovered, at low tide.

In the Peabody Academy of Science, at Salem, Massachusetts, there is a crushing claw of a lobster said to have come from Gloucester and to have weighed 39 pounds. An outline drawing of this claw is given in plate 15 (see p. 115). This lobster probably

weighed not over 25 pounds. The shell of the last three joints of the claw-bearing limb (the parts represented in fig. 20), weighed 16¾ ounces. It has the thickness of thin pasteboard, excepting at the tips of the claw, where it is denser, and probably belonged to a lobster which had molted within three months of the time of its capture.

Putnam (*154*) records some interesting facts in regard to the molting habits of the blind crayfish, *Cambarus pellucidus*, and of the eyed crayfish, *Cambarus bartonii*, captured in Mammoth Cave November 13. The blind species was of a milk white color. One molted on January 29 and a second time April 20. Another specimen of this species, exposed to the light over nine months, had eaten little and molted once. One of the specimens of *C. bartonii* molted about February 20, and when observed was eating its own shell. It had devoured about half of it. This habit of eating the remains of the old shell is very interesting, and is undoubtedly induced by the need of lime. It was noticed in the crayfish by Baker (*7*) over a hundred years ago, but it is so seldom recorded that it would hardly seem to be a fixed habit. It is probably occasionally practiced by the lobster and all the higher crustacea, especially when in confinement. Warrington (*199*) estimated that the molting period of prawns (*Palæmon serratus*), which he kept in aquaria, varied from twelve to twenty-four days, depending upon food, the temperature, and other conditions. When the cast skins were not removed the prawns devoured all the soft parts. Young lobsters, immediately after molting, fill their stomachs with any calcareous matter at hand, such as the fragments of the shells of mollusks and crustacea. Pieces of the integument of the lobster are commonly found in the stomach-bag, so that it is not at all improbable that the young lobster sometimes devours its cast-off skeleton. Brook (*26*) thus speaks of a lobster the day after ecdysis:

> It had partially buried its cast shell under the gravel. During the previous fortnight this specimen has shown great irritability and pugnacity, and when offered food seized it savagely, but instead of eating proceeded immediately to bury it.

Spence Bate (*9*), who tried without success to observe the common green crab (*Carcinus mænas*) in the act of molting, concluded that this animal had the power of inhibiting the process until a favorable time arrived.

THE CASTING OF THE SHELL.

A male "shedder" was caught in the harbor of Woods Hole July 13, 1891, and placed in an aquarium. At exactly 2.48 p. m. this lobster began to molt and in six minutes was out of its shell.

When the lobster is approaching the critical point the carapace or shell of the back gapes away a quarter of an inch or more from the tail. Through the wide chink thus formed the flesh can be seen glistening through the old and new cuticle, giving it a decidedly pinkish tinge. Take the lobster up in the hand now and the tail drops down as in death, the strong muscles which bind the pleon to the carapace being completely relaxed. When this stage is reached the time of exuviation is at hand and the process becomes purely automatic, the animal having lost all control over its own movements. There are other signs, though not equally infallible, which point to the same conclusion—the dull, faded colors of the old shell, scratched and marred often with the marks of many conflicts. The shell is frequently of a dark, dirty green color, the mottled tints having become very much obscured. The contrast in color is very great if the shedder happens to be among a lot of new-shell lobsters, and the

term "black lobster," used by the fishermen on the coast of Maine, is not altogether inappropriate. The old shell is also brittle, owing to the absorption of organic matter, and if the carapace or large shield which covers the anterior half of the body is pressed between the fingers, it will sometimes split down the back in the longitudinal median furrow. In most cases the shell does not crack in this place unless artificially compressed. In the course of the preparation for the molt the lime salts of the shell are absorbed along the middle line of the carapace, leaving a narrow perfectly straight gutter, extending from the spine or rostrum to the posterior margin of the shield. The chitinous portion of the cuticle still remains, forming an inelastic hinge, on which the lateral halves of the carapace bend without breaking asunder. In the molted shell there is also a linear membranous area on either side of the rostrum. Absorption of the hard matter of the shell at these points tends to give greater latitude to the movements of the two halves of the carapace. If you examine a hard-shell lobster you will find in place of the median furrow a blue line, drawn as if with a fine pen and rule. Below this line the epidermic cells of the skin become so modified as to bring about the total absorption of the lime salts of the cuticle. In sections of the skin, however, it is difficult to detect any histological change in this linear area. Other areas of absorption, to be described hereafter, occur, which are of even greater importance to the success with which the lobster comes out of his old covering alive and whole.

The period of uneasiness, which foreshadowed the molt and was very marked, ended in this lobster by its rolling over on its side, agitating its appendages, and bending its body in the shape of the letter V, the angle of the V coinciding with the gaping chink between the dorsal shield and "tail." Presently the old cuticle, holding these parts together and through which the new shell is seen, began to stretch, the wall of the body pressing against it with considerable force, and the hinder end of the shell being slowly lifted up, while its anterior part remained attached to the rest of the skeleton. The slow but sure pressure of the parts within cause an increasing tension in the yielding cuticular membrane, which finally bursts, revealing the brilliant colors of the new shell. The legs and other appendages are occasionally moved, but no marked convulsive movements are to be seen. The carapace has now become raised upward to an elevation of perhaps 2 inches behind, in consequence of which, the anterior end being fixed, the rostrum is bent downward and the animal now has a very singular appearance.

When this much has been achieved the lobster becomes quiet for a few seconds and then resumes its task with renewed vigor. From this time on until free its muscles work intermittently. The doubled-up fore part of the body is with each effort of the animal more and more withdrawn from the old shell, and this implies the separation of the skin from the complicated linkwork of the internal skeleton and the freeing of the twenty-eight separate appendages, which are attached to this portion of the body, from their old cases, and at the same time the release of the muscles from the internal tendons of the large claws and other parts. The cuticular part of every ectodermic structure is stripped off. This exoskeleton folded up to fit such a complicated mold is in reality a continuous structure, and from the method of its regeneration the sloughing of one part necessitates the shedding of the whole.

The carapace is now elevated to such an extent behind that the rostrum is directed obliquely downward and backward. The lobster is still lying in comparative

quiet upon its side, but the muscles of all its appendages are undergoing violent contraction as the animal tugs and wrestles violently as if to free itself from ropes which bind it down firmly on every side. The carapace is unbroken, yet the two halves bend as upon a hinge along the median furrow. Presently the pressed-down bases of the antennæ, the eyestalks, and the bent-down rostrum of the new shell can just be seen. No part of the covering of the large claws or of any of the legs has been split or cracked. The muscular masses of the powerful claws have been withdrawn through their narrow openings without a rent. Finally a few kicks free the entire anterior half of the body, the antennæ, chelipeds, and various other parts, which now lie above or to one side of the old covering. The "tail" has been gradually breaking away from its old case, and as soon as the forward part of the body is withdrawn the lobster gives one or two final switches and is free. The newly molted lobster has a very sleek and fresh appearance, and its colors were never brighter or more attractive. Try to take it up in the hand, after some time has elapsed, and it feels as limp as wet paper; but immediately after casting the shell the muscles of the crustacean are hard and tense, probably from being in a state of cramp or tetanus. Every part of the old shell down to a microscopic hair has been reproduced in the new one, but in the latter the fringes of stiff setæ are as soft as silk, the strong ends of the claws, the rostrum, and every spine of the body so soft as to easily bend beneath the finger. The large claws are considerably distorted, as well as some of the other parts, being squeezed and drawn out to an unnatural length. After getting clear of the old shell the animal is not inclined to activity. It soon orients itself, however, resting in the usual way, and is capable of moving about with some degree of agility by the flexure of the tail. Fishermen who have had lobsters shed in cars and traps have often been surprised by the ease with which they sometimes slip through their fingers.

The length of the cast shell of this lobster was $11\frac{1}{4}$ inches. Shortly after the molt the lobster was 12 inches long. On July 17, four days after molting, the length was a little short of $12\frac{1}{2}$ inches. The increase in length was thus very nearly $1\frac{1}{4}$ inches. The actual increase in size of the different parts of the body can be best appreciated by comparisons of plates 45 *a*, and 45 *b*, which represent life-size drawings of a lobster before and several hours after the molt. The measurements in this case were $5\frac{1}{2}$ and $6\frac{1}{2}$ inches, the increase in length being just 1 inch.

Réaumur remarked on the hardness of the flesh of the crayfish immediately after exuviation, and, as Huxley says (*103*):

> In the absence of the hard skeleton there is nothing to bring the contracted muscles at once back into position, and it must be some time before the pressure of the internal fluids is so distributed as to stretch them out.

Hyatt (*104*) said of the large claws of a molted lobster:

> They were exceedingly hard and firm, and I have no doubt would have been extremely good eating if we had dared to indulge in such extravagance. This is entirely contrary to the usual accounts, but it agrees with my former observations on the common blue crab, of which I have seen hundreds directly after molting, and they are always firm and delicious eating if taken at this time. In fact, the watery aspect usually attributed to the newly molted crustacean did not appear until some time after the lobster was placed in our live tank.

Very soon after molting the lobster is ready to take food, the body, owing to the absorption of water, plumps out to its natural shape, and the limit of increase in the volume of the body is reached.

The interesting observations of Hyatt on the molting of a lobster were made at Matinicus Island, Maine, July 21, 1880. The ecdysis was accomplished at 9.30 a. m., and the lobster lived forty hours, when the shell had become but little hardened, being still papery and pliable. In twenty-four hours after shedding the claws had swelled out and assumed a transparent, watery aspect. An under tint of green was observed in the shell. The crowns and points of the spines and teeth of the large claws had become whitened. The ratio of increase in bulk was found to be 1.211; the ratio of increase in breadth, 1.192; the ratio of increase in length, 1.010. This lobster came out of its shell without splitting the carapace, and the "tail" was the last part to be set free.

Vitzou describes the molting of a lobster which he watched in the marine laboratory at Roscoff on the 21st of July. He speaks of the membrane between the carapace as being early ruptured, and points to this as a sign that the animal is about to molt, but this can not be a normal occurrence.

WITHDRAWAL OF THE LARGE CLAWS.

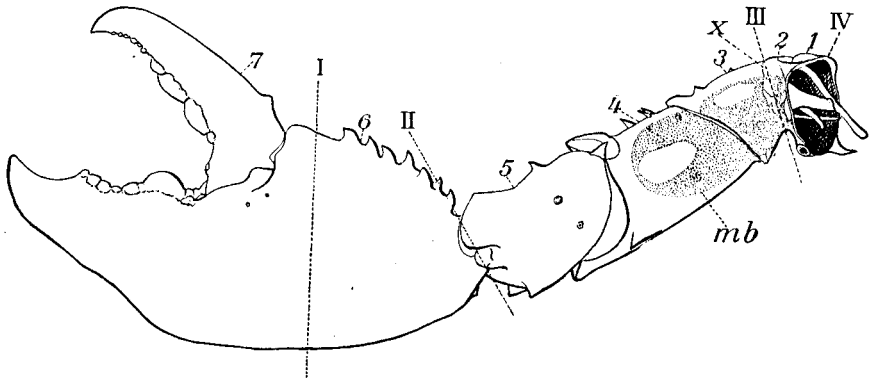
The shell of the large claws is molted entire without a rupture in any part. This means that the great mass of muscles which fills the terminal joints must undergo distension and compression to an extraordinary degree. This will be better appreciated by an examination of cuts 6 and 7, plate B. Cut 6 represents the cast shell of the left cheliped of the lobster (No. 7, table 24) which molted on July 13, and cut 7 cross-sections of the shell with their plotted areas, in the planes indicated in cut 6. The flesh which fills the area I*a* is drawn through the opening of the joint II (plotted area shown in II*a*), and later through III, the smallest part of the claw. The shell is here distensible, however, owing to the absorption of lime from the upper surface, so that probably in this part the area of the cross-section is increased until it equals that of II*a*. Finally the compressed and distorted limb is drawn through the quadrilateral opening at the base IV (plotted area, IV*a*), as Salter says, much as a wire is drawn through the contracting holes of a draw-plate. The latter is somewhat larger than the opening of the subterminal joint II. The area of the section of the largest part of the claw (I, I*a*) is more than four times that of the opening II*a*, through which all the tissues of the claw must pass. The muscles appear to be stretched out like a stick of candy, but, apart from their elasticity, they are probably aided in accomplishing this by the removal of water from the blood. The parts are very much distorted immediately after they are free, and are quite hard, but they soon take up water and assume their natural form, with a proportional increase in size.

The areas of absorption in the three basal joints of the limb are easily distinguished, though less plainly circumscribed, in the hard-shell lobster. The shell of the basal joint becomes a slender ring, which is not broken, as has been inferred, but remains intact, as Salter (*174*) has already observed.

In the crayfish, on the contrary, Réaumur (*161*) maintained that in molting the shell of the "second and third" joints (meaning, as shown by his figure, the meros and carpus—fourth and fifth joints) opens by a longitudinal fissure on the outer side.

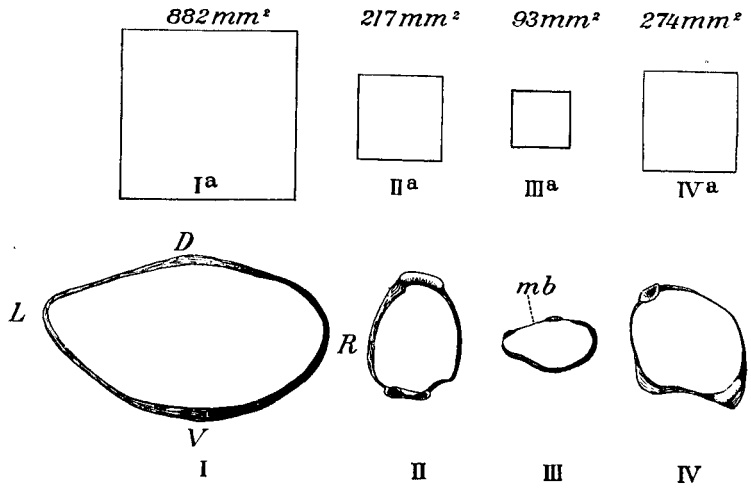
The two pieces are so perfectly adjusted to each other that they appear as one, but at the time of the molt, when the crayfish subjects them to strain, these tubes gape apart and thus permit the passage of the extremity of the limb.

After the molt the crack closes up and appears to be glued together again, as if no rent had been made. This explanation of the withdrawal of the large claws is



CUT 6.—Left cheliped of lobster seen from the dorsal side. From specimen which molted in an aquarium July 13, 1891, and which is described in Chapter III, pp. 83 to 85. See No. 7, table 24. One-half natural size.

The Roman numerals I-IV correspond to the planes of section illustrated in cut 7; Arabic numerals 1-7 to segments of limb. *mb*, area of absorption, on upper surface of third and fourth joints. *x*, plane of fracture.



CUT 7.—I-IV represent transverse sections of cheliped shown in cut 6 in the planes indicated by corresponding numerals, II and IV showing the natural openings at the proximal ends of the sixth and first segments respectively. *Ia-IVa* represent the areas of the respective sections expressed graphically and numerically. (The plotted areas are two-thirds natural size; the numerical expressions above them refer to actual areas.) At *mb*, cuts 6 and 7 (III), the lime salts of the shell have been absorbed, so that the cuticle is capable of distention, and the area of the transverse section is thereby slightly increased. The muscles and other tissues which fill the transverse section *Ia* must be drawn through an opening the size of *IIa*, then through one but little larger than *IIIa* (allowing for the distention of the membrane), and finally through the small ring, IV, *IVa*, at the base of the limb, since there is no rupture of any of these parts. Drawings two-thirds natural size.

Drawn by F. H. Herrick.

repeated by Rymer Jones (*106*) and others. It is, without doubt, erroneous, but possibly based originally upon an exceptional occurrence.

At the time of the casting of the shell the large claws must be practically free from blood, since, as Vitzou has pointed out, if the claw were to be increased in size it would be next to impossible for it to be withdrawn without rupture. The older naturalists used to explain the withdrawal of the large claws by a wasting of the tissues. The lobster was supposed to become sick and emaciated, which, of course, was an error. The most significant fact in this process is the displacement of the liquids which normally belong to these appendages.

Couch (*47*), in his account of the exuviation of the common edible crab of Great Britain, *Cancer pagurus*, maintains that the membranes in the areas of absorption at the base of the chelipeds split along the edges and open like hinges, thus freeing the limb from its constraint. This does not happen in the lobster, as Couch inferred, and even if it did no benefit would arise, since there is the unbroken ring of the coxopodite, through which the tissues must still pass. Spence Bate (*10*) thought that the splitting of the walls of the cheliped, alluded to by Couch, might be to enable "the animal to withdraw the great osseous tendon." It is difficult to understand what is here meant. The great osseous tendons are never withdrawn at all (past the absorption areas at the base of the limb), but remain attached to the old shell, of which they form a part.

THE CAST-OFF SHELL.

At the time of the molt there is an intermediate membrane which makes its appearance between the new and old shells. It is non-cellular, has a gelatinous appearance, is very transparent, and may be found adherent to the old shell after the molt is past. When examined microscopically it has the appearance shown in fig. 177, pl. 44. It bears the impress of a mosaic of cells, which can be none other than the cells of the chitinogenous epithelium. Vitzou is thus in error in supposing that this substance is a secretion of the chitinogenous epithelium underlying the new carapace, which it traverses by endosmosis. It must be either the first secreted product of the new shell or the innermost layer of the old shell modified by absorption.

In this cuticular membrane the parts which correspond to the cell boundaries (of the chitinogenous epithelium) have the form of elevated ridges on the under side, and in the center of each polygonal area there is a slight thickening. Réaumur (*162*) had in view a similar structure in the crayfish when he spoke of a glairy matter, "as transparent as water, which separated the parts which the crayfish was soon to cast off from the rest of the body, and which allowed these to glide smoothly over one another."

There is normally no rupturing of the shell in any part in the course of the molt. The entire exoskeleton, with the linings of the œsophagus, stomach, and intestine, comes off as a whole,[1] and the animal leaves it by drawing the anterior parts of the body backward, and the abdomen and its appendages forward, through an opening made by the elevation of the carapace. When the old carapace falls back into its

[1] The lining of the alimentary tract is of course ruptured. In small lobsters, at the fifth or sixth molt, I have noticed that the break takes place not far behind the stomach-bag, and that while the linings of the masticatory stomach and œsophagus come out by way of the mouth, as in the adult, the lining of the intestine is withdrawn from the anus.

natural position one might, at the first glance, as Réaumur said of the crayfish, mistake the empty shell for another lobster.

In old lobsters, where the membranes are thick, a rupture of the carapace may arise possibly from want of complete absorption of the lime, but this rarely happens, and the lobster gains nothing from the complete dehiscence of the parts.

It has been stated so many times that it has come to be generally believed—the result of the reiteration of error—that the carapace of the lobster is ruptured along the middle line to assist ecdysis. A careful examination of the cast-off shell, which would have settled in short order the disputes over this subject, is the very thing which apparently has not occurred to anyone to make. When this is done, we find that rupture of the shell is guarded against in the most ingenious way. The areas of absorption of lime salts in the carapace, which we have only to consider in this connection, are as follows: (1) The wide lateral margins of the branchiostegites, including what in life appears as a light-blue area, about three-eighths of an inch wide in a lobster 10 inches long; (2) a narrow median stripe extending from near the apex of the rostrum to the posterior margin of the carapace; (3) the endotergites (three small teeth like projections from the under side of the carapace, on which muscles are inserted); (4) a linear area on each side of the rostrum; (5) two small round areas in front of the endotergites—not always noticeable. The linear area (2) extending down the back acts as a hinge, rupture in the rostral region being provided against by the narrow absorption areas on each side of it (4), while the softening of the margins of the carapace makes the lifting of this from the body an easy matter during the molt. The result of such areas of absorption is plainly to prevent the rupture of the shell, which, however, does accidentally occur from other causes. The softening of the endotergites is also necessary to prevent injury to the soft tissues.

THE GASTROLITHS.

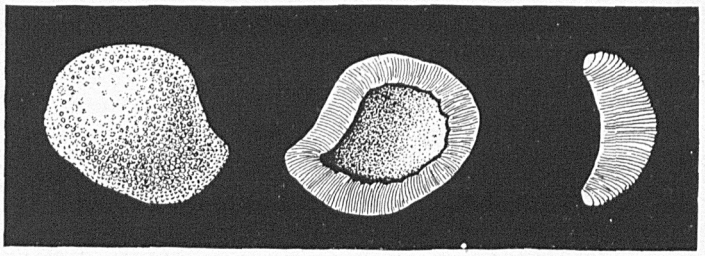
THE GASTROLITHS OF THE LOBSTER; THEIR STRUCTURE AND DEVELOPMENT.

The gastroliths, though often called crabs' eyes, are found only in the crayfish and lobster, so far as is known. Discovered first in the river crayfishes, they early figured in the old pharmacopœia as *oculi seu lapides cancrorum*, and have excited the interest of naturalists from early times. Owing, however, to their very transitory nature, they have been generally overlooked in the lobster. A satisfactory explanation of the function of the gastroliths has, in my opinion, never been given, and in the following section I shall offer one which I think is in harmony with the facts.

The first reference to these bodies, which I have found, is by Geoffroy the younger, in 1709 (*74*), who says, in his paper on the molting of the crayfish:

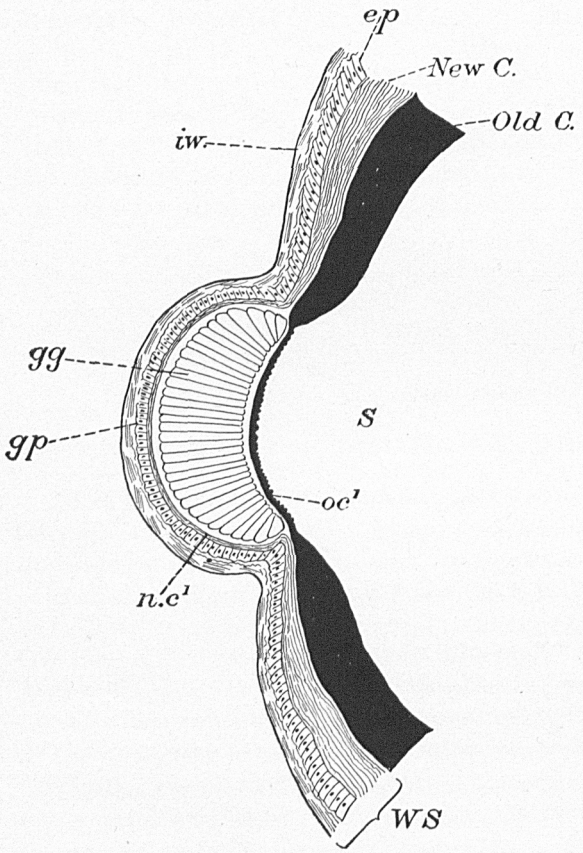
> Although I have spoken only of the stones which are found in the river crayfish, there is, moreover, a kind of crayfish, called *Astacus marinus*, in French *Homar*, in which they also occur.

More particular reference was made to them in 1874 by Chantran (*41*), and they are mentioned for the first time in the American lobster by Wheildon in 1875 (*202*), who says that "just before shedding a white substance, the size of a 5-cent coin, is found on either side of the stomach. These bodies harden into limestone and are absorbed in the process of forming the new shell." They are described by Vitzou (*197*) as an inorganic reserve composed of small truncated rods, free or delicately bound together.



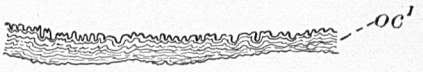
CUT 8.—The gastrolith of a lobster nearly ready to molt, removed from the wall of the stomach.

a, seen from the outside; *b*, from the inside (toward cavity of stomach), and *c*, in transverse section. From adult male, lobster No. 2, table 24. For chemical analysis of this gastrolith, see Appendix II, No. 4*a* of table. Natural size.

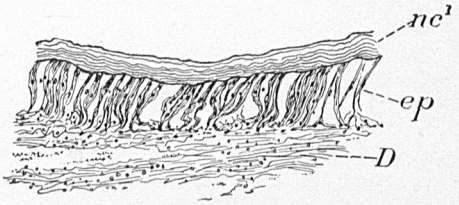


CUT 9.—Diagrammatic section through the wall of the stomach of a molting lobster, cutting gastrolith.

ep, chitinogenous epithelium. *gg*, gastrolith, a differentiated part of the old cuticle. *gp*, gastrolithic sac. *n. c*¹, new cuticle of gastrolithic sac. *iw*, outer side of stomach-wall next body-cavity. *New C*, new cuticle. *oc*¹, the deciduous part of cuticle overlying gastrolith. *Old C*, old cuticle. *S*, interior of stomach. *WS*, wall of stomach.



CUT 10.—Section of the deciduous portion of old cuticular lining of stomach overlying gastrolith. See cut 9, *oc*¹. 89 diameters.



CUT 11.—Section of gastrolithic sac from wall of stomach underlying gastrolith, as it appears while the latter is still in place in the stomach. From a lobster nearly ready to molt. August 2, 1894. See cut 9, *gp*. 89 diameters.

D, connective tissue of dermis. *ep*, chitinogenous epithelium. *nc*¹, new cuticle.

Drawn by F. H. Herrick.

If the shell of a lobster which is nearly ready to molt is carefully removed, there will be seen two glistening snow-white masses, one on either side of the stomach (fig. 184, pl. 44, and cut 9, pl. C). The shape and dimensions of the gastrolith are shown in cut 8 *a–c*, pl. C. This particular one, from a lobster 11 inches in length (No. 2, table 24), was an inch long, three-quarters of an inch wide, and a quarter of an inch thick. Its outer, convex side is applied to the sac in which it lies, while its concave surface is separated from the cavity of the stomach by the old cuticular lining of this organ (cut 9, pl. C). When the stomach is raised the gastroliths almost break through its delicate outer wall by their own weight. They lie between the old cuticular lining of the stomach, which may be stripped off, and its delicate outer wall, next the body cavity. The impression of the gastrolithic plate is seen on the new cuticular lining only (*n. c.*[1]) If the sacs in which they are formed are cut open, each mass separates into a large number—a thousand or more—of ossicles or columns. The majority of these are slender, truncated prisms of irregular shapes, and 5 mm. or more long. Each ossicle resembles a piece of milk-white glass, with transparent edges, and is faintly marked with transverse and longitudinal striations, like those seen in the cuticle (fig. 165, plate 42).

On August 2, 1894, I examined a lobster which was very nearly ready to molt. The old shell came off easily. The gastroliths were fully formed. We can detect upon the new cuticular wall of the stomach the gastrolithic plate, from which the next gastrolith will be formed. When the old cuticular lining of the stomach is removed the new teeth appear of the same brown color and nearly of the same hardness as the old. The supporting calcareous parts are, however, quite soft. (For analysis of these gastroliths, see No. 3*a* of table, Appendix II.)

The gastrolith shown in its natural position in the sac (fig. 184, pl. 44) was from a male lobster 7.5 inches long. This is the smallest animal in which I have found these structures, and it is possible that they are not developed until the lobster is several years old, although I have not obtained enough material to establish the time of their first appearance with definiteness. A female lobster $3\frac{11}{16}$ inches long, which was taken in Small Point Harbor, Maine, by Mr. M. B. Spinney, was as soft as wet paper, and had apparently just molted. Upon dissecting this animal I was surprised to find the stomach stuffed full of fragments of calcareous matter, consisting chiefly of waterworn pieces of the shells of dead mollusks, such as are commonly thrown upon a beach. The largest of these fragments was a quarter of an inch long. Many of the shells were softened or corroded and were easily broken by needles. There were, besides, a considerable number of small mollusks, such as the young stages of *Mytilus edulis*. Some of these shells, when devoured, were undoubtedly alive. No trace of gastroliths could be seen. The old cuticular skeleton of the stomach had been discarded, and the new "teeth" were but little hardened, save upon their brown, horny surfaces.

Another small lobster, a male, $4\frac{9}{16}$ inches long, taken at the same place and at about the same time, had recently molted, probably within a few days. The shell was very delicate and fragile. In this case, also, the stomach was loaded with fragments of the dead shells of mollusks, crabs, and small lobsters. The hardest parts of the shells of the latter seem to have been chosen, such as the stony mandibles, spines, and teeth of the large claws. There was no fleshy substance which might serve as food in this stomach. It is possible that these shells are swallowed by the young lobster, after each molt, to furnish lime for the hardening of the cuticular skeleton. The absence of

gastroliths may have no significance in these cases, but in order to determine this one should examine the stomachs of larger animals which have recently molted under natural conditions.

The gastroliths, though a part of the cuticle, are not cast off during the molt, but are retained in the stomach. When the old lining of this organ is withdrawn, the gastroliths are soon set free, and breaking up into their constituent parts are speedily dissolved.

In the lobster referred to above (No. 2, table 24), which was preserved immediately after the old shell was shed, the gastroliths were still in place in the stomach, and unchanged. (For chemical analysis of these, see table, Appendix II, No. 4*a*.) The horny parts of the gastric ossicles agree closely with those of the cast shell, having the same light-brown color and approximately the same hardness. The supporting calcareous parts are, however, quite soft. In every case which I have examined, the old teeth are expelled from the stomach at the time of ecdysis, and not left with the gastroliths, as Réaumur (*161*) said was true of the crayfish.

Experiments upon the crayfish have seemed to show that the gastroliths are necessary for the hardening of the new shell, but this is undoubtedly an error.

The length of time required for the development of the gastroliths of the lobster has not been determined. It is probable, however, that the latter part of their development is rapid, and that they are conspicuous objects for a few days only before the shell is cast off.

A female lobster which was examined August 10, 1893, had a very hard, dull-colored shell, which one might infer would be shed before many weeks. In place of the gastrolith there was a very thin gastrolithic plate in the lateral wall of the stomach (fig. 183, pl. 44). A section through this plate (fig. 171, pl. 43) shows how the gastrolith is developed. The cuticular epithelium is columnar, consisting of very long, slender cells. The thick excreted cuticular product is traversed by undulatory striations, which mark off the columnar ossicles, the separation of which begins at the outer surface.

The inner section of the gastrolithic plate (*G P*) appears much more homogeneous than the outer portion, although the demarcation is not quite so sharp as appears in the figure. The striations in the inner part are only conventionally represented. The undulatory striæ extend inward, and with the deposition of lime the ossicles are developed and completely separated. When the gastroliths are fully formed (cut 9, plate C) the deciduous cuticle of the gastrolithic sac is differentiated into two parts, the gastrolith (*gg*) and a thin outer layer (oc^1, cuts 9 and 10) corresponding to the outermost part of the cuticle shown in figure 171 and in continuity with the old lining of the stomach (*Old C*). The new cuticle of the stomach (*New C*) is represented in the gastrolithic sac by a thin stratified layer (nc^1, cuts 9, 11), from which the next gastrolith will be developed.

The condition of the gastrolith at this stage bears a resemblance to that which is finally reached in the crayfish, where, according to Huxley (*103*):

> It is a solid body which, in vertical section, is seen to be composed of thin superimposed layers, the densest of which form the hard projections of the outer surface next the epithelial substratum.

The outer side of the gastrolith in the crayfish is roughened with irregular prominences, so that it resembles a "brainstone" coral. When from any cause the stones are not dissolved, they lose their normal blue or white color and become brown or green; the shell remains soft and the animal, according to Chantran, soon dies. When the

formation of the stones is arrested, as Chantran had often observed in October and November, the crayfish was unable to molt, and died.

Chantran (*42*) presented to the Academy of Sciences of Paris a paper, giving an account of the natural concretions, called "crayfishes' eyes," produced from the time of birth in this crustacean up to the age of six years—that is, during 22 successive molts. It was found that the stones are not absorbed at the moment they become free in the stomach, but that they are gradually worn down by reciprocal rubbing and contractions of the stomach. The plane faces of the stones are thus rubbed together until they are gradually worn down, and at the tenth hour after ecdysis they are reduced to pellicles of 1 to 2 mm. in diameter. The destruction of the concretions may be complete at this time, or they may persist up to the eightieth hour.

According to Chantran (*41*, *42*), the number and succession of molts in the European crayfish are as follows: First year, 8; second year, 5 or 6; third year, 3. After the third year the males molt twice and the females once annually. He further believed that every molt involved the formation of calcareous masses in the stomach, and that these numbers consequently show how often the gastroliths have been formed and used up. The time occupied in their formation increases with age, being 10 days the first year, 15 days the second, 25 days the third, and 40 days in subsequent years. The time which elapses after the molt before the stones are reabsorbed also varies with the age of the individual, from 24 to 30 hours in the young, which have not molted more than twice, to from 70 to 80 hours in adults.

HISTORY OF THE GASTROLITHS—THEIR PROBABLE FUNCTION.

The gastroliths were the subject of much curious speculation among the older naturalists—Gesner, Bellonius, and Agricola—who, according to Herbst, assigned to them a position in the brain. Van Helmont, who first described their true position, was not far from right in thinking that they were formed by a milky secretion which was poured out between the old and new linings of the stomach. Geoffroy's observations (*74*), published in 1709, were the best made up to his time.

> I have opened [Geoffroy says] vigorous crayfishes which had entered upon the process of molting and have found in the place of each stone a scale or white plate, which swims in the middle of a mucus, and which was apparently the undeveloped condition of the stone. This stone and the glairy liquor were enveloped in a small, membranous, and very delicate sac.

In crayfishes which have recently molted the stones are not in their usual places, but lie in the stomach, joined together by their concave parts. No vestige of a stone was found in the stomachs of crayfish in which the shell had hardened after molting. He concludes however that the stones play no part in the formation of the new shell, although they appeared to serve as food after the molt.

Réaumur (*162*), besides repeating Geoffroy's observations, added much that was new to the subject, and placed the general facts of the molting of crustacea beyond the doubts which had existed up to his time. By dissecting crayfishes which had molted he found that the stones gradually dwindled and disappeared. He says:

> Is it not natural to suppose that these stones are dissolved, and that their substance is then carried and laid down in the interstices of the fibers of which the skin is composed?

Roesel (*168*), in his beautiful Insecten-Belustigung, published in 1755, discusses at some length the function of the gastroliths, coming to the conclusion that they are useless material which is formed during the molt, to be afterwards expelled from the

œsophagus. According to Mayer, whom Roesel quotes with some reserve, it was the custom of the inhabitants of Asiatic Tartary and Ukrania to collect crayfish at the time of the year in which they were in the best condition and place them in large pits in the ground. Here they were broken up and allowed to remain all winter, during which time the evil odor kept everybody away. In the spring the owners would return, wash out the remnants of the crayfish in water, and sift out the stones with a sieve which they used for this purpose. It was formerly the custom also in Poland and Russia, on the River Don, to collect crayfish in large quantities and allow them to rot in the fields or in pits. The stones were afterwards carefully collected and sent to market to be used as medicine.

Mr. Baker (*7*) communicated to the Royal Society on February 25, 1748, an interesting letter on "crabs' eyes" from Dr. James Mounsey, a Russian physician. He noticed the seal-shaped spots on the wall of the stomach, which mark the position of the developing gastroliths, and concluded that the latter helped to form the new shell, which, he says, "does not greatly recommend the opinion that these stones have a dissolving quality of service against the stone in the human kidneys and bladder." "The price comes to a groat or sixpence a pound. All the apothecary shops throughout the whole Russian Empire are furnished with them, and great quantities are exported." Notwithstanding their cheapness, "fictitious bodies, made of chalk" and "tobacco-pipe clay" were cast in molds and substituted for real "crabs' eyes." In this case the counterfeit undoubtedly possessed all the virtues of the genuine article.

K. E. von Baer (*6*) thought that the gastroliths were salivary stones, developed in the lumen of a salivary gland, an idea which was not destined to bear much fruit. Some writers even pretended that they were cast out through a fissure in the walls of the stomach and body.

Van der Hoeven (*195*) seems to have been one of the first in the present century to protest against the theory that the sole function of the gastroliths was to provide lime for the new shell. In his Handbook of Zoology, a translation of which was published in 1834, he says:

> The part, however, which the crabs' eyes take in the secretion [of the hard shell] can not be great when we compare their weight with that of the calcareous matter of the shell. During the time that the shell is still increasing in hardness no new crabs' eyes are produced; but only after the shell has attained its greatest hardness is calcareous matter again secreted on the walls of the stomach, and new crabs' eyes again appear. Thus the production of crabs' eyes would seem to be a vicarious secretion of such constituents of the blood as, if too abundant, would be injurious to the organs, like the secretion of urine for instance, but with this difference, that the calcareous matter is not set at liberty shortly after its secretion, but remains accumulated for a long time in continuance.

Max Braun, in his work on the molting of the crayfish (*22*), concluded that the gastroliths were cuticular products analogous to the integument, but paid no attention to their function or growth.

Vitzou (*197*) says that shortly after the molt in the lobster the gastroliths are dissolved in the acids of the stomach and, entering the lymph, form an inorganic reserve comparable to the phosphatic plaques which are found in the membranes of the fœtus in ruminants.

The problem of the gastroliths has recently been attacked by Irvine and Woodhead (*105*) in one of their valuable communications on the secretion of carbonate of lime in animals. They conclude that, if the gastroliths play any part at all, they must be converted into phosphates and thus carried in the lymph. If the brachyura have

a lime reserve, it must be in the lymph, in the form of calcium phosphate, since they have no gastroliths. "We think," they say, "that this theory [of the gastroliths contributing to the formation of the new shell] may be dismissed as of comparatively little importance, since, even if the teeth and whole calcareous structure could be absorbed by the animals, the amount of carbonate of lime at their disposal from this source is so small (a very small fraction of the outer covering) that it could not account for any considerable part of the new structure. Consequently such an explanation must be abandoned."[1]

These writers are undoubtedly right in attributing little importance to the gastroliths as a source of lime for the new shell. Lime is usually at hand in abundance in the form of the dead skeletons of mollusks and other animals, and, as we have seen (see p. 89), young lobsters make free use of it at the time of the molt. The fact that the brachyura have no gastroliths should also possess some significance.

I have already shown that there are considerable areas in the shell where the lime is completely absorbed preparatory to the molt. What becomes of the lime thus removed? So far as known, there is no means of eliminating it directly from the body, and it is not likely that this amount of lime can be retained in the blood in addition to that which the latter is constantly receiving from the food. It seems to me much more probable that the gastroliths in the lobster represent the lime which has been removed by absorption from the old shell preparatory to the molt, as well as, possibly, a small amount which may have entered the blood from the food during the molting period. The blood probably contains a maximum quantity of lime at this time, so that very little can be absorbed from the food. Upon this hypothesis the absorption of the gastroliths is a purely secondary phenomenon and of comparatively little importance in the vital economy. In the brachyura, where no gastroliths are developed, we should expect to find the absorption of lime from the shell to be relatively much less, which, so far as I can ascertain, is the case. It seems to be a fact also that the absorption of lime from the old shell proceeds *pari passu* with the growth of the gastroliths.

Chantran observed (see p. 90) that when the formation of the stones was arrested in the crayfish the animal died. This might be true of the lobster, and would not conflict with the theory proposed. When once formed, the question of the subsequent absorption of the gastroliths is not of vital importance. Vitzou speaks of a lobster which died six days after the molt, without absorption of the gastroliths having occurred. It would, of course, be very illogical to conclude that the gastroliths were necessarily in any way concerned with the death of this animal.

[1] In an interesting letter from Dr. Irvine, describing some of his recent experiments, he says in reference to a former attempt to determine the proportionate quantities of carbonate of lime in the exoskeleton: "But as these experiments were made with the common shore crabs, containing much less carbonate of lime proportionately to a full grown animal, I have repeated the determination, using a full-sized lobster which weighed 15,000 grains. On carefully separating the stomach, and freeing it from merely fleshy appendages and drying it, I find it to weigh about 50 grains or $\frac{3}{1000}$ of the whole animal, while the gastroliths weighed only 20 *grains* or $\frac{1}{750}$ of the whole. I then carefully dried the outer calcareous structure and found it to weigh 3,720 grains, the proportion between the carbonate of lime in the gastroliths and in the outer structure being 20 grains to 3,720 gr ains The $CaCo_3$ in the gastroliths thus stood in proportion to the $CaCo_3$ in the exoskeleton as 1 part in 186, an amount too trifling to be of any practical service in providing calcareous matter for it."

CHEMICAL ANALYSIS OF THE SHELL AND GASTROLITHS.

It seemed to me that a chemical analysis of the shell of the lobster in its different conditions imposed by the molting habit might prove of interest, especially when compared with the composition of the gastroliths, and I am fortunate in being able to add as an appendix of this work the results of several analyses made by my friend, Professor Albert W. Smith.

The most striking facts brought out by Professor Smith's work are, first, that lime salts, carbonates and phosphates, form about half the constituents of the hard shell, there being from three to five times as much carbonate as phosphate. We also find that in the cast shell of the lobster, the brittleness of which we have already noticed, the proportion of organic matter present is considerably less than under other conditions. An absorption of organic matter thus takes place during the period in which the new shell is formed, and this fact explains the fragility of the cast-off shell.

It is also interesting to notice that small quantities of alumina and silica are normally present in both the shell and gastrolith.

The composition of the gastroliths is very like that of the shell, a conclusion which we would be led to draw from the fact that the gastrolith is but a specialized part of the dead chitinous integument. The same substances are found in both, but in different proportions. The gastroliths are far richer in lime, chiefly in the form of carbonate ($CaCO_3$), than is the shell, and the amounts of magnesium carbonate ($MgCO_3$), alumina (Al_2O_3), ferric oxide (Fe_2O_3), and silica (SiO_2) are more or less reduced.

Lime estimated as carbonate ($CaCO_3$) constitutes about three-fourths of the gastrolith, but less than two-fifths of the carapace. Lime reckoned as phosphate ($Ca_3(PO_4)_2$) forms about 10 per cent of the gastrolith and but little less in the case of the shell; about 10 per cent of the gastrolith is water and organic matter, probably mainly chitin, and the rest is made up of the various salts and oxides given in the table. In the only molted shell analyzed about 38 per cent was water and organic matter, while in two hard-shell lobsters this percentage was considerably greater, 42.21 in one case and 51.80 in the other.

The gastroliths of the crayfish were analyzed by Dulk (*54*) in 1834,[1] but apart from this rough determination no later work has been done on this subject.

He also analyzed the contents of the stomach of a crab newly molted, and found a free volatile acid, probably hydrochloric, present, besides lime salts (*53*).

THE HARDENING OF THE NEW SHELL.

Since the total quantity of lime contained in the gastroliths is insignificant compared with the amount necessary for building up the hard crust, the rapidity with which the new shell hardens depends, in some measure, upon the individual, and particularly upon the quality of its food. We have seen that the adolescent lobster, under 4 inches long, after molting swallows fragments of shells and other calcareous materials, which are dissolved in the stomach and help in strengthening the new shell. It is possible that older lobsters have the same habit.

[1] The results of Dulk's work were as follows:

Animal matter soluble in water	11.43	
Animal matter insoluble in water (probably chitin—Huxley)	4.33	
Phosphate of lime	18.60	98.93
Carbonate of lime	63.16	
Soda reckoned as carbonate	1.41	

According to the researches of Irvine and Woodhead lime salts, in whatever condition absorbed, are changed during digestion into acid phosphates, and in this state are carried by the blood to the protoplasm of the chitinogenous cells. The nascent carbon dioxide gas, which the active protoplasm of these cells throws off, precipitates calcium carbonate ($CaCO_3$) and calcium phosphate ($Ca_3(PO_4)_2$). These salts are then dialyzed into the dead chitinous matrix, where they are finally laid down. Lime is deposited in an insoluble condition only in vitally inactive tissues. They found that crabs which began to shed late in the season were retarded by the cold. Heat thus seems to be a necessary factor in the assimilation of lime salts from seawater by these animals. They also found that the crabs died in water containing only sodium chloride (NaCl), but lived without molting in water containing NaCl and magnesium chloride ($MgCl_2$); they lived and molted in water which contained NaCl, $MgCl_2$, and calcium chloride ($CaCl_2$), the latter in the amount equivalent to the lime in normal sea water.

A lobster which molted while under observation (No. 7, table 24) was watched particularly with reference to the hardening of the shell. One hour after the molt the cuticle seemed to the touch of the finger to be perceptibly hardened, but this may have been partially due to the turgescence of the tissues. Eighteen hours after shedding the cuticle had a leathery consistency, and the tubercles and spines had hardened slightly. The shape of all the parts was perfectly normal. Four days after the molt, when the animal died, the cuticle was still coriaceous, and but slight increase in the stiffness of any parts had occurred.

A lobster which also molted in confinement (No. 6, table 24) was kept for a period of twenty-five days. The carapace at the end of this time was easily compressible between the thumb and finger. The large claws could be made to yield in the same way, but not without using considerable force. It was in the state which the fishermen call "paper shell" or "rubber shell." If sent to market it would be classed as a soft-shell lobster. It is possible, of course, that in this space of time a lobster under natural conditions would have become harder. It is safe to conclude, however, that from six to eight weeks are necessary, under ordinary conditions, to produce a shell which is as hard as that cast off; and if the lobsters were destined for the market they would probably be in a still better condition in ten weeks or three months. Many lobsters are caught and shipped to dealers a few weeks after they have molted, but their meat is then soft and of inferior quality, as we have already remarked. According to the opinion of a canner of lobsters in Maine, 7 pounds of soft-shelled lobsters in summer or fall will yield no more than 4 pounds in spring, when the flesh is more solid.

Réaumur says of the crayfish (*162*) that he has seen the new shell become as hard as the old in 24 hours, but that it usually takes from two to three days. This observation is confirmed by Chantran (*37*), who says:

> Twelve hours after the molt, the nippers are already hard enough to pinch sharply, and in 24 hours they are completely hardened. The sides of the back remain flexible for a much longer time, but at the end of 48 hours they have attained a degree of consistency which is almost normal.

Vitzou remarks that the carapace of the crabs has perceptibly hardened after 24 hours, but is not completely hardened until after 72 to 80 hours.

It has been stated that the shell of the newly molted lobster becomes as hard as formerly in the space of 24 hours. This and many similar conjectures which have been made upon this subject are entirely erroneous, as proved by the statistics of the fishery during the summer months. It is probable, however, that under exceptional conditions this process is subject to much variation.

THE RATE OF GROWTH.

The question often asked is, How long does it take an adult marketable lobster to grow? It is impossible to answer this with certainty, since complete data for solving the problem have not been gathered. We can, however, give a tentative answer which is probably not far from the truth.

In order to ascertain the average age of a lobster 10½ inches long (weight, 1¾ pounds), it would be necessary to know, first, the number of molts which the animal had passed through, and, secondly, the time interval between each molt. The number of molts can be approximately determined by means which I shall presently discuss. The time interval can only be ascertained by keeping the animals alive for a period of years and carefully recording their growth. Both factors are very variable quantities, as I have already shown. The length of one yearling lobster which was raised from the egg was only 36 mm., while three other lobsters measured from 35 mm. to 51.8 mm., when not over five months old. Lobsters which live in harbors where they find abundant food undoubtedly grow much faster than those farther from shore. It would hardly be expected, moreover, that lobsters kept under artificial conditions would grow as rapidly as when free in the ocean.[1]

In table 24 I have recorded the molts of eight lobsters varying from 5½ to 11¼ inches in length. The actual increase in length varied from 1 inch to 1½ inches, and the increase percentage (that is, the ratio which the increase bears to the total length before molting) from 6.66 to 18.18. The average percentage of increase in all these cases is 12.01.

TABLE 24.—*Increase in the length of lobsters at the time of molting.*

No.	Date.	Sex.	Length before the molt.	Length after the molt.	Increase in length.	Increase per cent.	Remarks.
			Inches.	*Inches.*	*Inches.*		
1	Oct. 22, 1890	Female.	5½	6½	1	18.18	Carapace of molted shell unbroken; preserved a few days after molting; gastroliths gone; stomach filled with pieces of fish, which had been fed to it; carapace leathery. Plates 45*a* and 45*b*.
2	Oct. 29, 1890	Male....	11	12	1	9.09	Carapace unbroken; preserved immediately after molting; gastroliths in their sacs in the walls of masticatory stomach. See cut 8, plate C. For chemical analysis of gastroliths, see Appendix II, No. 4*a* of table.
3	Nov. 6, 1890	...do	7½	8⅛	⅝	9.68	Carapace unbroken.
4	Nov. 10, 1890	.....	9	10½	1½	16.66	Do.
5	Nov. 11, 1890	.....	7½	8	½	6.66	Do.
6	June 8, 1891	...do	9 9/32	10½	1 7/32	13.13	Carapace unbroken; measured July 2. See table 28.
7	July 13, 1891	...do	11¼	12½	1¼	11.11	Carapace unbroken; measured July 17. See account of molting of this lobster, pp. 83–85; also plate B.
8	.....	.....	6½	7¼	¾	11.54	Recorded by Packard (*147*).
	Average...	.....	.....	.....	.....	12.01	

[1] The best way to ascertain the growth of the lobster would be to fence in securely with wire netting a convenient area in a lobster pound, place a few lobsters in the inclosure, and feed them regularly. They should be examined every week and carefully measured. They could be distinguished by branding the tail-fan. By selecting lobsters of different sizes (3, 5, 8, 10 inches long), the rate of growth at different periods of life could be gradually determined.

The increase per cent in the growth of larvæ is recorded in table 34. Sixty-six molts belonging to more than half as many individuals are tabulated. The average increase per cent in length in stages 2 to 10 varied from 11 to 15.84. The average for stages is 13.67; for individuals, 13.89. These facts seem to warrant the conclusion that the increase percentage in the young is very similar to that of the adult, a result of considerable interest. The average length of the young lobster during its first ten molts is given in the following table. The data are taken partly from table 34:

TABLE 25.—*Actual length of lobsters during the first ten molts.*

Number of molt or stage.	Average length.	Extremes in length.	Number of lobsters examined.
	mm.	*mm.*	
1	7.84	7.50 to 8.03	15
2	9.20	8.3 10.2	47
3	11.1	10 12	79
4	12.6	11 14	64
5	14.2	13.4 15	15
6	16.1	15 17	12
7	18.6	18 19.5	4
8	21.03	19.75 22	5
9	24.5	24 25	2
10	28.03	26.6 29.5	3

The rate of growth expressed by the average of lengths in the second column of table 25 implies an increase per cent of about 15.3 instead of 13.67 (the average increase in stages recorded in table 34). Assuming the average length of the first larva to be 7.84 (the average of 15 individuals, table 25), and allowing the increase in length at each molt to be 15.3 per cent of the length before molting, we would have the following series of lengths attained during the first thirty stages.

TABLE 26.—*Estimated length of lobsters during the first thirty molts.*

Stage.	Length.	Stage.	Length.	Stage.	Length.
	mm.		*mm.*		*mm.*
1	7.84	11	32.55	21	135.17
2	9.04	12	37.54	22	155.86
3	10.42	13	43.28	23	179.70
4	12.02	14	49.90	24	207.20
5	13.86	15	57.53	25	[1]238.90
6	15.98	16	66.34	26	[2]275.45
7	18.42	17	76.49	27	317.59
8	21.24	18	88.19	28	366.16
9	24.49	19	101.68	29	422.21
10	28.23	20	117.24	30	[3]486.81

[1] 9.5 inches. [2] 11 inches. [3] 19.1 inches.

According to this estimate a lobster 2 inches long has molted 14 times; a lobster 5 inches in length, from 20 to 21 times; an adult from 10 to 11 inches long, 25 to 26 times, and a 19-inch lobster 30 times. These estimates do not, I believe, go very far astray. We see them practically verified up to the tenth molt by comparing the figures given above with those in the second column of table 25.

The time interval between successive molts is the next point to consider. The yearling lobster undoubtedly varies greatly in size. A young female lobster already mentioned reached the length of 51.8 mm. by December 10, or when from five to six months old (No. 19, table 33). On the 28th of January 16 small lobsters, measuring from 39 to 83.7 mm. in length, were driven ashore at Woods Hole during a storm. It is

certain that some and possibly all were hatched in the preceding summer. Allowing the lobster (No. 19, table 33) whose length was 51.8 mm. long on the 10th of December to have molted, in case it had lived, three times before the following June, and this is well within the bounds of probability, it would then have attained a length of a little over 3 inches. During the first year the young lobster probably molts from 14 to 17 times and attains a length of from 2 to 3 inches, but it is likely that the length reached often exceeds these limits.

Of the young lobsters recorded in table 32 a few may be the young of the year (Nos. 1–4), that is hatched in the previous June, but the majority are probably from one to two years old. It is further possible that some of these were hatched at other times of the year than June.

Brook appears to be the only one who has given a trustworthy account[1] of the successive molts of individual lobsters. He succeeded in keeping a lobster (female, length $6\frac{15}{16}$ inches) alive in an aquarium 506 days, from July 1, 1883, until November 19, 1884, during which time the animal molted four times (on July 1 and December 25, 1883, July 25 and November 19, 1884) and increased in length $2\frac{7}{16}$ inches. During the first year of its captivity it molted twice, in summer and early winter; again it molted in summer and late fall. The lengths at successive stages were as follows: $6\frac{15}{16}$, $7\frac{3}{16}$, 8, $8\frac{14}{16}$, $9\frac{6}{16}$ inches.

In another captive lobster (a male, length $7\frac{3}{16}$ inches) four molts were also passed, one in the spring and fall of two successive years (May 19, September 20, May 13, October 13). The lengths at successive stages were as follows: $7\frac{3}{16}$, $7\frac{15}{16}$, $8\frac{15}{16}$, $9\frac{6}{16}$, $9\frac{12}{16}$ inches. There was an increase here in length of $2\frac{9}{16}$ inches in 414 days.

These experiments are instructive in showing that in the unfavorable conditions of life in an aquarium a lobster from 6 to 7 inches long will make a gain in length of $2\frac{1}{2}$ inches in 14 to 17 months. It is therefore extremely likely that in nature a 6-inch lobster will often attain the length of from 9 to 10 inches in two years.

How long a time is the 3-inch yearling lobster growing to become 6 inches in length? Reference to the series of molts given in table 26, deduced from study of the young, leads us to expect five molts (Nos. 18 to 22) between the 3 and 6 inch stages. It is certain that these do not embrace more than two years, and it is probable that they require somewhat less. We may therefore conclude that a 10-inch lobster is between four and a half and five years old, the higher degree of probability favoring the smaller number.[2] The reader is reminded that this is only an estimate, based, it is true, upon rather slender data, but upon the only facts which we possess. In future years some experiments will be made by which this result can be tested.

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[1] Buckland (29) says that "according to some careful observations made at the marine laboratory, Concarneau, it appears that the first year the lobster sheds his shell six times, the second year six times, the third year four times, and the fourth year three times." If this were amended so as to read *careless* instead of "careful" observations, no complaint could be made. We have seen that the American lobster molts ten times in the space of three or four months, and it is not probable that the record is very different for the English species. No crustacean is known in which the molts are as numerous during the second year of its life as during the first. A table is also given by Buckland showing the rate of growth during successive molts, but it seems to be based upon error. At the eighth molt the lobster is said to be 2 inches long, whereas the American lobster is less than 1 inch in length at the eighth molt (21 mm., see table 25), and there is no reason to believe that the European species is more than twice as large as its near ally at this stage.

[2] Coste maintained that the European lobster was about 5 years old (length 24 cm.) before becoming sexually mature, and this supposition, though unsupported at the time by any detailed facts, seems to be very near the truth. (See *61*, p. 285.)

Vitzou records the following observations (*197*) upon the increase in size and weight of molting lobsters. In a lobster which was measured immediately before and after the molt it was found that the carapace had gained 11 mm. in length and the abdomen 8 mm. The last joint of the right claw was smaller by 3 mm., which is explained, first, by the thickness of the chitinous layer in this joint, and, secondly, by the almost complete absence of blood in the claw at this time. This is a forced condition, since if the last joint of the claw were increased in size it would be next to impossible for it to be withdrawn (see pp. 86–87). The same lobster 17 hours after the molt showed no increase in size of carapace or abdomen, but the claws had gained from 12 to 15 mm. in length. No increase in any of these parts was noticed on the third to the sixth days following the molt, but there was a gain in weight.

TABLE 27.

Time of observation.	Weight.	Increase.
	Grams.	*Grams.*
Immediately after molt	500	
The day following molt	610	100
Third day following molt	619	9
Fourth day following molt	642	23
Fifth and sixth days following molt	642	0

The following measurements show the increase in various parts of the body after the molt. They refer to lobster No. 6, table 24 (compare plates 45*a* and 45*b*):

TABLE 28.

Measurements.	Before molt.	Five days after molt.	Increase.
	Inches.	*Inches.*	*Inches.*
Length	9.28	10.50	1.22
Length of carapace	4.38	5.03	.70
Greatest width of carapace	2.2	2.33	.13
Length of crushing-chela (propodus)	4.12	5.62	1.50
Width of crushing-chela at base of dactyl	2.06	2.56	.50
Length of dactyl	1.90	2.25	.35
Width of dactyl at base	.72	1.00	.28
Length of small cutting-chela (right)	4.53	5.53	1.00
Width of small cutting-chela	1.53	1.47	— .06
Length of dactyl	2.53	3.06	.53
Width of dactyl	.56	.65	.09

Chapter IV.—DEFENSIVE MUTILATION AND REGENERATION OF LOST PARTS.

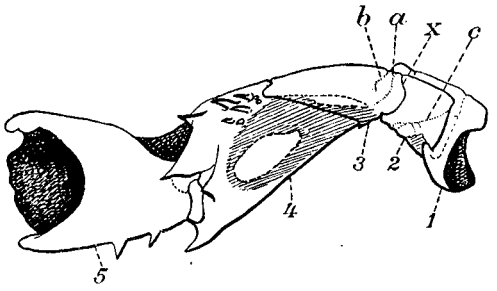
AUTOTOMY IN THE YOUNG AND ADULT.

It is well known that among the invertebrates the crustacea possess, in a remarkable degree, the power of reproducing parts of their bodies which have been lost. This is most pronounced in those Decapods, such as the crab and lobster, which practice defensive mutilation or autotomy. Thus, if one catches a land crab and holds it by the carapace it brandishes its chelipeds in its vain attempts to get free, but once seize it by the claws, the crab immediately scuttles off, leaving you in possession of its only effectual weapons. The leg is broken off at a definite place near its base; there is very little bleeding from the old stump, and a new limb soon sprouts and grows again. This power of thus detaching a limb at the right time is a valuable means of defense, which, as Père Du Tertre remarked, would be very useful for pickpockets. The lobster has the power of casting off its legs, but those which carry the "nippers" are the most commonly sacrificed.

The limb (cut 6, plate B) consists of seven joints, two basal ones—coxopodite (1) and basipodite (2)—and five succeeding joints, the last two of which form the claw (6 and 7, cut 6). In autotomy the five terminal joints are always cast off; that is, fracture takes place between the second and third segments. In the large chelipeds of the lobster the second and third joints—basipodite (2) and ischiopodite (3)—are fused together. This is the case in all the pereiopods of the crab. There is a distinct groove which marks the union of the two fused joints, and it is always in this groove that disjunction occurs (x, cut 13, plate D). This fact was noticed by Réaumur (*161*) at the beginning of the last century, but he did not offer an explanation. He noticed that it was not at the functional articulation that the limb was broken, and that the shell of the "second joint" (second and third, cut 13) was "composed of several different pieces. The evidence of this was found in the presence of two and sometimes three sutures, which occur in this part. It is in the middle suture, moreover, that the leg is broken." He noticed also that the leg could be broken off by exerting very little force. The interesting fact did not escape his attention that if you cut off the leg at or near the terminal joint you will find after a time that the mutilated limb is always thrown off at the suture between the second and third joints.

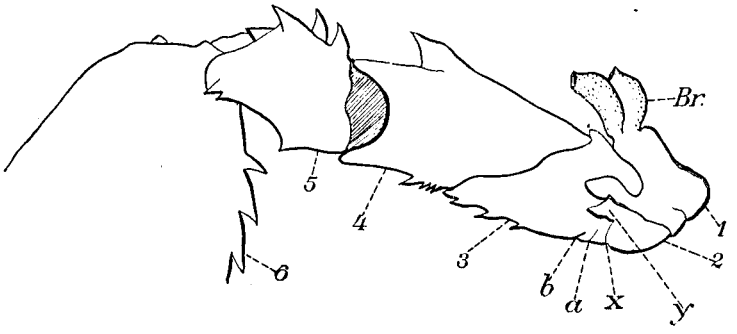
Fredericq (*71*) has published several papers on the defensive mutilation of the crab, and has given a physiological explanation of this phenomenon. I will now add a brief abstract of some of his experiments, which were performed chiefly upon the common green crab, *Carcinus mœnas*.

The breaking off of a leg, which so often happens when we handle these animals, is not due to their fragility, for experiment proves that the limbs of a dead crab are very resistant and that they will support a weight of 3½ to 5 kilograms (7.7 to 11 pounds), which represents about one hundred times the weight of the entire body of the animal. If one breaks off a leg of a dead crab, it separates either between the cephalothorax and first joint, or between the first and second joints, and a mass of muscles is usually drawn out of the body with it. The fracture of the leg of a living crab occurs, as we



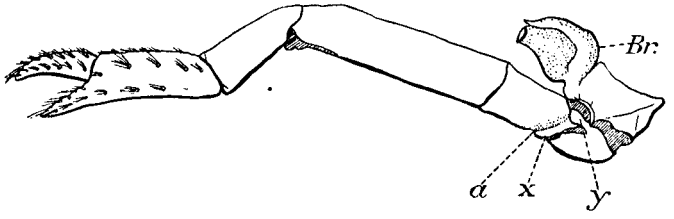
CUT 12.—First left pereiopod of adult lobster, seen from in front, showing anterior border at base of limb. Two-thirds natural size.

a, *b*, constrictions in cuticle of third joint. *c*, oblique linear impression upon upper surface of second joint. *x*, plane of fracture. *1–5*, segments of limb.



CUT 13.—Basal portion of first left pereiopod of adult lobster from under side. Two-thirds natural size.

a, *b*, grooves on surface of third joint external to *x*. *Br*, podobranchia. *x*, plane of fracture. *y*, spur of second joint. *1–6*, segments of appendage.



CUT 14.—Second left pereiopod of female, 10 inches long, seen from under side. Two-thirds natural side.

a, constriction upon second joint immediately in front of *x*. *Br*, podobranchia. *x*, articulation between second and third joints, corresponding to plane of fracture in cuts 12 and 13. *y*, spur on second joint.

Drawn by F. H. Herrick.

have seen in the large cheliped of the lobster, in a definite plane. It involves only the nerves and blood vessels of the soft tissues, and is provoked by a vigorous muscular contraction, which occurs whenever the nerve of the leg is stimulated violently, whether by a mechanical stimulus, as by snipping off the terminal joints, or by electricity, heat, or chemical action. The nervous mechanism is reflex, and thus beyond the control of the animal. Autotomy occurs when the whole of the dorsal and cephalic regions of the body, including the supra-œsophageal ganglion or brain, is removed. The reflex nerve center is found to lie in the thoracic ganglionic mass of the crab, or ventral nerve-chain of the Macrura.

The second compound joint is moved by two muscles, a flexor and an extensor, of which the last only is essential to autotomy. Fracture of the limb was produced so long as the extensor muscle and its tendon were unimpaired, but when these were sectioned autotomy was suppressed.

The mechanism of the crustacean limb has been explained by Milne Edwards (*58*, vol. 1, p. 152). The leg consists, as we have already seen in Decapods, of seven joints, each of which is a lever of the third order. Any two joints are articulated like a hinge, touching at only two points, and are capable of simple extension and flexion only. The whole limb, however, is capable of executing complicated movements, since the axes of articulation of the several segments are not parallel, but nearly at right angles to each other. Each segment possseses two or more cuticular tendons at its proximal extremity, upon which its flexor and extensor muscles are inserted, the fibers of the latter being fixed upon the inner surface of the next proximal joint.

Fredericq has shown that the distal extremity of the second joint, or basipodite, is separated from the third joint, or ischiopodite, by a diaphragm, perforated near its center only, for the passage of the nerves and blood vessels; and Andrews (*3*) has pointed out that "in the spider crab, *Libinia canaliculata*, there extends from the plane of rupture" a distinct membranous fold, "from the epidermis to the central nerve and blood vessels." With the rupture of the limb the outer half of the membrane is torn away, leaving a clean stump. This double membrane possibly represents, as Andrews suggests, the invagination of the body wall, like that seen at an ordinary movable joint. This membrane has thus experienced a complete change of function, and has become modified so as to prevent excessive hemorrhage.

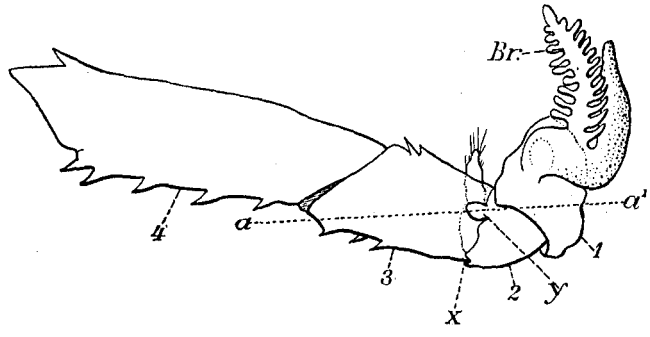
In order that autotomy may occur it is necessary that the peripheral portion of the limb should offer a greater resistance than the traction of the extensor muscle is able to overcome, allowing the traction of the muscle to be equivalent to a weight of 250 grams. Ordinarily the sides of the carapace, the hard parts of an adjoining leg or the clutch of an enemy afford the necessary resistance.

If the compound—second and third—joint of the cheliped of the lobster be examined a fine hair line is seen leading from the small spur next to the articular facet on the under side, round the anterior border to the upper side of the joint. It then bends forward and abruptly backward, crossing the small proximal end of the joint, to near its point of departure (x, cuts 12, 13, plate D). There are incomplete grooves in front of this line (cut 12, *a*, *b*,) and a more oblique one behind it (cut 12, *c*). On the upper side of the second joint of the small walking legs of the lobster a delicate hair line is also seen, which turns abruptly forward at the anterior border of the appendage and joins the arthrodial membrane. This groove looks as if it might mark the plane of rupture in

a part of the joint, but it does not correspond to the intersegmental groove (cuts 13, 14, x) of the cheliped.

I have never observed the casting of a claw at any time before the fourth larval stage. Autotomy seems to be occasionally practiced at this period, and in the fifth and following stages it is common. This is illustrated by the history of larva No. 23, table 34. When this lobster in the fourth stage was placed under observation, July 25, it was 13 mm. long and had lost both its large chelipeds and its right fifth and left fourth pereiopods. When, fifteen days later, August 9, it molted to the fifth stage (length, 15 mm.), the large left cheliped (figs. 92, 96, plate 33) and the fourth and fifth walking legs were regenerated; the right cheliped appeared as a rudimentary stump. Eight days later, August 21, it had molted to the sixth stage (17 mm. long), when its large right cheliped appeared regenerated. The animal was placed in a flat glass dish, and in disturbing it, upon changing the water, it shot off its large left cheliped again and died two days after.

In the first larva there is a free articulation between the second and third joints of the great chelipeds (fig. 66, plate 30), and there is no true fusion of the segments until after the fifth stage. In the fourth stage the articulation is distinct, as represented in cut 15. This not only shows that the plane of rupture in the large chelipeds



CUT 15.—*Part of first cheliped of fourth larva, showing the base of the limb and distinct articulation between the second and third joints.*

a–a', plane of section shown in fig. 169, plate 43; *br*, podobranchia; *x*, articulation between second and third joints, corresponding to plane of fracture in adult appendage; *y*, articular process in second joint; *1–4*, segments of limb. Drawn from molted shell.

corresponds to what was formerly a free articulation, but also that this autotomy is a comparatively recent acquisition. It may have been acquired independently in the Macrura and Brachyura. Autotomy of a pronounced character occurs only in limbs where fusion of two neighboring joints has been effected, and was probably produced as a result of natural selection while the fusion was taking place.

The habit of "casting a claw" being of a purely reflex character, and therefore not subject to the will of the animal, there is needed only the proper stimulus to call it into play. Unintentional experiments in autotomy have often been made by tethering a lobster or crab by its large claws. The animal, of course, escapes, leaving only its members behind. When lobsters are drawn out of the water by the claws, or when a claw is pinched by another lobster, or while they are handled in packing, especially for the winter market, they often "cast a claw;" and the transportation of lobsters at this season is said to be attended with considerable loss in consequence. The old custom of plugging lobsters, which consisted in driving a wooden wedge between the

joints of the claws, to prevent them from injuring each other, has been generally abandoned. Mutilated lobsters are now often placed in pounds, where they are allowed to repair their injuries.

One has only to examine a lot of freshly captured lobsters to be assured of how common the practice of casting the claw is. "Out of a hundred specimens," says Rathbun (*155*), "collected for natural-history purposes in Narragansett Bay in 1880, fully 25 per cent had lost a claw each, and a few both claws." In a total of 725 lobsters captured at Woods Hole in December and January, 1893–94, 54 or 7 per cent had thrown off one or both claws.

It is often stated that lobsters sometimes cast their claws during thunder storms, but until some proof of the truth of this statement is afforded it must be regarded as a fable. One of the earliest versions of this idea which I have seen is that of Travis (*191*), who wrote to Pennant in 1777 that—

> Lobsters fear thunder, and are apt to cast their claws on a great clap. I am told they will do the same on firing a great gun, and that when men-of-war meet a lobster boat a jocular threat is used, that if the master does not sell them good lobsters they will salute him.

Since autotomy is the result of a reflex nervous impulse, and has been acquired by the animal as a means of defense, we should expect to find that the reflex center would always be aroused into activity by stimuli coming through the nerves of the limb, as is always the case in experiment, and not through a higher center like the brain. When an animal is frightened by loud noises it is impelled to flee, and it would manifestly be of no advantage to the animal to immediately drop its legs.

REGENERATION OF APPENDAGES.

The regeneration of lost limbs in crustacea has been studied by Réaumur (*161*) Goodsir (*80*), Chantran (*38*, *40*), and Brook (*26*).

Réaumur's general account of the process in the crayfish is one of the best which has been written. He quotes Du Tertre (*55*), who had "made similar observations on the crabs of Guadeloupe, of which he has given a very curious history." Réaumur began his experiments on the seacoast, but the sea broke and carried away his boxes or filled them with sand. He then experimented with crayfishes with more success. He says:

> I took several of them, from which I broke off a leg; placed them in one of the covered boats which the fishermen call "Boutiques," in which they keep fish alive. As I did not allow them any food, I had reason to suppose that a reproduction would occur in them like that which I had attempted to prove. My expectation was not in vain. At the end of some months I saw, and this without surprise, since I had expected it—I saw, I say, new legs, which took the place of the old ones, which I had removed; except in size they were exactly like them; they had the same form in all their parts, the same joints, the same movements. A kind of regeneration like this hardly less excites our envy than our imagination; if, in the place of a lost leg or arm, another would grow out again, one would be more willing to adopt the profession of the soldier.

He noticed that the time necessary for the production of new legs was indeterminate, depending upon a variety of conditions:

> These limbs arise and grow more or less rapidly, like plants, according as the season is more or less favorable; the warmer days are those which hasten the more their formation and growth.

Sometimes new legs sprout out in three weeks; sometimes not until after six, and when the legs are broken off in winter they do not grow again until summer.

Réaumur cut off the "tails" of crayfishes in various places, but there was never any reproduction of these parts, and the animals invariably died after a few days. It sometimes happens that a lobster loses a part of its "tail," and the accident probably results fatally in most cases, but not always, according to the statement of Mr. Thomas Barton, who is employed at the lobster pound at Vinal Haven, Maine. He says that in the winter of 1892–93 he caught several lobsters with the tail-fan and the last one or two joints of the "tail" gone, apparently bitten off. There was a scar where the wound had healed, but no sign of a regenerated tail.

Chantran (*38*) says of the crayfish that the antennæ are regenerated in the period between two successive molts, while three molts are required to restore the other appendages. In the first year of life, seventy days, according to this observer, are necessary for the generation of new limbs. The adult female requires 3 to 4 years, the male 1½ to 2 years to repair its limbs, and we are told that the adult male molts twice and the female but once in the year.

Chantran has also some interesting notes on the regeneration of the eyes in the crayfish (*40*). This process takes place more or less normally and rapidly according to the age of the animal. When the eyes are cut off in October, at the end of the season of molting, there is no new growth apparent until the following May. At that time a series of molts is begun, and by July, nine months after excision, the eyes are regenerated. If the eyes are operated on in the molting season, the regenerative processes are disturbed. In his experiments about one-half of the optic peduncle was cut away; with total excision of the peduncle the eye was never regenerated.

Goodsir (*80*) explains the production of new limbs from the basipodite in the following way:

> A small glandular-like body exists at this spot in each of the limbs, which supplies the germs of future legs. This body completely fills up the cavity of the shell for the extent of about half an inch in length. The microscopic structure of this glandular-like body is very peculiar, consisting of a great number of large nucleated cells, which are interspersed throughout a fibro-gelatinous mass. A single branch of each of the great vessels, accompanied by a branch of nerve, runs through a small foramen near the center of this body, but there is no vestige either of muscle or tendon, the attachments of which are at each extremity. In fact, this body is perfectly defined and can be turned out of the shell without being much injured. When the limb is thrown off the blood vessels and nerve retract, thus leaving a small cavity in the new-made surface. [See the account given by Fredericq.] It is from this cavity that the germ of the future leg springs, and it is first seen as a nucleated cell.

These statements, some of which—as the existence of a glandular body and the origin of the limb from a nucleated cell—are entirely erroneous, will be discussed hereafter (see pp. 107, 108).

REGENERATION OF LARGE CHELIPEDS.

The regeneration of the large chelipeds in the fourth and fifth larval stages is essentially the same as in the adults. The external changes are illustrated by figs. 176, 182, and may be described as follows: At the moment the limb is broken off blood immediately oozes out and coagulates, forming a dense crust over the stump. In a short time a small white papilla which represents the rudiment of the new limb appears in the midst of the brown, hardened clot, fig. 176, plate 44. This papilla continues to grow, independently of the molting process, though covered with a cuticular membrane, until a miniature appendage is formed. The papilla lengthens, and gradually the constrictions which mark the future joints of the new limb make their appearance. At first colorless, the new appendage becomes bright, transparent red, with

bluish pigment at the constrictions of the joints (fig. 182). In this stage the limb is surrounded by a thickening cuticle and soon ceases to increase until after the next molt. It may, according to Brook, attain a length in young lobsters of 1¼ to 1½ inches. If autotomy occurs just after a molt, the appendage will reach a much greater size than if it happens a short time before. When the molt finally takes place the new stump becomes very much larger and now resembles the normal appendage in all respects except size. With each succeeding molt the normal size is gradually attained.

Two stages in the regeneration of the large cheliped of the larva already referred to (No. 23, table 34) are illustrated in figs. 92, 96. After a period of 15 days, during which time two molts had occurred, this limb had become completely regenerated. It was reproduced in 12 days after the emergence of the papillary bud.

A larva in the fifth stage, length 15 mm., was placed under observation July 28, when the first right cheliped was clipped off. On August 12, 15 days after the injury, the animal molted and the cheliped appeared restored. The lobster was now 17 mm. long. The length of the sixth joint—propodus—of this rudiment at the time of the molt was 2 mm., while the length of the same joint of the limb after ecdysis was 4½ mm., and the length of the corresponding joint of the unimpaired limb was 5 mm. In this case the new limb had been developed during a single molting period to nearly its normal size.

A similar result was obtained in the following experiment: A fifth larva, length 15 millimeters, was placed under observation on July 28, and the first right cheliped was clipped. The right antennary flagellum had been previously cropped close to the stalk, from which a new bud was growing; 6 days later, on August 3, the sprouting antennary flagellum was coiled, and a very small bud represented the right cheliped. August 12, 15 days after the first observation, the flagellum of the second antenna on the right side was nearly normal in appearance and size. The rudiment of the right cheliped was segmented, and about 3 mm. long. This larva molted on or near August 15, or 18 days after mutilation, to the sixth stage, when it attained the length of 18 mm. The right cheliped was regenerated, but, as in the other case, it was somewhat smaller than the other. The measurements are as follows:

Regenerated right first cheliped: Length of propodus, 5 mm.; greatest width, 1.3 mm.
Unimpaired left first cheliped: Length of propodus, 6 mm.; greatest width, 1.5 mm.

On the one hand, the large cheliped of the young lobster may be regenerated in from 15 to 18 days, and after a single ecdysis, and on the other it may require a month's time, during which the animal has molted twice.

The time required for the renewal of a limb thus depends upon the time at which an injury occurs with reference to the molt, and also upon the physiological condition of the animal. If the tips of the large chelipeds are clipped off, autotomy does not always or usually occur, and the limb is completely repaired after one molt. If the limb is injured below the sixth joint (propodus or large joint of claw in cheliped), it is usually cast off at the plane of fracture.

REGENERATION OF ANTENNÆ AND OTHER APPENDAGES.

The antennæ are very liable to injury, particularly the delicate, sensitive flagella. Autotomy does not occur in these appendages, so far as is known, but regeneration may take place at any articulation in the flagellum or stalk.

In the young the flagellum of the second antenna may be completely restored without a molt taking place; in the adult one molt at least appears to be necessary for complete restoration. In the fifth stage already mentioned, the antennary flagellum was restored in about fifteen days. The flagellum appears first as a papilla or bud, which becomes sickle-shaped and finally coiled (figs. 100, 179).

Fig. 100 is from the molted shell of a lobster 18 mm. long (No. 34, table 34). It lost its right antennary flagellum in molting, July 25, and molted again in two weeks' time. The drawing shows the condition which the regenerating appendage had reached in the interval between the molts. After the last molt it was completely restored. This figure illustrates the stage which the appendage usually reaches before its complete renewal with the next molt. The flagellum then resembles a small, spirally coiled, red-wax taper. In fig. 179 this appendage is being renewed from the first joint.

The cuticle of the limbs in process of restoration must be elastic or capable of considerable distension, although the limit of this distensibility is, in most cases, soon reached.

In the isopod crustacea the antennæ are regenerated in a somewhat different manner. In the case of the large *Ligea oceanica*, illustrated in figs. 180, 181, plate 44, the rent is repaired, and the new bud does not grow out from the stump, but coils up within it. The cuticular wall of the stump serves as a sort of brood chamber for the growing part, until it is set free at the next molt.

Autotomy often occurs in the second to fifth pereiopods, but is much feebler than in the large chelipeds. Two stages in the regeneration of these appendages are shown in figs. 175, 178. The fourth pereiopod of a fourth larva, drawn from the molted skin, is illustrated in fig. 99, plate 33.

Réaumur (*161*) was one of the first to attempt to give a philosophical explanation of regeneration in crustacea. He says:

> We may suppose that these little limbs which we see grow out were each inclosed in a little egg, and that when a limb was broken off the same juices which nourished this part were used to develop and bring to the birth the little germ of a limb inclosed in this egg. Moreover, according to this theory, we should have to suppose that there was no spot in a leg of the crayfish where there was not an egg which incloses another limb or, what is more marvellous still, a part of a limb like that near the point where the egg is situated at the end of the limb; in short, at any point in the leg which you may name there must be one of these eggs, which contains another part of the limb. The eggs which are at the origin of each claw, for example, would contain only a claw: but one egg would not be sufficient, since if a new leg is cut off another comes.

How many times this process could be repeated without exhausting the supply of "eggs" he did not determine, but Spallanzani, according to Weismann, "observed in the case of a young Triton, that the four limbs and tail when they were cut off grew again six times in the space of three summer months." (The Germ-Plasm, p. 120.) Réaumur believed that each new limb must contain an infinite number of eggs, and in conclusion says:

> It would seem that the reproduction of the legs of the crayfishes is a matter where we can scarcely hope to see clearly; besides its peculiar difficulties, it has all those which envelop the generation of the fœtus.

It is over eighty years since these words were written, and the solution of the problem of regeneration seems to some as far away as ever. The new limb is not formed from a definite cell or cell-mass recognizable before the time of injury, but from a budding growth very much as in the embryo.

The power of regenerating a lost part varies in both vertebrates and invertebrates in direct proportion to the physiological importance of the part, as Weismann has clearly shown. Just as the enemies of the lizard seize it by its long trailing tail, so the lobster is almost invariably caught by a claw, and the life of the animal is often saved in either case by the breaking off of the member. The plane of fracture in the limb, as in the large cheliped of the lobster and in the five pairs of pereiopods of the crab, is a secondary structure which coincides with the plane of articulation of two coalesced joints, yet Leydig has shown, according to Weismann, that the tail of the lizard is specially adapted for breaking off, "the bodies of the caudal vertebræ from the seventh onward being provided with a special plane of fracture, so that they easily break into two transversely." (The Germ-Plasm, p. 116.) The regenerative power is probably a secondary characteristic which has been acquired by natural selection, for the good of the species, while autotomy is a much more recent acquisition. As Weismann says, "there is no such thing as a general power of regeneration" among animals as with crystals, but "in each kind of animal this power is graduated according to the need of regeneration in the part under consideration."

Weismann rejects the idea of a spiritus rector, or external directing agency, and assumes that the nisus formativus is situated in the "idioplasm" of the cell, and "that each cell capable of regeneration contains an accessory idioplasm, consisting of the determinants of the parts which can be regenerated by it in addition to its primary idioplasm." He furthermore infers that the general capacity of all the parts for regeneration may have been acquired by natural selection in the lower and simpler forms, and that it is gradually decreased in the course of phylogeny in correspondence with the increase in complexity of organization.

Weismann attempts, in a very ingenious way, to harmonize the facts of regeneration in animal embryos with the "mosaic theory" of development of Roux, but, as E. B. Wilson (*206*) remarks, the two fundamental postulates of this hypothesis, "namely, qualitative nuclear division and accessory latent idioplasm, are purely imaginary." The theory of Roux and Weismann has its counterpart in the view advocated by Whitman (*204*), that "in the development of the germ, in the repair of injured parts, and in the regeneration of lost parts the organism as a whole controls the formative processes going on in each part."

While no final explanation of the process of regeneration can now be given, and the idea of a formative power is, as Whitman says, one of profound mystery, the solution of which appears to lie as far beyond our grasp to-day as at any time in the past, yet we are in a better position to-day, if not to give answers to these questions, at least to point out the probable direction in which they should be sought.

I shall consider the question of regeneration again in connection with the origin and perpetuation of deformities in the lobster.

INTERNAL CHANGES IN REGENERATION.

The histogenesis of the new limb is not easy to understand, although it can be followed without much difficulty after the papilla stage.

I am unable to find any trace of "glandular-like" bodies such as Goodsir described (*80*) as furnishing germs of the new limb. On the contrary, the new limb appears to arise mainly by growth of the connective tissue cells already present in the stump.

After the blood has clotted over the wound and has produced a hard crust, the cuticular cells, in response to the stimulus thus received, grow over the wound and

produce a new cuticle which has a certain degree of elasticity. My material was insufficient to trace with certainty the origin of the reticulated tissue which soon appears under the new skin.

A minute papilla grows out, having the general structure shown in fig. 173. It is a spongy network of fibers, containing the potential elements of muscles, nerves, connective tissue, and blood vessels. Blood flows in an irregular system of large and small sinuses. The epidermis of the new skin, which is relatively much thinner than the old, is composed of a single stratum of very tall, slender cells, the chitinogenous epithelium, and of an elastic cuticula. The epidermis of the papilla is thus structurally similar to that which covers all parts of the body when a new shell is being formed under the old. (See p. 77.)

As the papilla grows out the fibrous tissue becomes gradually differentiated into the muscles, blood vessels, and nerves (fig. 172), as in an embryo, and constrictions in the cuticle arise, which mark with absolute precision the limitation of the future joints. The cuticle at this stage appears to be destitute of hairs, but it contains pores. In the stump at the base of the appendage a great mass of large oval bodies is seen. These appear as thin solid discs, and when compressed break like starch grains (fig. 121, pl. 36). They represent connective tissue cells in a certain stage of metamorphosis, and in all probability contain glycogen, which furnishes material for the growth of the epidermis—that is, of the chitinogenous cells and the shell which they secrete. (See p. 78.) They seem to be the same structures which Leydig has described in the integument of crabs, under the name of lime concretions (Kalkconcremente), and which Hoeck calls "Krystall Plattchen" (*121–122*). Mayer (*137*) has also figured and described what are probably similar bodies in the indurated shell of certain swellings which are found in the large claws of the male *Heterograpsus lucasii*. These he designates as "amyl-like chitinous inclusions."

In the lobster these bodies stain very diffusely, and sometimes a central figure, possibly the impression or remains of the original nucleus, may be detected. The histogenesis of these structures and the changes which they undergo have apparently never been studied. Their origin is clearly demonstrated by fig. 122, plate 36, from a preparation of the maxilliped. It is evident that the large granular mass is the product of the parent mesoblastic cell, the protoplasm of which is reduced to a thin enveloping shell.

Fig. 169 represents one of a series of sections cut in a longitudinal plane through the first three joints of the right large cheliped of the lobster (sixth stage, length 18 mm.), the history of which has been already given (p. 105). The appendage of this larva had been cut off July 28, and had grown to nearly its full size by August 17, when the animal was preserved. Since autotomy occurs in the very young animal as well as in the adult, we should be able to determine from this specimen whether there is any preformed organ or store of embryonic cells for the supply of the new limb at this time. The examination of serial sections through this part of the limb reveals nothing but normal tissue cells. Embryonic cells may be present but are not discernible. The opening between the basipodite and ischiopodite is reduced to a narrow passage by the ingrowth of cuticular cells, to form ectodermic pillars like those seen in the carapace of the embryo. The several tissues are bathed in blood, which is here confined to no definite channels. Some circumscription of the passage leading from the second to the third joint is thus necessary.

Chapter V.—LARGE LOBSTERS.

THE GREATEST SIZE ATTAINED BY THE LOBSTER.

Stories of gigantic lobsters made their appearance at a very early period, and one could probably gather as many exaggerated accounts of this animal now as in the days of Olaus Magnus. Time, however, has narrowed the bounds of credulity, even among the ignorant, and we no longer hear some of the interesting legends which the old writers have carefully handed down. Thus Olaus Magnus tells us in his description of northern lands and seas,[1] published in 1555, that between the Orkneys and Hebrides there lived lobsters so huge that they could catch a strong swimmer and squeeze him to death in their claws. His curious figures are copied by Gesner (*75*), who has many others equal to any which are described in the old mythologies.

Giants are met with in all the higher groups of animals. They interest us not only on account of their actual size, but also in showing to what degree individuals may surpass the mean average of the race. It may be a question whether lobsters which weigh from 20 to 25 pounds are to be regarded as giants in the technical sense, or simply as sound and vigorous individuals on whose side fortune has always fought in the struggle for life. I am inclined to the latter view, and to look upon the mammoth lobster simply as a favorite of nature, who is larger than his fellows because he is their senior; good luck has never deserted him until at last he is stranded on the beach or becomes entangled in some fisherman's gear.

Gesner gives a very poor figure of a lobster, but a very good drawing of the large crushing-claw of one which he had preserved in his collection on account of its great size. The length of this claw is $8\frac{3}{4}$ inches, and its breadth at the junction of the dactyl about 4 inches, so that it must have belonged to a lobster which weighed not far from 8 pounds.

Pontoppidans (*152*) relates a fable, which is repeated by Herbst (*88*) and others, of the Störjer, or lobsters of huge size which fishermen reported having seen in Utvaer in the Bay of Erien, Norway. One of these was so large and terrible that no one dared to attack it, and it measured between its claws at least a fathom. This, says Herbst, probably belongs with the Kracken, the natural products of Norwegian superstition.

Boeck says that he had seen the claw[2] of a lobster which must have been about 18 inches long, and Sir John Graham Dalyell (*50*), according to Boeck, tells us, in The Powers of the Creator, published in 1827, that he had seen a joint of the left claw of a lobster which measured 9 inches in length. It does not follow, however, as Boeck infers, that "the whole claw[2] must have measured 18 to 24 inches, and the whole animal 3 to 4 feet."

The European lobster of to-day seldom attains so great size as the American species, and its average weight is considerably less. Buckland (*28*) gives the following account of large lobsters from the British Islands:

> The Skye and Orkney lobsters are probably the largest in the British Islands. At St. Mawes we heard of two lobsters, one 10 pounds and the other $9\frac{1}{4}$ pounds; and at Durgan and Sennen of one of 13 pounds. A large lobster was caught in a large earthenware pot at Gosport in 1870 which weighed

[1] Historia de Gentibus Septentrionalibus, Rome, 1555.

[2] The word *claw* is here inaccurately used to mean the entire claw-bearing limb (cheliped).

8 pounds 10 ounces. In May, 1875, a lobster, weight 12 pounds, was found at Saints Bay, Guernsey. I find a record of a lobster exhibited at Billingsgate July 30, 1842, which measured 2 feet 5½ inches; the size of the body was 16 inches; the claws measured upward of 14 inches. In August, 1873, a lobster weighing 11¼ pounds, caught in Guernsey, was exhibited by Messrs. Grove, of Bond street. In July, 1874, a lobster, weight 7½ pounds, was caught on the Fife Banks of the Forth. The lobsters from the Lizard ground are one-third heavier than those in Falmouth Bay, but crabs are smaller.

The largest lobsters that have come under my individual notice are, first, a lobster weighing 10½ pounds, sent me from Tenby and now in my museum; secondly, a lobster presented to me by John Byatt, of Messrs. Winder's, Haymarket, measuring 8 inches in the barrel [that is shell of back or carapace], the total length being 19½ inches and the weight 9¾ pounds. In the York Museum there is a magnificent specimen of a lobster, of which the following are the dimensions: Barrel, 9½ inches; tip of beak to tail, 19½ inches;[1] left claw, the crusher, length 10½ inches; right claw, cutting, length 10½ inches; left claw at widest part, 5 inches. This was an American specimen.

Another very large lobster we came across in our inquiry was a grand specimen which we examined in the house of Mr. Scovell, at Hamble, near Southampton. The following are the dimensions: Length of barrel to tip of horn, 9¼ inches; length of tail turned under the body, 12 inches; total length, 2 feet, all but three-quarters of an inch. Right claw, 19½ inches[2] long; girth, 12¼ inches; weight when killed, 14 pounds. This lobster, Mr. Scovell informs me, was caught in a trammel net on the coast of Cornwall.

Fourteen pounds is the greatest weight recorded in the notes just quoted, and European lobsters of this size are undoubtedly very rare.

In the museum of the Academy of Natural Sciences of Philadelphia there is preserved a large lobster, *Astacus vulgaris*, for the particulars concerning which I am indebted to the kindness of Professor Ryder. Unfortunately it is not known where or when it was captured, nor what its living weight was; but from the measurements given below (table 29, No. 1 *a*) I conclude that it weighed from 21 to 22 pounds. If these measurements are compared with those given in table 30, No. 1, it will become evident that this specimen could not have weighed less than 20, and not more than 23 pounds. This specimen has been carefully examined by Professor Ryder, who writes that there is no doubt of its belonging to the European species; that it was normal in every respect, and that the skeleton is in an admirable state of preservation.

TABLE 29.

Measurements.	No. 1 *a*.—Male; 20 to 23 pounds; obtained from Europe; preserved in the museum of the University of Pennsylvania.	No. 2 *a*.—Male; 10 pounds; captured on coast of Norway some time between 1850 and 1865; preserved in museum of Bergen, Norway.
Total length, rostrum to end of telson (not including hairs).....inches..	19.4	18.73
Length of carapace (rostrum to posterior margin).....do....	9.29	8.58
Large forceps:		
Length of propodus (straight measurement).....do....	13.1	10.23
Greatest breadth of propodus.....do....	6.8	4.32
Girth of propodus.....do....	16.8	10.62
Small forceps:		
Length of propodus.....do....	12.4	10.03
Breadth of propodus.....do....	4.8	3.30
Girth of propodus.....do....	10.15	8.07

[1] The claws of this specimen were considerably undersized (compare tables 29 and 30).

[2] This is intended for the measurement of the entire right claw-bearing limb or cheliped; by "total length" is probably meant, as above, the distance measured from the tips of the extended chelipeds to the end of the tail.

In speaking of the size attained by the European lobster, Sars says:

> It is a remarkable fact that the lobsters on our southern coast never get as large as those farther north. I have never seen an unusually large specimen among the many lobsters which I examined at the different fishing stations. The lobsters which are occasionally caught farther north are generally much larger, and to judge from their appearance much older. At Florö I once saw a lobster which was not much smaller than the immense specimen in the Bergen Museum. This specimen, as far as I remember, comes from a still more northerly point of our western coast. (*176.*)

I am able to give some comparative measurements of the "immense specimen" to which Sars refers in the passage just quoted, through the kindness of my friend, Dr. Einar Lönnberg, of the University of Upsala. If the length of this lobster and the measurements of its large claws (No. 2 *a*, table 29) are compared with the other specimen (No. 1 *a*), and with lobster No. 7, table 30, we shall see that in all probability the Bergen specimen did not weigh above 10 pounds. It is nearly an inch longer than lobster No. 7, which weighed after preservation in alcohol a little less than 10 pounds. On the other hand, the claws of this American lobster are larger than those of the Norwegian specimen, and the claws constitute in old lobsters more than one-half the weight of the entire animal. (See table 31 *a*.) The latter probably weighed when alive not over 10 pounds.

In reference to my questions about the Bergen lobster, Dr. Lönnberg writes:

> The specimen is now dry, and, as we never weigh any lobsters in our country, the weight is not recorded.

He says the date of capture is doubtful, but it was probably between 1850 and 1865.

It has been an accepted belief that the American lobster attains a greater size than its European counterpart, but it seems to be a fact that the maximum size of each species is nearly the same. The lobster fishery is much older in Europe than in this country, and the average size has there been long reduced to a minimum by overfishing. At the time when Sars's paper was written (about twenty years ago) it would not have occurred to one familiar with the American species to look upon a 10-pound lobster as an "immense specimen," though at present there are comparatively few of this size which find their way to markets. In fact the same gradual falling off in size, due to the same cause, has been experienced in recent years on the coast of Maine and in the Maritime Provinces. It is probable, however, that the American lobster is stockier than the European, and that length for length the American species will weigh the more.

Buckland (*29*) speaks of a "breed" of lobsters caught at Bognor which are always small. They are called "chicken lobsters," and it takes 14 to 20 to weigh a pound. This merely illustrates how the size may be kept down by the persistency of fishermen.

Rathbun (*155*), in speaking of the occurrence of large lobsters in American waters, says:

> A dealer at New Haven states that twenty years ago 12 to 16 pound lobsters were common, but during the past ten years a lobster weighing 10 pounds has been rarely seen. A Boston dealer writes that during the past season (1880) he had received and sold lobsters weighing from 12 to 15 pounds each. * * * A specimen taken at Boothbay, Maine, and said to weigh between 30 and 40 pounds, had such claws that the meat from one of them was equal to that of an ordinary-sized lobster.

I have examined and carefully measured a lobster taken at Boothbay which is probably the one here referred to, and will describe it presently. The actual weight of this lobster was probably not over 22 pounds.

A lobster "shipped from Eastport in 1875" is said to have weighed 19 pounds and to have "measured 3 feet 5 inches in length (measurement from tips of extended

claws to end of tail), the claws being 18 inches long and 8 inches across." (*155.*) If the weight is given correctly, the measurements are certainly at fault, as I shall presently show.

There can be nothing in literature more unreliable than accounts of the size and weights of animals, gathered at random. The first estimate is often a guess, which immediately acquires an air of accuracy by being expressed in figures. It does not usually get into print until it has been rolled over many tongues, and during the process it increases in size like the snowball which is rolled along the ground. But it undoubtedly comes hardest for a man who has a large lobster for sale to resist temptation. In describing a few very large lobsters I shall therefore limit myself to those which I have actually seen and measured or weighed.

I will now give the history of a lobster which came into my possession in August, 1893.[1] It is probably one of the largest lobsters ever taken on the Atlantic coast. Its history has been carefully authenticated, and I have obtained some excellent photographs of it, which are reproduced in plates 1 and 2. This mammoth specimen was captured in Penobscot Bay, southeast of Moose Point, in line with Brigadier Island, near Belfast, Maine, May 6, 1891, in about 3½ fathoms of water, by Mr. John Condon. Its capture was accidental, since it was brought to the surface on the end of a lobster pot, the "tail" of the lobster resting in the funnel of the trap, while the huge claws hung down at the sides. The animal, attracted by the bait, had doubtless been making fruitless attempts to enter the trap. A dealer in fish at Belfast soon came into the possession of this lobster while it was still alive. The shell was then very dark in color, almost black on the upper surface, and supported a number of prosperous colonies of marine animals. The common barnacle (*Balanus balanoides*) was growing on the shell of the back and also on the upper surface of the crushing-claw, near the joint of the thumb or dactyl, where it may be seen in the plate. Several species of mollusks, particularly the common mussel (*Mytilus edulis*), were fixed to various parts of the shell, and hydroids (Pennaria or Eudendrium) were flourishing at the articulations of some of the legs. The presence of these messmates pointed to a rather sluggish habit of life, which the animal may have possessed. The entire upper surface of the shell and both the upper and lower surfaces of the claws are scarred, scraped, and gouged like the side of a cliff over which a glacier has passed, and present a graphic record of the struggle for life which this animal had so long and so successfully fought.

When laid on its back the lobster could move but little, but when in its normal position it would crawl over the floor, and if worried with a stick it seized it savagely and crushed it with its claws. It was weighed on a Fairbanks scale in the presence of a number of people. Its living weight was found to be a little over 23 pounds.[2]

This lobster was finally killed by boiling in the usual way, the membranes being first cut at the articulations to let out the blood and admit the water. It was afterwards placed in a large kettle of water to which a bushel of salt was added, and was boiled in this brine for more than an hour.[3] After it was boiled, the meat of the

[1] This lobster is now preserved, in excellent condition, in the museum of Adelbert College, Cleveland, Ohio.

[2] When I first saw this lobster I was assured that the animal was not weighed until after it had been boiled. Allowing a shrinkage of 20 per cent in boiling, I estimated the living weight to have been about 28 pounds. (See *99.*) The first statement was not true. I have since ascertained that the facts are as given above.

[3] Old-shell lobsters are said to shrink 20 per cent and new-shell lobsters 25 per cent in weight after boiling.

"tail" was of a pink color and very tough. The skeleton was perfectly preserved by removing the muscles of the abdomen and the "tomally" or "liver," and some of the other organs of the body. This lobster was a male, and it is a noticeable fact that all very large lobsters which I have records of or have examined belong to the male sex. I have never heard of a female lobster which exceeded 18½ pounds being caught.

The total length of this lobster, whose history I have just given, is only 20 inches (measured, as in all cases, from the end of the spine or rostrum to the end of the tail-fan), but would have been nearly 21 inches had the rostrum been perfect. The body seems surprisingly short for so powerful an animal, and it is in fact in the large claws that the greater part of its weight and strength resides. This may be seen by a comparison of the plates (see also table 31 *a*), and may be possibly explained by the fact that as age advances the increase in length at each molt becomes less, while there is a corresponding gain in the size of the claws. Thus Ehrenbaum (*61*) mentions a lobster 42.2 cm. long, which showed an increase in length of scarcely 1 mm. on molting The length of the crushing-claw of the Belfast lobster is nearly 14 inches, and its greatest girth is 16½ inches. It was probably powerful enough to crush a man's arm at the wrist.

TABLE 30.

General descriptions: No. 1 was a male, 23 pounds, captured at Belfast, Maine, May 6, 1891. No. 2 was a male, 20 to 22 pounds, captured at Boothbay, Maine, about 1856. No. 3 was a male, 20 to 22 pounds, captured at Salem, Massachusetts, in 1850. No. 4, 23 to 25 pounds, was captured at Gloucester, Massachusetts. No. 5 was a male, 20 to 22 pounds, captured on the Delaware coast. No. 6 was a male, 20 to 22 pounds, captured at Lubec, Maine, September, 1892. No. 7 was a male, 9⅞ pounds, in alcohol.

Measurements in inches.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Total length, rostrum to end of telson (not including hairs)	20	*20¼	†21¾	.....	.....	20⅝	17¾
Carapace:							
Length of rostrum	¾	.....	2 1/16	.....	.....	2	.....
Length of carapace	.....	.....	.....	.....	8 5/16	.....	.....
Length of carapace, including rostrum	8 5/16	9⅜	9 5/16	.....	.....	9¼	8⅜
Distance from cervical groove to posterior edge of carapace	.....	4	3 5/16	.....	.....	3⅜	.....
Greatest breadth	.....	.....	.....	.....	.....	.....	.....
Breadth between spines, near base of rostrum	1¼	1 3/16	1⅛	.....	1¼	1⅛	.....
Breadth between spines, near base of second antennæ	2 5/16	2⅛	2¼	.....	2⅜	2⅛	.....
Girth of carapace behind cervical groove	14¾	13¼	13¼	.....	.....	11	.....
Pleon:							
Length of second segment (including facet)	.....	1⅜	.....	.....	2	1¾	.....
Breadth of second segment	4¼	3 11/16	3⅝	.....	4⅛	.....	.....
Girth of second segment (spine to spine)	8⅝	8¼	8¼	.....	8⅝	.....	.....
Length of sixth segment (including facet)	1¾	1 11/16	.....	.....	.....	1⅞	.....
Greatest width of sixth segment	4	3	.....	.....	.....	.....	.....
Length of telson (not including setæ)	1 13/16	2⅝	2⅝	.....	.....	2⅛	2¼
Breadth of telson at base	2⅞	2⅞	2⅜	.....	.....	2¼	2¼
Antennæ:							
Length of stalk of first antenna	1 11/16	1⅜	⅝	.....	.....	1½	.....
Length of basal segment	½	9/16	.....	.....	.....	½	.....
Breadth of basal segment	½	7/16	.....	.....	.....	½	.....
Length of eyestalk	9/16	.....	.....	.....	.....	½	.....
Breadth of eyestalk	7/16	.....	.....	.....	.....	.....	.....
Length of stalk of second antenna	2 5/16	1⅜	1⅜	.....	.....	1⅝	.....
Length of exopodite (scale)	¾	¾	1 3/16	.....	.....	¾	.....
Greatest width	½	⅝	7/16	.....	.....	½	.....
Pereiopods:							
Large forceps (*crushing-claw*)—							
Length of propodus (straight measurement)	13⅞	12½	12½	13	13⅛	12	10¾
Greatest breadth of propodus at level with articulation with dactyl	7⅞	6	6⅛	4⅝	9½	9½	5¼
Girth of propodus just behind articulation of dactyl	16½	15¼	15	17½	16⅛	15	13¼

*Body nearly straight. †Body somewhat bent.

TABLE 30—Continued.

Measurements in inches.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Pereiopods—Continued							
Length of dactyl	6	6	5 5/8	6	5 1/4	5 3/8	4 1/2
Greatest breadth of dactyl	2 1/8	2 3/8	2 1/4	2 1/8	2 1/8	2 1/4	.....
Greatest girth of dactyl	7 3/8	6 3/4	.....	7 5/16	6 7/8	.....	.....
Length of carpus (on inner margin, not including proximal spine)	4 1/2	3 7/8	4 1/2	.....	.....	3 3/4	.....
Greatest breadth of carpus	2 3/8	2 1/4	3	.....	.....	2 3/4	.....
Greatest girth of carpus	8 5/16	8 1/2	8 1/2	.....	.....	9 1/2	.....
Length of meros (outer border)	5 1/16	.....	4 1/2	4 3/8	3 1/2	.....	.....
Greatest breadth of meros	2 1/2	.....	2 1/2	3 1/4	2 3/8	.....	.....
Small forceps—							
Length of propodus (from tip to spine near proximal end)	14	13 1/4	12 3/8	.....	12 7/8	11 1/8	.....
Breadth of propodus	4 7/8	4 1/8	4 1/2	.....	3 1/2	4 3/8	.....
Girth of propodus	12	11 1/8	.....	.....	8 3/4	11	.....
Length of dactyl	7 3/4	7 3/8	6 7/8	.....	7 3/8	6 1/2	.....
Greatest breadth of dactyl	1 3/4	1 3/8	1 1/4	.....	1 1/2	1 1/2	.....
Greatest girth of dactyl	4 3/4	.....	4	.....	4 1/4	.....	.....
Length of carpus (on inner margin, not including proximal spine)	4 1/16	.....	3 3/4	.....	.....	3 5/8	.....
Greatest breadth of carpus	2 1/16	.....	2 3/4	.....	.....	2 3/4	.....
Greatest girth of carpus	8 1/16	.....	8	.....	.....	8 1/2	.....
Length of meros (outer border)	4 7/8	3 3/4	4 1/2	.....	4	.....	.....
Greatest breadth of meros	2 7/16	2 3/4	2 1/2	.....	2 3/8	.....	.....
Second and fifth pereiopods:							
Length of propodus, second pereiopod	3 5/16	.....	3 1/8	.....	.....	3	.....
Breadth at articulation of dactyl	1 1/16	.....	1 1/16	.....	.....	7/8	.....
Length of dactyl	1 11/16	.....	1 1/2	.....	.....	1 1/2	.....
Breadth of dactyl (at articulation)	1/16	.....	1 1/2	.....	.....	.....	.....
Greatest length of carpus	2 1/8	.....	2 1/8	.....	.....	2	.....
Breadth of carpus	3/4	.....	7/8	.....	.....	7/8	.....
Length of dactyl, fifth pereiopod	1 1/8	7/8	1	.....	.....	1	.....
Breadth of dactyl	3/4	7/16	5/16	.....	.....	.....	.....
Length of propodus	2 13/16	2 3/4	2 1/4	.....	.....	2 3/8	.....
Breadth of propodus (distal extremity)	1 3/8	.....	.....	.....	.....	.....	.....
Breadth of propodus (proximal extremity)	1 1/16	7/8	1/2	.....	.....	7/8	.....
Length of carpus	1 11/16	2 1/8	1 5/16	.....	.....	1 1/2	.....
Breadth of carpus	5/8	3/4	1/16	.....	.....	5/8	.....
Pleopods:							
Length of first pleopod	2 1/4	2 3/8	2 1/2	.....	.....	2 1/2	.....
Length of distal segment	1 5/8	1 5/8	1 5/8				
Greatest breadth of distal segment	1/2	5/8	5/8	.....	.....	.....	.....
Length of stalk of second pleopod	1 7/16	.....	.....	.....	.....	.....	.....
Breadth of stalk of second pleopod	5/8	9/16	.....	.....	.....	.....	.....
Length of exopodite	1 1/16	.....	.....	.....	.....	.....	.....
Breadth of exopodite	1/2	.....	.....	.....	.....	.....	.....
Length of exopodite, sixth pleopod (from angle between spines of protopodite)	3 3/16	3	3	.....	3 3/8	2 1/2	.....
Greatest breadth of exopodite at hinge	2 3/8	1 7/8	2 1/8	.....	2 7/16	2 1/4	.....
Length of endopodite of sixth pleopod	2 5/16	1 1/2	2 1/8	.....	.....	.....	.....
Greatest breadth of endopodite of sixth pleopod	2 1/16	2	2 1/8	.....	.....	.....	.....

The detailed measurements of this animal are given in table 30, No. 1, where they may be compared with those of the small lobster, seen on plate 2, and with those of the large specimens which I have recorded above.

The large Boothbay lobster, which has already been referred to (p. 16), is reported to have weighed as much as 40 pounds. I was told that it tipped a scale which weighed up to 25 pounds, and would have weighed somewhat more. Its measurement, however (table 30, No. 2), proves it to have weighed less than the Belfast specimen, and a comparison of its length and the dimensions of its claws with the large European lobster (No. 1 *a*, table 29) show that it could have exceeded this in weight very slightly, if at all. Its true living weight was probably between 20 and 22 pounds. The shell of this lobster was cleaned by placing it in an ant-hill, and it is now in a bad state of preservation. The claws are furrowed, pitted, and scarred, and the carapace is scratched, as is apt to be the case with large old-shell lobsters.

In the museum of the Peabody Academy of Science at Salem, Massachusetts, there is a perfect specimen of a lobster (No, 3, table 30), said to have been taken at Salem

in 1850, and to have weighed, when alive, 25 pounds. The body is a little longer than the two first mentioned, but it is also slenderer, and the large claws, which count so much in the weight of this animal, are, upon the whole, smaller and weigh less. The greater length of the Salem specimen is due largely to the long, perfect rostrum. The large claws correspond closely in size with those of the Boothbay lobster, and we may be almost certain that its living weight did not exceed 22 pounds.

A lobster but little under the Salem specimen in size is in the possession of Mr. George R. Batson, of Campobello Island, New Brunswick. This lobster weighed, when alive, according to the somewhat wavering memory of the man who weighed it, 24½ pounds. The measurements fail to corroborate this statement. (No. 6, table 30.) The dimensions of the large claws and the girth of the carapace prove conclusively that it weighed less than 23 pounds, the authenticated weight of the Belfast lobster (No. 1, table 30). It was captured in a hoop pot, a few of which are said to be still in use, in South Bay, near Lubec, Maine, in 15 fathoms of water, September, 1892. This lobster is a very shapely and perfect specimen. It had a hard shell, and showed great activity when alive.

In the museum of the Peabody Academy of Science there is also the right large claw of a lobster marked, "From a lobster weighing 39 pounds; from Moses H. Shaw, Gloucester." This is said to have been in the museum for over fifty years. Measurements of this claw (No. 4, table 30), supposing the animal to have been normally developed, show that it could have been but little larger than the Belfast specimen. The only available comparisons lie between the large claw and the fifth joint the only parts preserved. A full-sized drawing of this huge claw is produced on plate 15. The crushing claw of the Belfast lobster was nearly an inch longer and much broader than the specimen figured, but less by one inch in girth. The claws of these two animals must thus have been of nearly equal weight, and I think it a safe conclusion that the Gloucester giant did not weigh above 25 pounds. The shell of the claw was very light for so large an animal, weighing only 16¾ ounces, including the fifth joint. (See chapter III, pp. 82, 83.)

In the museum of the Smithsonian Institution there are fragments of the skeleton of a lobster which was captured with hook and line on the coast of Delaware, and is said to have weighed over 25 pounds. Measurements of these parts show that its weight was probably somewhat less, certainly not much over 22 pounds. (No. 5, table 27.) The shell of the large claw of this lobster weighs 1½ pounds.

In 1863 a large lobster was caught on a hand line at Bald Head Sands, near Small Point, Maine, which I was assured by a fisherman weighed 38 pounds. I afterwards had the opportunity of examining the large crushing-claw, all that has been preserved of this lobster, at the market house of Mr. Lewis McDonald, Portland, Maine. The claw is 12½ inches long, has a breadth of 6½ inches, and a girth of 15½ inches just behind the terminal joint. It was thus of about the same size as the crushing-claw of the Salem lobster (No. 3, table 30), and the animal probably did not exceed 22 pounds in entire weight. I mention this as an example of how the weight of the lobster, though dead, increases with the lapse of time.

There may be seen at the St. Nicholas Hotel in Boston, Massachusetts, the skeleton of a male lobster said to have weighed 35 to 40 pounds. It was captured off Provincetown, in August, 1894. When I examined this specimen, June 25, 1895, it was mounted in a glass case in a very perfect state of preservation. Though not allowed to take careful measurements, I could see that its weight had been greatly exag-

gerated. The total length of the body, measured from the rostral spine to the end of the tail-fan, when the tail was naturally articulated with the thorax, was not far from 20 inches, and not over 21 inches. The length of the large crushing-claw is from 12 to 13 inches. The cutting-claw is relatively smaller than in any of the large lobsters which I have examined, and it seems fairly certain that the living weight of the animal could not have much exceeded 20 pounds.

I am indebted to the kindness of Professor Leslie A. Lee for the measurements of the large crushing-claw of a lobster which is preserved in the museum of Bowdoin College, Maine. It was taken from an animal which came from Cape Breton, which is said to have weighed 33 pounds 11 ounces. The length of this claw is $13\frac{1}{16}$ inches, its breadth $6\frac{7}{8}$ inches, and its girth (measured just behind the first joint) is 16 inches. In this case the weight is specifically given, yet it is certainly erroneous.[1] If normally formed, this animal probably did not weigh over 23 pounds. I base this opinion upon the fact that the Belfast lobster (No. 1, table 30) has a somewhat larger crushing-claw, is normally formed, has a hard shell, and therefore could not, in all probability, have weighed less and may have weighed more than the specimen from Cape Breton.

In the museum of Yale University there is preserved the large crushing-claw of a lobster, which is said to have weighed 39 pounds.[2] The length of the claw is $12\frac{9}{16}$ inches, the greatest width 6.9 inches, and the greatest girth $16\frac{3}{4}$ inches. It is shorter by half an inch than the Cape Breton specimen, and but little larger in circumference. The length of the crushing chela falls short of the Belfast lobster (No. 1, table 30) by one inch. Its weight probably did not much exceed 23 pounds, if at all.

In the collections of the Smithsonian Institution there is a lobster which weighed, after preservation in alcohol, 9 pounds 14 ounces (No. 7, table 30).[3] The cutting-claw on the right side was undersized. A few measurements of this specimen are given for purposes of comparison. There is far less difference between some of these and corresponding measurements of larger lobsters than one might expect. Thus the telson in this case has the same dimensions as in lobster No. 6 (table 30), which weighed more than twice as much.

I was informed by Mr. F. W. Collins that a male lobster which weighed nearly 25 pounds was taken on a trawl below Monro Island, 5 miles east of Rockland, Maine, in the summer of 1890. The large claw is said to have measured 16 inches in girth.

I heard through Mr. Vinal Edwards of a lobster, said to have weighed 27 pounds, which was caught off Breton Reef, Newport, Rhode Island, in June, 1894. This was taken by accident, one of its claws having been entangled in a lobster-pot, in 10 to 12 fathoms of water. It was a male, and its shell was freely sprinkled with barnacles.[4]

I will add a few notes on the occurrence of large lobsters, which I gathered on the coast of Maine, in August and September, 1893. I give them upon the testimony of others, but believe them trustworthy.

Mr. J. W. Savage stated that he received from the region of Eastport, Maine, in

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[1] Professor Lee writes as follows concerning this specimen: "The large lobster's claw in our museum was obtained many years ago in Cape Breton. It came into our possession in 1881. The weight of this animal is not well authenticated on our records."

[2] I am indebted to Prof. A. E. Verrill for the opportunity of examining this specimen. The inscription upon it, which is almost illegible, is as follows: "Boston, Mass., March, 1823; 39 lbs."

[3] The weight of this lobster was kindly determined by Mr. James E. Benedict of the Smithsonian Institution.

[4] I was unable to obtain any direct information about this lobster, or to verify its weight, which I do not consider authentic.

June, 1893, a large male lobster which weighed 20 pounds. In the same lot was one weighing 16 pounds.

In May, 1892, Mr. N. F. Trefethen obtained a lobster from the vicinity of Eastport, Maine, which weighed 15½ pounds. He weighed it himself, and sent it to market. It had a very hard shell and had lost its smaller claw; if it had been perfect it would have weighed considerably more.

In August, 1891, according to Mr. F. W. Collins, a lobster (sex undetermined) was taken at Blue Hill Falls, 40 miles east of Rockland, which weighed 18½ pounds, and in November, 1892, a perfect female lobster was taken at Green Island, Maine, which weighed 18 pounds. This outer island is noted for its fine lobster fishing. Mr. Collins states that in August, 1891, he had fifty lobsters at one time in his establishment which would weigh from 10 to 18½ pounds. About half of these came from Castine and the remainder from Blue Hill Falls, Maine. All of these were "new shell lobsters"—that is, they had shed that year, probably in July.

Mr. Thomas Garrett, who was one of three men who first engaged in lobster fishing at Vinal Haven, Maine, over forty years ago, and has been engaged in this pursuit most of the time since, says that he has taken a great many lobsters which would weigh from 15 to 20 pounds. He says that a perfect male lobster weighing 30 pounds[1] was taken in a hoop-net in Golden Cove, in Vinal Haven Harbor, in about the year 1858, and that in 1887 a lobster was caught in the basin (near the site of the present lobster pound on Vinal Haven Island) which weighed 11 pounds and had only one large claw.

The mouth of the Skillings River is said to have furnished large lobsters in plenty in the fall of 1888. It was very common to take lobsters there weighing 15 pounds. The place had not been previously fished with regularity, but it soon became the resort of fishermen and the lobsters were rapidly reduced in numbers and size.

Fishermen in Rockland, Maine, have gaffed lobsters in the harbor in the past two years weighing from 8 to 9 pounds. I heard of a large lobster which was caught on a trawl, the hook catching in a joint of the shell, in June, 1892, on White Island grounds, near Vinal Haven. It was said to have weighed over 20 pounds.

Mr. F. W. Collins informs me that he received at Rockland, in 1893, a larger number of lobsters than usual measuring about 15 inches in length and weighing about 5 pounds.

These notes furnish evidence, if any were needed, that very large lobsters, weighing 20 pounds or more, are even now occasionally taken, but I have never obtained any reliable evidence that lobsters weighing over 25 pounds have ever been caught. Where lobsters are said to have attained a greater weight, measurements of the parts of the skeleton which have been preserved invariably prove that the figures have been exaggerated. I do not maintain that the American lobster does not reach a greater weight than 25 pounds, but that I have been unable, up to the present time, to discover any well-authenticated evidence that this is the case.

Many points on the coast of Maine and the Maritime Provinces still furnish large lobsters weighing 10 pounds or more, but not in any considerable number, and lobsters of 5 pounds weight are frequently common; yet it is at the same time true that the size of the lobster has been declining for many years, until the average weight has, in most places, fallen below 2 pounds.

[1] The weight of this large lobster may have been unintentionally exaggerated. One can hardly avoid such an inference from the evidence already given.

THE RELATION OF WEIGHT TO LENGTH.

The weights and lengths[1] of 2,657 lobsters captured at Woods Hole under the conditions already described (p. 25) are recorded in table 31. The weight does not bear a constant relation to the length, but is very variable owing to the loss of the appendages, particularly the large claw-bearing legs. These alone constitute from one quarter to one-half the entire weight of the animal, and probably in the Belfast lobster (plate 1), and in all giants of similar size, the weight of the large chelipeds is more than two-thirds that of the entire body (see table 31*a*). The lost limbs are regenerated, as we have seen, but never completely so without the intervention of one or more molts, so that a lobster with an undersized claw is a common occurrence.

The weight also is subject to great variation in consequence of the molt, when a dense heavy armor or cuticle is exchanged for a much lighter though larger one. In the soft lobster the specific gravity of the solids and fluids of the body is considerably reduced. Very few soft lobsters, however, were taken during the period of these observations, only about 3 per cent (see table 23), so we may ascribe the great variations shown in the table below chiefly to disparity in the size of the large claws. This is particularly noticeable in smaller individuals, as in the 9-inch lobsters, where out of 170 males the smallest weighed only 10 ounces and the largest three times as much.

TABLE 31.—*Relation between the lengths and weights of male and female lobsters, taken in Woods Hole Harbor, December to June, 1893–94.*

Length in inches.	No. of males examined.	Average weight of males.	Extremes of weight of males.	No. of females without eggs examined.	Average weight of females without eggs.	Extremes of weight of females without eggs.	No. of females with eggs examined.	Average weight of females with eggs.	Extremes of weight of females with eggs.	Total number of males and females examined.	Average weight of all the males and females.
		oz.	*oz.*		*oz.*	*oz.*		*oz.*	*oz.*		*oz.*
6	3	5.33	4 to 6	4	8.75	8 to 10	.....	.....	.....	7	7.29
6¼	1	8	.....	.....	.....	.....	.....	.....	.....	1	8
6½	3	8	8 8	4	7.25	6 8	.....	.....	.....	7	7.57
6¾	5	7.60	6 10	.....	.....	.....	.....	.....	.....	5	7.60
7	45	10.18	7 13	46	10.76	9 13	1	12.00	.....	92	10.49
7⅛	.....	.....	.....	1	10	.....	.....	.....	.....	1	10
7¼	10	10.40	9 13	4	10.25	9 13	.....	.....	.....	14	10.36
7⅜	66	11.80	9 15	47	11.43	8 15	.....	.....	.....	113	11.68
7½	20	12.75	10 15	9	12.44	9 16	.....	.....	.....	29	12.66
8	168	15.16	8 18	138	15.30	11 18	2	12.50	12 to 13	308	15.21
8⅛	.....	.....	.....	1	14	.....	.....	.....	.....	1	14
8¼	44	15.30	11 20	29	15.24	12 18	.....	.....	.....	73	15.27
8⅜	143	16.61	13 22	108	16.36	12 19	7	16.14	15 17	258	16.50
8½	26	17.46	13 25	26	17	13 21	1	17	.....	53	17.23
9	170	18.96	10 30	153	18.61	.....	13	18.69	15 21	336	18.79
9⅛	.....	.....	.....	.....	.....	.....	1	16	.....	1	16
9¼	32	19.91	11 28	34	19.32	16 24	4	20	17 25	70	19.63
9⅜	148	21.24	16 30	145	20.51	16 28	24	20.42	18 24	317	20.84
9½	27	24	18 30	26	21.19	18 24	3	20.67	19 21	56	22.52
10	107	24.41	19 32	148	23.76	17 32	36	23.86	20 28	351	24.08
10⅛	.....	.....	.....	.....	.....	.....	1	28	.....	1	28
10¼	62	27.44	20 35	54	24.63	21 33	17	23.12	20 28	133	25.76
10⅜	79	28.89	22 36	75	27.52	23 41	28	28.11	23 33	182	27.66
10⅝	1	26	.....	.....	.....	.....	.....	.....	.....	1	26
10¾	18	29.94	25 34	16	24.19	24 33	2	26.50	25 28	36	27.19
11	31	34.65	30 42	42	30.48	23 40	20	32.10	29 37	93	32.22
11¼	10	37.20	32 42	11	32.09	27 37	.....	.....	.....	21	34.52
11½	11	42.36	34 54	26	34.46	30 44	4	32.25	30 34	41	36.37
11¾	2	36	32 40	2	34.50	34 35	.....	.....	.....	4	35.25
12	9	43.78	34 54	11	42	36 54	3	43.67	37 48	23	42.91
12¼	1	50	.....	.....	.....	.....	.....	.....	.....	1	50
12½	4	50.25	48 52	7	42.71	36 49	.....	.....	.....	11	45.45
12¾	.....	.....	.....	.....	.....	.....	1	45	.....	1	45
13	4	51.80	44 60	4	47.25	40 55	.....	.....	.....	8	49.75
13½	1	68	.....	.....	.....	.....	.....	.....	.....	1	68
14	1	88	.....	.....	.....	.....	.....	.....	.....	1	88
14½	1	74	.....	2	65	64 66	.....	.....	.....	3	68
15	.....	.....	.....	3	69.33	66 72	.....	.....	.....	3	69.33
.....	1,313	.....	.....	1,176	.....	.....	168	.....	.....	2,657	.....

[1] The length of the lobster is measured from the apex of the rostral spine to the end of the telson, not including the terminal fringe of hairs.

The fact that the male is heavier than the female of the same length is very clearly brought out by the observations recorded above. In passing the eye down the columns to the left only three cases will be discovered where this is not true, namely, in the 6, 7, and 8 inch lobsters. The difference here in favor of the females, where a sufficient number of observations were made to entitle them to much confidence, is only a question of fractions of an ounce in average weights. After passing the 8-inch limit the balance is in favor of the male. The 10-inch males are about half an ounce heavier than the females of the same length. From this stage the excess in favor of the male becomes very marked. The 11-inch male exceeds the female of the same length by a full quarter of a pound. In the lobster 12½ inches long there is a greater difference in favor of the male, 7½ ounces in the cases cited in the table.

It is evident from the facts here recorded that the greater size of the male, which is a sexual characteristic, does not appear until the animal has passed the 8-inch limit. At this period the sexes are of about equal weight, but from this point the male surpasses the female in weight, owing chiefly to the greater development of the large claws.

The average weight of females without and with eggs recorded in columns 6 and 9 of table 31 brings to the surface a rather unexpected fact, namely, that females with spawn are in a poorer condition or weigh relatively less than females without. In one-third of the cases here recorded the weight of females with eggs was actually less than that of females of the same length without eggs. In the 10-inch series, 184 females were examined; 36 of them had eggs, and weighed on the average but one-tenth ounce more than those without eggs. Turning to table 16, we find that the average quantity of eggs borne by a 10-inch lobster is 1.73 fluid ounces, and since a fluid ounce of lobster eggs weighs very nearly an ounce avoirdupois, the average weight of the 10-inch female deprived of her eggs is 22.13 ounces, as compared with 23.76 ounces, the average weight of non-egg-bearing females of this size. There is a difference of 1.63 ounces in favor of the female without eggs. In the case of the 9½-inch lobsters, where 169 in all and 24 bearing eggs were examined, the average weight of the spawners is less by 0.09 ounce than that of the corresponding females without eggs.

The facts which have just been stated do not support the conclusion of Buckland and his associates on the fisheries work in Great Britain, that "the lobster, when berried, is in the very best possible condition for food." (*28*, p. XVI. See p. 64.)

In the last column of table 31 the average weights of lobsters corresponding to definite lengths are given. A lobster of the minimum length at which it can be legally sold, 10½ inches, weighs on the average 1¾ pounds, while a 12-inch lobster attains a weight of 2 pounds 11 ounces, and a lobster 15 inches long weighs from 4 to 4½ pounds, and probably more in some cases.

Lobster No. 7, table 30, 17¾ inches long, weighed nearly 10 pounds (though in this case the cutting-claw was undersized), and the mammoth specimens recorded in this table, weighing from 20 to 23 pounds, varied only from 20 to 21¾ inches in length (pp. 113–116).

In the early part of this chapter I mentioned the fact that the disparity in weight between lobsters of the same length was due largely to the difference in the size of the large claws. This is illustrated by the following table, which is compiled from the observations made by Vinal N. Edwards.

TABLE 31*a*.—*Variation in the weights of lobsters with and without the great claws.*

Length in inches.	Sex.	No. of lobsters examined.	Weight with large chelipeds, in ounces.	Variation in weight.	Weight without large chelipeds, in ounces.	Variation in weight.
7¾	Male	1	13	.....	10	.....
7¾	Female	1	13	.....	10	.....
8¼	Female	3	13 to 15	2	11	0
8¼	Male	1	17	.....	12	.....
8½	Male	1	17	.....	12	.....
8½	Female	1	16	.....	12	.....
8¾	Male	1	17	.....	12	.....
9½	Male	6	22 to 31	9	15 to 17	2
9½	Female	2	23 to 24	1	15 to 16	1
10	Male	1	28	.....	17	.....
10	Female	3	24 to 27	3	17 to 18	1
11	Male	1	48	.....	22	.....
11	Female	1	39	.....	22	.....

Chapter VI.—ENEMIES OF THE LOBSTER.

ANIMALS WHICH PREY UPON THE LOBSTER.

The adult lobster, whether with eggs attached to the body or not, is the prey of numerous fish which feed upon the sea bottom, like the sharks, skates, and rays. When of considerable size or in soft condition it is also devoured by the cod, pollock, striped bass, sea bass, tautog, and probably by many other species. In fact every predaceous fish which feeds upon the bottom may be looked upon in general as an enemy of the lobster.

A fisherman at Beal Island, West Jonesport, Maine, stated that he had caught cod on trawls 10 to 15 miles from shore with lobsters 4 to 6 inches long in their stomachs. Cod were also caught at Grand Manan, in summer, in 20 fathoms of water, by Mr. J. W. Fisher, of Eastport, with very small lobsters,[1] 1 to 2 inches long, in their stomachs. Lobsters an inch long have also been taken from the stomachs of codfish on the shores of Prince Edward Island (*209*, p. 232), and soft lobsters 3 to 8 inches long have also been found in the stomachs of these fish taken in deep water off shore.

The observations of Mr. Vinal N. Edwards are quoted by Mr. Rathbun (*156*, p. 782) to show the great destruction of lobsters in the Edgartown district, Marthas Vineyard. Out of hundreds of cod caught about No Man's Land and examined by Mr. Edwards, nearly every fish "contained one or more young lobsters, and in many cases the stomachs were almost entirely filled with them." So great did the destruction wrought upon the lobster by the cod impress one fisherman (*156*, p. 728) that he thought the cod a greater enemy than the lobstermen, and said: "I have caught one hundred cod in one day that I knew had the amount of one thousand lobsters and shadows in their entrails."

[1] These young lobsters were identified by Professor Baird.

The cod has an equally bad reputation among English fishermen. Frank Buckland says (*28*, pp. 14, 15):

> Among the animate enemies the principal enemy [of the lobsters] I believe are cod. A witness at Burghead stated that codfish are great enemies to lobsters; he hardly ever opens a cod without finding young lobsters in the stomach, particularly in February and March. He has seen cod throwing up lobsters on the deck of a vessel, as many as five or six lobsters in one cod. These lobsters would be 3 or 4 inches in length or even smaller. Cod eat lobsters all the season. In the spring and in January, February, and March there are many cod about. Skates and congers, and codling and haddock also eat crabs and lobsters.

On July 16, 1894, Dr. J. I. Peck showed me the "tail" of a soft lobster which he had taken from the stomach of the weakfish or squeteague (*Cynoscion regale*). The lobster had been out of its shell but a few hours when it was snapped up by this fish.

Verrill (*196*) records the finding of lobsters in the following fish: Dusky shark (*Eulamia obscura*), Woods Hole, in July and August; dogfish (*Mustelus canis*), Woods Hole, in August; sand shark (*Eugomphodus littoralis*), Woods Hole, July and August; peaked-nose skate (*Raia lævis*), Menemsha, July; long-tailed stingray (*Myliobatis freminvillei*), Vineyard Sound, July; rabbit-fish (*Chilomycterus geometricus*), Woods Hole, July; striped bass (*Roccus lineatus*), Woods Hole, August, 1871; tautog (*Tautoga onitis*), "two caught July 8 and 15 contained small lobsters."

Mr. Mosher, who had prepared striped bass for market for upward of thirty years, said:

> Striped bass do not feed upon live menhaden, but upon crabs and lobsters. * * * I have always observed that bass fishing was best where lobsters and crabs were most plentiful. (Bull. U. S. F. C., vol. 11, p. 410.)

Small lobsters are probably to some extent the prey of sea-roving birds, such as the gulls and terns, but in regard to this nothing is known. According to Boeck (*20*, pp. 227–228), the Norwegian lobster is sometimes attacked by crows. His account is as follows:

> An interesting scene may be witnessed near Bukkenö, north of Stavanger, where an Englishman has constructed a large pond between some small islands for keeping live lobsters. Whenever the pond becomes too full of lobsters, so that they do not find sufficient food, they leave the water and crawl about, seeking to reach the sea, but during their wanderings they fall an easy prey to large numbers of crows hovering round, which take them in their claws, fly high up, and let the unfortunate lobster drop down on the rocks, where their shells are broken, so that the crows can eat them in comfort. The crows are not easily scared away, but show a remarkable degree of sense, only flying away when anyone approaches with firearms, and later they carry on their depredations in the early morning, when they have less to fear.

That lobsters ever leave the water and attempt to crawl upon the land can not be credited, and it is likely that this story passed through several hands before reaching its present form. Herbst (*88*) says that the lobsters have a great enemy in the Steinbeisser.[1]

If the lobster is thus attacked and destroyed in large numbers by fish after it has acquired the habits of the adult and has many devices to avoid its enemies, what shall we say of the destruction which is wrought on the young during the first eight or ten weeks of their life? From the time of hatching up to the sixth stage the young lobster swims at the surface and becomes an easy prey to all surface-feeding

[1] It is uncertain what fish is here meant. The name is applied to the fresh-water genera *Cobitis* and *Lota*.

fish, some of which, like the menhaden,[1] roam about in vast schools, straining the water as effectively as the towing net. During this period the lobster measures from one-third to two-thirds of an inch in length, and is not only helpless in the hands of its animate enemies, but is subject to a vast amount of indiscriminate destruction from the forces of inanimate nature. (For the further consideration of this subject see pp. 187–189.)

PARASITES, MESSMATES, AND DISEASES OF THE LOBSTER.

One of the two parasites known to infest the lobster is a trematode (*Stichocotyle nethropis*). This was first described by Cunningham, who found it in the intestine of the Norwegian lobster. It has recently been discovered in the American lobster by Dr. Nickerson, to whom I am indebted for the following particulars. The larva of this singular parasite, which is from 3 to 7 millimeters long, is found sometimes to the number of 70 or more embedded in the mucous coat of the intestine about the cœcum. It is relatively rare, hardly more than 2 per cent of the lobsters which Dr. Nickerson examined being infested by it. Its position at the hinder end of the alimentary tract seems to argue that it comes in by way of the anus rather than through the mouth. Its final host is probably some species of fish which feeds upon the lobster, but the adult trematode is unknown. It may prove to be of a different species from the larva discovered by Cunningham.

The only other strict parasite which the lobster is known to possess is the large Gregarine (*G. gigantea*), which was discovered in the intestine of the European lobster by Van Beneden. (*194*)

In 1853 Van Beneden (*69*) called attention to a small green worm which he found on the eggs of the lobster, and which he supposed was a larva of Serpula. Later, in 1858, he concluded that the animal was not a larva, but a fully developed individual, which he called *Histriobdella homari*, placing it among the Hirudineæ (*69*). Foettinger, a later student of this form (*69*), proposes to change its name to *Histriodrilus benedeni*, and concludes that is is an Enterocœlian, allied to Polygordius. It is not a parasite in the strict sense.

Although parasites are rare, the lobster is encumbered with a great variety of messmates, which attach themselves to the external shell.

Whenever the lobster is confined in inclosures, or compelled for any reason to lead a sluggish life, the common barnacle fixes itself to the arched carapace and begins to secrete its tent-like covering as securely as it might upon a stone; mussels of various kinds insinuate themselves in convenient angles of the shell and joints, small tunicates sometimes becoming attached firmly to the under side of the shell between the legs. Tube-forming annelids, lace-like bryozoa, form incrustations in various parts, and red, brown, and green algæ often decorate the antennæ and carapace with long streamers which are waved with every movement of the animal. At each molt the lobster of course frees itself completely from these troublesome companions.

[1] Regarding the menhaden as an enemy of the larval lobster, I have consulted with my friend, Professor J. I. Peck, who has made a very careful study of the habits of these remarkable fish. He writes as follows: "I have never found lobster larvæ in the stomachs of menhaden, and yet it must be remembered that the localities whence my material was nearly all secured were brackish-water inlets. Copepods in all stages of growth are abundant and shrimp of the smallest size were common at New Bedford, but in the material from Buzzards Bay I have never seen lobster larvæ." He thinks that the evidence can not be conclusive until menhaden are examined which have fed both day and night in localities which abound in lobsters.

At the lobster pound in Vinal Haven, Maine, which I visited on August 26, 1893, I examined a number of lobsters whose bodies and free appendages supported a surprisingly varied flora. A hard-shelled female which I took out of the mud in very shallow water was decorated with algæ in a very striking fashion upon the upper part of the body, the big claws, and antennæ. The long whip-like "feelers" were weighed down with fronds of the brown laminaria, or devil's apron, as shown in fig. 118, plate 36. The common green lettuce (*Ulva latuca*) was sprinkled freely over various parts, and barnacles had gained also a foothold upon the shell. A frond of laminaria, which was fixed to the side of the abdomen, was 7 inches long and 2 to 3 inches in width. Besides the larger fronds, there was a matted undergrowth upon the antennæ, composed of several species of algæ and attached fungi. One of the men employed at this pound said that he had taken hard-shell lobsters with "kelp" 2 feet long growing upon the shell.

A lobster now in the Peabody Museum of Yale University was incrusted with Nullipores, when it was captured in Nantucket in April, 1880. This specimen was a male and weighed about 10 pounds.

Mussels sometimes glue themselves in extraordinary numbers to the under sides of the bodies of living lobsters, in places where the animal is unable to scratch them off. A good illustration of this may be seen in the museum of the Peabody Academy of Science at Salem, Massachusetts, where there is a male hard-shelled lobster about 12 inches long with fifty or more shells of the common *Mytilus edulis* attached to its body. The shells of some of these bivalves are 1½ inches long. They have wedged themselves between the bases of the thoracic legs, the plates of the tail-fan, and have fastened themselves even to the head between the antennæ and about the eyes.

It is not uncommon to find the barnacle (*Balanus balanoides*), as we have already seen, attached to the shell of both very old and relatively young lobsters (fig. 1, plate 1). The large Belfast lobster carried about with it several species of mollusks, as well as barnacles and hydroids.

On July 15, 1894, I found a lobster which had been kept for several days, or perhaps for a longer time, in a floating car, with one of its eyes completely hooded by a colony of bryozoa. When set free, the eye appeared perfectly normal.

The messmates of the young lobster consist chiefly of fungi (of which bacteria are the most characteristic) and of diatoms. Young lobsters captured at sea seem to be peculiarly free from foreign matter of every kind, but when the young of almost any of the crustacea are confined they soon become clogged with solid organic or inorganic floating particles and bacteria with which such material is invariably associated. The hairs which garnish the body and appendages of crustacean larvæ serve to gather up and hold solid particles from the water, so that one of the first considerations in the artificial rearing of crustacea is to give them as clean a water supply as possible.

I have seen larvæ in the fifth stage of development literally covered with a mass of diatoms (*Tabelaria*, *Navicula*, etc.) like those found in the brown sediment at the bottom of the jar in which they lived and in the undigested food contained in their stomachs. Old lobsters, in which the molting period has become very infrequent, are commonly the worst sufferers from enemies of this kind, but the physiological condition of the animal is, as we have seen, the most important consideration.

The crayfish, which is devoured eagerly by numerous species of fish in fresh-water lakes and rivers, both in this country and in Europe, is infested by Trematode worms, which become encysted in the tissues of the animal. *Distomum nodulosum* has been

described from *Cambarus propinquus* by Wright and Linton, and Ward (*198*) has found in the same crustacean still another species, *Distoma opacum*. "The cysts occupied the space in the cephalothorax above the heart and sexual organs."

The "tomally" or liver of the lobster is free, so far as is known, from parasites of all kinds, yet this is not the case with all the decapod crustacea. In June, 1885, while dissecting the southern shrimp (*Penæus setiferus*), I found numerous stages in the development of a cestode worm, *Tetrarhynchus* (species undetermined), in the liver of this prawn. The youngest were oval, about $\frac{1}{170}$ inch in long diameter; the oldest larvæ measured $\frac{1}{15}$ inch; they had a round, flattened body, an anterior segment or neck, with four well-developed proboscides, and a "tail" of about equal length, and unsegmented. Two pairs of bright red pigment spots were borne on the upper anterior part of the body.

DISEASES OF THE LOBSTER.

There are no specific diseases to which lobsters are subject, so far as known, yet they sometimes die off so rapidly as to lead one to suspect that they may have fallen a prey to some contagious disease.

Mr. N. F. Trefethen, of Portland, Maine, who owns a lobster pound in South Bristol, 35 miles east of Portland, relates the following experience: In May, 1893, he placed 100,000 lobsters in this pound, the area of which is about 3 acres. Very soon they began to die, and in a few days all of them were dead. There were 12 to 13 feet of water in this pound at flood tide and not less than 9 feet at low water. The pound was probably very much overstocked, but it is difficult to understand why these lobsters should have all died so suddenly, unless they were either poisoned or attacked by disease.

In the summer of 1889 a lobster with a large bunch on the side of the carapace was captured in Vineyard Sound. On the top of this tumoid growth was a crater-like depression covered with a membrane. This was probably a sore resulting from a wound which the animal had received in the back, and which had failed to heal. A similar case is mentioned by Rathbun (*155*).

Chapter VII.—THE TEGUMENTAL GLANDS.

The shell of the lobster, as has been seen already (pp. 77, 78), is not a solid armor, but is everywhere perforated by capillary canals which open by minute pores at the surface. One set of these ducts is called the hair pores. These lie immediately beneath the hairs or setæ of the shell. The other set constitutes the ducts of the tegumental glands.[1]

The tegumental glands are very generally found in the decapod crustacea, and they are more widely distributed over the body of the individual than almost any other organ. Nevertheless their structure has never been accurately determined, and almost nothing is known of their function. They lie in the dermis or in the connective tissue and adjoining muscles immediately below the cuticular epithelium. They are opaque, subspherical or oblong, not usually over $\frac{1}{8}$ mm. in longest diameter, and each communicates with the exterior by means of a capillary duct, the entire length of which—not including the part which traverses the cuticle—is probably not more than $\frac{1}{10}$ mm. (cuts 4 and 5, pl. A, and fig. 208, pl. 49) and its diameter only $\frac{1}{1\,2\,5}$ mm. These minute organs are scattered all over the body and appendages; they are particularly abundant about the mouth and in the œsophagus, and Vitzou has found them in the walls of the intestine of Palinurus (*197*). As he remarks, "one may study these organs indifferently in a macruran or brachyuran, for they have the same structure in both."

GENERAL STRUCTURE OF THE TEGUMENTAL GLAND.

The tegumental gland, wherever found, whether in the appendages or beneath the skin of the body proper, has the structure shown in cut 5. It consists of a central reticulate body or rosette, the exact nature of which is unknown. In the midst of this there is a small cavity, which is continued into a short capillary duct. The latter perforates the cuticle and thus places the organ in direct communication with the exterior. Grouped about the rosette is a cluster of gland cells of various shapes and sizes. Each has a broad base and tapering central end, which is united to a process of the rosette. Each organ is supplied with a nerve and contains an eccentric, bipolar cell, which resembles a ganglionic cell. One of the processes of the latter joins the rosette, while the other unites with the nerve. Rarely two such cells appear in the same organ. The duct and nerve usually issue from the gland together, the former possessing apparently, for at least a part of its course, a thin sheath. Each organ is usually surrounded with a delicate capsule, probably of connective tissue, though it is not always possible to detect such an envelope.

I have seen no branching of ducts, each organ opening independently at the surface, and I have not succeeded in determining with any degree of satisfaction the relation which the nerve fibers bear to the gland cells.

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[1] Similar structures have been called *dermal glands*, *salivary glands*, and *cement glands*. While it is probable that they originate in the epidermis, it may be better to classify them under the generic term of *tegumental glands*.

In the work of this chapter, relating to histology and technique, I wish to acknowledge my indebtedness to Professors Patten and Watase for valuable suggestions.

What is the function of these organs which are distributed so widely over the surface of the body? It has been found that glands of a similar character play a part in excretion. (Text-book of Comparative Anatomy, Lang, part I, p. 330.) Those found in the œsophagus were regarded as salivary glands until the embarrassing fact was discovered that they were also found in the walls of the intestine. When occurring in the swimmerets and ventral abdominal region of the female these organs have been considered responsible for the liquid glue or chitin-like cement which is poured over the eggs at ovulation, and have been accordingly called cement glands. It seems probable that they have such a function, and I shall proceed to describe them in detail as they occur in the lobster.

THE CEMENT GLANDS.

If we strip off the hard cuticle from the pleopod of a female lobster just before the eggs are laid (fig. 144, plate 40), we will see thousands of opaque whitish bodies lying upon the strands of muscular tissue. Each is a gland not more than an eighth of a millimeter in diameter, and each opens to the exterior by a capillary duct which pierces the cuticle. The grounds for attributing a cement-producing function to these organs lie chiefly in their periodical changes coincident with the sexual condition of the female, and in their absence or restricted occurrence in the pleopods of the male. Their position upon the swimmerets also favors such a view. We can not look elsewhere for such an organ, unless it is to the oviducts, and I know at present of no evidence showing that the latter possess this function in the macrura.

CEMENT GLANDS IMMEDIATELY BEFORE OVULATION.

As the time of oviposition draws near, the swimmerets of the female become more and more opaque, especially along the free margins of their branches. At this time a milky-white substance can be pressed out, upon removing the cuticle. This is analogous to what Lereboullet observed in the crayfish (*120*), and is composed of the glandular tissue.

At this period the glands have the appearance shown in plate 49, fig. 212. Stained with the Ehrlich-Biondi anilin mixture the cells have a cloudy, granular appearance. Their peripheral ends contain a coarser material, which takes a deeper red than the central parts; the latter appear much lighter, and select and hold some of the green. The distribution and appearance of the zymogen granules may be compared to that seen in the pancreas of a well-fed dog, or the resting cells of the submaxillary gland.

An attempt to get a secretion from these glands while in this condition by stimulating the nerve cord by induction currents was not successful, possibly owing to the fact that these organs had not quite reached the stage of their periodical activity.

THE CEMENT GLAND IMMEDIATELY AFTER OVULATION.

The structure of the exhausted gland, taken shortly after the eggs are laid, is illustrated by fig. 211, plate 49. If this is compared with fig. 212, which is treated in the same way, we will find a marked difference in its cytological condition. A very conspicuous zone of deeply stained zymogen granules surrounds the central rosette, while the outer parts of the gland cells are poor in zymogen and stain but feebly. This central darker zone is very variable in breadth, being sometimes reduced to a thin circle, involving only the apices of the cells, and is often very sharply marked

off from the rest of the cells. It should be remarked, however, that in two or three days after ovulation (external eggs with segmented yolk) there is a striking lack of uniformity in the condition of the glands, in many the central zymogen zone being entirely absent. This may be due to the fact either that some of the glands recover from exhaustion faster than others, or that they secrete unequally, or that some are not roused to activity at all.

Fig. 210, plate 49, is from the swimmeret of a female which had probably recently hatched a brood and was close upon the point of shedding. As may be seen, the glands are much shrunken in size, the cells transparent and non-granular, as if they were completely exhausted. This seems to be a perfectly normal case, but whether it has any significance in respect to the molt I am not able to say.

HISTORICAL SKETCH OF THE CEMENT GLANDS.

Cement glands have been described in numerous species of macrurous crustacea, but their structure seems to have been imperfectly made out.

Cavolini,[1] according to Cano (*32*), maintained that the cement came from the oviduct, and Rathke (*160*) regarded the genital organs as the probable source of this secretion. Erdl (*62*), in 1843, described three membranes in the egg of the lobster, and considered the outermost of these to be the secreted product of the oviduct.

Lereboullet (*120*) barely escaped the discovery of the cement glands of the crayfish in 1860, but correctly stated that the cement substance came from beneath the skin of the under side of the abdomen. He had indeed communicated this discovery to the Natural History Society of Strasbourg in 1852 (published in a note in L'Institut, in 1853. See ref. *120.*) As he says, zoologists had up to this time been almost mute upon this subject, some explaining the attachment of the ova to an extension of the primary egg membrane, others, like Milne Edwards (*58*), to an albuminous secretion from the epithelium of the oviduct. Lereboullet described a milky-white matter rich in fat and nuclei, which is present in the epimeral regions of the abdomen of the female crayfish at the time of oviposition, but is not found in the male at any period of the year. He supposed that this substance oozed through pores in the cuticle, coagulated in the water after fixing the eggs, and that all trace of it subsequently disappeared until the next reproductive period.

The true source of this secretion was first recognized by Braun (*22*), who, in 1875, described cement glands in the crayfish. He showed that they consisted of clusters of cells, which open to the surface of the abdominal appendages by narrow ducts penetrating the cuticle—a single duct to each cluster. A little later (*23*) he figured and described these glands in the six species of decapods. Similar structures were found in the carapace and œsophagus. Œsophageal glands (Speicheldrüsen) had been already seen in several species of crabs, such as *Grapsus* and *Eriphia spinifrons*, and analogous structures were found in the labrum and maxillæ.

Vitzou, whose work was published in 1882 (*197*), found glands generally present in the œsophagus of all the crustacea examined, and they appear in many of his drawings, but no attempt seems to have been made to study their histology. The œsophageal glands were extremely abundant in the lobster and Palinurus. The ducts are said to

[1] Memoria sulla generazione dei pesci e dei granchi. Napoli, 1787. I have not had access to this work, and quote it upon the authority of Cano.

be sometimes united into groups of five or six, and in the intervals small hairs[1] occur upon the surface of the cuticular lining.

Cano (*32*) devotes considerable attention to this subject, in a paper published in 1891, describing the distribution and structure of the cement glands in a large number of decapods. Bumpus attributes the "varnish-like layer" which surrounds the ovum of the lobster after oviposition to a secretion which is supposed to come from the columnar cells lining the oviducts (*30*).

In 1893 I gave a short and incomplete account of the cement glands of the lobster (*96*). See also *97*, note p. 79.

TEGUMENTAL GLANDS IN OTHER PARTS OF THE BODY.

I am not able to map the entire distribution of the tegumental glands, but have found them in many parts. The labrum and metastoma are packed almost full (fig. 208, plate 49). In the latter the ducts open for the most part upon the side next the mandible. We find them also in the basal stalk (protopodite) and respiratory plates of the maxillæ and maxillipeds, where they are already developed in the larval stages (plate 29, figs. 59, 62), and in the flagella of the antennæ.[2] The skin of the carapace and abdomen abound in these organs, and they are clustered in large numbers about the anterior lower margins of the former, just below the cervical groove, where the surface of the shell is raised into prominences like a grater. The ducts of many of these glands open into the respiratory cavity. I have also found a few of the organs in the walls of the seminal receptacle.

In sections through the dorsal posterior surface of the carapace of a lobster nearly ready to molt I find glands in precisely the same condition as shown in fig. 211, plate 49, where there is an inner deeply staining granular zone. Figure 208, plate 49, represents an organ from the metastoma, after maceration for three days in Béla Haller mixture and staining in methylen blue. The duct, running in the nerve bundle, shows very clearly and can be readily traced to the surface of the gland. By focusing with care I was able to follow the tubular duct into the central lumen or space, so characteristic of these organs. The relative number and distribution of glands in any part can be determined from macerated portions of the shell, as in fig. 170, which represents the inner surface of the first maxilla.

By maceration and pressure the structure of the gland can be made out in most of its details. In fig. 203, plate 49, the eccentric "ganglion" cell (*s. c.*) is seen to give off two branches, one of which joins the rosette (*R*), while the other passes into the nerve bundle, not shown in this drawing. A single gland cell is still joined to a process of the rosette by its attenuated central end. By rolling this specimen under the cover slip I was able to confirm the relations here pointed out. In fig. 214, drawn from a similar preparation, fewer glandular cells are detached, and but one process of the "ganglion" cell is shown. In many instances I have noticed that the inner ends of the gland cells have a very refractive, tubular appearance where they join the central rosette (figs. 209, 213, etc., plate 49), as if they had been snapped off at this point of delicate union. Figs. 206, 207 show a single gland cell drawn from opposite sides, from a cement gland of a female with nearly ripe ovaries. Besides the promi-

[1] I think it probable that the ducts of the glands really open upon these "hairs," as they do in the labrum. (See p. 133.)

[2] I have seen them in the outer flagellum only of the first antenna.

nent nucleus at the peripheral end of this cell, there are two other bodies—one near the tubular neck—which take up the stain like nuclei and are considerably refractive. From the larger end of the cell (fig. 206) a slender process is given off (compare figs. 201, 204 from the maxillæ), which suggests a nerve fiber. All that I can say definitely is that this process is in continuity with the cell, probably with its wall. I did not see many cases of a similar character.

EXPERIMENTS UPON THE SENSORY AREAS OF THE BODY AND APPENDAGES.

Before discussing the function of the tegumental organs in general, I will record some experiments which were made to determine how the lobster reacts to stimuli directed against the dead shell or cuticle.

The lobsters experimented upon were taken from the sea, placed on their backs on a table, and allowed to remain in this position until quiet. At first they move their appendages vigorously in trying to right themselves, but soon come to rest. By sprinkling them with sea water they may be kept fresh for experiment for a considerable time.

Various stimuli, such as electricity, heat, weak acetic acid, ammonia gas, clam juice, were applied to different parts of the body, with a view to ascertain the most sensitive areas where the quickest and most vigorous responses were given.

The degree of sensibility to external stimuli is surprisingly great in many cases, where the skin of the lobster with its shelly covering seems quite as sensitive as that of the frog. In other cases, however, the animal is much less responsive, a fact which we may attribute in some degree to the thickness of the shell.

To sum up the experiments in a general way, all or nearly all the appendages react strongly to chemical stimuli, and in many cases the surface of the body is capable of receiving and responding to stimuli of various kinds. If a jet of ammonia gas is injected against the intersegmental membranes or appendages of the "tail," the pleopods may be set in very lively motion and violent flexion of the whole abdomen may follow. Direct the jet upon the anterior swimmerets, and the last three pairs of walking legs are drawn backward and make scratching movements to remove the offending object, reminding one of the motions of a "reflex frog" when its skin is stimulated in a similar way.

The reaction is more violent when the stimulus is applied to the swimmerets than when directed against the intersternal membranes. The seminal receptacle is very sensitive, and when stimulated the walking legs make violent scratching movements toward it. If the jet of gas is directed along the surface of the walking legs, the reaction is usually greatest at their tips.

If the extremities of the large chelæ, especially the propodus, are touched by the gas the claw opens and shuts. The first pair of antennæ are much more sensitive to the stimuli than the second pair. If the jet is directed over the region of the mouth, very violent chewing movements are set up.

If the ammonium vapors be squirted on the dorsal surface of the carapace or abdomen, a vigorous response is sometimes seen by the immediate movements of the legs. Both males and females respond to the ammonia stimulus on the abdominal appendages and intersegmental membranes.

Very similar reactions are obtained if a small piece of blotting paper wet with weak acetic acid is used. In some cases no response is obtained if the wet paper is

placed on the intersternal membranes of the abdomen, but if laid upon either the inner sides of the pleura or upon the surfaces of the pleopods the reaction is more marked

If clam juice is placed on the mouth parts, as upon the flattened basal segments of the second maxillæ or first pair of maxillipeds, vigorous chewing movements are immediately begun, and are continued for several minutes. If the stimulus is applied to one side, the movements are at first restricted to that side only, but eventually, in some cases, the appendages of the opposite side begin to move also.

If clam juice is dropped upon the swimmerets of the female, a response is usually forthcoming, and the same is true if this stimulus be applied to the terminal segments of the walking legs. In the case of the large chelæ the response may be very slight. In one instance, where three females and one male were experimented upon, the abdominal appendages gave no response to clam juice, but the mouth parts were always extremely sensitive. In this case the pleopods gave a marked reaction when touched with weak acetic acid.

As a rule, the pleopods of the female were more sensitive to the various stimuli than those of the male. The abdominal appendages of the body give no reaction when breathed upon, and show but slight sensitiveness to heat. Weak electrical currents from an induction coil produce marked responses in the maxillæ and first pair of maxillipeds, and if the swimmerets are touched by the electrodes, violent contractions of the flexor muscles of the abdomen speedily follow.

The preceding experiments would lead us to suppose either that certain areas of the skin of the body and appendages are very sensitive to a variety of stimuli or that the skin or parts below it possess special sense-organs. In either case, excepting electrical stimuli, the organs must be reached by means of the canals which penetrate the inert cuticle.

Since there are only two possible roads for the entrance of chemical stimuli—the hair pores and the pores of the glandular ducts—the question is therefore raised whether the glands possess a subsidiary sensory function. If it could be shown that the setæ of the carapace were not perforated at their tips, it would be certain that ammonia vapor could not enter them[1] and extremely probable that the reaction from this chemical stimulus had its seat in the gland. I believe that these organs do possess such a subsidiary function, and that this is shown to be the case by a study of the sensitive labrum, in which hair pores and their corresponding setæ are entirely absent.

The function of the tegumental glands in various parts of the body has been a subject of much embarrassment. Max Braun (*22*) thought that the œsophageal glands of the crayfish were salivary organs. Vitzou inclines to acquiesce in this opinion, but admits that the presence of organs of exactly the same structure in the walls of the intestine (in Palinurus) is puzzling, to say the least.

Professor Patten (*150*) has recently discovered certain organs in Limulus to which he attributes a sensory function. They have essentially the same structure as the tegumental glands of the decapod crustacea. There occurs in front of the mouth of Limulus, on the middle line, a wart-like swelling, which Patten regards as the cuticular portion of an olfactory organ. "Directly beneath the ectoderm", he says, there "are a great many—at a rough estimate, from 1,500 to 2,000—clear, flask-shaped sense buds, each of which is connected by a narrow neck with a cuticular canal." The structure

[1] Where the setæ are moist it might be possible for ammonium vapor or any other chemical stimulus to reach the sensory cells by diffusion through the thin chitinous wall of the tubular hair.

of these "olfactory buds," their cuticular canal, gland-like cells, and large eccentric, in this case multipolar, ganglion, prove conclusively that these organs are essentially similar to the glands which I have described in the lobster. In discussing this subject with Professor Patten we have always been mutually agreed upon this point. What the function of these organs in all cases really is, may well be an open question. In Limulus the lumen of the organ varied much in appearance, being more sharply circumscribed in the young than in the adult, where it might be reduced or even absent. The tubule was sometimes coiled and very brittle. It is "undoubtedly composed of chitin, for, as with the gustatory tubules, it can still be seen in the cast-off shells of immature specimens and in the fresh shells cleaned with potash." The same is true of the cuticular canals of the glands of the lobster, except that the tubule is always apparently straight and is never effaced.

Lang (*114*) mentions some of the many cases in which glands have been described in the body and appendages of various crustacea, attributing to some of these "dermal" structures an excretory function, a fact which, he says, may be proved by feeding with carmine.

Unicellular glands of a remarkable character have been described in the appendages of various amphipods by Nebenski (*140*), Claus, and others. Here they are found in both sexes, but are confined in Orchestia to terrestrial species. Nebenski thinks that in the latter they may serve a respiratory function by keeping the gills moist.

The glands situated in the mouth parts, when stained in Ehrlich-Biondi anilin mixture, select the green with more regularity, the nuclei taking up the red. This, however, may be due to slightly different methods of treatment in washing out the stain.

The differences between what appear to be the resting and active gland, illustrated in figs. 212, 211, which are fairly characteristic of the swimmerets, immediately before and after ovulation, respectively, should not be given undue importance, since these conditions are met with, though less commonly, in other parts of the body.

Micro-chemical reactions point clearly to the glandular nature of the large peripheral cells of which these organs in certain places are composed. It is probable that in the pleopods they are concerned with the secretion of cement, for the reasons already given. What, then, is the function of the eccentric bipolar cell? Is it a reflex center for the gland, or is this a sensory cell which conveys impulses received from without to a reflex center in the central nervous system governing the secretory activity of the glandular cells? If the former supposition were correct, another question would remain to be answered: What are the organs of the sense of taste? The remarkably quick responses which are obtained upon stimulating the mouth parts immediately suggest the presence of gustatory organs. Such animals as the lobster and crab undoubtedly possess the sense of taste, but no organs have yet been described to which this function could be ascribed. Huxley says:

> It is probable that the crayfish possesses something analogous to taste, and a very likely seat for the organ of this function is in the upper lip and the metastoma; but if the organ exists it possesses no structural peculiarities by which it can be identified.

The labrum of the crayfish, so far as I could ascertain from a single specimen which I sectioned, contains no such glandular organs as occur in the lobster.

If it is inadmissible to regard any of the tegumental "glands" as gustatory organs, we must conclude that no distinct organs of taste can be detected in this animal, which has the power of discriminating its food. Is it possible, as Lemoine suggested (*118*), that the sense of taste is in some species blended with that of smell

and touch? Lemoine, who experimented with the crayfish, found that even the thickest parts of the carapace were sensitive, and that the parts which abounded in hairs were the most sensitive. Touching the hairs determined the movement of the claws and thoracic legs.

Milne Edwards considered the buccal cavity as the seat of the sense of taste, but although the experiments made by Audouin and himself convinced him that the sense was developed, he failed to find any special organs. (*58*, I, pp. 112–113.)

Lemoine experimented upon the buccal cavity, and especially the labrum, using a great variety of stimulants, such as salt, pepper, tobacco, ammonia, and electricity. He describes the labrum of the lobster, but, strange to say, did not discover the organs, with which it is packed full. He found that the inner face of this body was extremely sensitive. A nerve enters the labrum on each side. This gives off lateral twigs near the point of entry and numerous terminal branches toward the median plane. He supposed that these terminal filaments supplied the short hairs which were erroneously supposed to cover the surface.

The setæ of crustacea have tactile, auditory, and probably olfactory functions. The sensory seta is hollow and stands over a canal, which penetrates the integument, and a nerve fiber passes up into the lower part of the canal. (*84.*)

The organs of taste in insects, according to Lubbock, are modified hairs, situated either in the mouth or on the organs immediately surrounding it. Nine different antennal organs have been described in the Hymenoptera. Some of these antennal hairs serve as organs of touch and smell, and possibly for hearing also.

I have already called attention to the fact that while the pleopods are studded with thousands of microscopic glands, these appendages in the male are almost devoid of them. Their occurrence in the brachyura, where indeed they were first described by Braun (*23*), might support the theory that they had, in such cases, a function to perform independent of the production of cement, since it has been shown that the crabs possess a special cement-forming organ in the epithelial lining of the glandular receptaculum seminis. We must therefore conclude that in the brachyura the work of the glandular receptaculum seminis is supplemented by that of the pleopodal glands, or that the latter possess another function.

On the other hand, Leydig (*122*) has maintained that there is a close relation between gland cells and sensory cells, the two kinds of cells resembling each other in general structure and in the disposition of the cell contents. He found in the sensory cells of the skin of some vertebrates what seemed to correspond to cuticular secretions in gland cells.[1]

The gland of the type which we have been considering is undoubtedly a very primitive organ in Arthropods. It has probably been modified to perform different functions, with a minimal change of gross anatomical structure. What the function in every case is we can not for the present say with any degree of certainty. While the question is a puzzling one, it seems to me safer to regard all such structures, wherever they occur, in œsophagus, the intestine, the labrum, pleopods, or outer integument of the body, whether in Decapods, Limulus, or in other forms, where they will doubtless be discovered, primarily as *glands*. We may add that in the labrum, and perhaps in other parts of the external integument of the lobster, and in Limulus, they may have

[1] Jickeli, according to Leydig, believes that in certain Hydropolyps which he studied sensory cells are converted into gland cells. (*122.*)

a secondary sensory function. I have not examined the glands which occur in the alimentary tract, and can not say whether they possess a precisely similar structure.

Upon the supposition that the tegumentary organs are *never* sensory in function, we would have to conclude that the reactions which were obtained upon stimulating the dead shell had their seat in sensory elements in the vicinity of hair pores, and that the sensory hairs themselves are open at the tip, or at least have thin walls. I have usually found sensitive areas covered with setæ,[1] and while these do not normally open at the tip, the cuticle is so thin at this point that chemical stimuli might be readily conducted through them.

There is, however, one organ which is very sensitive to chemical stimuli, and which is entirely devoid of true setæ in the adult animal. This is the labrum or upper lip. Its structure certainly favors the view that the peculiar tegumental organs which it contains in such abundance may be the seat of the sense of taste.

There can be no doubt that the labrum is very sensitive to various stimuli, as Lemoine clearly showed many years ago. In the specimens which I examined with particular care no setæ of the ordinary kind were present on either the upper or lower sides, and the only direct channel for the passage of chemical stimuli from the surface of the dead cuticle to sensitive structures below it were the ducts of the tegumental glands. After the labrum had been cleaned by boiling it in a strong solution of potassium hydrate, the cuticular structures were clearly demonstrated. The only setæ present lie in four small rounded clusters of 12 to 15 each, near the base of the labrum and on its upper surface, where the cuticle has been reenforced by deposits of lime. These setæ are microscopic, measuring only one-tenth millimeter in length. Moreover, each is traversed by a duct which apparently opens at the surface and without doubt belongs to a tegumental gland. The upper surface of the labrum is abundantly sprinkled in other places, especially about the tip, with the minute pores of glands. These are sometimes in clusters, and their aggregate number is very great. When we examine the inner surface of the labrum we see it covered with sieve-like patches, each sieve containing sometimes as many as 60 or 70 holes, the openings of tegumental glands. At the anterior end these merge together so that the openings are exceedingly numerous. (Compare figure by Lemoine, *118*.)

Lemoine evidently mistook the ducts in the sieve-like areas for hairs, and has figured them incorrectly. The ducts project from the *inner* surface of the cuticle, (compare fig. 170) and in no instance were true setæ or hairs present on any part of the adult labrum.

Experimental evidence seems thus to point to the possession of a subsidiary gustatory function on the part of tegumental organs of the labrum, and possibly of other appendages about the mouth. This would imply that the stimulating particles are conveyed to the lumen of the organ, and thence to the central rosette. It would of course be absurd to suppose that the apparently similar organs in many other parts of the body, as in the carapace, possessed a similar function. While such a conclusion is not perfectly satisfactory, it is at least worthy of consideration.

[1] The walls of the seminal receptacle contain very few glands, but are copiously supplied with clusters of setæ. As I have already shown, they are very sensitive to chemical stimuli.

Chapter VIII.—VARIATIONS IN COLOR.

In the study of the color of animals we must distinguish between (*a*) variations in colors themselves and (*b*) variations in color patterns. The variation in colors, which Bateson calls "substantive variation," may be the result of a physical or chemical change and has no vital significance, like the change of yellow phosphorus to the red variety, of blue to red litmus, or of green to red pigments in autumn leaves and in the shell of the living lobster when the latter is boiled. "Different colors," says Bateson,[1] "are liable to different discontinuous variations; as instances may be mentioned black and tan in dogs, olive brown or green and yellow in birds, red and blue in the eggs of many Copepoda," etc. "Discontinuous color variation of this kind is one of the commonest phenomena in nature." The dark green and golden yellow in the eggs of several species of Alpheus and many other macrura is a characteristic example (*94*). Such changes can have no protective or adaptive significance.

The color of the lobster[2] is primarily due to the presence of pigments, either in solution in the blood or in the form of granules in the protoplasm of certain cells, particularly the chromatoblasts, which lie beneath the cuticular epithelium. The chromatoblasts are richly supplied with blood, which flows in a system of irregular sinuses through the spongy tissues underlying the epidermis.

In the adult lobster the shell is an opaque, dead substance, and the pigments which give it color are excreted by the chromatoblasts lying in the soft skin which is exposed upon removing the shell. This skin is flecked and mottled with scarlet, and it takes only a simple magnifying glass to see that its color is due to the branching pigment cells, accumulations of which correspond to the blotches of pigment on the shell. The excreted pigments undergo physical and probably chemical changes in the shell, and become of a very different color from that of the chromatoblasts.

Since the colors of the adult lobster reside in a dead body—the pigment layer of the shell (see pp. 77–78)—it is evident that no changes of a vital nature can take place after this is definitively formed. A young male, 10 inches long, drawn and colored from life, is represented on plate 16, fig. 22. This may be taken to represent the average color in lobsters with moderately hard shells.

NORMAL COLORATION.

There is no apparent sexual variation in the color of the lobster. The following detailed description is drawn from a female 10⅝ inches long, with elastic or "buckle" shell and with nearly ripe ovaries.

The general cast of color of the upper parts is dark bluish-green, mottled and speckled with very dark greenish-black spots; tail-fan light greenish-olive; sides of carapace brownish-olive, conspicuously spotted with small greenish-black spots; sides of abdomen marked in the same way, spots not as numerous; no spots on upper surface of uropods; large chelæ above dark bluish-green, almost black, with suffusions of orange on propodus; tubercles and spines bright red; spines of rostrum, antennæ,

[1] Materials for the study of variation, treated with especial regard to discontinuity in the origin of species, by William Bateson. 1894.

[2] The color variations in the young are discussed on p. 184.

pleura of third to sixth abdominal segments, and of appendages generally, vermilion; worn points of spines or worn surfaces of tubercles whitish; orange area of crushing chela (on propodus) mottled with dark green; walking legs bluish-green; bright sky-blue on basal joints, and tufts of setæ reddish.

Tendon marks: (1) A large porcelain-like whitish spot at junction of the cervical and branchio-cardiac grooves. Passing down the cervical groove are (2) numerous white or greenish white spots; (3) a large irregular yellowish-white spot occurs in a depression which lies about an inch behind the first antenna, and one-half inch from the dorsal surface, measured vertically; (4) a small white spot is seen about five-eighths inch behind the second antenna and five-sixteenths inch above the cervical groove. These spots are very characteristic, and are more prominent in the young than in the adults. They first become conspicuous in the fifth stage. (Compare plates 24, 25.)

The edge of the carapace is scalloped opposite the appendages, probably an adaptation for the movement of the legs;[1] largest scallops opposite the large chelipeds; a wide seam-like border, disappearing behind, forms part of the lateral area of absorption (see p. 88); color of absorption area light blue; yellowish spots on either side of second to sixth terga of pleon, most marked on second, third, and fourth segments.

Lower surface of large chelæ reddish-orange; bright red at the tips; bluish-green at edges, and on hinder parts of the propodus, and on the other joints; basal joints of smaller legs sky-blue varied with brownish-olive; wing-like pieces of seminal receptacle bright blue; swimmerets flesh color, edged with reddish; intersegmental membranes of abdomen nearly colorless; lower side of tail-fan brownish-olive; telson and uropods edged reddish-brown; fringes of silky hairs of the same color.

There is generally an under tint of olive on the body verging into a greenish-blue on the one hand or light reddish-brown on the other, the whole upper and lateral surfaces being spotted or mottled with dark greenish-blue or blue-black, the spots often confluent on the upper surface.

VARIATIONS IN COLOR.

The coloration is uniform in plan, but exceedingly variable in details, much more so than we see in the case of the intricate color patterns of many insects. The brilliancy and purity of the shell pigments depend largely upon the age of the shell or its condition with respect to the molting period. The pigments are usually most brilliant immediately after the molt, when the cuticle is thin and translucent, and dullest just before ecdysis begins, when the old shell encumbers the body.

The pigment cells themselves, which, as we have seen, reside in the skin or immediately below it, are subject to vital changes, but when the shell is once hardened the color of the animal is fixed. It is certain, however, that under the action of light, or from other causes, the shell pigments undergo molecular or chemical changes. Men who handle lobsters have frequently observed that when they are exposed in shallow cars to unusually intense light they become decidedly bluer in color. I recently witnessed a very interesting demonstration of this fact. The fishermen at Menemsha, at the western end of Vineyard Sound, saved all the egg-bearing lobsters which they caught in June, 1894, for the hatchery of the Fish Commission, placing them in a floating skiff, covered only with netting and thus exposed to the full glare of the sun. Toward the last of the hatching season, when operations in the hatchery had

[1] The development of the carapace shows that these notches have nothing to do with the primitive segmentation of the body.

ceased, I made no visits to Menemsha from June 22 until July 16, when I found about a dozen lobsters in the car, where they had been imprisoned from two to three weeks. They were without exception of a brilliant blue color, and were very conspicuous when placed with other lobsters recently taken in the Sound. They were all old-shell females, most of which had hatched their eggs and were approaching their molting time. All the green pigment of the shell had become light cobalt-blue, which, interspersed with the usual Naples yellow tints, gave them a very striking appearance.

According to the observations of MacMunn (*132*), the coloring of the skin of the lobster (*Astacus gammarus*) and crayfish (*Potamobius fluviatilis*) is due to the presence of chromogens, which are converted on very slight provocation, as by dehydration, oxidation, or some molecular change, into a red lipochrome, resembling rhodophan. Everyone is familiar with the wonderful change of color which the adult lobster undergoes when boiled,[1] and according to MacMunn the beautiful blue pigment of the larval lobster is converted by alcohol into a true lipochrome.

Alcohol quickly converts the chromogens in the lobster's shell into lipochromes, and dissolves them at the same time. This is well seen in recently molted lobsters, where the colors are very brilliant. When placed in alcohol, the soft-shelled lobster is first reddened, and then in a short time completely bleached, while a lobster with a hard shell treated in the same way will retain some of its color for a long time, if not indefinitely. The same changes are seen when the dark-green eggs are treated with alcohol or boiling water.

The lipochromes are pigments of a very wide distribution in the living world, occurring in green leaves, in yellow flowers and fruits, and it is said that the vertebrate retina, "egg-yolks of different species of animals, the yellow, green, or red pigmented integuments of various invertebrates and vertebrates from fishes to birds, owe their coloration, with few exceptions, to dissolved, granular, or diffusely distributed lipochromes." (*132*, p. 95.)

Lipochromogens are found in a natural state in the gastric glands, blood, soft skin (as the blue prismatic cyano-crystals, which are reddened by alcohol or by boiling), and in the exoskeleton of crustacea. MacMunn is of the opinion that they are "built up in the digestive gland and carried in the blood current to be deposited in other parts of the body." (*132*, p. 62.) If this is true, it would not be remarkable if the color of the animal were affected by the nature of its food, yet this does not seem to be often the case.

The following substantive variations have been met with: (1) Blue lobsters, in which the prevailing color is blue; (2) red lobsters, which are pure red or reddish-yellow; (3) cream-colored lobsters, characterized by the almost entire absence of color; (4) we should also add black lobsters, to include possible cases of melanism, where the colors are extremely dark. A specimen of this kind was reported to me at Beal Island, near West Jonesport, Maine, where a fisherman recently captured, in 3 fathoms of water among the eelgrass, a lobster about 6 or 7 inches long with moderately hard shell and almost jet-black. He supposed at first that it was covered with coal tar. It did not appear to be preparing to molt. Malard (*133*) speaks of meeting with cases of melanism in crabs, where in consequence of a lesion of the skin the crab becomes entirely black—"charbonné," as the sailors describe it.

[1] In France the lobster, *Astacus gammarus*, is said to be called the "red cardinal of the sea," and the Norwegian lobster, *Nethrops norvegicus*, I am informed by Dr. Lönnberg, is called by the fishermen in Sweden *Kejsar hummer*, or emperor lobster, on account of its color and spines.

Changes in color pattern are more elusive. There is (1) the normal variety, in which the upper part of the body is mottled with green, blue, and cream color; (2) spotted or "calico" lobsters, the coloration of which is a bold pattern of green and light-yellowish or cream-colored spots; (3) pied or parti-colored varieties, in which the contrast of tints is abnormally pronounced. This may perhaps be better classed under substantive variation. The changes are due apparently to vital or physiological causes, which have at least no adaptational significance.

We will presently consider in more detail the variations which have just been enumerated, but must first speak of the eggs.

COLOR OF THE EGGS.

The eggs of the lobster furnish a good example of substantive variation. The body of the animal is opaque, so that it is affected but little by the color of the ovaries, and not at all when seen from above, by that of the external eggs.

The freshly laid ovum is of a dark green (fig. 24, pl. 17), sometimes almost black, color, due to the presence of a dissolved lipochromogen. The golden-yellow variation, which is often associated with dark green, as in the eggs of *Alpheus heterochelis* and *A. saulcyi* (*94*, p. 375), has never been observed, but occasionally the ova are of a light, almost pea-green color, or some tint between this and very dark green. Rarely the new eggs are light grayish green. I received a lobster from Woods Hole in December, with external eggs of a very light greenish straw-color. (See fig. 23, pl. 17.) These were in an early stage of development, and had been laid but a few weeks. It was the most striking color variation in the ova which I have yet seen. Such changes as these can not be interpreted as having any adaptational significance.

If the eggs are treated with hot water, alcohol, or other killing reagents the green lipochromogen is quickly converted into red lipochrome. When the water is heated gradually the red color appears slowly, and it is interesting to observe that if these red eggs are now plunged into cold water the green color is restored. This change may be somewhat analogous to the breaking up and reconstruction of the blue compound of starch and iodine upon the successive application of heat and cold, and to the variation in color which sometimes appears in the living animal at the time of the molt. Soon after the water has been brought to the boiling point the red color becomes permanent.

BLUE LOBSTERS.

Lobsters of a deep, almost uniform ultramarine color are sometimes met with and never fail to attract attention.[1] The color, which is often of a rich indigo along the middle of the upper part of the body, shades off into a brighter and clearer tint on the sides and extremities. The upper surface of the large claws is blue and purple, faintly mottled with darker shades, while underneath is a delicate cream tint. The under parts of the body tend also to melt into a light cream color, and this is also true of the spines and tubercles of the shell and appendages, which are usually bright red.

A lobster of the foregoing description was caught off Hurricane Island by Thomas Garrett, in April, 1874. It was a female, had a hard shell, and weighed about 2 pounds. A very bright blue lobster was taken at Grand Manan, Maine, in August, 1893.

[1] DeKay (*51*) speaks of a variety of lobsters called Bluebacks, but his impressions that they are derived from one part of the coast, that they have thin shells, and that they are chiefly seen in early May, were all erroneous. He also remarked that they were highly prized by epicures.

I have never seen a blue lobster of perfectly uniform tint or without markings on the shell; yet lobsters which very nearly answer this description are occasionally taken, according to abundant testimony. Passing from this condition, there is a graded series of colors, from the decidedly blue to the distinctly blackish or bluish green.

There is a well-preserved skeleton of a blue lobster in the museum of the Peabody Academy of Science at Salem, Massachusetts.[1] This specimen is a male, 11⅞ inches long, and has a hard shell. The carapace is deep indigo above, but lighter on the sides with rather faint spots of light blue. The "tail" is of a purplish cast, with fine spots or marbling of dark blue. The large claws are purplish above, with abundant darker blotches, while they are cream-colored below, with some fine blue spots. The other legs are cream-colored, washed or speckled with blue.

Mr. J. W. Savage received at Boston, in June, 1893, about a hundred exceptionally blue lobsters from Nova Scotia. They had "hard shells," and would average 1¾ pounds each in weight. As he expressed it, "they were as blue as bluejays." In April of the same year Mr. A. P. Greenleaf, of Boothbay, Maine, received also from Nova Scotia, as he informed me, two thousand or more very blue lobsters. He says that the usual spots and other markings of the shell were not conspicuous, and that the colors were so bright that he was almost afraid to ship them to market. A female egg-bearing lobster from Nova Scotia, which I examined in September, was of a dull leaden-blue color over the whole upper part of the body. The lateral edges of the carapace were sky-blue, the claws very dark, almost black, above, and dull red below. I have already referred to the bluing of lobsters (p. 135), which is due to either a physical or chemical change in the shell pigments and has no adaptational significance.

Blue crayfishes described by Lereboullet (*119*) were "of an azure or cobalt color more or less intense; the claws deeply colored; the legs paler, and the lower parts of the body of a pale red." He thought that the shell contained three kinds of pigment—red, blue, and green, and that in the red and blue varieties one of these pigments was excessively developed.

RED LOBSTERS.

Occasionally red living lobsters are seen, which are very rarely as bright in color as those which have been boiled. Mr. F. W. Collins, of Rockland, Maine, had a lobster of this variety in September, 1890. It was taken in Dyers Bay, near Jonesport, Maine. It had a hard shell, and when in the floating car with other lobsters was very conspicuous for its bright color.

Mr. S. M. Johnson informs me that lobsters of this interesting color variety are met with "more or less frequently." Speaking of one which was obtained in 1892, he says that "although taken by itself the color was somewhat paler than the ordinary boiled lobster, yet if put with others that had been boiled it would have been hard to distinguish the difference."

Through the kindness of Messrs. Johnson and Young I received on April 9, 1894, a remarkably perfect specimen of a red lobster, of which I have made a drawing colored as accurately as possible from life (plate 16, fig. 21). It was alive and active when it reached Cleveland, had a fairly hard shell, was without external eggs, and measured 11⅜ inches. Except in color, it was perfectly normal. It was caught in the vicinity of Mount Desert, Maine. The ovaries, which were immature, were of a light-

[1] I had the privilege of examining this and other specimens in the museum through the courtesy of Mr. John Robinson, treasurer of the Peabody Academy of Science.

green color. Messrs. Johnson and Young consider this variety very rare, since they have seen but one other in which the red color was so bright and uniform in life.

The color of this animal, as shown on plate 16, was very brilliant. There was not the slightest trace of any blue or green pigment about any part of it, except at some of the articulations, nor of any other color except a light-reddish russet or orange. The eyes, however, possessed the usual black pigment, and on this account were exceptionally prominent. The flagella of the antennæ, the tips of the walking legs, and posterior margins of the tail-fan were brilliant red. The color on the upper surface of the large claws was rather brighter red than on the lower. A good idea of the natural color of this lobster may be had by imagining the color of the whole animal to be of the orange-red tint which is normally seen on the under side of the large claws.

The spines were not brighter red than the other parts, but were worn white at the tips, as is usually the case. The setæ over the various parts were of the usual reddish-brown color. The color of the carapace may be described as light orange-red, covered with a reticulate or very delicately lined pattern of darker red, and mottled with white. The light spot which is seen midway between the roots of the second pair of antennæ and the cervical groove was very large, as were also the whitish tendon-marks of the cervical groove itself.

The sternal calcified portions of the animal were snow-white, washed faintly with orange-red. The seminal receptacle, which is usually bright blue, was pure white; the swimmerets very translucent and faintly tinged with red; under side of tail-fan a uniform pale reddish-orange.

This seems to be a remarkable case of a discontinuous color variation, which is the result of a chemical change similar, in all probability, to that which occurs after death, as when the animal is boiled.

Lereboullet (*119*) says that a red variety of the crayfish was found in certain streams in the Rhine valley. It was usually small, though sometimes of the average size. "They are all of a uniform brick-red color, without spots, and resemble cooked crayfishes perfectly; the legs and lower parts of the body are always very pale."

CREAM-COLORED LOBSTERS.

A light cream-colored lobster, without any darker spots visible upon it, was captured at North Waldoboro, Maine, about 1882. It was between 10 and 11 inches long. I saw this specimen, but not until it had been preserved in alcohol.

Mr. J. W. Fisher, of Eastport, Maine, informed me that in the winter of 1893 a lobster was caught at Deer Island, Maine, which was 11 inches long and of a light cream-color. It appeared very white in the water. There were no visible spots or markings upon it. A lobster of similar appearance was taken in Boston Harbor by Mr. J. W. Savage, in August, 1892. The under side of the claws was light red, which was not intensified upon boiling.

Perfect albino lobsters, without trace of natural pigment in the eyes, or parts of the exoskeleton, have never been captured. "Albinism," or the various stages of an approach toward this condition met with among crustacea, are, according to Malard (*133*), in all probability but particular cases of adaptive coloration. It seems to me far more likely that such cases are primarily non-adaptive. In the lobster there has been a degeneration, and in some cases a final loss of pigment. This may be the last of a series of changes which we see begun in the live red lobster. The latter is no more or less protectively colored than the former.

A specimen of a gray lobster (*Astacus gammarus*) was described at a meeting of the Société Philomathique of Paris, on December 12, 1891, by M. Martin. It was captured at St. Vaast-la-Hougue, in a trap with several perfectly normal lobsters. The dorsal part of the carapace of the abnormal specimen was of a dark yellowish-green color, with greenish-black spots. The green color disappeared rapidly on either side of the dorsal median line, the yellow remaining, and passing into almost pure white on the sides. There was not the least trace of marbling and none of the pronounced blue color of the average lobster. The pleon was yellowish-green above, and yellow on the sides. Large irregular spots of a deep bluish-black color ornamented each segment, even in the dorsal parts, but without forming the usual marbled pattern.

Martin rejects the hypothesis that this deficiency of color may be due to the absence of light, supposing the lobster to have lived in a dark crevice in very deep water, and regards this variation as adaptive, a conclusion which seems to me gratuitous. He says, in a note, that M. Biétrix, of Concarneau, had a white lobster, kept in a pond, which recovered its blue color at the next molt. A young male of *Alpheus saulcyi*, which I once kept for several days in an aquarium, molted and lost completely the bright vermilion color of its claws. (*94*, p. 381.)

Casual or temporary decoloration occurs in many species of crustacea, as in *Cancer pagarus*, of which Malard (*133*) says that he has met with many cases of young individuals living under stones in old oyster parks in the island of Tatihou, while the permanent absence of pigment is characteristic of certain well-known burrowing crustacea which live in the sand, such as Hippa, Callianassa, and Gebia. It is doubtful if the entire absence of pigment in such a form as Callianassa can be regarded as adaptive; first, because the animal burrows, and is for the most part concealed; and secondly, because its whiteness makes it a more conspicuous object on the sand than it might otherwise be. This condition may, however, be the last term in a series of changes, some of which were distinctly adaptive.

VARIATIONS IN COLOR PATTERNS.

SPOTTED LOBSTERS.

The spotted lobsters—"calico," or "leopard lobsters," as they are variously called by fishermen—exhibit an interesting and striking coloration, which is somewhat rare. They appear to be occasionally captured, however, all along the coast. An experienced fisherman at Rockland, Maine, said that he usually took one or two of this variety in the course of the season.

There is a well-preserved spotted lobster in the museum of the Peabody Academy of Science, a female with hard shell, 11½ inches long. The whole upper part of the body is of a light-yellow color, with purplish blue pigments (in the dried shell) so arranged as to give a spotted or marbled appearance. The light-yellow spots on the carapace vary much in size and shape, the largest being half an inch in diameter and of a slightly irregular, rounded contour. The spots are confluent at the hinder end of the carapace, where they form a marked yellowish area. On the sides of the carapace the spots are small and tend to flow together. The "tail" is marbled above with irregular yellow spots, in excess of the darker color. The tail-fan is yellow, beautifully mottled with reddish-purple. The appendages are spotted in the same way, light yellow predominating. The large claws are dark purplish-red above, with obscure spots; but on the under side, they are of the usual bright reddish-orange color, spattered with purple.

PARTI-COLORED VARIETIES.

Once in a while a lobster is caught which exhibits a remarkably abnormal coloration. A lobster which would weigh about 2 pounds was captured near Long Island, Portland Harbor, about the year 1886. One half of the body was light yellow, clearly defined up to the middle line of the back from the color of the other half, which was bright red. There were no spots on the shell. This specimen was exhibited in Boston, and afterwards sent to Professor Baird.

De Kay mentions a similar case (*51*). He says:

> In June, 1840, I saw in the Fulton Market a lobster which was of two colors, distinctly separated by a medial line from the tip of the rostrum to the middle extremity of the plate of the tail. One side of the body and all the members were of a light sky-blue, and the other of the usual olivaceous green.

Mr. S. M. Johnson informs me that it is not uncommon to get a lobster in which a part of the body is pale red while the rest is normal in color, and that a few years ago he had a specimen in which this difference in color was marked by the line running through the middle of the back, and that even one-half of each "feeler" was light and the other dark.

Buckland (*28*) mentions the case of a half "albino" lobster, which he received in May, 1868. He says:

> One side of the barrel was blue and the other was white. The blue turned red on boiling, but the white did not. There appeared to be no pigment in the white part of the shell.

Boeck (*20*, p. 225) says that in 1868 he found a lobster near Haugesund, one half of which was of a greenish-black and the other of a light-orange color, there being a sharp and clearly defined line, which ran lengthwise and divided the shell into two parts of equal area. This closely resembles the odd variations which we have just noticed in the American species.

Lovett (*128*) has described a number of color variations in lobsters from the island of Jersey. One which is particularly mentioned—a female with eggs—was of a pale lavender color, with a mauve spot on the carapace and with bright blue claws. The usual mottled markings on the sides of the thorax were rather indistinct. He speaks also of having observed a full-grown female with eggs of a pale-reddish color, with bright antennæ.

Carrington and Lovett have described the great chromatic adaptability of the common green crab, *Carcinus mænas* (*35*).

Boeck says that the European lobster, taken near the mouths of fiords in Norway, is lighter in color than is usual, while farther out to sea it becomes much darker.

Malard thinks that these peculiar color variations are due to the loss of certain pigments, in consequence of insufficient light, in the deep grottos or rocky crevices where the lobsters may have lived.

Protective coloration and chromatic adaptability to the immediate environment are common to a large number of the crustacea. It seems to be least observed in the highest representatives, the Brachyura. According to Malard this chromatic adaptation is effected either (1) chemically, by the modification of pigment under the direct action of light, or (2) physiologically, by the action of pigment cells stimulated by light, indirectly through the eyes and central nervous system.

Pouchet has made some interesting observations (see *133*) on the variations of color in the common shrimp, Palæmon. It was found to be most variable when 3 to 4 cm. in

length. When captured by the fishermen they are usually of a rose or delicate lilac color, but lose these tints or become of a light-yellowish hue when kept in vases with white bottoms. In black vases they turn to a deep brown. These effects are produced by the reaction of two kinds of pigments, the cyanic pigments which are generally in a state of solution, and the pigments of the xanthic series (red, orange, and yellow), by the action of the chromatoblasts. Malard states that Jourdain has shown that if the eyes are removed and the animal is kept in darkness, a red color is always obtained.

Certainly, one of the most striking cases of protective coloring met with in the crustacea is that of the inhabitants of the floating islands of sargassum which are encountered in the Gulf Stream or along its borders. This alga is of a dirty yellowish-brown color, often flecked with white, when its floats are incrusted with the bleached skeletons of bryozoa. This appearance is emphasized by the numbers of goose barnacles which are attached to the fronds. A small crab which is an important colonist of these islands is brown, with a large snow-white spot on its back; and the shrimp, of which there are several species, are colored in a similar manner, the body being dappled with brown and white.

We must place in another category the gaily dressed shore crab of the West Indies, *Gegarcinus ruricola*, whose brilliant hues and bizarre coloration are clearly without protective significance. This beautiful crab burrows in the mangrove swamps at about the level of high water, and is very common throughout the Bahama Islands. After a drenching rain the green boughs of the mangrove suddenly blossom out with crabs. Some of them have crimson legs, a dark purple body, with a large yellow spot on each side of the carapace, while in others these colors are reversed. Others again are nearly black, or the carapace is orange or straw color, flecked or marbled with purple, in an endless series of patterns, so that no two are alike. It is possible that this is an example of warning coloration, such as is seen in many gaudy insects, serving to protect them from the assaults of birds and other enemies, or it may be a case of substantive variation, without any vital significance.

The colors of deep-sea animals which live in total obscurity can not be of any utility to the animal as a source of protection. The colors may be very brilliant—red, scarlet, orange, rose color, purple, violet, and blue being frequently reported—but they appear to be developed quite independently of the light. It has been shown by experiment with sensitive photographic plates that luminous rays do not penetrate ordinary sea water to a greater depth than 400 meters. In depths of 50 fathoms or more there might be an appreciable amount of light on clear days, but even then, when the water was loaded with sediment and the bottom composed of dark materials, it seems hardly probable that colors would have any protective value whatever.

The normal colors of the lobster, which are spread like a mantle over its whole upper surface, tend undoubtedly to screen its movements while crawling over a weedy or rocky bottom. The absence of all color or a more generous display of bright pigment would make it a more conspicuous object, especially upon sandy bottoms in shallow water, which it is usually careful to avoid in the daytime. The vivid red of the claws appears to be overlaid by a darker pigment in spots, particularly on the upper surface. The under side of the pleon, which rests upon the bottom when the tail is not folded, is very meagerly supplied with pigment, as is usually the case with marine animals which inhabit the bottom.

Chapter IX.—VARIATIONS IN STRUCTURE.

Deformities in the adult stages of the higher crustacea center chiefly in the large claws, which are more subject to mutilation than any other parts, owing to their constant use as weapons. We will therefore consider first the variations in these appendages.

NORMAL VARIATIONS IN THE LARGE CLAWS.

Aristotle (*4*) says of the claws of the lobster: "In the Astaci alone it is a matter of chance which claw is the larger, and this is in either sex." The difference between the right and left claws is greatest in the small fiddler-crabs where, as in Gelasimus, the large claw, according to Bate, can not reach the mouth, a power which it must have originally possessed.

It seems, as Aristotle remarked, a matter of chance whether the crushing-claw is on the right or left side of the body; but this is not really the case. I have shown that in *Alpheus saulcyi*, where the large crushing-chela can be recognized even before the animal is hatched, the members of a brood are either right-handed or left-handed, that is, have the crushing-claw on the same side of the body. This seems to be a case of direct inheritance from the parents, though not enough data were collected to settle this point. (For a statement of the facts, so far as they are known, see *94*, p. 376.)

The large claw occurs about as frequently upon the right side of the body as upon the left, without distinction of sex, as shown by the following table, embracing 2,433 individuals:

Sex.	Crushing claw on right side.	Crushing claw on left side.	Both claws similar.
Males	562	628	1
Females	602	638	2
Total	1,164	1,266	3

ABNORMAL VARIATIONS IN THE CLAWS.

SIMILAR CLAWS DEVELOPED ON BOTH SIDES OF THE BODY.

A variation sometimes occurs in which the normal differentiation of the great claws is wanting. Both claws are similar, developed either for cutting or crushing.[1] In examining over 2,400 lobsters, only 3 were found in which this abnormal variation was present. It is, therefore, undoubtedly rare, and apparently has never been previously described. Before examining these cases in detail it will be best to notice the normal characteristics of the claws. This description is taken from a female—length, 11 inches; weight, 24 ounces—with hard shell (compare fig. 20*a*, plate 15):

Crushing-claw: On right side; seven marginal spines on propodus, third spine (from peripheral end) depressed; a small spine opposite the latter on upper side of propodus. There is a small tubercle on the upper side of propodus, near articulation of dactyl; in a corresponding situation below there are two tubercles, one considerably

[1] I have heard of a single case reported by a fisherman, where similar crushing-claws were developed on both sides of the body.

smaller than the other; a small tubercle on upper side of propodus, on outer margin, near carpus. There is considerable variation in the number and prominence of these processes, particularly the marginal ones.

Cutting-claw: Six marginal spines on propodus, second and fifth depressed; other processes present, as in corresponding claw.

ABNORMAL VARIATION.—(1) Female; length, 10½ inches; hard shell; cutting-claws on both sides similar; Woods Hole, Massachusetts, March, 1894.

Right cutting-claw: Small tubercles of propodus, near dactyl, wanting.

Left cutting-claw: Transverse scar-like groove on propodus, at level of articulation of dactyl; one small tubercle on upper surface of propodus, near dactyl; two very minute ones below; five marginal spines, third bent inward, rest turned forward and upward.

(2) Female; length, 10⅛ inches; hard shell.

Right cutting-claw: Five marginal inner spines on propodus, third depressed; no small tubercles near joint of dactyl present.

Left cutting-claw: A little smaller than right; 5 marginal spines, none depressed; one small tubercle on lower side of propodus near dactyl.

(3) Male; length, 10 inches; hard shell; both claws relatively small, having been regenerated; length of propodus, 3⅜ inches. (Plate 14, fig. 19, from photograph.)

Right cutting-claw: Seven marginal spines, second and fourth depressed; one small tubercle on under side of propodus, near dactyl.

Left cutting-claw: Five marginal spines, second depressed; one very small tubercle on upper side of propodus near dactyl; two very minute ones below.

There seems to be about as much variation as regards the details here mentioned in normal symmetrical claws as in the abnormal symmetrical ones, and it is probable that in either case the conditions met with are to some extent congenital.

DIVISION AND REPETITION OF APPENDAGES.

The curious monstrosities which occur in the appendages, particularly in the large claws of the lobster, have attracted the attention of naturalists for a long time. They were noticed by Von Berniz (*17*) over two hundred years ago, and some good figures of the deformed claws of the crayfish were published by Rösel in 1755 (*168*). A careful review of crustacean deformities, concerning the lobster in particular, was given by Faxon in 1881. His paper was accompanied by valuable figures and a bibliography (*66*). The general subject of variation as it affects the appendages of arthropods has been recently treated in a masterly manner by Bateson in his invaluable work on variation.[1] The variations which concern the crustacea, particularly the decapods, are fully described and illustrated, with references to the abundant literature. Bateson shows that in most of the cases of supposed duplication of limbs in both insects and crustacea the extra parts are double instead of single, as where two dactyls are formed at the extremity of the claw instead of a complete claw consisting of dactyl and propodus. He has also formulated certain principles according to which supernumerary appendages make their appearance in secondary symmetry. If the normal appendage which bears the extra ones is a right leg, "the ne rer of the extra legs is a left and the remoter a right."

[1] Materials for the study of variation treated with especial regard to discontinuity in the origin of species, by William Bateson, 1894.

The monstrosities noticed in the chelipeds of the lobster are mainly the result of a secondary outgrowth from one of the two terminal joints. Rarely the appendage is duplicated or triplicated; a case of the crayfish is reported with three extra claws (see Bateson, p. 537). In some cases the extra appendages are perfectly formed, while in others deformation has been carried to excess, resulting in irregular branching processes or grotesque contortions. Injuries to the claws are excessively common, while duplication of parts is rare. Defective or deformed claws, the result of injuries (see figs. 194, 198) in different stages of repair, are met with every day by dealers, while thousands of lobsters may be examined without meeting a single case of repetition or duplication of parts.[1]

If the tips of the claws are snipped off near the articulation of the dactyl, the lost parts are restored (see p. 105) as we have seen at the next molt. This restoration is often perfect, but not always so. The condition seen in fig. 198 might have been caused by a pinch and arrest of growth while the claw was soft (before the last molt), or by the unequal growth from a stump, the end of the propodus having been cut off by an enemy just before the shell was cast. In the latter case the member could be only partially restored, and unequal growth would account for the distortion.

The dactyl shown in fig. 194 has probably had a similar history. All such cases are the results of regeneration after injury. This can not be said of such a specimen as that represented by fig. 189, where the dactyl bears upon its inner margin near the tip a small conical prominence. This is smooth and is separated from the tip of the dactyl by a shallow groove, as if there had been a normal bifurcation or division at this point. What the primary cause of such a growth or swelling may be is not known, but it is impossible to suppose it to be the result of injury.

With the appearance of such a simple outgrowth a progressive series of changes seems to take place with every molt, such as is illustrated by figs. 189–193, plate 47. With the growth of the animal, the superadded part, whether it be upon dactyl or propodus, seems to be shifted at each molt farther and farther back upon the claw, and meantime, in most cases, to undergo fission in a vertical (figs. 190, 191) or somewhat oblique plane (figs. 187, 188). This fission apparently proceeds until one or both of the supernumerary dactyls are entirely separated (figs. 192, 193). The opposing edges of these become gradually toothed, so that each is almost an exact copy of the original (see especially fig. 193, plate 47). According to the principles laid down by Bateson, the part which is nearer the original joint corresponds with the appendages on the opposite side—that which is farthest away with those on the same side of the body. This is not strictly true in such a case as that shown in fig. 196, where the supernumerary parts do not face each other, and in some cases the repeated part is single, not double. In fig. 190 a short row of teeth marks the median plane of division and the opposing surfaces of the incipient fingers are also toothed. In fig. 191 the outgrowth is divided nearly to its base into two secondary processes, each of which resembles the joint of

[1] In 2,657 lobsters captured at Woods Hole, Massachusetts, from December to June, 1893–94, but one case of repetition or formation of extra parts in the large claw occurred. No account was kept of injuries, but in the months of December and January 7 per cent of all lobsters caught (54 in a total of 725) had thrown off one or both claws. (See p. 103.)

A man who had been engaged in the business of canning lobsters for a score of years in Maine told me that he had at one time nearly a bushel of deformed claws, which he had collected in the course of his experience.

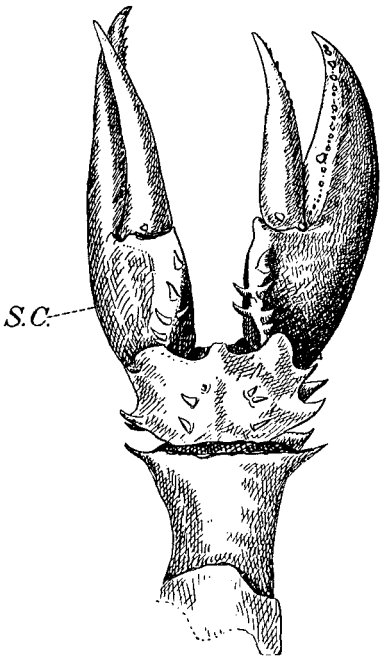
which it is a part. According to my interpretation, such a case as that shown in fig. 193 has gone through phases similar to those shown in figs. 189–191.

In figs. 192 and 197 the conditions are somewhat different, since the superadded dactyl is single. I think there can be no doubt that a progressive division of the propodus takes place in such cases. In fig. 192 the plane of fission in the propodus is marked by spines very much as in fig. 190. There may be a line of median, unpaired spines at the bottom of the groove, and bilaterally symmetrical spines upon its sides. It seems probable that the conditions like those seen in fig. 197 could be derived from such as are met in fig. 192 by the intervention of a single molt.

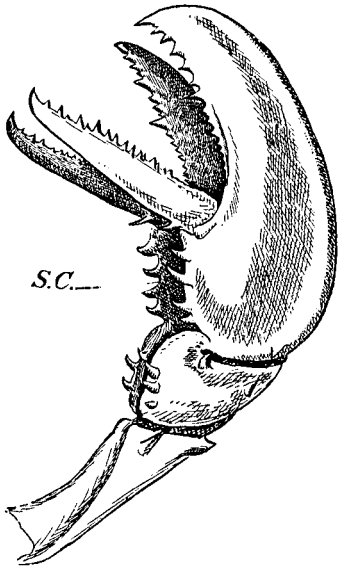
Faxon describes a very interesting case (*66*, plate 2, fig. 6) in which there appears to be a duplication of the right cheliped down to the meros. The latter is partially divided by a deep groove running across its distal end. It seems to me very probable that we have here an illustration of the same process which is seen in figs. 192, 197, only carried a step or two farther. In the former case the fourth joint of the limb is undergoing a process of fission begun nearer the outer extremity, while in the latter the sixth segment is involved. The supernumerary carpus in the case figured by Faxon bears a stump-like segment, which looks like an abortive propodus, corresponding probably to the abortive segment borne on the extremity of the supernumerary branch of the propodus in fig. 197. In the latter case it is an undoubted dactyl, and is smaller and more rudimentary than in fig. 192, where the fission of the propodus has not gone so far. It is thus probable that with the extension of this process, emphasized at each molt, the terminal segments may in some cases, as in those before us, atrophy and disappear, until we have, as in the example cited by Faxon, only an abortive propodus left. Bateson regards this superadded member as double, formed of two compounded parts. This may be so, but the same kind of reasoning would lead us to regard such an incipient member as that seen in fig. 197 as double, consisting potentially of two dactyls and two propodi. The only apparent reason for doing so lies in the supposition that such a superadded part arose as a tubercle or budding growth on some part of the claw, probably in this case on the dactyl, and was potentially a double member from the start, or at least capable of doubling by a process of fission, as we see actually going on in fig. 190. Whatever changes may have taken place precedent to the condition seen in fig. 197, there is no evidence of fission in the extra dactyl unless the two spines (S, S^1) be taken as such.

There seems to be a considerable gap between the condition seen in fig. 193, where three dactyls are present, one of which is free, and that shown in fig. 192, where there is a single process. The latter is bent downward and toward the primary dactyl. Its inner border has a spine (S) like that borne on the normal dactyl, showing this part to belong to the left side. It bears also another spine near its articulation with the propodus (S^1), which might indicate that this toothless appendage was really a double member. (See fig. 197, S, S^1.)

Another good example of repetition of the propodus, with division of the bud, is shown in figs. 187, 188, plate 46, which are from photographs. In this case the bud has grown out obliquely from the under side of the propodus instead of from the margin, as in fig. 190. The continuity of the outer margin is interrupted by a deep groove which divides the bud into perfectly similar parts. In this case the teeth on the inner margins of the supernumerary digits are not opposed. The outer or lowermost, which is usually symmetrical with the normal part, makes here an angle of about 42° with the normal digit, and the two supernumerary digits make an angle of 12° with



CUT 16.—Double right cutting-claw of female lobster, 11½ inches long, now in the American Museum of Natural History, New York City. Seen from the anterior side. One-half natural size
S. C, supernumerary claw.



CUT 17.—Double right cutting-claw of the same lobster, seen from above. One-half natural size.
S. C, supernumerary claw.

Drawn by F. H. Herrick.

each other. The pollux is depressed, so that when the claw is closed it falls almost exactly midway between the normal and first superadded digit. The fission is marked on the upper surface by a distinct groove. The total length of the propodus is about $2\frac{1}{2}$ inches (62 mm.), so that the lobster was not in all probability over 6 inches long. The size of this claw as compared with the basal joints of the limb suggests that it has been lately regenerated, and it is unfortunate that this interesting point can not be determined with certainty.

In fig. 196 a similar monstrosity is seen in the dactyl of the cutting-claw. Here the bifurcating branch is near the apex. Each prong is furnished with teeth on the inner side. A trimerous dactyl (fig. 195), one division of which is independent, in the second or third pereiopod presents precisely the same relations which occur in the first pereiopod (fig. 193), and probably they have been produced in the same way.

What is now most needed in clearing up questions in the interpretation of deformities in crustacean appendages is to watch the molting of the animals and to measure and record the change which occurs in the malformed individual at each stage of growth. The abnormal developments seen in figs. 189–193 probably represent a series of changes such as ordinarily occur in the same individual. What the course of events really is between the conditions represented by figs. 193, 192 is not so clear.

While the true duplication, or even triplication, of limbs or parts of limbs is rare in crustacea, it is occasionally met with; but it is an important fact, which Bateson has emphasized, that "in arthropods and vertebrates such a phenomenon as the representation of one of the appendages by two identical appendages standing in succession is unknown. No right arm is ever succeeded on the same side of the body by another arm properly formed as a right, and no crustacean has two right legs in succession where one should be."[1]

In the American Museum of Natural History, in New York, there is a specimen of a lobster in which the right cutting-claw is perfectly duplicated from the carpus or fifth joint. I was recently enabled to examine this interesting specimen and to make some drawings of it, which are given in cuts 16, 17, plate E.

The two cutting-claws resemble each other very closely in every detail and are of almost exactly the same size, but each is relatively smaller than normal. The measurements of each cutting-claw are as follows:

	Inches.
Right cutting-claws (abnormal):	
Length of propodi	$3\frac{7}{8}$
Greatest breadth of propodi	$1\frac{3}{8}$
Left crushing-claw (normal):	
Length of propodus	5
Greatest breadth of propodus	2

In the primary cutting-claw the dactyl closes normally on the propodus; in the superadded claw (*S. C.*) it is bent upward out of line with the cutting edge of the latter. The symmetry of the two claws extends, with few exceptions, to the spines upon their cutting edges and on the inner margins of the propodi. The carpus of the limb is apparently single, but it has duplicated spines, and a deep groove at its peripheral end shows that it is virtually double. The carpus and meros have been twisted through an angle of 90°, so that their posterior surfaces face upward.

This specimen was obtained some years ago from a marketman in New York City.

[1] Materials for the study of variation, p. 539.

Nothing is definitely known about the causes of repetition. It looks at first sight as if the deformities in the appendages of the lobster and other arthropods could be explained as phenomena of regeneration, though in this case there is addition rather than replacement.

We have seen that where the cheliped is thrown off by reflex muscular contraction the bud of a new leg forthwith appears, and under favorable conditions grows into a perfect limb. The tissues of this limb are developed out of the formed histological elements of the stump. The process of regeneration is begun in this case as a direct result of a loss or injury. The plane of fracture lies between the second and third joints, and all parts peripheral to the second joint are reproduced. Repetition of parts, however, occurs in many insects and vertebrates where no such regeneration of lost appendages is known. However, the power of regeneration, which is present in all organisms, differs rather in degree than in kind, and Weismann has shown that it has probably been developed in many cases as a means of defense and protection to the individual. (See p. 107.)

In the specimen of Palinurus (No. 808, Bateson, originally described by Léger in 1886), where the left penultimate leg bears two supernumerary legs, both of which spring from the basipodite, it certainly looks as if what would have taken place in the case of loss of the original limb—namely, the growth of a new one from this joint—had happened repeatedly, so that instead of the regeneration of one limb at a time there is the superaddition of two; but where the limb is not cast off the first superadded one is in secondary symmetry and belongs to the opposite side. If such an interpretation will apply to this case, the various other repetitions and abnormal growths which arise in more peripheral joints, as upon the sixth and seventh, fall into the same general category. In the case of the growth of a new limb in consequence of loss, however, all parts which are external to the plane of fracture are reproduced. In the cases of repetition this is not usually the case, as Bateson has shown. The bud which arises on the propodus (as in figs. 187, 190) may by fission give rise to a second propodus, but not usually, if ever, to a dactyl.

It seems as impossible to suppose that such a deformity as that seen in fig. 187 or fig. 189 is congenital as that it is the result of injury. The monstrosities which occur in the embryo, which are considered in another place, are, however, in some cases at least, the result of injury or unfavorable conditions.

Autotomy, or the casting of the claw at the second joint, is probably directly accountable for the rarity of abnormal growths in the limbs of the higher crustacea. It is extremely improbable that any deformity at the extremity of a limb could survive autotomy, but the experiments to settle this interesting point have yet to be made. While it would appear that the various deformities which have been described can not be explained as the results of injuries and the attempted regeneration of injured parts, since the limb is usually thrown off in such cases to be completely renewed or it is retained to be completely restored, yet I can not escape the conviction that the problem is in some way directly concerned with that of regeneration. The mechanism by which so complete a structure as a limb is regenerated can not be regarded as simple. As Weismann says, the machinery of a cotton factory can not be made out of a few simple levers. It is probably exceedingly complex, and it is no wonder that the parts do not always work harmoniously, that the thread is sometimes knotted or the product useless.

VARIATIONS IN OTHER ORGANS.

ROSTRUM.

I have met with a single case of bifurcated rostrum, a small male, represented in figs. 162, 163. The median groove, which corresponds to an area of absorption in the shell (see p. 88), divides near the apex, each branch going to a terminal spine. Instead of a single spine below the terminal, there are several smaller ones.

In *Alpheus saulcyi* the median rostral spine is sometimes wanting, as in the genus Betæus, of Dana. (See *94*, p. 384, plate XXII, fig. 11.)

OVARY.

Two instances were observed in which the ovarian lobe on one side has suffered division, one that of a small female (44 mm. long, fig. 131, plate 38) in which one of the posterior lobes is involved, the other an adult lobster (fig. 164, plate 42) with similar division of the left anterior lobe.

HERMAPHRODITISM.

A malformed hermaphrodite lobster, *Homarus gammarus*, was described and figured by Nicholls in the Philosophical Transactions of the Royal Society of London in 1730 (*141*). "The specimen," he says, "if split from head to tail, is female on the right side and male on the left side." This was true of both the internal and external organs. A similar case of hermaphroditism has been described by Gissler (*78*) in the Phyllopod *Eubranchipus vernalis*.

La Valette St. George (*193*) discusses a very interesting case of hermaphroditism which he discovered in the crayfish. He found eggs present in the nearly ripe testis of *Astacus fluviatilis* in July and August. The eggs were placed usually at the periphery of the testis lobe. They were round or oval, 0.06 mm. to 0.015 mm. in diameter, and showed the usual constituents of ovarian eggs. They had a larger germinal vesicle than the normal egg, were sometimes inclosed in a follicle, and contained yolk spheres. He asks how the presence of the eggs in the normal testicle is to be explained and gives the following answer:

> These eggs are evidently derived from spermatogonia, which have become unfaithful to their original functions. Instead of multiplying by division to form a number of spermatocytes, they have chosen a shorter way, which makes it possible for a single egg to arise from them by simple growth.

Under certain conditions a primitive sperm cell may be converted into an egg cell, and this, he says, furnishes a new proof of the relation of spermatogonia and oogonia. Follicle cells may arise from a spermatogonium, but the latter can never arise from follicle cells.

The spermatogonia, according to La Valette St. George, produce, chiefly by mitosis, the spermatocytes, which eventually give rise to the spermatids. Spermatosomes, as well as large follicular nuclei, may be found in the process of degeneration in the testis.

Hermaphroditism has also been described in the lobster by Hermann (*89*), who, according to La Valette St. George, was the first to prove the presence of hermaphroditism in the testes of decapods. Hermann discovered in the anterior parts of the testis of the lobster large round or oval cells with granular protoplasm, each possessing a large germinal vesicle with nucleoli. Eight or ten such cells, which were regarded as undoubted eggs, were found in one specimen. In some of the figures given by La Valette St. George the ovum fills nearly the entire lumen of the testis.

Chapter X.—STRUCTURE AND DEVELOPMENT OF THE REPRODUCTIVE ORGANS.

THE FEMALE REPRODUCTIVE ORGANS.

THE OVARY.

In order to understand the structure of the ovary and the changes it undergoes it is necessary to examine this organ at different stages of development and in the various phases of the sexual life of the animal. The external eggs borne on the swimmerets of the female serve as a gauge to determine the age of the developing ovarian ova.

I have already given an account of this organ in my paper on Alpheus (*94*, see also *90* and *93*) and have illustrated the growth of the eggs. Bumpus (*30*) has also devoted considerable attention to this subject and has figured certain structural phases of the ovary, but the early development of this organ has not been touched upon and there are important anatomical facts which have not yet been noticed or illustrated. I shall therefore deal with this subject in detail, though in doing so it will be necessary to repeat some facts which are already known.

The time of the year when the ovary becomes mature and the size which the spawning female attains are discussed in other parts of this work.

THE RIPE OVARY.

The ripe ovary, which I will first describe (plate 36, fig. 123), occupies, as we have seen, the dorsal part of the body cavity. The anterior lobes encircle the stomach, while the hinder ones extend sometimes as far backward as the fifth abdominal somite. The ovarian wall, though often quite thick, is very transparent, and the ripe eggs give it a dark green, beaded appearance. The walls, if mutilated, immediately collapse and the perfectly ripe eggs flow out in a stream.

The structure of a nearly mature ovary is seen in fig. 141, plate 39. Most conspicuous are the massive ova filling the lumen of the thick, tubular wall. Immediately next to the latter are seen very characteristic structures which I shall call ovarian glands (*O. G.*). Immature ova of varying size are interspersed among the glands and dip down between the ripe peripheral eggs. These structures, together with irregular blood sinuses (*Bl. S.*) and strands or nodules of muscle and connective tissue, make up the substance of this organ.

The glands are folds of follicular epithelium similar in origin to that which encapsules the larger ova. The long axis of the fold is parallel with the ovarian wall. The glandular fold consists of a structureless basement membrane and of columnar epithelial cells (fig. 152, plate 41). The nuclei generally lie at the deeper ends of the cells, the protoplasm of which is decidedly granular, and cell walls are very indistinct after the ordinary methods of treatment. Occasionally a glandular fold is seen (plate 41, fig. 153) which has a very different character from the structure just described. It is expanded into an oval or oblong form, and its epithelial wall appears in a much disordered state. It is highly vesicular, containing numerous vacuoles, which probably represent fat globules (*F. G.*); cell walls are absolutely effaced; nuclei,

no longer spheroidal, have become shrunken and scattered about the meshes of a protoplasmic network. There are, besides, globules (fig. 153, *y. s.*), probably of an albuminous nature, which resemble spherules of yolk, and lie either in the lumen of the fold or are embedded in the protoplasmic reticulum. They are most abundant in the reticulum, where they sometimes occur as large granular masses. In fig. 145, plate 40, a single large spherule (*y. s.*) of this kind is seen interpolated between the follicular cells. A number of nuclei surround it and, however anomalous its position, the appearance is not artificial. In other cases, where no degenerative processes are at work, the lumina of these folds are filled with a fine granular residue. The intimate relations which these structures bear on the one hand to the vascular sinuses, and on the other to the growing ova, point to their probable function, that of the formation of yolk. If this is the case, it is evident that the ovarian glands can play but a minor rôle in this process. The massive yolk of the ripe egg is formed for the most part in the protoplasmic reticulum of the egg cell from materials which are drawn directly from the blood. A third source of the yolk is the follicular cells themselves, large masses of which pass into the egg at this stage, where they undergo complete degeneration, as I have pointed out in another paper (*93*, *94*), and shall describe more fully presently.

THE OVARY AFTER OVULATION.

The appearance of the ovary shortly after egg-laying is represented in plate 38, fig. 136. It has collapsed from its distended condition, and is now of a yellowish-white color, flecked with green and orange spots. The green bodies are ripe ova which failed to be forced out at the time of the last laying. The ducts are often full of them (compare fig. 119). The orange specks are the remains of similar eggs left over from the previous ovulation. While the latter have thus been in the ovary for at least two years, they are not yet completely absorbed. The primary membrane of the egg still remains, inclosing a small disorganized residue (fig. 150).

The structure of an ovary at this period is shown in fig. 139, plate 39. The external eggs were in an early stage of yolk segmentation, showing that not more than thirty-six hours had elapsed since the last egg-laying. The ovarian lobe is now a solid mass of tissue, the youngest ova being disposed about the axis, the older at the periphery. Irregular blood sinuses penetrate to every part, between folds of follicular epithelium. These folds take the form of irregular pouches and represent, as Bumpus has shown (*30*), invaginations of the ovarian epithelium. This is better seen in Palinurus, or in the ovary of the adolescent lobster.

The ovarian glands have now attained their greatest prominence, and their relation to the growing eggs is well illustrated in fig. 139, plate 39, and figs. 151, 152, plate 41. In fig. 151, from a horizontal section, the eggs lie in strings, or rather tiers, between the double walls of the epithelial folds, which dip down vertically from the surface of the ovary. This is from a later stage than fig. 152, which represents a section through the central or terminal boundary of the fold. It is from the same ovary as fig. 139, where the glands are in the ascendant. The glandular cells have the form of tall columns, the nuclei lying at their deeper ends. Cell boundaries are very vague, the central ends of the cells merging into what appears as a granular reticulum. The columnar cells, though apparently stopping short at the sides of the egg, are directly continuous with the less conspicuous cells of the true follicle. This glandular cœcum resembles, in section, a narrow bag with an egg pushed into its mouth. A thin layer

of follicular cells, however, screens this particular egg (fig. 152) from the lumen of the glandular fold. In some cases, however, I have seen the glandular cells in direct relation with the yolk, with amœboid cells passing into the egg along the line of contact (plate 40, fig. 149). At this point cells are sometimes seen completely engulfed in the food yolk. Their nuclei swell to a somewhat larger size, and then speedily degenerate. Faint ghost-like outlines can be detected for some time; then the chromatin becomes concentrated about the walls of a gradually dwindling vesicle (plate 39, fig. 142, *Dg.*). Finally the chromatin is reduced to very small stainable fragments. In other cases the chromatin probably breaks up more immediately into a swarm of minute particles, which remain in the interstices of the yolk spheres in the peripheral parts of the egg. The "plasmic vesicles" or vacuoles, which Bumpus (*30*) has described, are products of the cell degeneration just considered.

Eggs which have been well started on the road of normal growth suddenly go into a decline and are probably finally absorbed into the blood, somewhat as the follicle cells are converted into nutriment within the eggs. (See pp. 211–213.) A number of such degenerating ova are seen to the right of fig. 150, plate 41. They are filled with refractive globules, which are undoubtedly of an albuminous nature.

After the lapse of from ten to fifteen days after ovulation (the external eggs being then in the egg-nauplius stage), the ovarian glands have almost wholly disappeared. The walls of the follicular folds, now crowded to the extreme periphery beneath the ovarian wall, are shrunken and crumpled. At a still later period (attached eggs with eye pigment, from four to five weeks old) the glands are reduced to shriveled remnants. Later still, no vestige of them is seen.

STRUCTURE OF THE OVARY AT TIME OF HATCHING OF EXTERNAL EGGS.

When the external eggs are ready to hatch, the ovarian ova have had nearly a year's growth. The appearance of the ovary at this time is shown in fig. 138, plate 38, and its structure in fig. 147, plate 40. It has a characteristic pea-green color, and the largest peripheral ova (fig. 133, plate 38) have a diameter which is equal to only one-tenth that of the mature eggs. The ovarian wall is thinner than in previous stages, and in the axial portions there are the usual germogenal folds.

Fig. 137 (plate 38) represents the ovary of a lobster taken August 21. An examination of the external eggs shows that they are about six weeks old. The ovary was light green, sparingly flecked with yellow. The individual eggs are greenest at the center, which gives the organ a finely dotted appearance. There is no trace of glands.

The ovaries of "paper-shells" taken in July, after having produced a brood and molted during the current season, contain ova which measure fully half the diameter of the mature egg. This shows that after ovulation and again after the hatching of the young—that is, during the first, second, and twelfth, thirteenth, and fourteenth months after egg-extrusion—the ovarian eggs experience their most rapid growth. (See p. 71, and in particular the description of fig. 138, p. 246.)

At a still later period, when the ovarian eggs have been growing for the space of nearly two years,[1] and the ova have attained a diameter which is from 80 to 90 per cent that of the ripe egg, the organ has the structure seen in fig. 140, plate 39. There may be considerable variation, but in the specimen from which this drawing was made (female, taken July 30) the ovarian wall is excessively thin and the lumen is packed full

[1] This is an estimate based upon the general facts of growth and development of the ovary, and not upon the observation of single individuals during this length of time.

of eggs of fairly uniform size. The stroma of germogenal tissue is reduced to a minimum, and there is no trace of the ovarian glands which subsequently appear (fig. 141).

The anatomy of the ovary and the slow growth of the ovarian egg, which we have followed from the time the new eggs were laid during a period of two years, when the next batch are ready for extrusion, proves conclusively, as I have pointed out in earlier papers (*93* and *97*), that the breeding season of the lobster is not an annual one, as had been supposed. (See pp. 70–73.)

We have seen in the foregoing account that the massive yolk of the eggs is produced in three ways: (1) It is manufactured in the protoplasm of the growing ovum from materials absorbed from the blood—the most fruitful source; (2) it is produced by the activity of the ovarian glands; (3) by the direct absorption of follicular cells.

The fact that parts of the follicular epithelium become differentiated into glands at a definite period, and that these later become totally obliterated is certainly remarkable, but I do not see how the phenomena which have been described can receive any other interpretation. The yolk in *Peripatus novæ-zealandiæ* is described by Lilian Sheldon (*180*) as arising in part from follicle cells. The latter pass into the egg through the tubular stalk by which this is attached to the ovary, and become converted into yolk. Yolk is said to originate also in the protoplasm of the ovum, as is commonly observed in Arthropods; also from the breaking up of a part of the germinal vesicle, and finally it is produced by certain parts of the ovarian tube itself. The condition usually found in Platyhelminthes, where there is a permanent yolk-secreting gland, may thus be compared with that of Peripatus and the lobster, where this function is in some measure performed by parts of the follicular epithelium.

THE ORIGIN OF THE OVA.

The ova arise from nuclei of the germinal epithelium, as I have described in detail in a former work (*94*). The origin of the primary egg membrane from the follicular cells (fig. 148, plate 40) is well known, but it should be remembered that this chitin-like envelope is not completed until after the decay of the ovarian glands. Thus, in the eggs shown in fig. 142, plate 39, and fig. 149, plate 40, there is no membranous boundary between the yolk and glandular cells.

Cases of the apparent fusion of young ova, mentioned by Bumpus (*30*), are occasionally met with, but it seems to me probable that no real fusion ever occurs—the impingement of cell upon cell often seeming, however, to support this idea.

THE METAMORPHOSIS OF THE GERMINAL VESICLE.

The very young ovum has a large, rapidly growing germinal vesicle or nucleus, as shown in fig. 154. At this stage the cell protoplasm forms a thin peripheral zone having a fine granular appearance in stained sections.

The metamorphosis of the germinal vesicle from this early stage to the perfectly ripe condition is illustrated by figs. 155 to 161, all of which are drawn to the same scale. The nucleolus is formed at a very early period (fig. 154) and is soon vesiculated (fig. 155). Rarely two or more nucleoli are present (fig. 156); there is usually but one.

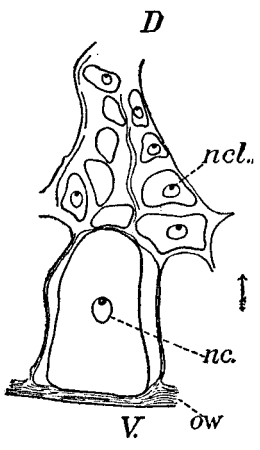
The nucleus reaches its largest size (about $\frac{1}{11}$ mm. in diameter) at the close of the first year after ovulation. It is now regularly oval, its long axes being parallel with the long diameter of the egg (fig. 158). As at an earlier stage, the nucleolus is vesiculated and almost always found lying close to the nuclear membrane, as if it had fallen of its own weight like a shot in a bag.

The nuclear membrane is very distinct up to the time when the ovum approaches maturity (figs. 159 and 160), when its outlines have become hazy. In the case illustrated (fig. 140) the long diameter of the nucleus corresponds with the short diameter of the egg. The nucleolus and nuclear fluid have undergone a very marked change. When stained in Kleinenberg's hæmotoxylon, the nucleolus has a hazy, almost homogeneous, appearance, and stains rather feebly, while the karyoplasm is of the same character, but takes the stain more feebly still.

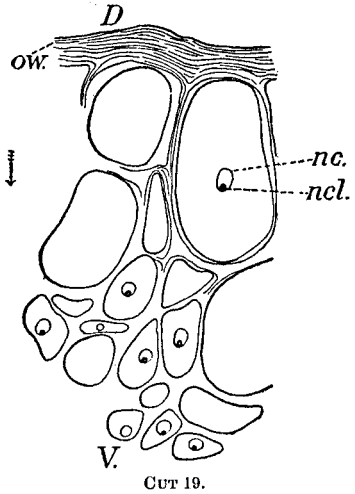
When the eggs are ripe and lie free within the ovary ready for extrusion (fig. 141, plate 39), it is difficult to find the nucleus (partly, no doubt, on account of the great mass of yolk and the difficulty in cutting it). In one case, where I succeeded, what appeared to be the metamorphosed nucleus was a somewhat eccentric island of karyoplasm (fig. 160; for position in ovum, see fig. 141) without membrane or trace of a nucleolus. This vesicle stains uniformly, and has a very fine-grained texture. It has started for the surface of the egg, and in the next stage examined (fig. 161) is in contact with it. In this particular egg, taken from the oviduct of a female shortly after ovulation, the cell is dividing, or giving off a polar body; the nucleus has diminished in size, and no membrane is distinguishable.

THE MOVEMENTS OF THE NUCLEOLUS THROUGH THE ACTION OF GRAVITY.

I have already pointed out the eccentric position of the nucleolus, which is always observed whenever the immature ovary is sectioned. This was noticed by Bumpus in 1891, but no explanation of the fact was offered. (*30*, p. 225.)



CUT 18.



CUT 19.

CUT 18.—From transverse section of a part of ovary of lobster, hardened with ventral side uppermost, to show the effect of gravity upon the nucleolus. From hard-shell lobster which had recently hatched a brood. July 18, 1894.

CUT 19.—From transverse section of a part of same ovary, hardened with dorsal side uppermost, to show the effect of gravity upon the nucleolus. *D*, dorsal surface of ovary; *nc*, nucleus of ovum; *ncl*, nucleolus of ovum; *ow*, ovarian wall; *V*, ventral surface of ovary.

The arrow in each cut shows the direction of the force of gravity.

It seemed very probable that this phenomenon was due to gravity acting directly upon the nucleolus, which was free to move in every part of the nucleus. A few simple experiments immediately proved that this was the case. The ovary of a lobster which had recently hatched a brood was selected and cut into several pieces. These were then hardened in different positions, in Mayer's picro-sulphuric acid, with ventral or

dorsal side uppermost or in vertical suspension. This was repeated, and it invariably followed that the nucleolus fell from its own weight, to the lower side of the nucleus, like a shot within a tennis ball. This is well illustrated in cuts 18 and 19. The latter shows in section a part of the ovary hardened in its natural position, with the dorsal surface uppermost; the nucleoli are here invariably on the lower side, in contact with the nuclear membrane. In 18, where the part of the ovary was turned bottom side up, the nucleoli are eccentric, but lie against the opposite side of the nucleus. Suspend the ovary and kill the tissue in any position you please, the nucleoli sink like shot in the karyolymph and lie against the lower side of the nucleus. This is true of all but the smallest ova, in which the nucleolus may or may not so readily respond. Such eggs sometimes possess two or more nucleoli (fig. 156).

This phenomenon is a direct result of the structure of the nucleus and of the action of gravity, or else it is an artifact, the result of post-mortem changes. The nucleus consists of karyolymph, in which float granules of chromatin and other substances of but slightly less specific gravity, and a single large nucleolus of greater specific gravity than the surrounding fluids. The chromatophilous substance is distributed in flocculent masses (figs. 157, 158), which are commonly suspended in the nuclear fluid, but tend to "sink to the bottom" together with the nucleolus. There is no trace whatever of a nuclear network in the meshes of which bodies are suspended.

The nucleolus stains very intensely, but is often highly vesiculated, in some cases forming a hollow shell, owing probably to the extraction of soluble matter by some of the reagents used. When the nuclear membrane is strongly contracted over any part of its area (as in fig. 152) it leaves between it and the rest of the egg a regularly defined space, which is partially filled with a coagulable liquid. This may come partly or wholly from the nucleus.

I have never seen this phenomenon in the eggs of any other animal. If anyone have doubts about the facts, a very simple experiment like the one herein described will be convincing. The explanation which I have offered may, however, be questioned. I regret that the subject of post-mortem change did not come up for consideration when I was at the seashore.[1]

THE RIPE OVUM.

The ripe unfertilized ovum is illustrated by figs. 119 and 141. Those which I have examined have been taken from the ovary or ducts a few hours or days after ovulation.

The nucleus was in such cases found at or very near the surface of the egg. In fig. 161, as already mentioned, the nucleus was in karyokinesis. The plane of section passed through the equatorial plate, so that the poles lie, in reality, above and below the plane of the paper. This is apparently the division preliminary to the formation of the first polar body. The rest of the egg is composed of yolk disposed in spherules of fairly uniform size. A coagulable liquid is usually gathered at the surface, below the eggshell, where the yolk spheres are here apt to be smaller. There is a single egg membrane (about $\frac{1}{260}$ mm. in thickness), which is unaltered in the course of the passage of the egg through the oviduct.

[1] In regard to this question Professor Bumpus writes me that Belloncí found something very similar in the brain of Squilla, and that this was afterwards explained by Mayer as the result of the action of reagents, the nucleoli migrating from the killing fluids. Here, however, the action of gravity certainly plays a part.

THE DEVELOPMENT OF THE REPRODUCTIVE ORGANS.

GENERAL DEVELOPMENT.

In well-advanced embryos taken in January (for stage of development, compare cut 38) a very minute cluster of cells can be detected on either side of the middle line close upon the mesodermic partition which screens the heart from the intestine. These cells are mesoblastic in origin; they possess oval or spherical nuclei which, however, are not conspicuous for their size. At the time the embryo is about to hatch there is less doubt in the identification of the reproductive organ (fig. 116, plate 36). It now consists of a small oval, somewhat flattened mass of cells, lying close upon the mesentery, next to the intestine. It appears to arise as a proliferation of the mesoblast of the mesentery, but at this time is very distinct from it.

Later, in the first and second larval stages, the reproductive organ is a more compact, almost spherical, cell mass (about $\frac{1}{44}$ mm. in diameter). Its position, close to the anterior end of the heart, but in contact with the mesentery, is well shown in fig. 174, *ov*, plate 43. It is now differentiated into two kinds of cells: (1) Central cells with large nuclei; (2) peripheral cells with much smaller nuclei (fig. 117, plate 36). The latter probably give rise to the ovarian wall, the former to the ova and follicular epithelium. The clearer central cells contain a distinct reticulum in which masses of chromatin are held. The organ is delicately suspended to the side of the mesentery by connective tissue. I did not distinguish the outlines of cells in any part of it.

In as late as the sixth or seventh stages the reproductive organ is still of very small size and not readily seen.

THE OVARY.

In a female 44 mm. long (No. 2, table 32) the ovary was of the size shown in fig. 131. I did not observe the ducts, probably because of the poor condition of the specimen when dissected. These were undoubtedly present, since their openings are visible in the eighth stage (fig. 89, plate 32—No. 3, table 34), when the animal is less than an inch long. This ovary was 15 mm. long, and each lobe was about one-fourth mm. in diameter. The anterior lobes embrace the masticatory stomach, and one of the posterior lobes was branched.

If the condition of the tissue could be trusted—it was preserved in alcohol, considerably diluted—the organ now consisted of a distinct connective tissue wall and an inclosed mass of large cells, which are the ova (fig. 146, plate 40). There was no plaited or folded ovarian epithelium such as we see at a later stage.

In a young female $2\frac{15}{16}$ inches long the ovary had the size and appearance shown in fig. 132. It is about 40 mm. long and has a diameter of 0.5 mm. It is opaque white.

In a lobster $4\frac{3}{16}$ inches in length (No. 42, table 20) the ovary has the same appearance but is somewhat larger. Its structure is now much more complex than at any of the stages described. It consists of a thin connective tissue envelope and a compact stroma. Folds of epithelium dip down from the surface and penetrate the interior of the organ, thus dividing up the outer portions into radial compartments, in which the larger eggs are seen. These contain large nuclei, with one, two, or more nucleoli. The axis of the ovary lies in a stroma in which all stages in the development of ova can be traced. Karyokinetic figures of dividing cells are not infrequently seen. Blood now penetrates to the ovary by sinuses which come in from the wall along reentrant folds of epithelium.

THE OVIDUCT.

The oviduct is a straight tube of nearly uniform caliber (figs. 119, 123 *od*), which opens to the exterior in a hairy papilla on the coxopodite of the third pair of pereiopods. The skin is folded in the mouth of the opening so as to form a valve which prevents the ingress of water. The appearance of the duct when eggs are passing out is shown in fig. 119. The ovary had collapsed, but these eggs failed of passage.

The structure of the duct is the same throughout. It has a thin wall of muscular and connective tissue, and a characteristic epithelium of tall columnar cells. The latter undergo so marked a change at the period of ovulation that there can be little doubt that they have some important function to perform. As shown by a comparison of figs. 167, 168, taken respectively from a lobster just before and just after ovulation, these cells become very greatly elongated and vesicular. One would infer that they secrete a liquid which is poured out with the eggs when they are laid. Whether these cells take any share or not in forming the cement I do not know.

THE SEMINAL RECEPTACLE.

The sternal pouch of the female was noticed and roughly figured by Nicholls in the Philosophical Transactions of the Royal Society for 1731, but he entertained a wrong notion of its function. His interesting and unique account of this organ is as follows (*141*):

> Between the two last legs and the two legs above them there are two processes, which, from their resembling the nymphæ of women, I shall term nymphæform processes. These processes are covered with hair, and unite at their bases without leaving any passage. * * * The two processes, which I have termed nymphæform, in the female make a more obtuse angle at the union of their bases, are less hairy, and leave a passage, through which it is probable the ova are emitted, to be affixed to the appendages under the tail.

This remarkable conclusion reached in the last paragraph is unexplained even by the forced comparisons which were employed.

The observation of Nicholls was forgotten, and the structure which he imperfectly described was overlooked until its true function was discovered by Bumpus in 1891 (*30*).

The seminal receptacle lies on the under side of the female near the junction of the thorax with the abdomen. (For its position and general appearance see plate 7, in which the median slit is clearly shown, and for details, fig. 130, plate 38.) Its paired wing-like processes, the enlarged sterna of the seventh thoracic segment, are tinged with bright blue and form, with a wedge-like middle piece belonging to the sternum of the eighth thoracic segment, a somewhat heart-shaped body. There is a median slit with elastic edges, and if these are depressed, as Bumpus remarks, a grayish substance, the spermatic fluid, sometimes oozes out. The middle sternal piece is prolonged inside the chamber into a stout keel-shaped body strengthened with thick deposits of chitin, which have a yellowish color and horny consistency. This is supported by a pair of irregular rods belonging to the endophragmal system, which meet on the middle line. If the molted shell of a lobster is examined, in place of a solid, horny keel, a membranous pouch is found. The solid keel-shaped mass is probably absorbed before a new keel is formed. In the living animal the seminal receptacle is a narrow, irregular cavity.

THE DEVELOPMENT OF THE SEMINAL RECEPTACLE.

Development of the seminal receptacle is illustrated by figs. 79, 81, 89, and 98, plates 32 and 33. Fig. 98 is drawn from the molted skin of the fifth larva. The sex is not determinable with certainty, but it is highly probable that this is from a male; the sterna of the sixth to eighth thoracic segments (marked 3–5 in figure) are clearly defined. The sternal processes of the seventh thoracic segment are fused on the middle line, where they are distinctly depressed. The unpaired middle piece is marked as a slight transverse ridge or forwardly directed fold. It is clearly seen in the sternum of the adult male, where it is not so distinctly wedge-shaped or so intimately united with the wing-like sterna of the preceding segment. Three successive stages in the development of the seminal receptacle are shown in figs. 89, 79, and 81, plate 32; they are from young lobsters measuring 21.2 mm. (eighth stage, No. 3, table 34), 35 mm., and 52 mm., respectively. If these are compared with the condition in an adult lobster (fig. 130) we observe the following external changes: The sterna of the seventh segment, which are united on the middle line, diverge from their anterior extremities, forming a wide angle. The sternum of the eighth thoracic segment consists of a tongue-shaped fold (fig. 81) and a pair of backwardly diverging rods. The former is constricted off as a single piece, though originally paired, and develops into the wedge-shaped process seen in the adult organ. It grows forward into the narrowing angle made by the wing-like process of the preceding sterna. A secondary cleavage or division of the united sternal pieces of the seventh thoracic segment is now going on, and the cleft thus formed is the permanent opening of the seminal chamber. The latter is formed by the approaching walls of the wing-like folds of the seventh thoracic sternum and tongue-like process derived from the eighth thoracic sternum.

THE MALE REPRODUCTIVE ORGANS.

TESTIS.

Each testis of the lobster is a grayish white sacculated tube consisting of anterior and posterior lobes. There is no union between the organs of opposite sides. The testis of the lobster was figured and described by Milne Edwards, and its structure has been studied by Grobben (*83*) and Sabatier (*173*). According to Grobben, it is made up of (*a*) a capsular membrane, (*b*) tunica propria, and (*c*) the spermatogenous epithelium. Underneath the tunica propria a delicate, structureless membrane was seen. The epithelium is differentiated into spermatoblasts, from which spermatozoa are developed, and a syncytium—the *Ersatzkeim*—from which new spermatoblasts are derived. The spermatoblast is regarded as homologous with the egg cell, the Ersatzkeim with the follicular epithelium. A reserve albuminous material is laid down in the spermatoblast for use in the development of the sperm cell.

VAS DEFERENS.

The vas deferens or seminal duct is shown as it appears in its natural position on one side of fig. 120 and when dissected out on the other side. It consists of three fairly distinct sections: (*a*) A *proximal segment* (Zuleitungs-Abschnitt of Grobben), which serves to conduct the sperm from the testis; a very slender tube of uniform caliber, which curls, often in an irregular manner, over the posterior lobe of the gastric gland. This passes very abruptly into the enlarged (*b*) *glandular segment*, where the tube bends backward upon itself. It then turns forward again and, in somewhat the form of the

letter S, passes to the back of the last thoracic leg. The sperm may be traced along the course of the tube as a central, milk-white, linear mass of closely packed spermatozoa. In the glandular segment this is surrounded by a transparent, jelly-like substance which is secreted by the glandular epithelial cells (spermatophoral glands) lining this part of the duct. This is gradually constricted into the terminal (*c*) *muscular segment*, or *ductus ejaculatorius*, which ends in a valvular opening. A sphincter or swelling of the muscular layer is seen at the beginning of the ductus ejaculatorius, serving to force out the sperm.

The two distal segments (*b*, *c*) were called the penis or "verge" by Milne Edwards and Brocchi, because it was supposed that they were evaginated in copulation. It has been already pointed out that the evagination of these parts is mechanically impossible, a sufficient reason for dismissing this supposition.

The structure of the different sections of the vas deferens is illustrated by plate 37. The planes of section are marked in fig. 120, *1* to *5*. As Grobben has already shown (*83*), the vas deferens is surrounded by a distinct membrane and is composed of a connective tissue wall, inclosing muscles, and a lining epithelium; the latter gives rise to secretions which mingle with the sperm and surround it with protective envelopes. The connective tissue is fenestrated, abounds in blood channels, and the muscular tissue is disposed into an inner stratum of longitudinal fibers and an outer layer of circular bundles.

At the extreme proximal end of the duct (fig. 124) the epithelium is apparently stratified and the wall is thin. The tube is filled with a solid mass of ripe sperm (*sp*) and a surrounding coagulable fluid, which is the direct secretion of the epithelial cells. As the glandular segment is approached the epithelium becomes distinctively columnar (fig. 125). The glandular segment (figs. 127, 128) is partly subdivided by the infolding of the epithelium (*f*). The spermatophores (in some cases there are two) are restricted to one chamber and are immediately surrounded by a yellowish secretion (*Spr.*), which is probably formed in the proximal segment and stains very feebly in carmine. The remainder of the spacious cavity (*a* and *b*) is filled with a less dense coagulable substance which stains freely in carmine. Bodies resembling yolk-spheres can sometimes be seen.

Grobben says that the secretion of the glandular segment of the vas deferens of the crayfish appears chalky-white in reflected light and consists of small, shining granules.

In the ductus ejaculatorius (fig. 126) the muscular coats are strongly developed and the epithelium appears to secrete an albuminous, granular substance. The height of the columnar or cylindrical cells varies very much, as Grobben remarks, according as they are squeezed more or less closely together.

The external opening of the vas deferens is formed by an invagination of the skin, and according to Grobben is paved with thick cuticle.

SPERMATOPHORES.

The sperm is ejected from the muscular segment of the vas deferens in the form of spermatophores, which consist of elongated packets of sperm cells, surrounded by gelatinous capsules, the origin of which we have just seen. The spermatophores can be pressed out of the ducts when these are removed from the body. They quickly imbibe water and swell perceptibly when wet with it. The spermatophore is composed of two distinct secretions, as was first pointed out by Grobben. According to the

same investigator, spermatophores were first seen in Eupagurus by Schwammerdam in 1752, and were observed in the Brachyura also by Cavolini in 1792. They were rediscovered by Kölliker in 1841.

SPERM CELLS.

The sperm cells of the lobster were apparently seen for the first time by Valentin, in September, 1837 (*192*), and he gave a brief account of his discovery in the following year. A more accurate account by Kölliker, who also remarked on the apparent immobility of the "rayed cells," appeared in 1843 (*109*).

The structure and genesis of the spermatozoa of the lobster have been studied with much detail by Grobben (*83*), Gilson (*77*), Hermann (*89*), and more recently by Sabatier (*173*).

Each sperm cell (fig. 129, plate 37) consists of a cylindrical and partially hollow column or shaft, surmounted with a rounded dome, on what may be called the superior end. Between the capital and shaft three long, slender processes are given off, making an angle of 120° with each other. The processes are sharp-pointed, rigid, and very slender. The stiffness of the rays has led to the erroneous view that the rayed condition represented an immature stage in the maturation of the cell. The sperm cells withdrawn from the spermatic receptacle where they have lain weeks or months are still rayed, although the processes are often broken off or very limp (fig. 129, *a*). Apropos to this subject Grobben (*83*) says:

> The stiffness of the rays does not prove that these cells are completely immobile. Moreover, the observation of Owsjannikow that the rays sometimes draw themselves in, and certain structures which I have examined, enable me to conclude definitely that these rays are living protoplasm and that they represent amœboid processes, remaining almost in a state of rest. [Compare the observation of Cano quoted on p. 49.]

The genesis of the sperm cells from the spermatoblasts has been satisfactorily determined in most particulars, but there are some questions, which concern both this and the structure of the adult sperm cell, which are still undecided. The conclusion of Sabatier that the rayed cells become enucleated in the course of their growth can hardly be accepted. Sabatier has suggested that the stiff rays may serve at first to stick the cells together.

Nothing is definitely known either as to how the spermatophores are conveyed to the seminal receptacle or how the spermatozoa reach the eggs and fertilize them.

Chapter XI.—THE HABITS OF THE LOBSTER FROM THE TIME OF HATCHING TO THE PERIOD OF MATURITY.

When the lobster hatches from the egg it is scarcely a third of an inch long. It rises to the surface, where it leads for a number of weeks a free-swimming, larval life, totally unlike that of an adult. After the fifth or sixth molt, its larval locomotor organs having atrophied, it sinks to the bottom, and though now resembling the adult lobster in outward form it is scarcely more than half an inch in length.

The free-swimming habit of the lobster is characteristic of the first five or six stages of its existence. In Vineyard Sound and outlying waters we have taken the swimming stages during the summer months, the latest capture being a fifth larva on August 28. This period lasts from six to eight weeks, varying slightly with the season and greatly with the individual. It will be convenient to deal with the habits of the larvæ more fully in describing their structure and growth.

From the end of larval life until the later adolescent period the lobster drops out of sight almost completely. It is a singular fact that the habits of the young lobster, from 1 to 4 inches long, have never been well understood. Many fishermen have never seen a lobster less than 2 or 3 inches in length, although they have fished the greater part of their lives. Lobsters under 5 inches long pass readily between the slats of the traps and hence are seldom caught. Rarely, however, one is found clinging to some part of the gear and is brought up by accident.

Sars in the course of his studies upon the European lobster, traveled along the coast of Norway from Lurhavn to Bergen, June 19 to August 19, 1875, but was unable to obtain any young lobsters from an inch to a finger's length, and says:

> So far as I know, none are found in any museum. I consider it as certain, however, that the lobster keeps near the coast also during this stage of development. The reason why they can not be caught with the bottom scraper is partly because of their quick movements, and partly from the circumstance that they hide among the algæ on the bottom of the sea. (*176.*)

He says that young lobsters 3 to 4 inches long were the smallest known when he began his studies, and he has nothing to add beyond a description of the first three larvæ.

Spence Bate remarked in 1879 that "common as the European lobster is, it is very remarkable that a very young specimen has, as far as I know, never been met with."[1] He offered a reward for very young lobsters, but never obtained any less than 3 inches long.

Ehrenbaum, whose paper was published in 1894, refers to the same uncertainty which has so long enveloped the history of the lobster from the close of its free-swimming life until it reaches a length of 4 inches (10 cm.). The smallest lobster which had been taken at Heligoland up to that time had attained a length of 4.1 cm. The next largest was 7.8 cm. long. He speaks of a collector who, in the course of

[1] Report of the British Association for the Advancement of Science, London.

thirty years' experience about Heligoland, had obtained only three lobsters from 3 to 5 cm. long. (*61*, p. 285.)

It is evident that the long larval period of the lobster is an important means of securing a transport from the shore and wide distribution up and down the coast by means of the tides and ocean currents. As I shall point out in another place, this transportation is of the utmost importance to the larvæ, since it is in the bays and landlocked channels, where the competition among surface-feeding animals is keenest and destruction of life by animate and inanimate foes by far the greatest.

In consequence of the facts just mentioned, it must often happen that the young lobster settles to the bottom in depths much exceeding 100 fathoms. What does the little animal do on reaching its new abode? It probably begins to travel toward the shore, slowly at first but more rapidly when, in the course of six or eight weeks, it has become 1¼ to 1½ inches long. Meantime it hides in the crevices of the rocks or conceals itself under stones whenever danger approaches. Having reached the shore, it establishes itself in shallow water at the mouth of some estuary or river on the rocky sides of a bay. It lives under stones, or in stone piles, the tops of which are sometimes left bare at extremely low tides. It can then be found by turning over stones in much exposed situations, often where the water is not over 1 or 2 inches deep, but where at the flood there may be from 3 to 5 feet of water or even more. Sometimes several small lobsters are seen lying under one rock at the same time. While the lobster is very small, 1¼ to 2½ inches long, it crawls down deep into the piles of loose stones where no enemy can reach it. After attaining a greater length—of 3 or 4 inches—the young lobster begins to leave the rock piles and digs for itself a little cave under a stone. From this protection it stealthily crawls forth in search of its prey, and quickly returns when an enemy appears. It may take up its abode in the winding chamber of a deserted conch shell, or in any hole or niche which promises temporary security.

As the lobster increases in size it grows bolder and retires farther from the shore, although it never loses its instinct for digging and never abandons the usual habit of concealing itself under stones when the necessity arises.

Little is known about the habits of young lobsters in winter, but it is evident that they must leave the rock piles as soon as ice begins to form, perhaps as early as December in eastern Maine, and move out, as the adults do, into deeper water. The casting up of young lobsters on the beach at Woods Hole, in the latter part of January (see p. 165), proves that they sometimes remain in shallow water even at this season.

The colors of the young lobsters at the time they are from 1½ to 2 inches or somewhat more in length are very different from those of the adult. This may be seen by comparing figures 39 and 22, which represent, respectively, a young male 1.8 inches long (see No. 22, table 33) and an adult male 10 inches in length. In the young lobster the general cast of color is a russet or light reddish-brown, which is most pronounced on the sides of the body and under surface of the large claws. The borders of the carapace and segments of the body and legs are tinged with light Prussian blue. The upper parts of the body and appendages, especially the first pair of chelipeds, are spattered and marbled with a dull-bluish pigment. The terga of the abdomen have often a fine edging of dull bluish-black.

I am fortunate in being able to present a series of plates to illustrate the adolescent as well as the adult stages of the lobster. The original photographs[1] are in many cases so perfect that with the aid of a hand lens the finest details in the sculpturing

[1] These were made by the Edmondson Company, of Cleveland, Ohio.

of the exoskeleton can be seen. The adolescent forms are all from Casco Bay region, and are described in table 32. (See also descriptions of figs. 9–18, plates 8–13.) The smallest (plate 8, fig. 10, No. 1, table 32) is a male, 1.6 inches long. The right cutting-claw happens to be much under the normal size, since it is in process of regeneration. It would probably have attained its normal size after the next molt. The greater breadth of the "tail" or pleon of the female is not noticeable until at a considerably later period. Other secondary characteristics, such as the seminal receptacle and first pair of pleopods in both sexes, are not fully developed until the animal has reached the length of about 2 inches.

The most striking characteristic of these adolescent stages, in comparison with the adult form which they so closely resemble, is the large size of the stalked eyes (plates 8–12). The eye is very much compressed laterally, and in size and shape resembles that of Penæus. The eyes of the adult are relatively much smaller. (See table 38.) It is therefore possible that the large size of the eyes in the adolescent stages is an ancestral character. The present lobsters have probably descended from the Erymoid crustacea which inhabited the seas of the Liassic period. "In the latter part of the Jurassic epoch," says Huxley (*103*), "the Astacine type—that of the modern crayfishes—was already distinct from the Homarine type, though both were marine." Hoploparia, which is found in a fossil condition in the Cretaceous and early Tertiary formations, combines the characteristics of Homarus (Astacus in this work) and Nethrops. I have seen nothing but fragments of this genus figured, but in the *Eryma leptodactylina* of Zittel (*208*) the eyes are relatively quite large, as we see them in the adolescent lobster at the present time.

Another characteristic of these early stages is the fringe of very long setæ on the caudal fan and the matted tufts of setæ about the ends and toothed edges of the cutting-claw. (See figs. 13–15.)

In a female lobster measuring $3\frac{2}{5}$ inches in length (No. 22, table 32) the general color is a dull reddish-brown. The upper parts are spotted and mottled with darker brown; the tips of the claws and projecting spines are generally reddish, as in the adult. A suffusion of light blue is seen, as in younger forms, at the joints of the appendages and on the edges of the carapace and abdominal terga. This coloration closely resembled that of an adult egg-bearing female which I had at the time. A small male (No. 23, table 32) resembled this female very closely in color. The adolescent period is a long one, and the gradual development of the pigments of the adult is correspondingly slow. The history of the development of the color of the adult lobster from that of the larva will be discussed in another place. After this general account of the period of adolescence, I will now add all the notes which I have gathered that throw any light upon this important subject. In tables 32 and 33 the history of 63 immature lobsters, varying from 1.3 to 5.6 inches, is briefly given.

I am indebted to Mr. M. B. Spinney, of Cliffstone, Maine, for a valuable collection of small lobsters from the shores of Casco Bay and Small Point Harbor, which he has examined with great care. This collection embraces 36 individuals, 22 of which are males and 14 females. They were captured mostly in October and November. Mr. Spinney found young lobsters from $3\frac{1}{2}$ to 4 or more inches long in considerable abundance under small stones, where at an extreme low tide there would be but 1 or 2 inches of water; the smallest lobsters were found down among the stone piles, where the stones were four or five tiers deep. They crawl as far as they can into the labyrinthine passages between the stones, and are here secure from every enemy.

TABLE 32.—*Young lobsters from the vicinity of Casco Bay, Maine.*

[Length, 40.3 to 129 mm. or 1.6 to 5.1 inches.]

No.	Sex.	Length in mm.	Date of capture.	Place of capture.	Remarks.
1	Male	40.3	Oct. 9–19, 1893	Casco Bay, Small Point, Me.	Found in stone piles at very low tide;
2	Female	44	do	do	Do.
3	Male	48	do	do	Do.
4	do	52.5	do	do	Do.
5	do	58	do	do	Do.
6	do	62	Sept. 27, 1893	New Meadows River, 6 miles north of Small Point.	Found under stones at very low tide; tops of stones out of water.
7	Female	64	Oct. 9–19, 1893	Casco Bay, Small Point	Under stones and in stone piles at very low tide.
8	Male	67	Sept. 27, 1893	New Meadows River	Do.
9	Female	68		Basin Bay, east side Meadows River.	Do.
10	do	68	Aug. 31, 1893	Small Point Harbor	Do.
11	Male	69	Oct. 9–19, 1893	do	Do.
12	do	71	do	do	Do.
13	Female	73	Aug. 31, 1893	Small Point Harbor (inner harbor).	Do.
14	do	74	Sept. 26–28, 1893	do	Do.
15	Male	75	Oct. 9–19, 1893	do	Do.
16	Female	75.6	Sept. 26–28, 1893	do	Do.
17	Male	81.5	do	do	*Just molted*; stomach filled with fragments of shells of mollusks, etc.
18	do	83.5	Oct. 9–19, 1893	do	Found under stones and in stone piles at very low tide.
19	do	84	do	do	Do.
20	do	85.5	do	do	Do.
21	Female	86.5	do	do	Do.
22	do	87		Basin Bay	Do.
23	Male	92.3	Oct. 9–19, 1893	Small Point Harbor	Do.
24	do	93	Sept. 1, 1893	do	Do.
25	Female	93.4	Sept. 26–28, 1893	do	Do.
26	do	94	Oct. 7, 1893	New Meadows River, 8 miles E. of Small Point Harbor.	Just molted; stomach filled with fragments of shells of mollusks, etc.
27	Male	95		East side Casco Bay, Phippsburg, Me.	Under stones.
28	do	101.5	Sept. 1, 1893	Small Point Harbor	Do.
29	Female	102	Sept. 26–28, 1893	do	Do.
30	do	102.4	do	do	Do.
31	Male	104.5	Oct. 9–19, 1893	do	Do.
32	do	110	Sept. 26–28, 1893	do	Do.
33	do	112		Inner harbor, Small Point	Under stones; rostrum imperfect; soft shell.
34	do	119.5		Small Point Harbor	Rostrum deficient; soft shell.
35	Female	124	Sept. 26–28, 1893	do	
36	Male	129	Aug. 31, 1893	Inner harbor, Small Point	

TABLE 33.—*Young lobsters from Vineyard Sound, Massachusetts, in vicinity of Woods Hole.*

[Length, 35 to 142.8 mm. or 1.4 to 5.6 inches.]

No.	Sex.	Length in mm.	Date of capture.	Place of capture.	Remarks.
1	Female	36	Hatched about June 20, 1893.	Woods Hole	Raised from egg in hatchery of U. S. F. C. Station. June 27, 1894, it was 36 mm. long. It died early in August, 1894.
2	do	39	Jan. 28, 1882	do	
3	Male	40.5	do	do	
4	Female	41	do	do	
5	Male	48	do	do	
6	do	50	do	do	
7	do	52	do	do	
8	Female	55.2	do	do	
9	Male	55.5	do	do	
10	Female	60	do	do	
11	Male	66.4	do	do	
12	do	74.8	do	do	
13	Female	75	do	do	
14	Male	80.3	do	do	
15	Female	83.5	do	do	
16	Male	83.7	do	do	
17	Female	35	Preserved Dec. 10, 1886.		Hatched and raised at the U. S. F. C. Station, Woods Hole, Mass.
18	Male	36.3	do		Do.
19	Female	51.8	do		Do.
20	do	69.5	June 1, 1891	Woods Hole	
21	do	74.6	June 30, 1891	Woods Hole Harbor	No. 98, table 20.
22	Male	47	July 18, 1891	do	Brought up in lobster pot. (See plate 26.)
23	do	92	July 22, 1890	Gay Head	No. 43, table 20.
24	Female	106.3	do	do	No. 42, table 20.
25	do	107.9	do	do	No. 46, table 20.
26	do	112.8	Aug., 1892	Vineyard Sound	Dredged by U. S. F. C. steamer Fish Hawk.
27	do	142.8	July 22, 1891	Woods Hole Harbor	No. 91, table 20.

When the lobsters have attained a length of 3½ or 4 inches they become more bold, leave their burrows among the rock piles, and seek the shelter of stones, beneath which they excavate a shallow hole. Here they lie concealed from their enemies and are ready at all times to strike a blow at the smaller and weaker animals which pass within the reach of their claws.

The young lobsters enumerated in table 33 were captured in or near Vineyard Sound or raised in the hatchery of the station of the Fish Commission. Fifteen of these (Nos. 2–16) were collected by Mr. Vinal N. Edwards on Nobska Beach, in Woods Hole, January 28, 1882, after a hard storm, when there had been much anchor frost. Mr. Edwards recorded in his journal the finding also of crabs with eggs, thrown upon the beach, together with isopods, holothurians, sea-anemones, and a large number of fish, such as cunners, tautog, hake, sculpins, smelt, flatfish, herring, tomcod, and eels. Mr. Edwards writes that many young lobsters came ashore at the same time on the point of land where the Fish Commission station is now built. Several years ago, when small lobsters were used for bait, he used to find them in comparative abundance, from 1½ to 3 or 4 inches in length, under stones in shallow water, near Pine Island, on the north side of "The Hole." Some of the stones would be out of the water at low tide. No small lobsters are found in this place or vicinity at the present time. Whether this disappearance is due to the general decrease in the number of lobsters brought about by overfishing or to local changes in the environment, it is difficult to say. Both influences may be at work. It is possible that owing to warmer waters inshore, or to other causes operating in summer, the young lobsters are driven into deeper water, yet they seem to be equally scarce at all seasons. The finding of small lobsters cast up on the beach in the winter shows, as already pointed out, that they sometimes remain at this season in comparatively shallow water.

The inspector of fisheries of Prince Edward Island says (*209*) that lobsters 2 or 3 inches long "are occasionally washed ashore after storms and have been found alive clinging to the meshes of hoop traps." Lobsters not much over an inch in length are also said to have been taken from the stomachs of codfish. (See p. 120).

An old lobster fisherman, Mr. Thomas Garrett, at Vinal Haven, Maine, whom I have already quoted, informed me that he used to see thousands of small lobsters in the spring, beginning about the 1st of April. He would find them in sounds in about 20 fathoms of water, on both rocky or sandy bottom. They would come up sticking to the lobster pots, often in considerable numbers, and would average about 1½ inches long. He had never seen many lobsters 2 to 3 inches long, probably because they go so readily through the traps.

I made particular inquiries about the occurrence of young lobsters in the lobster pound on Vinal Haven Island. The smallest lobsters caught in the pound in 1893 by seining were about 5 inches long. Half a dozen measuring 8 inches had also been taken. Small lobsters were noticed in the larger of the two lobster pounds at Southport, Maine, in March, 1892, and about half a dozen were found from 4 to 6 inches long. In July and August, 1893, thirty or more lobsters were taken, varying from 3 to 6 inches in length. Lobsters 6 to 8 inches long could be taken in the seine. The smaller lobsters were discovered by turning over rocks, after partially draining the pond. None were seen under 2 inches in length. It is possible that some of these young ones were raised in the pounds, yet it is not certain that this was the case, since they could readily pass between the iron rods of the fence. The older lobsters, which are placed in the pounds in very great numbers, would tend to drive out the smaller ones, whether hatched in these inclosures or not.

An intelligent lobsterman of Rockland, Maine, said that thousands of small lobsters, an inch long or under, came up on the warps and pots every day while he was fishing at Hare Island in October and November. The lobsters would tumble off the traps as they came up. He took one of them home and examined it with a hand lens, and said that it had the general form and appearance of a lobster. The bottom in that vicinity was muddy or rocky, and covered with seaweed. He had never seen a 2-inch lobster. The smallest of the young lobsters recorded in table 32 is about an inch and a half long. These, as we have seen, were taken from the rock piles in the fall of the year, and most of the lobsters which are hatched in early summer and survive are more than an inch long by October. Still, this fisherman's observation may be correct, and the lobsters seen by him may represent that period between the sixth larval stage (length 16 mm.) and the smallest of those found in the rock piles.

A small lobster, about 1½ inches long, was said to have been taken from the shell of a living clam in Rockland Harbor not long ago. This was evidently a case of accidental imprisonment, and the animal may not have been a lobster.

A fisherman at West Jonesport said that he had seen small lobsters brought up on traps which were set on trawls, in deep water outside, in winter.

Mr. Adolph Nielsen, superintendent of the fisheries of Newfoundland, says that small lobsters 1½ to 2 inches long can be found in shallow water among the "goose-grass" in the latter part of September, and that he has seen lobsters an inch long in the same situations in the latter part of August and first part of September.

Very few fishermen among many whom I have consulted can give any definite information about the occurrence of lobsters from 1 to 3 inches long, and probably very few can discriminate between the young of the lobster and many other crustacea. Those who have made any observations agree that such young lobsters are very seldom seen in winter, but are usually found at other times in shallow water, in bays, harbors, or the mouths of rivers, on rocky (rarely muddy) bottom, where they can be found by turning over stones at low tide. Mr. George E. Cushman, of Cape Elizabeth, Maine, says that lobsters 2 to 4 inches long are found in coves and rivers, in eelgrass, and on sandy bottom, in from 2 feet to 5 fathoms of water.

Mr. Rathbun, of the United States Fish Commission, informs me that hundreds of lobsters 4 to 6 inches long were captured in the summer of 1880 in Narragansett Bay by the beam trawl. The bottom was sandy, and the water 3 to 4 fathoms in depth.

I think it is plain from the foregoing observations that a large number of the adolescent lobsters over 1½ inches long seek protected places, such as beds of eelgrass in shallow water, rocky shores of bays, and the mouths of rivers, where shelter from an enemy is always at hand; but it is quite likely that some remain in deeper water.

The habits of this animal are molded by its immediate environment and vary to some extent with the varying elements in the complex of its surroundings.

If we examine the lengths of lobsters described in table 32 we shall find they form a gradually ascending series, so that when we lay off these lengths as ordinates upon a horizontal base line, and construct a curve, the latter forms a slightly undulating ascending line. This means either that the breeding season is indefinite or at least prolonged, or that the young are extraordinarily unequal in their development. The number examined is perhaps too small to enable us to draw any conclusions, but it is a fact, as already shown, that the hatching is not *strictly* confined to a definite period. Individual variation in size in a state of nature may, moreover, be considerable.

The interesting question of the age of these adolescent lobsters is considered in the chapter on the rate of growth of this animal.

Chapter XII.—THE HISTORY OF THE LARVAL AND EARLY ADOLESCENT PERIODS.

The transition from the caterpillar to the chrysalis and from this to the winged butterfly or moth is apparently so sudden that it strikes every one with wonder. This is, however, deceptive, since changes in the internal organs go on very slowly. The hard supporting skin of the chrysalis masks the changes which are taking place within. The young crustacean, on the other hand, has a soft cuticle which is readily cast off; it thus changes with every molt and in most cases acquires very slowly the external form and habits of the adult state. It is therefore possible to follow its metamorphosis step by step. For convenience I shall divide the life-history into three periods—the *larval*, *adolescent*, and *adult*. The larval period will embrace the free-swimming life, during which the animal molts five or six times, and the adolescent state the long interval thereafter before sexual maturity is reached.

The larval history of the lobster is one of exceptional interest and importance, and must be thoroughly understood before the problem of hatching and rearing the young can be intelligently discussed, much less solved. I therefore decided, at the beginning of this work, to devote as much attention as possible to this part of the subject. This seemed particularly desirable since the individual larval history had never been traced molt for molt; only four pelagic stages had been described, and the relations of these were not fully understood. Of the later adolescent period (length of animal ½ or ¾ inch to 2½ inches) nothing, as we have just seen, was definitely known.

HISTORICAL NOTES.

J. V. Thompson, who was first to establish beyond any doubt the important fact that the decapod crustacea underwent a metamorphosis after hatching from the egg, was also the first, so far as I am able to learn, to point out that the European lobster was no exception to this very general rule. His letter (published in 1835) to the editor of the Zoological Journal is dated at Cork, December 16, 1830. A "rough sketch of the cheliferous member of the larva of the lobster" accompanies this letter. He says:

> With regard to the marine species, *Astacus marinus* or Lobster, I can aver that it actually does undergo a metamorphosis, but less in degree than any of the above-mentioned genera (Pagurus, Porcellana, Galathea, Crangon, Palæmon, etc.), consisting in a change from a cheliferous Schizopode to a Decapode; in its first stage being what I would call a modified Zoe with a frontal spine, spatulate tail, and wanting subabdominal fins; in short, such an animal as would never be considered what it really is were it not obtained by hatching the spawn of the Lobster. (*189.*)

Brightwell (*24*) gave in 1835 a very imperfect description of the young lobster which he dissected from the egg membranes. He was the first to notice the occurrence of double monsters in this species. (See p. 216.)

The embryo of the European lobster when ready to hatch was described by Rathke in 1840 (*159*), and a fuller account with figures of the embryo and of some of its appendages appeared in 1842 (*160*). He found lobsters with external eggs in early stages of development at different times of the year—at the end of May in Christiania, in June and July at Molde and Christiansund, in September at Gothenburg, and in the first half of October in Hamburg. He therefore concluded that lobsters either laid their eggs at different times of the year or that their development was very slow.

Kröyer also, in 1842 (*110*), described with drawings the first larva of the lobster. In the following year the paper of Erdl was published on the development of the egg of the lobster (*62*), in which some good colored drawings of the older embryos are given.

About thirty years later, in 1874, the first circumstantial account of the metamorphosis of the European lobster was published by Professor Sars (*175*). His studies, however, included only the first three larval stages, and, as he remarked, the changes which these early larvæ undergo, before they reach the adult state, were still unknown. Some comparisons are drawn in this paper between the first larvæ of the European and American species. (For figures of *Homarus americanus*, see *175*, Tab. I, figs. 18–20.)

The first description of the metamorphosis of the American lobster was given by Professor S. I. Smith, in 1872 (*182*), his fuller paper being published in the following year. He described and figured the first three larval stages and what appeared to be a fourth or fifth stage from specimens obtained in Vineyard Sound, Massachusetts, in the summer of 1871. At that time the United States Fish Commission did not possess the laboratory facilities which afterwards grew out of the labors of Professor Baird, but notwithstanding these drawbacks this work is so carefully done that subsequent studies will find little to correct, so far as they deal with the external anatomy of the larvæ described. Professor Smith says that between the third stage and what he called an "early stage of the adult form" "there is possibly an intermediate form. The changes in the whole appearance of the animal have been so much greater than between the first and second or between the second and third larval stages that, although the difference in size is inconsiderable, the whole change did not perhaps take place in one molt."

Professor Ryder, who published a short paper on the metamorphosis of the lobster in 1886 (*171*), supposed that the first adult-like form of Smith was preceded by four stages, but by only three ecdyses, the first molt (which occurs at the time of hatching, as Sars (*175*) had found to take place in the European lobster) having been overlooked. The fact of the case is that the lobster molts four times before reaching the stage in which it resembles so strikingly the adult animal. It is still essentially a larva in habit and structure and swims at the surface, although its earlier natatory organs are reduced to mere rudiments (plate 23).

Figures of the late embryos and of the first larva or its appendages have also been published by Erdl (*62*), Couch (*48*), Gerbe,[1] and Faxon (*67*), the work of the latter containing drawings by Stimpson and Alexander Agassiz, but it is not necessary to refer to these in detail.

METHODS OF STUDYING THE YOUNG.

In the course of my studies on the metamorphosis of the lobster I have endeavored to follow the history of individual larvæ. This seems to the inexperienced a very simple matter, but the task is beset with serious difficulties. We may isolate the delicate larva from its natural enemies and place it under the most favorable conditions which we can devise, when new foes immediately spring up or unexpected disasters happen. The larvæ which I studied were in most cases hatched at a known period by the artificial methods now in use. Healthy specimens were then selected and placed,

[1] The figures of Gerbe are very crude, as reproduced by Blanchard (*19*) and Duncan. They are intended to represent the embryo shortly before hatching, the young immediately after hatching, and after the second molt. The original paper of Gerbe I have not seen.

usually singly, in a 4-gallon glass jar, which was covered with coarse linen scrim and supplied with running sea water. The mesh of the cloth soon became clogged, thus fouling the water in the jar, which had to be cleansed daily. Under these conditions young lobsters have been kept alive over 100 days and carried through ten molts. The only food which they had beside that contained in the water was lobster eggs. These were rarely touched by the very young larvæ, unless they were floated. Had my stay at the seashore been prolonged some of the young could have been kept alive, I am sure, for an indefinite period, but other duties calling me away before the close of summer, they usually died from lack of attention.

There is now (August 1, 1894) alive in the hatchery of the Fish Commission station a lobster which was hatched from the egg in June, 1893, and which is, therefore, considerably over a year old.[1] The length of this lobster is only 36 mm., while three lobsters which were hatched and kept alive until December 10, 1886, being then between five and six months old, measured 35, 36.3, and 51.8 mm., respectively. I mention this fact, now, to show how variable individuals are in their molting or, what amounts to the same thing, in their rate of growth. It is improbable that such a marked variation would occur in a state of nature, yet it is likely, as I shall later show, that even here variation in individual growth is by no means slight. (See table 34 and p. 97.)

Before describing the structure and habits of the larva we will glance at the condition of the embryo at a late period in embryonic life.

THE EMBRYO IN LATE STAGES OF DEVELOPMENT.

A photograph of a living lobster with external eggs taken in Cleveland, Ohio, December 8, 1893, is reproduced in plate 7. A cluster of these eggs, showing how they are attached to one another and to the setæ of the swimmerets, is illustrated by fig. 25. Drawings of the living egg and of the embryo teased from the egg capsule (figs. 26 to 28) give us some idea of the stage of development reached, in this instance, at the very beginning of winter. Progressive stages of growth in the case of a lobster whose eggs were laid July 1, 1890, and were beginning to hatch June 1, 1891, are illustrated by figures in the text. (Plates G to J.)

At the stage shown in fig. 27 the bright green yolk occupies nearly one entire hemisphere of the egg. This massive store of food, at the expense of which the organs of the body are gradually developed, becomes reduced at the time of hatching (fig. 29, plate 18) to a mere remnant within the stomach of the larva, and often undergoes changes in color, at the last stage becoming a dull yellowish-brown. The paired compound eyes have already become most conspicuous, both on account of their size and color. The pigment area, which has a peculiar contour, is almost black when light is transmitted or when reflected, except at a certain angle. It then glistens with great brilliancy, owing probably to the interference of light in the thin peripheral pigment-layer. Bright red chromatophores are distributed in a characteristic manner on the appendages, particularly on their basal segments and along the sides of the carapace. The yolk is divided by conspicuous dorsal and lateral indentations, corresponding to the folds of the digestive tract and its diverticula, which gradually inclose it.

During the course of development the ova increase considerably in size and, losing their original globular form, become distinctly oval or oblong.

[1] See No. 1, table 33.

Peculiar concretions are developed in the intestine of the embryo when 5 or 6 weeks old, as shown in figure 233, plate 51, and persist up to the time of hatching (fig. 30, pl. 18). They were noticed as early as 1843 by Erdl (*62*). We see them to better advantage in a section of the intestine of a much older embryo, as in figure 253, *P*. There is great variation in both the size and shape of these bodies, but they consist of a stainable, apparently structureless core, surrounded by a nonstainable substance. The latter has distinct concentric striæ and resembles the cyst of a parasite. A concretion teased from the intestine of a similar embryo is illustrated in figure 256.

In the living animal they have a white lustrous appearance, and are quite conspicuous, moving to and fro with the peristaltic contractions of the intestine. On the suspicion that they might be of a parasitic origin I submitted them to Dr. Stiles of the United States Bureau of Animal Industry. He has kindly examined them, and concludes, so far as it was possible to reach a conclusion from the material at command, that the bodies in question were nonparasitic. In this event it is probable that they are the fæcal residue of the egg yolk which undergoes digestion in the course of embryonic life. The animal is entirely rid of them soon after hatching.

THE HATCHING OF THE LARVA.

A lobster in the act of hatching is represented in fig. 29, plate 18, and one teased from the egg in fig. 30. The embryo at this time is inclosed by three membranes, namely: (1) the outer or secondary egg membrane; (2) the primary egg membrane, improperly called the chorion; (3) a larval membrane, which is seen inclosing, like a glove, the various appendages in fig. 30. These are better shown in a much distended condition in cut 20, plate F. In this case, however, the innermost cuticle is not the larval membrane, but an earlier embryonic molt, which is absorbed long before the time of hatching is reached.

When burst by internal pressure the secondary egg membrane splits (in the vertical longitudinal plane of the embryo) into two halves like the cotyledons of a bean, and is drawn off in most cases over the head by the strand or stalk with which it is continuous. It is a thick, translucent bag of a yellowish-brown tint, slightly elastic and easily torn. It completely separates from the underlying membrane, except at one point, that beneath the stalk of attachment. Here it adheres to the primary membrane, which has now become reduced by distention into an exceedingly delicate pellicle. In this particular case (fig. 29) it was whole, until ruptured by needles (just above eyes), and thus completely inclosed the exposed parts of the embryo. When the outer membrane of attachment bursts, it contracts and usually drags the delicate inner cuticle away with it. The embryo thus slips out in the condition shown in fig. 30.

This is a very critical period in the life of the artificially hatched lobster. If it is healthy it soon molts, the swimming hairs are rapidly evaginated, and it emerges into what may be properly called the first locomotor larval stage. If less fortunate, it lies on its back for hours, struggling to get clear of some part of its larval covering. The failure to pass this molt is the cause of death to many embryos which have been reared successfully up to this point in the hatching jar.

THE FIRST STAGE.

When the lobster has successfully escaped from the egg capsule, and shaken itself free from its larval cuticle, it emerges as a free-swimming animal, rising to the surface, where it remains until its pelagic life is over. A sketch of one of these young lobsters is represented in plate 19, and a lateral view is given in plate 20.

The animal is but little over a third of an inch long. The average length of 15 specimens was 7.84 mm., the extremes being 7.50 and 8.03 mm.

The body is segmented as in the adult form, the most striking characteristics being the enormous compound eyes, the conspicuous rostral spine, the spatulate telson, and the biramous swimming appendages, which, from their resemblance to the permanent swimming organs of the Schizopods, have given to this and the two succeeding forms the name of "Schizopod larvæ." Functional appendages are wanting only in the abdominal segments, where, however, very small buds of the adult swimmerets can be seen beneath the cuticle, in the second, third, fourth, and fifth abdominal somites.

The cuticle of the larval lobster is now as translucent as glass, and the organs of the body—the heart and blood vessels, the alimentary tract, and rudimentary gills—are seen with great clearness. The green food yolk has disappeared entirely, or is reduced to a mere remnant, now more yellow than green, in the masticatory stomach. Perhaps the most conspicuous internal organ is the yellowish-brown liver, or gastric gland, the form of which on either side of the body, resembles a cluster of grapes.

VARIATIONS IN COLOR.

The color of the larval lobster is produced, as we have already seen, by a blue pigment dissolved in the blood plasma and by chromatophores which lie in the dermal layer of the skin, besides the pigment cells of the eyes. The distribution of the chromatophores is very characteristic and it is to these that the brilliant colors of the larvæ are largely due. (See plate 19.) The pigment which they secrete is of two kinds, bright vermilion and yellow. The red cells are the larger and play the most prominent rôle. The expansion and contraction of the chromatophores, by which the animal becomes brightly colored or pale, ordinarily requires from ten to fifteen minutes when stimulated by pressure. The chromatophores are distributed in the region of the carapace, along its sides, and in front of the cervical groove. When they are contracted the animal is pale blue and very translucent; when expanded the red cells give it a very decided color. Larvæ when struggling on the bottom to get free from their old cuticle or when crippled in any way are usually red, a commonly recognized symptom of weakness. This, however, does not seem to be an infallible sign. Larvæ which were placed in a pool out of doors on a bright day in June became red in a few hours while swimming at the surface in apparent vigor. (See p. 188.)

Both the blue pigment of the blood and the yellow and red pigment of the chromatophores are lipochromogens, which are converted into lipochromes under the influence of alcohol and other reagents (see pp. 135–136). The stomach and liver are sometimes bright red, which recalls an observation by MacMunn (*132*), who concluded from spectroscopic evidence that in the lobster (*Homarus gammarus*) the enterochlorophyll of the liver might be carried to the hypodermis and converted into a lipochrome.

HABITS.

The habits of young lobsters differ but little during the various "stages" of their free-swimming life, which is spent near the surface. Their pugnacious instinct is undoubtedly strongest immediately after hatching, when their activity in killing and devouring one another invariably attracts the notice of the spectator and forms an insurmountable barrier to raising them in small aquaria. Like the young of most pelagic organisms, they can not bear crowding, either in vertical or horizontal limits. As Weldon and Fowler (*201*) have remarked:

> They must, if they are to thrive, have a large superficial range, as well as a considerable depth of water in which they may sink when such conditions as light and heat demand it.

In swimming the larvæ use both the exopodites of the thoracic limbs, by the beating movements of which they are impelled upward and forward, and the abdomen, by the contraction of which, with its broad telson-plate, they dart rapidly backward. Each thoracic limb consists of a short stalk, with two diverging branches, the outer branch, which serves as an oar, being flattened and fringed with long feathered hairs. The oars or exopodites work independently of the inner branches, which are mainly prehensile organs, and alone give rise to the adult limb. The exopodites atrophy and disappear completely after the fifth stage. In the common swimming or floating position at the surface the thorax is usually held in a horizontal position, with bent abdomen. In rising the head is inclined downward, often with the "tail" uppermost. When too weak to keep at the surface, they vacillate over the bottom, standing on their head, as if probing for food, which, however, is not the case.

The larvæ appear to be quite hardy under certain conditions. Thus I have kept them alive, and apparently healthy, in small flat dishes of sea water, without change, for from one to four days at a time, or until they molted to the second stage.

The time which elapses between two successive molts varies, as at all subsequent stages, with the supply of food and general condition of the animal. In the larvæ which I had under observation the first stage lasts from one to four or five days, the healthier ones molting in the shorter period.

THE SECOND STAGE.

All the larvæ of this stage which I have examined were raised from the egg. The average length in forty-seven cases was 9.2 mm., the extremes being 8.3 to 10.2 mm. It is evident that some of these were undersized, and the measurement of this stage given by Professor Smith, 10.6, is greater than any which I have observed. His specimens were all taken by the towing net, and if the number examined was sufficiently large it would indicate that under natural conditions a greater size is attained.

A profile view of the second larva is given in plate 21. This is drawn to the same scale as the first larva on plate 20, and illustrates the increase in size effected at the second molt. All parts are now much larger, excepting the swimming thoracic appendages, which have grown but little. The swimmerets, visible as buds below the cuticle of the first larva, have now grown out on the second to fifth abdominal somites, and the rudiments of the last pair of appendages can be seen beneath the skin at the proximal end of the telson plate (fig. 102, plate 34).

The habits of the second larva differ in no respect from those of the first, and in color the two stages are very similar. In transparent larvæ, with contracted chroma-

tophores, great variety may be produced by the color of the gastric gland, which is often orange or some cast of yellow, and by the contents of the alimentary tract, which shows plainly through the body walls. Bright green pigment now appears for the first time upon the dorsal surface of the carapace and upon the tergal surfaces of the first five abdominal somites.

As in the first stage, the larvæ thrive only on one another when kept in close quarters. I have often watched one of these larvæ as it attacked another which appeared to be its equal in size and strength. The aggressive lobster usually tried to seize his fellow by the small of the back or between the carapace and abdomen, using for weapons the walking appendages, chiefly the first three pairs. He was soon astride the back of his victim, and dragged him to the bottom of the jar, where he began to devour him.

The second larval stage lasts from two to five days.

THE THIRD STAGE.

The average length of the third larva in seventy-nine individuals examined was 11.1 mm., the extremes being 10 to 12 mm.

The third larva resembles the preceding stages very closely in habits. Structurally, it differs but little from the second larva. (Compare plates 21 and 22.) The outer branches of the thoracic legs are still the principal swimming organs. However, the last pair of abdominal appendages, which form the outer blades of the tail-fan, are ready for service, and the swimmerets are fringed with short setæ. The large claws, which were already conspicuous, are relatively much larger.

COLOR.

The third larva resembles the preceding stages closely in color. When the chromatophores close the animal is quite pale, as was the case with one which I examined in the act of molting. As a rule, the color is enhanced by this stimulus. When this specimen was examined with the microscope it was seen that the red chromatophores were contracted so as to resemble small dots or stipple marks. The yellow pigment cells were more irregular.

When this transparent, almost colorless, larva is placed in a dish with others the contrast is very striking. The colored form, in which the pigment cells are expanded, is a rich, deep brown, varied with a vivid yellowish-green. The appendages are for the most part reddish-brown, excepting the terminal parts of the smaller ones, such as the exopodites and endopodites of the pleopods and the flagella of the antennæ, which are bluish. The large chelæ are a deep reddish-brown. The same color occurs sparingly on the sides of the carapace and on the lateral and ventral surfaces of the abdomen. The hinder parts of the carapace are touched with bright yellowish-green, as are the third, fourth, and fifth terga of the abdomen. These intense metallic colors greatly resemble those of the fourth larva. In reflected light a whitish pigment is seen in the lateral eye, which is strongly iridescent, as in the earlier larvæ.

One larva (10.8 mm. long) has the thorax and upper half of the abdomen greenish-blue; abdomen reddish below; tail-fan reddish; red pigment cells occur on the appendages and on the sides of the branchiostegites, as in the earlier stages.

In another, examined in the act of molting, on July 3, the colors were very bright. Especially noticeable were the metallic green spots on the fourth and fifth abdominal segments.

Another larva (11 mm. long) has colors similar to the first just described: Large chelæ reddish-brown; lower half of the abdomen, caudal fan, and sixth abdominal segment of same color; carapace yellowish-green, rather less transparent than in earlier stages; bright peacock-green with yellowish tinge on the terga of the fourth and fifth abdominal segments; considerable blue at the joints of the appendages (probably because the cuticle is here thinner) and in different parts of the body. It must be remembered that the transparency of the larva is now determined in an important degree by the greater or less time which has elapsed since the last molt—that is, by the greater or less proximity to the ecdysis which is to follow. The old cuticle becomes partially opaque as soon as any lime is deposited in it, which happens at about this period.

The third larval stage lasts from two to eight days.

THE FOURTH STAGE.

The young larva[1] emerges from its fourth molt into a form which bears such a striking resemblance to the adult lobster that an intervening stage between this and the preceding was supposed to exist; but such is not the case. A dorsal view, colored to life, of one of these larvæ is represented by plate 23. The swimming branches of its thoracic legs have been abruptly shed, or rather have been reduced to functionless stumps (plate 31, figs. 74, 75). It still swims at the surface, with greater agility and speed than at any former stage, and is still virtually a larva, although it has the adult locomotor organs.

It swims rapidly forward by means of the swimmerets, and darts backward with quick jerks of the abdomen, "frequently jumping out of the water in this way," as Professor Smith says, "like shrimp, which their movements in the water much resemble" (*182*). As they move forward they hold the large chelæ extended straight in front of the head; when disturbed they raise the chelæ to defend themselves like an adult lobster.

It has the larval rostrum and the large antennal scale or exopodite, and the first abdominal somite is without trace of appendages.

The average length of 64 larvæ was 12.6 mm., or about half an inch, the extremes being 11 and 14 mm.

COLOR.

The range of variation in color is now very great. A typical color pattern is represented in plate 23. Occasionally, even at this period, a larva is very light-colored and its transparency is nearly equal to that of the third larva.

The cast of color may be (1) yellow and red; (2) red; (3) green; (4) green and reddish-brown. In the first case the carapace is light yellow, translucent, and sprinkled with red chromatophores. The abdomen and large chelæ are reddish-brown, and there is a quadrilateral yellowish-green area on the terga of the fourth and fifth abdominal segments. In the red individuals the animal is bright red, especially on the abdomen and large chelæ. The carapace is yellowish, spotted with red, and the abdomen is marked in the way just described. In the green variation, the whole animal is bright

[1] The use of the word "larva" for the fourth and fifth stages is not without objection, but it is perhaps better than the phrase "adult-like form." It is very probable, as I have shown, that the young lobster may remain at the surface of the ocean, even after the sixth molt. It will be most convenient, however, to define the larval period of the animal by the duration of its pelagic life, which is practically at a close by the end of the fifth stage.

green. Bright yellow-green areas are noticeable on the abdominal terga as before, and upon the hinder portion of the carapace. There is some brown pigment on the large chelæ and tail-fan. In the fourth variety (fig. 36), the abdomen and chelæ are rich reddish-brown, with light peacock-green on the terga of the abdominal rings, as is commonly seen, and on the carapace next to the abdomen. The rest of the carapace is greenish-brown. In this and all earlier stages the color of the carapace is partly due to that of the internal organs, especially to the alimentary tract and gastric glands.

The following notes illustrate the changes which individual larvæ undergo, with reference to molting and surrounding conditions. A fourth larva raised from the egg, when examined on July 13, was decidedly bluish. The whole animal was quite translucent, the heart and yellowish "liver" showing plainly through the shell. The claws and body were sky-blue, due, as in the first larva, to the blood pigment. The brown and yellow chromatophores were contracted to such an extent as to have no appreciable effect upon the general color pattern. Two days later the carapace was greenish and the chelæ dark brown. On July 17 the colors were deeper; on the 19th the general cast of color was dark bluish-green; reddish-brown on the abdomen and chelæ. On July 21, when the animal was nearly ready to molt, the carapace was bluish-green, the abdomen and chelæ brownish-red. Four days later, July 25, this animal molted to the fifth stage. The fifth larva was dark olive, tinged with brown on the abdomen and chelæ.

A larva which molted July 11 to the fourth stage was pale, and apparently almost devoid of pigment. The internal organs were plainly visible. There was a delicate wash of brown on the abdomen, tail-fan, and chelæ. The microscope showed that the closed chromatophores were very small.

Another larva, 13.1 mm. long, which was raised from the egg, had on July 6 the usual mixture of brown and green pigments. On July 15 the animal was very dark brown, excepting the carapace, which had a metallic green luster. The large chelæ are tipped with white or cream color, and there is a large light patch on the outer side of the hinder end of the exopodite of the uropod. Fainter and smaller whitish areas occur on the pleura of the first abdominal ring. This larva molted about August 3 to the fifth stage; color, reddish-brown.

Rarely is a larva seen which is reddish-orange, the blue and brown pigments being almost completely obscured. The pigments of the eye are similar to those of the earlier stages.

In a larva of 14 mm. long, observed July 25, the carapace was of the usual greenish-brown cast, with three light-greenish spots on each side—a very small spot behind the eye, a smaller one below this, and a larger one farther back below the cervical groove. These are the first traces of very characteristic areas, which I shall call "tendon marks," upon the skeleton of all later stages, and mark the places where certain muscles are attached to the integument. The significance of these color changes will be considered later on. (See p. 135.)

A fourth larva, which was caught at the surface near the Fish Commission wharf on a very bright day (July 25, 1891), was similar in color to some of those already described. The thorax was green, brightest posteriorly; the chelæ and abdomen dark reddish-brown; a brilliant light-green area appeared on the tergum of the third and fourth abdominal segments.

On August 10 I examined a number of lobsters in the fourth, fifth, and sixth stages, which had been kept in glass jars and fed upon meat. Many of these were so

completely covered with foreign matter that they could hardly swim, some lying upon their backs on the bottom of the aquarium. Colonies of zoothamnium-like protozoa were clustered over all their appendages. The setæ were loaded with sediment filled with bacteria, diatoms, and infusoria. This illustrates the fate which awaits the larvæ of all crustacea, when crowded in small aquaria.

The fourth larval stage lasted (in the average of nine individuals, which were raised from the egg) 13 days and varied from 10 to 19 days.

THE FIFTH STAGE.

In fifteen individuals known to have molted five times, the average length was 14.2 mm., and the extremes 13.4 and 15 mm.

There are no external marks by which the fifth stage can be distinguished from the fourth or even from the sixth stage with any degree of precision, at least by the unaided eye (fig. 31, plate 18). Neither the size nor color changes can be invariably relied upon. Microscopical examination, however, shows that the rudiments of the swimming exopodites, which could be readily detected in the fourth larva, have now become still more reduced, while in the sixth stage they have completely disappeared.

The following notes illustrate the changes of color which are observed in larvæ passing from the fourth to the fifth and sixth stages. On July 7 a fourth larva (No. 35, table 34) showed the typical colors, reddish-brown and various tints of green. When observed eight days later the color was dark maroon. The fifth molt occurred about July 17 (length, 14.8 mm.). The color was then greenish-brown; the large chelæ reddish-brown, tipped with cream color, most marked upon the propodi. As in some fourth larvæ, there is a terminal light spot on the exopodite of the uropod. Faint light spots are also seen on the sides of the abdominal segments. There are, moreover, two very prominent, white, discoidal areas on the carapace corresponding to the insertions of muscles, as already pointed out.

The following measurements of this larva will give a clearer idea of the length of some of the parts and of their increase after the molt:

Measurements of larva, third to fifth stages.	Millimeters.
Length of the fifth larva	14.8
Distance from tip of extended chelipeds to end of telson	19.5
Length of flagellum of second antenna	11
Length of carapace in third stage	5.4
Length of carapace in fourth stage	6.3
Length of carapace in fifth stage	7
Greatest width of carapace, fifth stage	3.1
Length of large chelæ, fourth stage	4
Length of large chelæ, fifth stage	5

Another larva raised from the third stage (No. 12, table 34) is olive-green, with the characteristic white marks very faint on the carapace. The large chelæ are yellowish-green, due to the presence of blue and yellow chromatophores.

In the case of a fifth larva reared in an aquarium the colors resemble those of the sixth stage, represented in plate 25. The white spots on the carapace have the disposition shown in fig. 37, plate 24. The third pair of maxillipeds are tipped with white.

No noticeable differentiation can be detected in the large claws unless occasioned by loss and subsequent growth or by injury to one of the members. It often happens

TABLE 34.—*Record of molts of larval and adolescent stages.*

Nos.	Time of hatching.	First molt.	Length.	Increase in length.	Increase.	Age.	Second molt.	Length.	Increase in length.	Increase.	Third molt.	Length.	Increase in length.	Increase.	Age.	Fourth molt.	Length.	Increase in length.	Increase.	Age.	Fifth molt.	Length.	Increase in length.	Increase.	Age.	Sixth molt.	Length.	Increase in length.	Increase.	Seventh molt.	Length.	Increase in length.	Increase.	Eighth molt.	Length.	Increase in length.	Increase.	Ninth molt.	Length.	Increase in length.	Increase.	Tenth molt.	Length.	Increase in length.	Increase.
	1891.		*mm.*	*mm.*	*Per cent.*	*Days.*		*mm.*	*mm.*	*Per cent.*		*mm.*	*mm.*	*Per cent.*	*Days.*		*mm.*	*mm.*	*Per cent.*	*Days.*		*mm.*	*mm.*	*Per cent.*	*Days.*		*mm.*	*mm.*	*Per cent.*		*mm.*	*mm.*	*Per cent.*		*mm.*	*mm.*	*Per cent.*		*mm.*	*mm.*	*Per cent.*		*mm.*	*mm.*	*Per cent.*
1	June 25										July 13	10.3			19	July 18	12	1.7	16.4	24	Aug. 1	13.4	1.4	11.7	38																			
2	...do										July 15	10.3			21	July 17	12.3	2	19.4	23																							
[1]3	May 27															July 13	13			48	July 15	14.2	1.2	9.2		[2]Aug. 2	15.5	1.3	9.1	Aug. 20	18.4	2.9	18.7	Sept. 10	21.2	2.8	15.2								
[1]4	...do																					15				July 13	16.5			July 27	19.5	3	18.2	Aug. 14	22.6									
5	June 25										July 17	10.9				July 18	13	2.1	19.3																								
6	June 30										July 18	11.9				July 20	13.6	1.7	14.3																								
7	May 27															July 16	13.5				July 17	14.6	1.1	8.1																			
8	...do																				July 13	14				July 14	15.3	1.3	9.3															
9	...do																				...do	14				July 22	16	2	14.3															
10	...do															July 13	14				...do	16	2	14.3		...do	16.8	.8	5															
11	...do																				...do	15				July 15	16	1	6.7															
12	...do																				...do	15				...do	16.6	1.6	10.7															
	1892.																																										
13	July 6	July 6	8				July 7	9	1	12.5																																		
14	...do	...do	8				July 8	9.1	1.1	13.7	July 13	11.3	2.2	24.2		July 17	13	1.7	15																										
15	...do	...do	8					9	1	12.5	...do	10	1	11.1		July 19	11	1	10																										
16	June 28						June 30	8.9			July 2	10.8	1.9	21.3		July 8	13	2.2	20.4																										
17	...do						...do	8.9			July 3	10	1.1	12.4		July 9	12	2	20																										
18	...do						...do	8.9			July 4	11.1	1.2	13.5																														
19	July 2						July 4	9.5			July 6	11	1.5	16.8		July 11	13	2	18.2																										
20	...do						...do	9.5			July 7	10.7	1.2	12.6																														
21	July 1										July 6	[3]11.5				July 13	[3]12.7	1.2	10.4		July 29	14.3	1.6	12.6		Aug. 10	16.5	2.2	15.4															
22	June 30										July 4	11.5				July 6	13.1	1.6	13.9		Aug. 3	13.5	.4	3																				
23	...do															July 25	13				Aug. 9	15	2	15.4		Aug. 21	17	2	13.3															
24	...do											10.7				July 4	12.8	2.1	19.6																								
25	June 29										July 3	10.5				July 8	11.7	1.2	11.4																								
26	...do										...do	10				July 9	12	2	20																								
27	...do										...do	10				July 8	11.1	1.1	11		July 27	12.5	1.4	12.6																			
28	...do										...do	11.5				July 11	12.8	1.3	11.3		July 22	14.5	1.7	13.3																			
29	...do											11.8				July 6	13	1.2	10.2																								
30	July 2										July 7	[3]11.3				July 15	13	[3]1.7	15		July 27	15	2	15.4																			
31	...do										...do	[3]11.3						[3]2	17.7		July 30	14.9	1.6	12																			
32	...do											10.6				July 7	12.2	1.6	15.1																								
33	...do											[3]10.8				July 8	12	[3]1.2	11.1																								
34	June 20																					15.3				July 25	16.3			July 25	18	1.7	10.4	Aug. 8	21	3	16.7					Sept. 22	29.5	8.5	
35	...do										July 4	10.8				July 7	12.9	2.1	19.4		July 17	14.8	1.9	14.7																			
36	...do										...do	11				...do	12.5	1.5	13.7		July 19	14	1.5	12		[4]July 30	16	2	14.3															
[1]37												11				...do	[1]12.5	1.5	13.7		July 30	13.4	.9	7.2		Aug. 13	15	1.6	11.9					[5]Sept. 22	19.75	4.75								
38																															18.5			Aug. 13	21.2	2.7	14.6	Aug. 23	25	3.8	27.3	...do	26.6	1.6	6.4
39	May 25																																					Aug. 1	24			Aug. 13	28	4	16.7
	Averages							9.1	1.03	12.9		10.87	1.44	15.84			12.65	1.65	15.27			14.34	1.48	11.53			16.12	1.58	11		18.60	2.53	15.76		20.99	2.83	15.5		24.50	3.80	27.3		28.0	2.8	11.55

{ Average increase per cent of stages, 13.67; of individuals, 13.89 (omitting No. 38, ninth stage). }
{ The time of hatching of lobsters Nos. 16–36 is only approximate. }

[1] Females.

[2] For colors of this lobster in sixth stage see plate 24: Ventral view of thorax, eighth stage, shown in fig. 89, plate 32.

[3] Accurate within 0.2 to 0.9 mm.

[4] For colored sketch of this lobster in sixth stage see plate 25.

[5] Died October 5.

that the dactyl is bent upward as much as forty degrees away from the propodus, so that the cutting edges meet but imperfectly.

Larva No. 36, table 34, was nearly ready to molt to the fifth stage on July 17. It was of an opaque greenish-brown color, the claws deep brown. The carapace had a dull, bluish luster when strong light was reflected from it, a well-recognized mark of the molting state.

Two days later it was in the fifth stage. The carapace and upper surfaces of the abdomen were now greenish-brown. The white tendon mark on the side of the carapace below the cervical groove was very prominent. The light areas on the first abdominal ring and upon the uropods were rather faint, and the chelæ, as usual, were tipped with cream color.

The remarkable "death-feigning habit," which I shall discuss later, was developed in this larva to an unusual degree. A colored drawing of this lobster after the sixth molt, which occurred about July 30, is represented in plate 25.

The fifth larval stage lasted in five observed cases from 11 to 18 days.

THE SIXTH STAGE.

The average length of five lobsters known to have molted six times was 16 mm., the extremes being 15 and 17 mm.

I have already referred to the color of this stage, which is represented in an individual raised from the egg on plate 25. The general cast of color of the upper parts is often dark green or greenish-brown, and the "tendon-marks" on the carapace have now become very conspicuous. Equally characteristic are the snow-white pleura of the first abdominal ring.

A dorsal view of another lobster of this stage is given on plate 24. The coloring is from the sixth stage of larva No. 3, table 34. The whole animal is of a reddish-chocolate color, against which the white spots contrast very sharply. In the cervical groove there is a narrow transverse white area, a large white spot on the distal extremity of the meros of the cheliped, in addition to those already mentioned and the flattened rostrum is conspicuous for its absence of color, being but faintly tinged with green.

A young lobster captured with the tow net in Woods Hole Harbor in the daytime, August 23, 1890, resembles the sixth stage, already described. The length of the lobster was 16.5 mm. (For record of the capture of other lobsters in sixth stage, see table on p. 187.)

The individual color-changes which these lobsters undergo were well illustrated in a specimen, 16 mm. long, captured in the net July 24, 1890. When first taken it was bright bluish-green, excepting a slight amount of brownish pigment visible on some of the appendages. This lobster was accidentally left over night in a glass dish of water on my work-table. In the morning it had a decided reddish-brown color and was very weak. One is reminded of the similar but more striking change in color which the remarkable little lizard *Anolis princeps*, of the Southern States, undergoes when it is suddenly stimulated.

Larvæ have also been captured in the tow, from 15 to 16 mm. long, which resembled more nearly the fourth stage in color, but undoubtedly belonged to the fifth and sixth stages.

A young lobster about six weeks old, raised from the egg, and probably in the sixth stage, was light brownish-olive on the upper surface, the chelæ being more decidedly brown. The under surface of the body was almost colorless. The usual cream-colored or white spots occurred on the carapace and appendages and the terminal spines of the abdominal pleura were whitish. The large claws, which show no special differentiation, are held together in front of the animal as it swims forward. When suddenly disturbed, the young lobster opens its claws, spreads wide its arm-like chelipeds, at the same time raising itself into a threatening attitude, ready to receive or strike a blow. The iridescent pigment of the eyes is no longer visible. Some measurements of parts of this lobster are as follows:

Measurements.	Millimeters.
Length	16
Length of thorax, including rostrum	8
Greatest width of thorax	4
Length of antennary flagellum	11
Length of propodus of large chela	5.5

Lobsters in the fifth stage, which are raised in aquaria, swim less at the surface than in preceding stages, going frequently to the bottom of the jars for their food, and it is during this and partly in the sixth stage that the pelagic life of the lobster comes to an end. It then sinks to the bottom and leads an entirely new life. Its larval characters have completely disappeared, and buds of the modified appendages of the first abdominal segment have begun to grow out. In locomotion and general habits it resembles the adult animal closely, but the final adult condition is only attained after a long series of molts, which require, in all probability, from four to five years.

The sixth stage lasted (in three cases observed) 9, 14, and 18 days, respectively.

SEVENTH STAGE.

The seventh stage can not be distinguished by any known characteristics from that which immediately precedes and follows. Unless one has watched and recorded the molts, it is impossible to say at this or a later period through just how many ecdyses the animal has actually passed. The larval stages merge insensibly into those of the adolescent period, and these pass as gradually into those of the adult, so it will be more profitable to follow the history of individual lobsters from this period onward rather than to attempt to describe stages which have no marked distinguishing characters.

In table 34 I have recorded the molts of thirty-nine young lobsters raised during the summers of 1891 and 1892. The increase at each ecdysis and the increase per cent (that is, the ratio between the actual increase and the former length) are also given. Many of the adolescent lobsters, which it should be understood are the remnant of a much larger number which I attempted to raise, died shortly after the last recorded molt. Some, however, were living when I was obliged to leave Woods Hole, at the middle or latter part of August, and doubtless could have been reared had they received the necessary care. The life-history, as illustrated in table 34, has been followed from the time of hatching to the tenth stage or ecdysis, when the animal is over an inch long and about three months old.

We have considered in detail at the close of Chapter III the bearings of these observations upon the rate of growth in the lobster.

DESCRIPTION OF SMALL LOBSTERS.

The number of molts or the rapidity of growth is a question which now assumes special interest and, as I shall eventually show, it is subject to considerable individual variation.

Two young lobsters after the seventh molt measured 18.4 and 19.5 mm. (Nos. 1, 2, table 35) and remained in this stage 21 and 18 days respectively.

Lobster No. 1 (table 35).—The first of these was raised from the fourth stage. Its color in the sixth stage is represented on plate 24. The animal after the seventh molt was light brown, tinged with green, when observed on August 20. It exhibited the "death-feigning habit" in a very marked degree. This lobster molted for the eighth time on September 10, and died the day following, when it measured 21.2 mm. It was hatched about May 27, and was therefore 107 days old.

Lobster No. 2 (table 35).—This young female lobster had just molted when first examined on July 13, and was then without doubt in the sixth stage. In color it closely resembled fig. 37, plate 24. It molted for the seventh time on July 27, when it attained a length of 19.5 mm. The color at this time was but little changed, being a deep chocolate above, with the tendon marks on the carapace equally prominent.

The triangular rostrum is somewhat narrower. The "finger" of the large claw and the outer branch of the tail-fan are cream-colored. The latter, as in the sixth stage, carries a very long fringe of setæ, which becomes characteristic of the adolescent period. These setæ are about two-thirds the length of the uropod. The left cheliped, which was thrown off at the time of the sixth molt, had grown out again, so that after the seventh ecdysis the length of the new appendage was about seven-tenths of that on the opposite side. The length of the right chela was 6.5 mm.; of the left, 4.5 mm.

The stalked eyes are now very large and continue to grow relatively faster than the rest of the body until they attain great prominence in the adolescent stages, as already described.

The first pair of abdominal appendages are present as small buds, and after the next molt their size is not greatly increased.

After the eighth molt (August 14, length 22.6 mm.) there was but little noticeable change in color. The general cast is still brown, with a bluish-green tinge on the carapace. The length of the fringing setæ of tail-fan—1½ mm.—nearly equals that of the telson. The median sternal spines are present on the second to fifth abdominal somites, and have a bluish color.

Lobster No. 3 (table 35).—This young female lobster was raised from the egg and placed under observation when in the third stage, July 4, 1892. At this time it was 11 mm. long. It molted to the sixth stage on August 13, and when I finally left Woods Hole on the 23d of this month there had been no noteworthy change. When examined on September 22, by Dr. E. A. Andrews, it had attained the length of 19.75 mm. It is therefore highly probable that only one intervening molt had occurred and that this happened late in August or early in the following month. It died before another ecdysis, on the 5th of October, when it was about 105 days old, having molted eight times.

Lobster No. 4 (table 35).—When this lobster came under systematic observation, on the 25th of July, it was in the sixth stage and 16.3 mm long. An account of its ecdyses, which were carefully watched, one occurring on that very day while in a dish upon my table, will be given in another place. (See p. 183.)

Before molting the animal was of a dark umber color and very sluggish. Immediately after this ecdysis (the seventh in number) the whole body was translucent, the general color being reddish-brown, with a slight greenish tinge on the carapace. The large claws were a bright terra-cotta color. There was a prominent whitish crescentic spot immediately behind the cervical groove and the three characteristic tendon marks on each side of the carapace were as prominent as in the sixth stage. (Compare plate 24.) The pleura of the first abdominal somite were snow-white, and the uropods of the tail-fan were tipped with cream color.

The lobster after the seventh molt keeps steadily upon the bottom, in walking over which it uses chiefly the last three pairs of thoracic legs. The large claws and smaller chelate legs next to them are extended forward in front of the head, although the latter appendages are occasionally used for locomotion. A very slight differentiation in the large chelæ is noticed, but in the eighth stage the difference is marked. At about the time of the seventh ecdysis the right antennary flagellum was lost; eight days later it appeared, in the process of regeneration, as a short spiral coil; this continued to grow, and after the eighth molt, which occurred on the 8th of August—an interval of two weeks from the last—it was about its normal size.

At the seventh stage pigment has been deposited below the enamel layer of the cuticle in an amount which, though at first very slight, increases with every molt, and the color pattern becomes more and more complex. In the eighth stage the general color is deep reddish-brown, with olive tints. The characteristic tendon marks and cream-colored spots are present. There is a dorsal light-green median stripe on the carapace, very much narrower than when first seen in the fourth stage.

This lobster had undergone no appreciable change by the 23d of August, but when next examined, September 22, it measured 29.5 mm. In the interval of thirty days it had undoubtedly molted twice and was in the tenth stage. The first abdominal somite has very delicate, white appendages, which are distinctly two-jointed and raised from the surface to a nearly vertical position.

Lobster No. 5 (table 35).—This lobster was hatched about May 25, and when isolated, on August 1, it measured 24 mm. It was probably in the ninth stage and was about 67 days old. The general color was dark green, touched with brown; large chelæ olive-brown, reddening toward the extremities, with glistening white tips; the under side was a tint lighter. The uropods and telson are whitish, bordered with reddish-brown. The contents of the intestine can be seen through the slightly translucent shell. Tendon marks on the carapace are prominent, as in the other cases described.

Some measurements of this lobster are as follows:

Measurements of lobster No. 5, in ninth stage.	Millimeters.
Length	24
Length of carapace	11
Greatest width of carapace	5
Length of antennary flagellum	23
Length of large chela on either side	9
Greatest breadth of chela of one side	3
Greatest breadth of chela of other side	2.5

In the smaller of the two claws the extremities are nearly straight; in the larger the "fingers" are more bent, and each bears a large tubercle at about the middle of the occludent margins.

The animal hides among the stones at the bottom of the aquarium, and behaves in most respects like an adult animal. The eyes are dull brownish-black, without iridescence.

When examined again on August 13 this lobster had molted, now for the tenth time, and was 28 mm. long. The general color was dark brownish-green, with reddish-brown on the large chelipeds, as before. The white or light color of the pleura of the first abdominal segment and tail-fan is obscured or has disappeared. The shell pigments are now more abundant, and the cuticle has lost its translucency in consequence.

The following measurements illustrate the growth of some of the parts:

Measurements of lobster No. 5, in tenth stage.	Millimeters.	Measurements of lobster No. 5, in tenth stage.	Millimeters.
Length	28	Length of cutting chela	11
Length of carapace	13	Greatest breadth of cutting chela	3
Greatest width of carapace	6.4	Length of dactyl of cutting chela	5.7
Length from tips of extended chelipeds to end of telson	34	Length of telson	4
Length of antennary flagellum	25	Breadth of telson	3.3
Length of antennal exopodite	5.5	Length of terminal fringe of hairs	2
Length of crushing chela	10.5	Greatest width of abdomen at second somite	5
Greatest breadth of crushing chela	3.5	Length of rostrum	4
Length of dactyl of crushing chela	5	Breadth of rostrum at base	2

Lobster No. 6 (table 35).—This was the only survivor out of a considerable number of lobsters hatched early in the season of 1892, and when first examined—about the first week in August—measured 18.5 mm., and was probably in the seventh stage. At this time a slight difference in the large claws could be detected, which increased with subsequent molts. There is nothing noteworthy in which this young lobster differed from those already described. (See No. 38, table 34.)

Lobster No. 1 (table 33).—I have referred to this young female lobster, which was hatched about June 20, 1893, and was alive when I left Woods Hole, August 6, 1894. It was therefore 412 days old, and allowing it to have attained the length of 28 mm. at the tenth molt—the average length of three individuals known to have reached this stage—it must have molted thirteen times, which I am confident is not far from the truth. It is probable that no molts occurred during the winter, the last two recorded having taken place May 21 and June 18, 1894.

The brilliant color is now wholly due to the pigments of the shell, which is no longer transparent, and the color pattern is so complicated that it almost baffles description. The body is light umber, freely speckled and mottled with darker shades. The appendages are reddish-brown and slightly translucent. Small light areas or suffusions are scattered over the body. The tendon marks on the carapace corresponding to those seen in the fifth and sixth stages are prominent, that below the cervical groove being over a millimeter in diameter. The pleura of the first abdominal ring are snowy white. The free edges of the segments of the body and appendages are bright blue. The large chelæ are tipped with white. The openings of the oviducts are clearly seen and the copulatory pouch is not yet closed. The color of the appendages on the under side is light reddish-brown. The tail-fan is of the same hue edged with deep red. The claws, which are tufted with setæ at their tips, show remarkably little differentiation. The eyes have a dark-purplish pigment and have acquired the characteristic large size and prominence of the adolescent stages.

The following measurements show the proportions of some of the parts:

Measurements.	Millimeters.	Measurements.	Millimeters.
Length, June 27, 1894	36	Length of left chela (propodus)	13
Length of carapace	16.5	Greatest breadth of chela (propodus)	3.6
Greatest breadth of carapace	7.9	Length of dactyl	7.8
Length of antennary flagellum	33	Length of telson	5
Length of right chela (propodus)	13.5	Breadth of telson at base	4.1
Greatest breadth of chela	4	Length of fringing setæ	2
Length of dactyl	7	Diameter of cornea of lateral eye	2

This lobster was kept in a small glass aquarium, and fed with clams and with lobster and cod eggs. It was undoubtedly undersized for its age, having molted about fifteen times.

The three lobsters raised in 1886, which on December 10 measured 35, 36.3, and 51.8 mm., respectively (Nos. 7, 8, 9, table 35), had probably molted twelve times in the first two instances and fifteen times in the last.

Lobster No. 10 (table 35).—When this young lobster was brought up accidentally on a lobster pot in Woods Hole Harbor July 18, 1891, it measured only 47 mm. (See colored drawing, plate 26.) If it was hatched in the summer season it must have been a little over a year old, and it is very probable that in this case also there had been fifteen molts.

The youngest lobsters taken in Casco Bay, Maine, October, 1893 (Nos. 1, 2, table 32), were doubtless hatched in the previous June, and were therefore about 16 weeks old. They had probably passed from thirteen to fourteen molts.

It is, therefore, clear that the young lobster varies very considerably in its rate of growth, whether under artificial or natural conditions. In a state of nature the young lobsters hatched in June are probably from 2 to 3 inches long when 1 year old. (See pp. 96–99.)

I will now add a tabular statement of the successive molts of the adolescent lobsters, whose development has just been considered. Further details of their history are given in table 34.

TABLE 35.—*Successive molts of young lobsters and their measurements in millimeters.*

No. of lobster.	Number of molt.															Date of last measurement.	Age in days.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1 (No. 3, table 34)	...	...	...	13	14.2	15.5	18.4	21.2	...	...	...	...	...	...	...	Sept. 11	107
2 (No. 4, table 34)	...	...	...	...	...	16.5	19.5	22.6	...	...	...	...	...	...	...	Aug. 14	79
3 (No. 37, table 34)	...	...	11	[1]12.5	13.4	15	[2]17.05	19.75	...	...	...	...	...	...	...	Oct. 5	105
4 (No. 34, table 34)	...	...	...	...	...	16.3	18	21	[2]25	29.5	...	...	...	...	...	Sept. 22	94
5 (No. 39, table 34)	...	...	...	...	...	...	...	...	24	28	...	...	...	...	...	Aug. 13	80
6 (No. 38, table 34)	...	...	...	...	...	...	18.5	21.2	25	26.6	...	...	...	...	...	Sept. 22	[2]94
7 (No. 17, table 23)	...	...	...	...	...	...	...	...	...	...	...	[2]35	...	...	...	Dec. 10	[2]173
8 (No. 18, table 23)	...	...	...	...	...	...	...	...	...	...	...	[2]36.3	...	...	...	...do...	[2]173
9 (No. 19, table 23)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[2]51.8	...do...	[2]173
10 (No. 22, table 23)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	[2]47	July 18	[2]390

[1] Approximate. [2] Number of molts, length, or age estimated.

THE MOLTING OF THE EMBRYO AND LARVA.

The first cuticular structure formed in the egg is a delicate blastodermic membrane, which appears in the later stages of yolk segmentation and has often been erroneously considered to belong primarily to the ovum. It becomes so firmly glued

to the primary egg-membrane that any attempt at its removal almost inevitably results in stripping off the blastoderm with it. It is, however, soon absorbed, or at least detached, so that in the early egg-nauplius stages the shelling of the egg is quite an easy matter, yet when the egg-nauplius is fully developed the inner layer of the capsule invariably sticks to the tips of the antennæ, which are usually torn off with its complete removal.

At a stage closely following the egg-nauplius the embryo is inclosed by three distinct membranes. I think it probable that the delicate inner cuticle, which can now be removed by the aid of hot water without injury to the parts, is a distinct structure from the blastodermic membrane just mentioned. The appendages at this time are gloved with a cuticular molt, evidently distinct from that which comes off with the egg-capsule when the animal is hatched. When eye pigment is formed these envelopes are very easily demonstrated, as seen in cut 20, plate F, where they have been distended by the prolonged action of picro-sulphuric acid. Up to this time it is therefore probable that at least three embryonic molts have occurred. Others follow during the long embryonic life, and, as I have already shown, when the animal is about to hatch it is inclosed in a cuticular molt which must be shed before it can enter upon its larval career.

In the second molt, preceding the second larval stage, the delicate shell is cast entire, the only break being, as in the later stages, along the margins of the inner fold of the carapace—that is, in the epimeral region of the branchial cavities and next the abdomen. The shed cuticula is transparent, colorless, and flexible, and contains little or no lime. The abdomen is usually withdrawn last, as is the case in adult life.

The cast shell at the fourth molt, which precedes the fourth stage, contains a little lime, but no pigment. The fifth ecdysis, which ushers in the fifth stage, is more noteworthy. A larva of this period molted in a glass dish on my table in the forenoon of July 13, 1892, and was soon attacked by others in the dish and killed. The carapace is gradually elevated from behind, and the animal escapes through the opening thus formed. The calcareous shell, which is of a beautiful light-blue color, retains its shape perfectly. The carapace, as early as the fourth stage, has a characteristic areolation (see figs. 113 and 115, plate 35) and is covered with short setæ. There is a wide median stripe or band of absorption which branches into the cervical groove on either side and widens at the rostrum. The carapace can be easily split along this thin unpigmented area.

The ecdysis of a lobster in the sixth stage, the color of which has already been described (No. 34, table 34), was observed under similar circumstances. On the 8th of August this lobster molted again while I was watching it. At about 9.30 a. m., when first examined, the abdomen was drawn away from the thorax, showing a distended pink membrane which connects these parts of the shell. Fifteen minutes later the carapace was elevated, the pressure of the inclosed body swelling out the membranes slowly. At 10.24 a. m. the young lobster turned over on its side and in three minutes was out of its shell, about an hour having elapsed from the moment when the process, already begun, was observed. The eyes and cephalo-thoracic appendages are withdrawn first, and when these are free the animal slips away from the old shell, the abdomen coming out last, as in the adult lobster.

The color of the cast shell is blue, with some green and brown pigment on the tergal surfaces. Pigment is now gradually deposited in the outer calcified layer of the

shell, which soon becomes wholly responsible for the color of the animal. The dorsal median stripe of the carapace is much narrower than when first observed in the fourth stage (fig. 115), and the areas of absorption of lime salts from the lower segments (meros and ischium) of the large chelipeds are clearly outlined. The molting and growth of the adult animal are fully discussed in Chapter III.

COLOR VARIATIONS IN THE YOUNG LOBSTER.

In the description of the larval stages just given I have purposely dwelt upon the color changes which the young animal undergoes. This is intended to supplement the previous observations upon the color variations of the adult. To sum up these detailed accounts, we find that the color of the first four larval stages is subject to considerable individual variation, due to the transparency of the shell and the contractility of the chromatophores which lie beneath it. In the first larva the pigment cells are relatively few, and respond to the slightest stimulus. With the growth of the animal they become very numerous, more differentiated, and so commingled that a very varied color pattern results. It is probable that in these stages their chief rôle is a physiological one. A transparent and almost colorless larva swimming at the surface of the ocean would undoubtedly be safer than a brilliantly colored one, but the indiscriminate destruction of these larvæ is so great, both on the part of animate[1] and inanimate foes, that such protection would count for little. That it really counts for nothing is shown by the fact that the fourth larva (also a pelagic animal) is almost invariably richly colored and is far more conspicuous at the surface than it would be if colorless. Again, it is not likely that larvæ know any such thing as fear, and the chromatophores appear to expand under any unusual stimulus.

The color variations of the larva are the expression of physical and chemical changes taking place in the body, as the result, for the most part, of physiological conditions. Some of these changes are sudden or discontinuous, and have no adaptive or protective significance.

After the fourth molt pigment begins to appear in the chitinous shell and a complicated color pattern is gradually produced which, as I have already shown, has, in all probability, a protective value. This happens when the young animal has given up its pelagic life and lives upon the sea bottom, having essentially the characters of the full-grown mature form.

The color variations of the adult are discussed in Chapter VIII.

THE DEATH-FEIGNING HABIT.

It was a matter of no little surprise to find that young lobsters in the fourth and fifth stages sometimes exhibit in a striking degree the remarkable phenomenon known as "feigning death." It is not strictly a habit, since it does not appear in all larvæ. Some display it upon the least provocation, the greater number but seldom or not at all. I have observed the same thing in a lobster over a year old, but have seen no trace of it in the adult.

A young lobster to which I have already referred (No. 36, table 34) when examined two days after the fifth molt showed this peculiarity in a typical way. When stroked lightly with the finger it would immediately stiffen, and lie stretched out at the bottom

[1] Such as herring, mackerel, and menhaden, which from their peculiar habits of straining water for food can hardly fail to be great destroyers of crustacean larvæ. (See note on menhaden, p. 122.)

of the dish, on its side or back, as if paralyzed. Its appearance is now, however, very different from that of a dead animal. The large chelipeds are stretched forward in front of the head, and the other thoracic legs are drawn after them and held close together with their tips pointing forward. It usually remained in this position from a quarter of a minute to a minute, when it would slowly orient itself and begin to move about, in a short time becoming very active. This lobster on one occasion remained in this stiffened, apparently paralyzed condition for the space of eight minutes, and would have continued in it a longer time still had it not been aroused.

While lying at the bottom of the dish in this state, a convulsive movement of the swimmerets was detected and a twitching of various muscles over the body. The appendages sometimes quivered, as if the muscles were in tetanic contraction. The chelipeds and other walking legs remained perfectly rigid. When the animal finally recovered, the thoracic appendages were gradually relaxed and, putting itself in a defensive attitude, it slowly swam off.

If water is squirted at it with a pipette it will sometimes roll over and immediately straighten out as if dead. When disturbed and treated roughly with the finger or a penholder, it stiffens in the same way; the abdomen is bent up slightly; all the appendages are straightened out; the swimmerets are bent backward and can be seen to quiver; the beating of the scaphognathite does not cease.

I have no doubt that this phenomenon is strictly analogous to the "shamming death" of insects, but it is neither a habit nor an instinct. It is, perhaps, the raw material, so to speak, out of which useful instincts are developed in some animals. According to Darwin, there is great variation in the degree in which this instinct is manifested in insects. He observed "a most perfect series, even within the same genus (Curculio and Chrysomela), from species which feign only for a second and sometimes imperfectly, still moving their antennæ (as with some Histers), and which will not feign a second time however much irritated, to other species which, according to De Geer, may be cruelly roasted at a slow fire, without the slightest movement—to others, again, which will long remain motionless, as much as twenty-three minutes, as I find with *Chrysomela spartii*." In seventeen different species which he observed, including an Iulus, a Spider, and Oniscus, "both poor and first-rate shammers," he found that "in no one instance was the attitude exactly the same, and in several instances the attitudes of the feigners and of the really dead were as unlike as they possibly could be."[1]

Romanes, in his Mental Evolution in Animals, has treated the subject of feigning death very fully, and has collected some very interesting facts. Two observations upon the crustacea are quoted, one of Bingley upon the "common crab, which, when it apprehends danger, will lie as if dead, waiting for an opportunity to sink itself into the sand, keeping only its eyes above it," and one by Preyer, who is said to have made crayfish "stand upon their heads while in the hypnotic state"! Romanes agrees with Preyer in attributing the shamming death in insects to "kataplexy," or mesmeric sleep (in many cases the physiological effect of fear), but gives some remarkable cases among vertebrates in which it seems almost equally probable that there is intentional purpose to deceive.

The "shamming dead" in insects and crustacea which leads simply to quiescence, and thus to their becoming conspicuous in the presence of their enemies, had been

[1] Chapter on Instinct written for The Origin of Species. See Appendix to Mental Evolution in Animals, by George John Romanes, p. 364.

intensified, as Darwin believed, through the agency of natural selection. It is evident that no such instinct could thus arise in pelagic animals, where the cessation of the natural movements through hypnotic or other influences would lead to vertical downward motion by the action of gravity, unless such movements were of decided benefit.

It may be significant that the phenomenon is seen for the first time in the lobster when it is about ready to sink to the bottom and assume the adult habits. I have not examined a sufficiently large number of the adolescent lobsters, from 1½ to 3 inches long, to say how commonly they exhibit this peculiarity. I believe, however, that it is in this case a sporadic phenomenon, which has not at present become a habit. It is not easy to see, moreover, how, in the environment of these animals, where so many of their enemies are scavengers or omnivorous, it could be of much service to its possessor when finally established on the bottom.

THE FOOD OF THE LARVA.

The food of the larval lobster must necessarily consist for the most part of minute pelagic organisms, such as copepods and crustacean larvæ. When watched in confinement they may now and then be seen giving chase to copepods, sometimes larger than themselves, and often without success.

The young lobster, however, shows little discrimination in its food. It seems to snap up almost any moving object, living or dead, which it is able to seize and swallow. Thus I have found in the stomachs of the older larvæ vegetable fibers, the scale of a moth or butterfly, and fine granules of sand.

On June 17, 1893, I examined the stomachs of a number of larvæ (raised in aquaria) 13 to 14 mm. long, probably in the fourth and fifth stages, and found them to contain the following substances: (1) diatoms in abundance, chiefly Navicula and the long tangled ribbons of Tabelaria; (2) remains of crustacea, probably parts of young lobsters; (3) bacteria in large numbers; (4) cotton and linen fibers and parts of algæ; (5) amorphous matter, with sand grains. The sediment of the jar contained the same species of diatoms in abundance, and amorphous débris similar to that found in the stomach and intestine.

The stomach of a larva captured in Vineyard Sound August 12 (length 15 mm.) contained the following organisms: (1) parts of crustacea; (2) diatoms; (3) shreds of algæ. In another young lobster taken at the same time (length 17 mm.) there were (1) parts of crustacea, (2) large numbers of diatoms, (3) filaments of green algæ and thin sheets or shreds of vegetable tissue, (4) the scale of a lepidopterous insect, (5) bacteria, (6) amorphous matter in large masses.

Messrs. Weldon and Fowler (*201*) came to the following conclusions after experimenting with different kinds of food which were thought might be acceptable to the larvæ:

> It was definitely concluded from these experiments that whatever food is used must be floating in the condition of small particles at a short distance below the surface, *i. e.*, in the same position as the natural pelagic food of the larvæ of the sea, whether this consist of Copepoda, other Decapod larvæ, trochospheres, fish ova, or other members of the pelagic fauna. As to the other two forms of food tried, the Noctilucæ were apparently eaten, the shrimp larvæ (Mysis stage) certainly were attacked, and from the fact that the young lobsters attack and devour each other it is probable that Decapod larvæ form at any rate part of the usual food. The contents of a tow net taken near the Eddystone on August 6, which held a young lobster, consisted chiefly of Megalops and Mysis stages of Decapoda.

The yolk of hard-boiled eggs, crushed crab, boiled liver, tow-net material, noctilucæ, copepoda, and live shrimp larvæ, were all partially, but none absolutely, successful as a food supply.

The self-destructiveness of the young lobsters when too closely crowded in aquaria has already been referred to. When one lobster attacks another under these conditions the pursuer usually endeavors to get astride of his victim and nip into the abdomen at its junction with the carapace with its sharp-pointed prehensile legs. When the object is too heavy to float, such as the egg or larva of the lobster, they frequently go to the bottom; but if the animal is healthy it will be usually seen swimming about the aquarium dragging its prey with it and feeding upon it as it goes.

HELIOTROPISM OF LARVAL LOBSTERS.

During the past six summers which I have spent at Woods Hole, 1889–1894, I have been struck with the scarcity of the larvæ of the lobster in the waters of Vineyard Sound. The tow net has been frequently used both by day and night, and I have made many unsuccessful trips in search of young lobsters in the season when one would expect them to be common. Thus, on July 11, 1891, I towed all around Gay Head, a mile beyond the Devils Bridge buoy, and in Vineyard Sound. We found only copepods, sagitta, young fish, and fish eggs. The day was bright and the water had been calm for two days. The prevailing winds had been from the northeast. At Menemsha we obtained one lobster with eggs hatching out, but the fishermen reported that very few lobsters with old eggs were then taken; that is to say, the hatching season was about over.

I had a similar experience on July 16. The water was smooth; the wind had been southwesterly for four or five days. There was very little surface material, a few barnacles, megalops and sagittas.

The following is a list of all the lobsters taken at the surface of the ocean during the six seasons mentioned—the capture was made in the daytime unless otherwise stated:

Date.	Observations.
July 9, 1889	One lobster (fourth or fifth stage) at surface of harbor.
July 8, 1890	One lobster, length 15 mm.; captured with tow net, in harbor, in the evening.
July 9, 1890	Five lobsters, 15 to 16 mm. long; taken by R. P. Bigelow aboard the *Grampus*, at station 32.*
July 16, 1890	Two lobsters in sixth stage, 16 mm. long; taken with dip net close to wharf of U. S. Fish Commission Station.
July 24, 1890	One lobster, 16 mm. long; taken with tow net in harbor.
July 28, 1890	One lobster, 15 mm. long; taken with tow net in harbor.
Aug. 23, 1890	One lobster, 16.5 mm. long; taken with tow net in harbor.
July 1, 1891	One lobster in sixth stage, 18 mm. long; taken at surface 7 miles southwest of No Man's Land.
June 29, 1892	One lobster in third larval stage; taken at surface, near wharf.
June 29, 1892	One lobster in fourth larval stage; taken at surface near wharf.
Aug. 15, 1892	Young lobsters, probably in fifth and sixth stages, seen at surface of Vineyard Sound by Professor Libbey.

* Location, latitude 41° N., longitude 71° 9′ W. Observations made by Professor Libbey, July 12, 1890, 10.47 a. m. Surface temperature 63.8° F.; bottom temperature, 54.1° F.

Larvæ in the first stage have been taken in Vineyard Sound as early as June 3. Lobsters in the fourth stage were captured by Vinal N. Edwards, August 12, 1887. Young lobsters (stages not determined) were also taken by him in Woods Hole Harbor, Vineyard Sound, and in the vicinity of Gay Head, in the month of July, 1888.

Surface towing was done at the following places in the same year without obtaining any lobsters: August 1, 17, and 18, Vineyard Sound; August 23, off Cuttyhunk; August 27, 30, 31, Woods Hole Harbor.

Professor S. I. Smith says of the young lobsters which he obtained in Vineyard Sound in the summer of 1871, that numerous specimens "were mostly taken at the surface in the daytime, either with the towing or hand net" (*182*). Of the older pelagic stages he says:

> They appear to live a large part of the time at the surface, as in the earlier stages, and were often seen swimming about among the surface animals. They were frequently taken from the 8th to the 28th of July, and very likely occur much later.[1]

We know that lobsters are now far less abundant around the Elizabeth Islands than they were twenty years ago, and we should expect to find that the young had diminished in a proportionate degree. Millions of larvæ, however, must still be hatched in Vineyard Sound and adjacent waters every year. What then becomes of them? I believe that they are eaten up by surface-feeding animals, principally fish, or meet their death from indiscriminate causes. The tides tend to disperse the young over a wide area, thus carrying them to and from the shores. Horizontal distribution alone would not account for the extreme scarcity of the young in Vineyard Sound at the present time. If, however, there were a corresponding vertical distribution, the conclusion which we have reached would not be warranted. It thus becomes a matter of much interest to determine the heliotropism of the larvæ, or the law which governs their vertical movements in the water.

The results of my observations and experiments with larvæ lead me to conclude that the young, free-swimming lobster usually displays what Loeb has called positive heliotropism (*125*)—that is, it tends to swim toward the light or near the surface in the daytime. The conclusion therefore which we stated above, *that the absence or extreme scarcity of young lobsters in a region where the adults still abound is due to their destruction, is supported by experimental testimony.* The bearing of this fact upon the artificial propagation of lobsters I have discussed in an earlier paper (see *97*).

I will add a few notes upon the experiments which were made to test the heliotropism of these larvæ.

Experiment 1.—On June 27, 1894, I placed about 25,000 young lobsters, in the first larval stage, in the observation pool at the Fish Commission Station, to watch their behavior. The sun was intermittently obscured by clouds during the greater part of the forenoon. When liberated, the larvæ formed a large cluster near the surface, where they remained for a short time. Then all went down to a distance of from 1 to 2 feet, some apparently reaching the bottom, a distance of 3 feet more. A lot of small

[1] With reference to this subject, Professor Smith has kindly written in detail substantially as follows: "All the larvæ captured in Vineyard Sound and neighborhood in 1871, on which my papers were based, were taken in the 'daytime.' My notes usually give only 'day,' or 'evening' for time of capture, but the larvæ of my first and second stages, taken July 1, are marked 'forenoon.' Since 1871 I have many records of first and second stages taken in the 'day' and, as far as I can find now, only two cases of capture in the 'evening,' and one of these cases was when the electric light was used in the water to attract the surface forms. The young in the adult form [equivalent to fourth and possibly fifth and sixth stages described in this work] were, however, often taken in the evening and were almost always attracted by the electric light. In my experience the young of the adult form were much more frequently taken at the surface than the larvæ."

cunners then made their appearance and snapped up the larvæ right and left. Two hours later the lobsters were diffused over the whole surface of the pool, a large number of them swimming close to the surface. The paler larvæ, with chromatophores contracted, can not be easily distinguished at a distance of a few feet, but when one of their eyes is turned at the right angle it glows, like a minute electric spark, with a greenish light. At 1 p. m. the surface on the lee side of the pool swarmed with larvæ. Occasionally one could be seen to attack and drag another down. They swim about aimlessly with considerable rapidity, now rising or falling, and changing their direction frequently. The majority had now become quite red. Later in the afternoon nearly all had disappeared, having been swept out by the tide or destroyed by the cunners and other fish in the pool.

Experiment 2.—On July 13, 1894, I placed a number of larvæ, mostly in the first stage, in a glass dish, next to the window in the hatchery. The larvæ immediately gathered on the side of the dish nearest the window. Turn the dish slowly through an angle of 180 degrees, and the lobsters invariably flock toward the source of light. This may be repeated indefinitely, but always with the same result.

Experiment 3.—A box was made with blackened sides, so that when a glass jar was set in it vertically, with its upper end exposed, ligh could enter only from above. When larvæ were placed in this, the stronger always rose toward the source of light into the illuminated zone. Some, however, apparently the weaker ones, remained below.

Experiment 4.—A light-proof box was then constructed with sliding lid and end, so that a long, closed jar could be laid in it horizontally. When the lid was removed, the larvæ swam up to the surface in different parts of the jar. When the diffused or direct sunlight was admitted only at the end the larvæ invariably flocked toward the illuminated end and remained there. If any lagged behind, it was because they were too weak to swim.

These simple experiments[1] seem to show conclusively that under ordinary circumstances the larvæ of the lobster are positively heliotropic. I made no experiments on the effects of changing the temperature conditions. The temperature of the water used was the same as that of the water running through the aquaria, or about 1° higher than the water temperature of the harbor (see table 2).

The second experiment was tried in the summer of 1893 with the reverse result, the lobsters swimming away from the source of light, showing possibly that under certain conditions the larvæ are negatively heliotropic (*97*, p. 82). This experiment is, however, the least trustworthy of all, since there are always cross lights in a room and the conditions are consequently changing. Professor Ryder found that under similar circumstances the larvæ gathered on the side nearest the source of light[2] (*172*).

The general conclusion reached, that larvæ swim up to the surface during the daytime and stay there, probably sinking at night and rising again with the approach of light on the following day, is supported by the record of the capture of larvæ which I have already given. The taking of larvæ at night seems to be the exception; their capture by day the rule.

[1] In the course of these experiments I had the advantage of consulting with Professor Loeb, to whose researches our knowledge of heliotropism in animals is very largely due.

[2] He also says: "At night, or if light is shut off, the young lobsters go to the bottom of the tanks; and it seems they may then be most actively engaged in feeding if food is placed within their reach."

THE MORTALITY OF LARVÆ.

The following notes illustrate the difficulty of raising the young of the lobster in close quarters. Old eggs were always placed in the jars, but even when the water was agitated so that these were floated, the young invariably preferred to feed on one another. The death rate, however, is due in part to other causes besides cannibalism.

On July 2d, 1893, 130 larvæ in the second stage were placed in a 4-gallon jar and supplied with running water. On July 3d, 108 were alive; on July 4th, 96; July 5th, 89, 3 of these in the third stage; on July 6th, 63 were alive, 47 of these having molted for the third time. In the course of four days 48 per cent had succumbed.

On July 1st, 100 second larvæ were placed in a hatching jar. On July 2d, 82 were living; July 3d, 73; July 4th, 64, 2 of these having molted to the second stage; and on July 5th, 50 were alive, 24 in the third stage. The third larvæ, 26 in all, were left in this jar, and on July 6th 24 were alive; on the following day only 6.

June 29th, 1893, I placed 12 lobsters in the first larval stage in four flat glass dishes (3 to a dish). By the 1st of July 10 were alive, 4 in the second stage; on July 5th 7 were living, all in the second stage, and July 6th 1 second larva only was alive.

July 6th I placed 6 first larvæ in two flat dishes (3 to a dish) with lobster eggs for food. Each lobster was 8 mm. long. On July 7th 2 in one dish were alive, both in second stage and devouring the remaining larva; no change in the other dish. On the 9th, at 9 a. m., 4 were alive, 3 in the third stage and 1 in the first.

I placed 4 third larvæ in a hatching jar on the 7th of July. All were living on the 13th, and on the 15th 3 were alive, having molted to the fourth stage. The smallest had been attacked by the rest and its thoracic legs were eaten off. I left 2 fourth larvæ in the jar, both of which were in the fifth stage on the 27th of the month.

THE EFFECT OF INCREASED TEMPERATURE ON THE RATE OF DEVELOPMENT OF THE LARVÆ.

The following experiment is interesting in showing how the rate of development is affected by raising the temperature:

July 1st, 1893, I placed 100 first larvæ of the lobster in a hatching jar, with food, and heated the water by means of a block-tin coil to 74° F. The water in the aquaria at this time registered 66.9° and that of the harbor 66°.

July 2d, 9 o'clock a. m., 56 were alive. Some were weak and lying on their backs at the bottom, an easy prey of the strong.

July 3d, 9.30 a. m., 56 alive, not looking healthy, many with air bubbles in branchial cavities; temperature raised to 78°.

July 4th, 41 alive, 28 in second stage, 13 in third stage.

July 5th, 24 alive; left third larvæ, 18 in all, in jar.

July 6th, 7 alive; temperature of water 80°.

July 7th, all living, another in fourth stage; left 6 third larvæ in jar.

July 8th, all alive, 3 molted to fourth stage. One fourth larva had one blind eye; the eye was small and pigment deficient. All left in jar.

July 11th, all alive, 4 in fourth stage, 2 in third stage.

July 13th, all alive; no change; temperature 79°; left 3 larvæ in fourth stage in jar.

July 15th, 2 alive.

July 17th, both living; temperature 79°.

July 19th, both living; temperature 78°.

July 21st, both living; temperature 75°.

July 30th, one alive; temperature 78°.

August 2d, one alive, in fifth stage (length 13 mm.); temperature 79°.

August 5th, last one dead.

We see that with a rise in temperature of from 7 to 13 degrees the third molt was passed in about 5 days, which is not far from the average age of these larvæ reared

under the usual conditions. The fourth stage was reached when the larva was 9 to 11 days old, the average age under normal conditions being about 13 days. The only fifth larva reared was from 33 to 34 days old, which is nearly twice the age of this larva living under the usual temperature conditions. If the larvæ had been less crowded in the early part of the experiment, and if the temperature of the water had been raised very gradually, without fluctuations, it is possible that the results might have been more favorable than they proved to be under the circumstances. This would require considerable care and close watching, but the experiment, as performed, seems to demonstrate the impracticability of making such attempts.

The development of the embryo can be hastened by artificially raising the temperature, but it is not certain that any advantage would attend the practice. Bumpus suggests (*30*) that if the young were hatched by artificially raising the temperature of the water during the cold months of the year, and were then liberated into the ocean, they would be certain to escape the attacks of many summer enemies. This is undoubtedly true, but it is almost equally certain that the young lobsters would encounter new enemies in winter and that indiscriminate destruction, which must be very great at any time, would then be enhanced.

THE DEVELOPMENT AND MORPHOLOGY OF THE BODY AND APPENDAGES.

It was my original intention to trace in detail the development of the form of the body and its appendages, but I have not been able to devote as much time as I had wished to this subject. With this in view, however, I have given a pictorial history of the development of the most important parts, which will be found chiefly on plates 27–35.

Professor Smith has already described the tegumentary appendages of the first three larvæ and the "early stages of the adult form," which, as I have shown, comprehend the fourth, fifth, and in some cases the sixth stages. In describing these I shall avoid repetition as far as possible, and pay most attention to those parts upon which few or no observations have been made.

THE BODY.

The carapace.—The carapace arises in the embryo as folds of the ectoderm, the lateral and posterior parts being the first to appear (cut 34 and fig. 234). In the first larva it has the form shown in fig. 110, plate 35. It is somewhat gibbous behind, and is armed in front with three downwardly directed processes, a median, slender, sharp-pointed rostrum, and two lateral teeth. There is also a keel-like process on the middle line near the base of the rostrum. The latter is nearly as long as the rest of the carapace. The position of the future cervical fold or groove is very faintly marked. In the second and third larval stages the rostrum becomes expanded horizontally into a thin plate with toothed margins, but increases very little in length (figs. 109, 111, 112).

In the fourth larva (figs. 113, 115, plate 35) the cervical groove is well developed; the rostrum is a thin, triangular plate, bordered with spines and plumose setæ. The terminal spine is usually bifid at its apex, carinate below, and turned slightly upward. The length of the rostrum is now but little more than one-third that of the entire carapace. The anterior lateral spines are much reduced. Tendon marks now make their appearance, but are more pronounced in the fifth and sixth stages (fig. 114). Areas of absorption, corresponding to the median longitudinal stripe, the "welt" and lateral

bright blue areas of the carapace of the adult lobster are clearly seen. The fine transverse hair line, just above the cervical groove, behind the second antenna, can also be detected. The cross-shaped figure seen on the upper surface is formed by the wide median absorption area and the cervical groove with which it is continuous on either side. Besides the fringing hairs, the whole surface is covered with short setæ which correspond in some measure at least to the hair pores of the adult carapace. In certain cases some of these changes, as in the relative lengths of the rostrum and anterior lateral spines, are far less marked. The anterior median carina is not prominent after the third stage.

The carapace of the fifth stage is illustrated in fig. 114. The characteristic tendon marks, which have been described, are very conspicuous. The rostrum is narrower and in the sixth stage is about one-fourth the length of the entire carapace.

In a young lobster 35 mm. long, which had molted about twelve times, the shape and areolation of the carapace were very similar to that of the adult.

The abdominal segments.—In the first larva (plate 20) the abdomen has its full number of segments. The first is unarmed and partially covered by the carapace. The second, third, fourth, and fifth somites bear early a prominent median spine, which projects upward and backward from the posterior end of the tergum. Each of these segments also bears upon either side a long, sharply pointed pleural spine, which projects backward.

The median spines, of which the last two are the longest, are gradually reduced during subsequent stages and finally disappear at the fourth molt. Meantime the pleural spines become shorter, shift their position slightly, and in the fourth larva point downward.

The disappearance of the median dorsal spines is, however, not uniform, but subject to considerable variation, as shown by the following observations upon eleven larvæ in the second and third stages.

TABLE 36.—*Variation in time of disappearance of the median tergal spines of the larval abdomen.*

No. of larva.	Stage of development.	No. of abdominal somite.			
		2	3	4	5
1	Second larva	Rud.	1	1	1
2	do	Rud.	1	1	1
3	do	0	1	1	1
4	do	0	1	1	1
5	Third larva	0	0	1	1
6	do	1	1	1	1
7	do	Rud.	1	1	1
8	do	0	1	1	1
9	do	0	1	1	1
10	do	0	0	1	1
11	do	Rud.	1	1	1

rud. = spine rudimentary. 1 = spine present. 0 = spine absent.

We see by the preceding table that the median spine of the second abdominal segment may entirely disappear at the second molt or persist in either a rudimentary or perfect condition even after the third ecdysis, while the spine of the third somite, though usually present, is sometimes absent in the third stage. (Nos. 5, 10.)

The sixth abdominal somite bears at its posterior margin a pair of dorsal spines on either side of the middle line. These curve backward over the telson, and are much smaller than the median spines (fig. 33, plate 20). They disappear at the fourth molt.

The respiratory organs.—In the adult lobster there are twenty pairs of gills, one of which, belonging to the second pair of maxillipeds, is rudimentary. There are 6 podobranchiæ, 10 arthrobranchiæ, and 4 pleurobranchiæ, distributed according to the following table:

TABLE 37.—*Branchial formula.*

Thoracic segments and appendages.	Podobranchiæ.	Arthrobranchiæ.		Pleurobranchiæ.	Totals.
		Anterior.	Posterior.		
VII, first maxilliped	0 (ep.).	0	0	0	0 (ep.).
VIII, second maxilliped	1 rud. (ep.).	0	0	0	1 rud. (ep.).
IX, third maxilliped	1 (ep.).	1	1	0	3 (ep.).
X, first pereiopod	1 (ep.).	1	1	0	3 (ep.).
XI, second pereiopod	1 (ep.).	1	1	1	4 (ep.).
XII, third pereiopod	1 (ep.).	1	1	1	4 (ep.).
XIII, fourth pereiopod	1 (ep.).	1	1	1	4 (ep.).
XIV, fifth pereiopod	0	0	0	1	1
Total	6 (ep.).	5	5	4	20 (1 rud.).

ep. = epipodite. *rud.* = rudimentary.

The first larva has no rudiment of a podobranchia in the eighth somite, but all the other branchiæ are represented. The podobranchiæ of the following segments are very small and are partially exposed, together with their reniform epipodites. In the second larva the podobranchiæ are covered by the carapace (plate 21) and the branchial formula is complete (fig. 101, plate 34).

The gills are developed in the embryo as simple folds or pouches in the body wall.[1] They belong to the trichobranchiate type, the respiratory surface being gradually increased by growth of the multiserial branchial filaments.

In the fourth larva (fig. 106, plate 34) the podobranchia carries four rows of filaments, and the mastigobranchia, or epipodite proper, is a long, tapering, hairy plate.

THE VISUAL ORGANS AND APPENDAGES.

The ocellus.—The median eye, which is present in the first larva, is situated at the apex of a prominent median papilla, between the paired eyes and antennules. It is marked by a pear-shaped mass of dark pigment. It disappears in the course of larval life, and no trace of it can be seen in the adult. The ocellus was observed by Sars (*175*) in the first larva of *Homarus gammarus*.

The paired eyes.—The compound or lateral eyes originate in the embryo as disk-shaped thickenings of ectoderm, and do not become lobate until a relatively late period (cuts. 27–34).[2] In the summer eggs eye-pigment is developed when the embryo is about 27 days old. It then appears as a thin line or crescent-shaped area, when seen from the surface. The eye-spot increases gradually in size, and its characteristic shape affords a convenient gauge to measure the embryonic development. (Plate J.)

In the first larva the eye is relatively very large. It is dorso-ventrally compressed or flattened, as in the embryo and in all subsequent stages. The stalks are proportionally shorter than in the fourth larva, and since they nearly meet in the middle line in front of the brain, they are practically sessile and immobile.

[1] For an account of the development of the Decapod gill see *94*, p. 392, figs. 193, 230–233.

[2] The structure and development of the compound eyes of the lobster have been carefully worked out by Parker (*149*).

The following measurements show the greatest diameter of the eye and the length of the eye-stalk, as compared with the length of the body, in the first and fourth larvæ, in a lobster 58 mm. long (No. 5, table 32) and in an adult male:

TABLE 38.

Measurements.	First larva.	Fourth larva.	No. 5, table 32.	Adult male.
	mm.	*mm.*	*mm.*	*mm.*
Greatest diameter of eye	0.74	0.8	3	7
Length of eye-stalk	.92	1.2	3.3	10
Length of body	8	14.5	58	264
Ratio of diameter of eye to total length of body	.092	.055	.052	.026

The diameter of the eye, expressed in terms of the total length of the body, is much greater in the first than in the fourth larva, but is relatively twice as great in the latter stage or in a lobster 2 inches long as in the adult condition. (See p. 163.)

Labrum and metastoma.—Both the upper lip and paired metastoma have in the first larval stage (fig. 54, plate 28) the general form and appearance which they finally possess. The surfaces of the latter abound in setæ. What look like setæ occur also on the labrum, but none are present in the adult organ. (See p. 133.)

First antenna.—The first antenna is a simple appendage up to the time of hatching. In an embryo about four months old (fig. 107, plate 35, and fig. 27, plate 17) it is tipped with short setæ and shows no trace of segmentation. When the embryo is five weeks old the first antenna has the appearance shown in figure 77. In the first larva this appendage is no longer simple, as described and figured by Smith (*182*), but the inner, secondary flagellum (plate 27, fig. 40) is present, though a small rudiment, and bears at its apex a single plumose seta. When the stalk is examined from the under side we can detect traces of segmentation into three parts, but on the upper surface the proximal cuticular fold only can be seen. The appendage terminates in a small bunch of setæ, one of which is conspicuous for its length. It is possible that in some cases the flagellum is not liberated until after the second molt, as described by Professor Smith, but none such were observed. These appendages are immobile in the first larval stage.

The superficial changes which take place in this appendage during the first five larval periods are illustrated in plate 27, and will not be described in detail.

In the second larva the segmentation of the stalk into three joints is sharply defined and the flagella show faint constrictions. The clusters of olfactory setæ, which increase in length and number with every molt, are developed during the first larval period and appear full-fledged immediately after the second molt.

The auditory pit becomes prominent after the third stage. In the fourth larva (fig. 43, *au*) it is a wide and shallow, -shaped depression, marked with brown pigment cells, bordered with short setæ, and containing a few otoliths or granules of sand. In the fifth larva (fig. 44) the closure of the auditory sac has already begun. The pit is filled with otoliths and the irregular orifice is guarded by short, feathery setæ. The constriction of the opening continues until in the adult state it becomes a small pore, into which it is barely possible to insert the point of a pin.

The first antenna of the European lobster, as represented by Sars (*175*, tab. I, fig. 4), agrees essentially with that of *Homarus americanus*, but the secondary flagellum

is more rudimentary. The antennular nerve was traced by Sars toward the end of the appendage, where it appeared to divide into two branches.

Second antenna.—The outer antenna of the first larva (fig. 45, plate 27) consists of three parts, which are represented in the adult (fig. 118)—a two-jointed stalk, a segmented endopodite, and a scale-like exopodite, terminating in a sharp tooth and bordered on its inner margin with long plumose hairs.

This is the first of the naupliar appendages to become bilobed (cut 30). In an embryo four months old, fig. 108 (compare fig. 77), the cuticular molt shows the traces of only a few terminal setæ on either branch.

The progressive changes in the second antenna during the first five larval periods (figs. 45–49) consist mainly in the reduction of the scale and its feathered setæ, in the rapid growth and segmentation of the slender endopodite, and differentiation of the latter into stalk and flagellum proper, and in changes in the stalk or protopodite. In the fourth larva (fig. 48) the first segment (coxa)[1] of the latter bears a prominent tubercle (already conspicuous in the third stage), on which the duct of the excretory organ opens, while the second segment or basis is divided by oblique constrictions into three parts, as in the adult lobster. The external division bears, next the articulation of the scale, a stout spine which grows with the gradual reduction of the exopodite until it finally nearly equals the latter in length. The terminal setæ of the flagellum are rapidly reduced and are barely recognizable in the third larva.

The mandibles.—The jaws of the first larva (fig. 54) consist of a stout basal portion, with toothed, indurated, coronal surfaces, meeting on the middle line opposite the mouth, and of a slender, three-jointed palpus, which terminated in the specimen figured in a single strong seta. The cutting edges are asymmetrical, and at the anterior angle there is a stout, variously toothed process which is separated from the rest of the coronal surface by a deep groove. As Professor Smith observed, this is most prominent on the left side.

In the third larva the asymmetry of the coronal surfaces is even more striking, particularly in the toothed process on the outer side at the anterior end. On the left side this forms a widely overlapping fold, which carries three sharp teeth. The process of the right side is smaller, but had also three teeth in the specimen examined.

In the fourth larva the mandible is deeply cleft by a wide groove, as in the adult (figs. 55–57), and the brush-like palpus folds over the cutting margin into the fossa.

In the fifth stage the mandibles are still asymmetrical, and the teeth are no longer sharp but tubercular, the smaller being at the posterior angle. The stout-toothed process of the first larva remains as a blunt tubercle on the left side, where it was most prominent, but has disappeared from the right side.

First maxilla.—The metamorphosis of this appendage from the larval to the adult condition is relatively very slight. It consists in the first larva (fig. 51) of coxa, basis, and a one-jointed endopodite. All are armed at their extremities with setæ of various kinds—slender, sensory hairs on the outer segment, a double row of stout masticatory teeth on the basis, and a cluster of less regular, distinctly serrated, stiff bristles at the extremity of the coxa.

[1] The following abbreviations for the segments of the decapod limb will be used: (1) *coxa* = coxopodite; (2) *basis* = basipodite; (3) *ischium* = ischiopodite; (4) *meros* = meropodite; (5) *carpus* = carpodite; (6) *propodus* = propodite; (7) *dactyl* = dactylopodite.

In the fourth stage (fig. 61) the endopodite is two-jointed, and is tipped with two nonplumose setæ. A few hairs occur at the distal articulation on the inner side and a larger number at the base on the outer side. The other branches have more of the configuration and character of the adult state.

In the fifth stage (fig. 62) the terminal segment of the endopodite is folded back toward the basal joint and bent somewhat as in the adult. The inner margin of the proximal segment has scattering setæ, and those on the outer side near the base now form a dense bunch, most of which are feathered. The tegumental glands, which later are so abundant in the foliaceous parts of the maxillæ, can now be distinctly seen in at least the basis.

Second maxilla.—The structure of the second maxilla of the first larva is represented by fig. 60, plate 29. It consists of two biramous lobes, the coxa and basis, the respiratory plate or "bailer" and median endopodite. The masticatory setæ are sometimes jointed and but sparsely plumose. The long sensory seta of the endopodite is also marked by transverse constrictions and has a few lateral hairs, while the fringing setæ of the scaphognathite are all plumose and of nearly equal length. The posterior lobe is the wider and somewhat spatula-shaped, and this difference is emphasized after the second molt. Minor changes which occur in the course of the three following molts concern chiefly the endopodite and the conformation of the mouth parts to the mandibles and of the scaphognathite to the branchial cavity.

First maxillipeds.—In the first larva these appendages have the form shown in fig. 58, and if this is compared with the condition met with in the fourth stage (fig. 59) we find that the principal changes concern the two-jointed endopodite and the flagelliform exopodite. In the fourth larva the latter is bordered on both inner and outer margins with plumose hairs. The setæ on both protopodite and endopodite are more numerous, and in the latter branch are much reduced. The respiratory epipodite is relatively a little larger.

Second maxillipeds.—In passing through the first four molts the second pair of maxillipeds undergo but minor changes (figs. 63, 64, plate 30). The exopodite becomes segmented, flagelliform, and setigerous. The segments of the endopodite, particularly their inner margins, become more densely studded with setæ, many of which are serrated. A rudimentary podobranchia is developed. The natural position of the appendages in the first three larval stages is shown in plates 20–22.

Third maxillipeds.—In the early larval stages (plates 20–22) these appendages are usually directed forward and bent into nearly a right angle at the third articulation from the extremity. In the first larva (fig. 69) the distal ends of the three terminal segments (dactyl, propodus, meros) are armed with stout setæ, some of which are serrated, while the inner margins only of the proximal divisions are setigerous. The exopodite reaches beyond the middle of the fifth segment, and is an important swimming organ during the first three larval stages.

The right third maxilliped of the fourth larva is shown in its natural form and position in fig. 65. The appendage is still partially bent upon itself, as in the first larva, but the proximal half (first to fourth segments) has been twisted through an angle of 90°, until what were the inner and outer margins have come to lie in a vertical plane. The proximal joints are trihedral, and what now forms the inner, upper margin has developed a row of stout, rather sharp teeth, which are very prominent in the adult. The podobranchia, which is rudimentary in the first stage, is now well developed.

The pereiopods.—The general structure of the pereiopods is shown in the various plates illustrating the larval and adolescent history. For a considerable period before the time of hatching the great chelipeds can be distinguished by their size. At the time of hatching all have prominent podobranchiæ and long exopodites. After the first molt the swimming hairs and setæ which garnish the endopodites are rapidly evaginated. The first three pairs of pereiopods are subchelate. After the fourth molt (fig. 67, plate 30) the exopodites are reduced to rudiments and leave no trace in the sixth stage.

The first pereiopods.—In the first larva (fig. 66) the first pair of pereiopods or large chelipeds are nonprehensile, armed with stout, scattering setæ, of which those seen on the inner margins of the meros and ischium are the representatives of stout spurs which are developed in the fourth larva. Both propodus and dactyl end in a strong, nearly straight spine, which in the latter joint is conspicuous for its length.

Autotomy of the large chelipeds occurs in the fourth larva, but fusion of the basis and ischium is not effected until at least after the fifth stage (plate 33, fig. 96, and plate 30, fig. 67).

In the second, third, and fourth stages the prehensile claw is gradually developed (plates 20–23). In the third and fourth larvæ the opposed margins of the large claws are distinctly toothed, and the latter end in incurved, horny tips.

There is usually but very little or no difference in the size of the large chelæ until after the seventh molt. In the sixth stage the extremities are already provided with numerous tufts of sensory setæ (compare plates 23–25). In the later adolescent stages, when the differentiation of the large claws is complete, these tufts are mostly confined to the *cutting* claws, where they form a dense mat over the toothed margins and extremity of the propodus (plates 10–12).

The differentiation of the chelæ for crushing and cutting is a gradual process, but is fairly well established in a young lobster 30 to 40 mm. in length (plate 8). It rarely happens that both claws are similar in the adult stages (see Chapter IX).

Second and third pereiopods.—The structure of these appendages, which agree, except in size, is illustrated by fig. 73. In the fourth larva (fig. 74) the chelate structure is pronounced and the exopodite is a rudiment.

Fourth and fifth pereiopods.—The dactyl of these appendages in the first larva (fig. 70, plate 31) ends in a very long, nearly straight spine, while the propodus bears a characteristic cluster of setæ close to its articulation with the dactyl.

In later stages (fig. 76, plate 31) the terminal spine becomes reduced and the terminal cluster of serrated setæ on the propodus is then very conspicuous. In the fifth larva the constriction at the proximal end of the ischium is clearly defined and the exopodite has disappeared except as a microscopic rudiment (not shown in fig. 76).

The pleopods.—The second, third, fourth, and fifth pairs of abdominal limbs are visible as buds beneath the cuticle of the first larva and emerge after the second molt (plates 20, 21).

The sixth pair of pleopods, which form with the telson the tail-fan, are seen as rudiments through the cuticula of the second larva and are released with the third molt.

THE DEVELOPMENT OF THE FIRST PAIR OF PLEOPODS.

No accurate observations have been made upon the development of the first pair of abdominal limbs, which are specially modified in the two sexes. They are the last appendages to appear, and their growth and differentiation are very gradual. In the

fifth stage they are represented by small rounded tubercles (fig. 78, plate 32). At this time there are no external characters by which the sex of the individual can be determined with certainty.

In the sixth stage (fig. 95, plate 33; lobster No. III, table 39) this appendage consisted of a small bud (0.1 mm. long); after the seventh molt (larva 18 mm. long) its length was doubled (fig. 83).

In lobster No. VI (table 39) this appendage in the eighth stage (larva 19.75 mm. long) was a simple bud of about the same dimensions (fig. 80).

In another young lobster, probably a male in the eighth stage (length, 19.3 mm., fig. 90), the appendages of the first abdominal somite are similar to those of the seventh and eighth stages just referred to.

In another case, that of a lobster in sixth stage (No. II, table 39, fig. 84, plate 32, length of lobster 16 mm.), this appendage was about equal in size to those just described. In still another lobster (No. VI, table 39), which was followed from the fourth stage onward through four molts, this appendage is a little larger and is partially segmented (fig. 85, plate 32) in the eighth stage. The under surface of the thorax of this lobster is shown in fig. 89, plate 32, where the openings of the oviducts are clearly seen, thus determining the sex.

In a young female 35 mm. long (No. X, table 39) this appendage measures 2 mm. and is composed of two joints (with possibly a small coxal segment) of about equal length (fig. 86). The distal joint is constricted into a number of smaller segments and bears a few very minute setæ. When the female is 2 inches long the first pair of abdominal limbs have attained the length of only 3 mm. (fig. 88, plate 32). The appendage is exceedingly slender and, as in earlier stages, is devoid of pigment. The peripheral segment is multiarticulate and is fringed with fine, short hairs.

In a male 36.3 mm. long (No. XI, table 39) the appendage, though very minute (2.3 mm. in length), has the same shape as in the adult. It consists of a two-jointed protopodite, a minute coxa and long basis, and a grooved distal segment (fig. 87). In a lobster but little larger (No. XII, table 39), length 40.3 mm., the appendages of the first abdominal somite are similar, but a trifle longer. As shown in the drawing of the under side of the thorax of this lobster (fig. 91, plate 32), they nearly meet on the middle line.

We see that the appendage of the first abdominal ring may assert itself either in the sixth, seventh, or eighth stages. The buds are developed on the posterior margin of the sternum of the first abdominal somite, and in the early period of their growth lie facing each other, transverse to the long axis of the animal (fig. 95, plate 33). These minute delicate appendages do not at first show any trace of pigment. After segmenting into two joints the appendage becomes elevated from the surface of the somite into a nearly vertical position.

The sex can be determined as early as the eighth stage, but not, as Professor Ryder supposed, by the appearance of the appendages of the first abdominal ring. At this stage these vary from 0.20 to 0.27 mm. in length, and may or may not be segmented into two joints (figs. 80, 85, 90). *It is only by the openings of the sexual ducts that the sex can be distinguished at the eighth stage.* The under surface of a female in the eighth stage (21.2 mm. long, No. VII, table 39) is shown in fig. 89, plate 32. The openings of the oviducts were discernible, and the development of the sterna of the last and penultimate thoracic segments which enter into the formation of the seminal receptacle is slightly different from the conditions seen in the male.

The sex can not be determined by the abdominal appendages alone until after the tenth molt. In two lobsters, 35 and 36.3 mm. long respectively (Nos. X, XI, table 39), which had probably molted twelve times, we have no difficulty in deciding from the structure of the abdominal appendages (represented by figs. 86, 87) that the first is a female, the last a male.

The gradual growth of the appendages of the first abdominal somite is illustrated in table 39. In a lobster 2 inches long (51.8 mm.) these have a length of about an eighth of an inch (or 3 mm.).

TABLE 39.—*Progressive stages in the development of the appendages of the first abdominal somite.*

No.	Number in tables.	No. of molt.	Length of lobster.	Length of first abdominal appendage.	Sex.	Remarks.
			mm.	*mm.*		
I	(36, table 34).....	5	14	[1]0.11	?.....	See fig. 78, plate 32.
II	(36, table 34).....	6	16	.27	?.....	See fig. 84, plate 32.
III	(34, table 34).....	6	16.3	[2].10	?.....	See fig. 82, plate 32.
V	(34, table 34).....	7	18	.2	?.....	See fig. 83, plate 32 (bud without joints).
IV	.....	8	19.3	.27	Male....	See fig. 90, plate 32.
VI	(37, table 34).....	8	19.75	.2	Female .	See fig. 80, plate 32.
VII	(3, table 34).....	8	21.2	.25	Female .	See figs. 85 and 89, plate 32.
VIII	(38, table 34).....	10	26.6	[3]1.5	?.....	Appendage not segmented.
IX	(34, table 34).....	10	29.50	[3]2	?.....	Appendage consists of two minute joints.
X	(17, table 33).....	[3]12	35	2	Female .	See fig. 86, plate 32.
XI	(18, table 33).....	[3]12	36.3	2.30	Male....	See fig. 87, plate 32.
XII	(1, table 32).....	.....	40.3	2.60	...do	See fig. 91, plate 32.
XIII	(19, table 33).....	.....	51.8	3.04	Female .	See fig. 88, plate 32.

[1] Tubercle. [2] Bud. [3] Not accurately determined.

Second, third, fourth, and fifth pleopods.—The condition of these appendages in the second, third, and fourth larval stages is illustrated by figs. 93, 94 and 97, plate 33. Each appendage consists in the second larva of a stalk with the blade-like endopodite and exopodite. Rudimentary fringing setæ are developed after the third molt, but the appendage is but little longer and otherwise unchanged. In the fourth larva (fig. 97) the natatory appendages come immediately into use. The long fringing setæ grow out and the limb itself is almost double its former size.

The telson and "tail-fan."—The flat telson of the older embryos is deeply cleft into two lobes (fig. 72), which bear on their free terminal edges short interlocking setæ. The bifurcate condition of the embryonic telson, which recalls very forcibly that of a protozoea and is probably the remnant of a former larval condition, is retained up to the time of hatching and is lost only with the molt preceding the first larval stage.

After the first molt the telson appears as a broad, triangular plate (plate 19, and plate 34, fig. 103) joined immovably to the abdomen and admirably adapted for swimming. By the aid of this paddle the animal darts rapidly backward with every flexion of the abdomen. The dorsal surface of the plate is convex, and its posterior margin is incurved and armed with spines and stout plumose setæ, as shown in the drawing.

The sixth pair of abdominal appendages, which, as already mentioned, are clearly outlined beneath the cuticle of the second larva (fig. 102), become broad lamellar paddles in the third stage (fig. 104), and in the fourth larva nearly equal the telson in length (fig. 105). The outer lamella is jointed at its posterior end and bears on its upper surface, near the line of the articulation, a short median tooth, as in the adult state. After the fourth molt the caudal-fan is very similar to that of the adult. The telson is

a quadrangular plate, about two-thirds as broad as long, with an even convex margin bordered with long fringing setæ at its hinder end. The median spine has disappeared and the long lateral spines are reduced to short, stout teeth.

In the later adolescent stages the fringing setæ of the caudal-fan become greatly elongated until they nearly equal the telson in length. The adult telson is somewhat spatula-shaped and about as broad as long at its base.

THE METAMORPHOSIS OF HOMARUS GAMMARUS.

Sars studied the first three larval stages of the European lobster in specimens which he collected at the surface of the ocean. He saw enough to convince him that they were at this time an easy prey to fish, swimming birds, and to ocean currents which swept them into unfavorable places (*175*).

At Espevaer, a fishing-place on the coast of Norway, his attention was directed to large numbers of lobster larvæ, which were there "packed together with an enormous mass of *Calanides* (a kind of herring) and other species of pelagic animals, upon which swarms of herring and birds were feeding."

The abbreviation of the metamorphosis has been carried a little further in *Homarus gammarus* than in the American species. The young of the two forms apparently agree in color, but are very dissimilar in size. According to Sars, the first three larvæ of the European lobster measure 10, 14, and 17 to 18 mm., respectively. If these measurements are representative, the first larva of this species is larger than the second larva of *Homarus americanus*, and the third larva larger than the sixth stage. (See table 25.)

The color of the third larva, according to Sars, is a mixture of yellow-red or brown and blue-green, and at this stage the integument has lost much of its transparency.

The carapace, the large chelipeds, and abdomen in the first larva of the European species have reached a stage of development which corresponds very nearly to the second larval stage of the American form. This is best illustrated by the rostrum, large chelæ, and telson. The second somite of the abdomen is devoid of the median spine, which, as we have seen (table 36), usually disappears in the American form with the second molt. Sars says that even in the first stage the anlage of the uropods can be discerned beneath the cuticle. These appendages, however, are not released until after the third molt, as in our lobster.

THE SHORTENING OF THE METAMORPHOSIS IN THE LOBSTER.

I have discussed in my work on the development of Alpheus (*94*, p. 380) the abbreviation of the larval period in Crustacea, and described the remarkable examples of this phenomenon which the study of the Alphei revealed. We will now consider the case of the lobster a little more closely than it was possible to do at that time. What is the cause of the suppression of the zoea stage in the metamorphosis of this animal?

We can not doubt that this is a secondary phenomenon which has appeared in comparatively recent times, and that some of the immediate ancestors of the lobster went through the long metamorphosis after hatching, as the majority of Decapods do to-day. It is equally certain that something in the environment of these animals has called forth this change. Why should the lobster be better off with a short metamor-

phosis than the common blue crab (*Callinectes hastatus*) or common shrimp (*Crangon vulgaris*) in both of which the larval life is prolonged? The only clew to an answer lies in the study of the habits and economy of these animals. The course which the larval development finally assumes in any species is a compromise between several conflicting paths. A wide surface distribution is necessary for the continuance of certain animals, but in order to secure this the larval period must be extended. On the other hand, a long life at the surface would be death to many species.

Natural selection is operative at all stages of development, and is effective in increasing the chances of survival mainly in two distinct ways: (1) Either by increasing the number of ova or young produced, or (2) by shortening the path of development. In the latter case the number of eggs is diminished and the size of the egg increased.

The crab and shrimp have adopted the former course and the lobster has followed the latter. A lobster 10½ inches long lays, upon the average, 11,000 eggs, each of which is about 1.9 mm. in diameter, while Callinectes produces, according to S. I. Smith (*184*), 4,500,000 eggs, each having a diameter of only 0.28 mm. Thus the crab, though much the smaller animal, lays over four hundred times as many eggs. With the same number of eggs as the lobster and a long larval life, the crab could not survive. The lobster lives in deeper water than the crab and is probably more sensitive to changes in temperature. The larval period lasts from 5 to 8 weeks; that of Callinectes probably longer, but this is not known. Any further shortening of the development of the lobster would lead to a considerable reduction in the number of eggs, and if the metamorphosis were lost completely so that the animal left the egg in what now corresponds to its sixth or seventh stage the conditions of life would be very unfavorable for the young, on account of the sedentary habits of the adults. The adolescent lobsters (being thus concentrated in a relatively small area) would fall in vast numbers the prey of fish and crustacea, especially to members of their own species, before they could establish themselves securely in their retreats along the rocky shores. (See Chapter XI).

The advantage of a larval life lies in securing distribution, in this case an absolute necessity, over wide areas up and down the coast, and at the same time in the immediate transportation of the young from the shore out of reach of many enemies. This being true, why, it may be asked, has the larval development been shortened at all? This has been brought about, in all probability, because of the general slowness which characterizes the whole period of development and because of the great destruction which is wrought upon the pelagic larvæ even under the most favorable conditions.

It is very interesting to notice, as I have already mentioned (p. 200), that abbreviation in development is carried a step farther in the European species.

It is a well-known law that a fresh-water life tends to shorten the development of animals, and this may be due to the fact that the seasonal changes of temperature are far greater and more abrupt in inland waters than in the ocean.

A life in deep water tends also to shorten development and eliminate the larval period. Where deep-water forms at the present day have an indirect development, it is possible that the problem is complicated by other conditions or that the bathic habit has been acquired in comparatively recent times.

Chapter XIII.—THE EMBRYOLOGY OF THE LOBSTER.

I shall not attempt to give a detailed account of the embryonic history of the lobster, although for several seasons I have spent much time both in collecting and preparing material for this purpose. I will offer only a few notes on the early phases of development, and, to lend continuity to the whole, will sketch briefly the changes in external form which the embryo undergoes.

Early embryologists, Rathke in particular, to whom reference has already been made (*160*), examined the older embryos of the lobster or dissected them from the egg membranes, but the only paper of this period which attempts to deal directly with the embryology of the animal is that of Erdl (*62*), published in 1843. Erdl treats of the laying of the eggs and the fastening of them to the appendages of the mother; of the nature of the laid egg and of the external anatomy of the older embryos; but his work was done before the modern methods of microscopical research had been discovered. This pioneer observer was thus greatly handicapped and his results are now of but little value.

Smith figured and described the external anatomy of a well-advanced embryo from a lobster captured May 2, 1872, at New London, Connecticut (*182*). This stage nearly corresponds to that shown in cut 38.

In September, 1891, a paper on the Embryology of the Lobster, by Bumpus, appeared, in which the early stages, to the close of the egg nauplius period, are carefully described and illustrated by very accurate and beautiful drawings (*30*).

A short account of my earliest studies appeared in 1890 (*91*), and this was followed by additional notes in May, 1891 (*92*), in 1893 (*96*), 1894 (*97*), and 1895 (*100*).

NORMAL DEVELOPMENT.

THE MATURATION AND SEGMENTATION OF THE EGG.

In the section on the growth of the germinal vesicle I have described the only stage in the maturation of the egg which has been directly observed (p. 154, plate 42, fig. 161), where the germinal vesicle has approached the surface and is undergoing indirect division, being overtaken in the metakinetic stage. As already stated, it is evident that in this particular egg the germinal vesicle was about to give off a polar body.

Bumpus, who was the first to detect polar bodies in the egg of the lobster, gives the following account of them:

> They are present in many eggs, and appear to be attached at no special point of the vitellus, so far as the flattened area is concerned, being sometimes within it and sometimes without. It may be, however, that I have only seen them in secondary positions; for in some cases they seemed to move freely about within the egg membrane. They were not observed in process of formation, nor were they invariably present. Before the blastula is formed they disappear. (*30*)

I was unable to satisfy myself that the polar cells could be distinguished with certainty, and so have not figured them. It is difficult to detect such minute bodies in so large and so opaque an object as the egg of the lobster, and owing to mechanical causes, possibly through the emission of the polar bodies themselves, minute spherical globules of food yolk are set free and float in the fluid which underlies the eggshell. A

single globule of yolk is practically colorless, and as I have never detected the polar bodies in stained sections I can not affirm that the small particles which seemed to answer to their assumed appearance were not detached globules of yolk. In ovarian eggs which had failed to pass out of the body at the time of ovulation I have seen what looked like polar corpuscles, but here, although the nucleus of the ovum was at the surface, the observation could not be confirmed by histological analysis. The position of the nucleus in such cases seems to point to the extrusion of the polar cells under normal conditions, while the eggs are within the ovary or its ducts.

I have already described and figured the egg of the shrimp, *Stenopus hispidus*, in which two cells and a single polar body can be distinguished in sections (*95*, fig. 1, plate 6). One cell lies at the surface, and very near it in the space beneath the yolk and shell a spherical mass of deeply staining chromatin, corresponding in size with the nucleus of the superficial cell. It is probable that the latter represents the germinal vesicle after one division, and that the deeper lying cell is the male pronucleus. (Compare *94*, description of plate, p. 474.)

THE EXTERNAL PHENOMENA OF SEGMENTATION.

A colored sketch of the fresh eggs of the lobster is given in fig. 24, plate 17. These were laid in an aquarium, and when examined August 11, 1893, were closely adherent and could be separated only with difficulty. The fresh egg is spherical, oblong, or somewhat irregular in form, and measures about $\frac{1}{16}$ inch in diameter. (See p. 55.) It has in appearance a fine granular texture all over, owing to the uniform distribution and character of the yolk spherules, and the shell hugs the egg closely in all its parts.

An early sign of development is the flattening of a part of the surface of the yolk and the consequent elevation of the shell over this area. A liquid, in which a granular substance is sometimes feebly developed while the egg is still fresh, is pressed out of the yolk and fills the free space between it and the shell. This flattened area marks the animal pole of the egg and is very characteristic. The surface of the ovum is often flecked with light spots due to the irregular grouping and perhaps looser arrangement of the yolk spherules. Light flecks, three to four in number, but of different character, now appear in the depressed area (fig. 215). These are cells which are approaching the surface, and their nuclei can now be seen shimmering through the green yolk.

The phases which immediately follow are represented in figs. 216, 217, and 218, which were drawn from the same egg at successive stages of development. The cells approach nearer to the surface, multiply by indirect division, diffuse about the animal pole, and bring on the superficial segmentation of the yolk into hillocks as seen in profile in fig. 218. The drawing shown in fig. 216 was made at 10.30 a. m. At the animal pole there are seen two double rows of cells, 8 in each double row, or 16 in all. These are arranged in pairs—four pairs of daughter cells in each double row—the products of recent division. This egg appears in profile in fig. 218. The yolk is now in contact with the shell over less than half its area, but the yolk hillocks appear about the animal pole only. At 10.55 a. m., 25 minutes later, 20 cells could be detected. At 12 m., or 65 minutes later, this egg had the appearance shown in fig. 217. The segments or yolk hillocks were then farther apart. This process continued until the entire surface of the yolk was segmented.

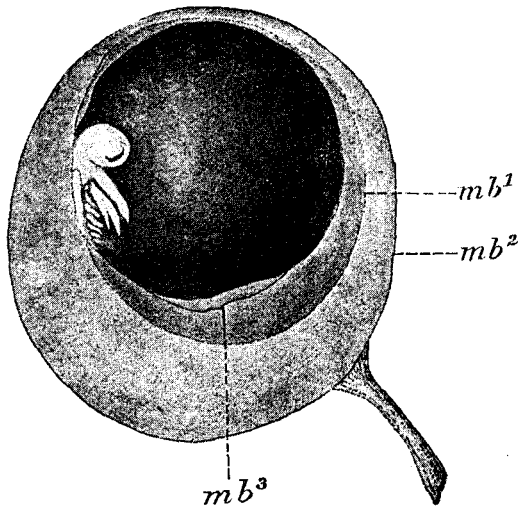
Opposite sides of the same egg in which that condition was already realized are represented in figs. 219 and 220. The former shows the animal pole, the latter the

vegetative. At about 9.30 p. m., when I began these drawings, the nuclei were in karyokinesis; at 10 p. m. nearly all were in the diaster stage (as represented here); at 10.10 p. m. superficial furrows began to appear, separating the daughter cells in the region of the animal pole. At 10.15 p. m. cell cleavage was completed. The cells on the opposite side of the egg lagged somewhat behind the others, the cleavage furrows in that region being completed about 5 minutes later. The yolk segments, both before and after division, were wedged rather closely together and were now polygonal in outline over the greater part of the egg. At 11 p. m. this egg had the appearance represented in fig. 221, when seen from the animal pole. The yolk segments or hillocks now protruded, becoming very convex, and the whole egg took on a beautiful mulberry-like appearance, the segments which were visible to the naked eye being dark green with whitish protoplasmic caps or centers. At 1 a. m., or 2¾ hours after the last cleavage period was completed, the segments flattened down, and by mutual pressure assumed a polygonal form, the energy which had been stored up during the interval being now directed to do the work of the next cleavage.

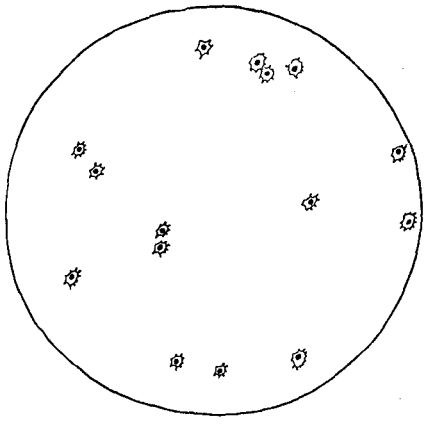
A similar phase is illustrated by cuts 23, 24, plate G, the former showing the vegetative pole. When these drawings were made, at 12.55 p. m., the nuclei were mostly in the diaster stage of division, and in 70 minutes cleavage furrows were beginning to appear.

An egg in a stage quite similar to that seen in fig. 221 is represented in fig. 222. When first observed, at 10 a. m., from thirty-six to forty segments were visible over that half of the egg corresponding to the animal pole. At 10.55 the nuclei were in active division. At 11.30, when the drawing was completed, cell-cleavage furrows were beginning to appear, and in 20 minutes the segmentation was completed over the greater part of the surface. At 12 m. (30 minutes from the time cell-cleavage became visible, and 65 minutes from the beginning of karyokinesis) the process was complete and the segments had begun to swell. The egg in this phase is represented by fig. 223. At 2.45 p. m. active karyokinesis again began, and at 6.25, or in less than 4 hours, division of the segments was again completed. This phase of the segmentation lasted nearly four times as long as the former period. The drawing of it (fig. 224) was made at 9 p. m., and represents the side including the vegetative pole. (See figs. 218, 219, and 220.) The polygonal cells, near the central part of the area represented, were the last products of this segmentation.

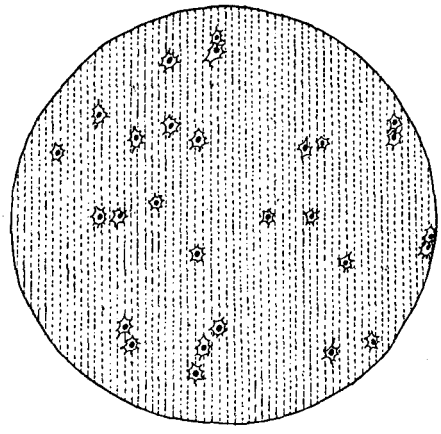
The time occupied in cell division is illustrated by another egg, which was under observation 7½ hours (10.55 a. m. to 6.25 p. m.). It was of about the same age as the egg shown in fig. 222. At 10.55 a. m. the nuclei were in the diaster or metakinetic stage of division. At 11.40 a. m., or 45 minutes later, cell division or segmentation was completed. At 1 p. m., 80 minutes later, the superficial furrows were very definite and the protoplasmic cap of each segment was more distinct when examined in reflected light. At 2.45 p. m., 105 minutes later, or nearly 4 hours from the beginning of the last period of segmentation, the segments were closely crowded and nuclei were again in active division. (Stage of the equatorial plate.) At 4.15 p. m., 1½ hours later, cleavage amphiasters were formed, but no furrows. At 6.25 p. m., 2 hours and 10 minutes later, or 3 hours and 40 minutes from the time of appearance of the equatorial plate, segmentation was completed. Here the total segmentation period lasted about 6 hours and 45 minutes, of which 2 hours and 20 minutes were spent in quiescence and 4 hours and 25 minutes in activity.



CUT 20.—Egg embryo, showing membranes abnormally distended after prolonged immersion in picro-nitric acid. 29 diameters.
*mb*¹, primary egg-membrane, formed in ovary. *mb*², secondary egg-membrane, prolonged into the stalk of attachment, formed by the cement glands. *mb*³, cuticular molt of embryo.



CUT 21.—Projection of an egg with 15 yolk-cells, all near the surface or approaching it.



CUT 22.—Projection of an egg with 28 yolk-cells, 3 in karyokinesis—mostly near the surface.

In these cuts the yolk-cells only are shown. Sections are represented by dotted lines in cut 22.

Drawn by F. H. Herrick.

About 110 cells are present in the egg shown in fig. 223, and not far from 220 in the next phase (fig. 224). The lack of uniformity in cell division which was present in the earlier stages now entirely disappears. In other words, the individual rhythms of the component cells of the embryo appear to be in harmony.

At the next and following divisions (fig. 225) the protoplasm approaches nearer and nearer the surface, and the animal and vegetative poles are no longer distinguishable. A surface view of an egg intermediate between the stages shown in figs. 224 and 225 is represented in fig. 244, plate 52. The invagination stage soon follows.

INTERNAL CHANGES IN SEGMENTATION.

The histological changes which take place in development up to the beginning of the invagination stage will now be considered.

The segmentation nucleus in a single egg, from a batch which I obtained on August 1, was very eccentric in position, and in appearance resembled the germinal vesicle of the unextruded egg. The nucleus was spherical and lay in a spherical island of granular protoplasm. The nuclear membrane was very delicate, and could hardly be demonstrated in sections, while the chromatin had a rather coarse granular appearance.

The first division takes place near the center of the egg, and the products move away from each other. In two eggs examined, each of which contained two nuclei (possibly the pronuclei), one nucleus in each case lay nearer the center and the other nearer the surface. The nuclei are relatively small, and after a few divisions become very much smaller. Each is surrounded by a rayed body of protoplasm, in some cases (as in fig. 249) the rays being exceedingly numerous and delicate, reaching far out among the yolk-spheres. In an egg which was cut into 56 sections, the first two cells appeared in the twenty-fourth and thirtieth sections, respectively. In each case the nucleus was spherical, and the cell protoplasm formed a compact oval island, giving off no long characteristic pseudopodia, as are seen in fig. 238. In another case, where the egg was cut into 64 sections, one cell appeared in the thirty-first and its sister cell in the thirty-ninth section of the series, the latter being in process of division.

In the second and third segmentations which follow, producing four and eight cells, the products separate and migrate toward the surface. The greater number tend to move toward the side of the egg corresponding to the animal pole, where the yolk is first segmented (figs. 215–218, plate 50).

In an egg containing nineteen cells, with yolk undivided, eight were in various stages of karyokinesis. Some cells were nearer, others farther from the surface, the majority being about midway between the center and periphery, in different parts of the egg.

In another egg, where the segmentation of the superficial yolk was completed, just thirty cells or yolk pyramids were present. (See figs. 219 and 220; a section of the egg is represented in fig. 242.) The constrictions of the yolk are not simply superficial, but cleavage planes often reach halfway down to the center of the egg. The nucleus with its rayed protoplasm lies toward the center of the convex face of each segment, but is still separated from the surface of the egg by a considerable layer of yolk. The entire protoplasm is thus distributed among the yolk segments, none of it remaining in the undivided yolk mass. In surface views the nuclei can be seen shining through the thin stratum of yolk which lies between them and the surface. Sometimes a segment is partly overgrown by the surrounding cells and squeezed below

the surface, as in fig. 238, but this must not be mistaken for one of the phagocytes or yolk cells, which are formed in an entirely different manner.

Karyokinetic figures, which are clearly seen in all dividing nuclei, show that up to this time the plane of cell division is radial, for all cells at least which have approached as near the surface as those shown in fig. 242. A little later than this, fig. 224, plate 50, and fig. 244, plate 52, when over 200 cells were present, phagocytes or yolk cells suddenly appear. One egg showed, when sectioned, the following condition:

Number of cells at surface	219
Number of yolk cells	11
Total number of cells in egg	230
Number of cells in active karyokinesis:	
Radial division 15 / Tangential division 2	17

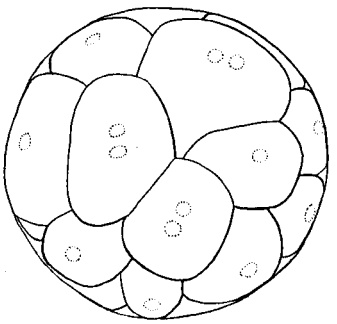
The yolk cells are in various stages of migration from the surface to the depths of the egg. Four have reached points about midway between the surface and center, and one of these is in the metakinetic stage of division. They originate by the tangential division of a certain number of the peripheral cells and by the multiplication of yolk cells thus formed. The peripheral cells at this time are not quite in contact with the surface of the egg, but are separated from it by a thin layer of yolk spherules. When a peripheral cell divides in a horizontal or tangential plane, the central daughter cell migrates into the great yolk mass, filling the egg, while the other remains at the surface and forms a part of the primitive blastoderm. The process is illustrated in figs. 236 and 243, the latter showing the formation of a yolk cell near the surface, and also the division of a yolk cell already formed.

THE INVAGINATION STAGE.

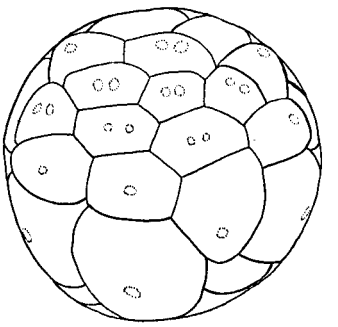
After a stage similar to that shown in fig. 225 is reached the peripheral cells continue to divide in radial planes, and their protoplasm soon bounds the surface of the egg. Cell division becomes more rapid over one side of the egg, possibly that corresponding to the animal pole, but this was not finally determined. An area of rapid proliferation is thus distinctly marked off, and in the midst an invagination of superficial cells occurs. This begins by the in-wandering of a few cells, which is followed by the multiplication of those thus immersed in the common food stock, and by the sinking in of a small area of the blastoderm about this point. In an ovate egg, like that shown in fig. 227, the invaginate area lies toward one of the poles.

The depression is at first very shallow, but increases considerably in depth and becomes a well-defined circular pit. Later it elongates transversely (cut 26), and in abnormal cases a deep gutter is formed. The character of this depression is indeed subject to great variation. The pit at the surface lasts from four to five days, when, after becoming elongated into a slightly triangular slit, by the ingrowth of the sides, it completely disappears.

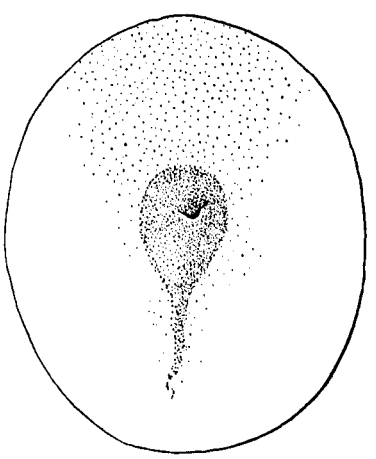
In an egg in which there is a distinct patch of cells marking the area of invagination, but where the depression is very slight or has entirely disappeared, the embryonic area which lies in front of the point of invagination is marked by a wonderful activity among the superficial cells. This is illustrated in fig. 252, plate 54. About the point of invagination there is a mass of several hundred cells, from which migration into the yolk has taken place. Many of the cells, both at and below the surface,



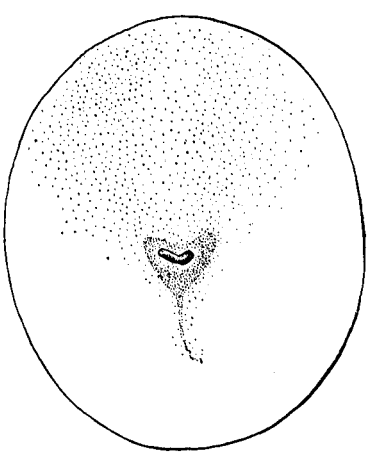
CUT 23.—Egg with about 32 yolk segments present, seen from vegetative pole. About twenty-eight hours after fertilization. At 12.05 p. m. the nuclei were dividing, and at 2.05 p. m. corresponding segmentation furrows in the yolk had appeared. 29 diameters.



CUT 24.—Reverse side of same egg, showing divided nuclei at the animal pole. Drawings from living egg. 29 diameters.



CUT 25.—Surface view of embryo 8 days old in invagination stage, showing pit at surface, embryonic area, and mass of in-wandering cells which penetrate deeply into the yolk. These appear now as a dense pear-shaped cloud when seen through the superficial parts. 29 diameters. From No. 3 (1), table 18, July 9, 1890.



CUT 26.—Surface view of egg in invagination stage. Pit very distinct, transversely elongated, showing tendency to become horseshoe-shaped. 29 diameters. Embryo about 8 days old. August 12, 1892.

Drawn by F. H. Herrick.

are in various stages of division, as shown by the clearly defined karyokinetic figures. The surface of the egg at the sides, but particularly in front of this area, presents a striking, and, for a transitory period, a very characteristic appearance. The nuclei are grouped in pairs, in short strings, or in clusters or nests of a dozen or more. In many cases these nuclei are breaking down and giving rise to the "plasma vesicles" and "chromatin nebulæ" of Bumpus (*30*). The degenerating chromatin of these disrupted cells still reacts vigorously upon the staining fluids, and appears as a clouded mass of fine particles (fig. 237, *Dg.*) which in time becomes more diffused and scattered amid the adjacent yolk granules (fig. 241). The pairs or chains of cells arise by the usual process of indirect division in radial planes.

The cell nests, as illustrated in fig. 245, plate 52, are the result of a multiple karyokinesis, and are formed immediately by either one or two divisions from a single cell (yn^1). Since the active phase of this process lasts but a brief interval, it is not surprising that it usually escapes attention. In this egg, nests of nuclei are very abundant at the sides and immediately behind the region of ingrowth, and occur, as is well shown in fig. 245, both at the immediate surface (*en*) and below it. In most cases a *yolk ball* is formed with very definite outlines, its size depending upon the amount of protoplasm which it contains. The yolk ball is strictly analogous to the superficial yolk-bearing cell and to the yolk pyramid. The superficial cell, which is a direct descendant of the enormous yolk segment or pyramid, has this peculiarity in the lobster: By the time a distinct blastodermic envelope is formed it tends to become distinctly separated from the rest of the egg. A definite stratum of cells is thus formed consisting of yolk-laden discoidal or columnar cells. (See figs. 251 and 255, *ec.*)

The appearance of the cell nest or cluster in a resting condition is shown in figs. 245 and 247. The yolk immediately surrounding it is usually, but not always, segmented into spherical masses. Upon the side of the egg, opposite the embryo nuclei are far less numerous and very uniformly distributed. No cell nests or evidence of active division are seen.

It will probably be found that, whenever clusters or nests of nuclei appear in the blastoderm or other parts of the embryo of Arthropods, they are the result of multiple cell division. Some time ago I suggested (*94*, p. 427) that this would account for the nuclear clusters which Reichenbach has figured in the large endodermal cells which form the lining of the mesenteron in Astacus, and which he supposed were due to a process of direct division (*163*). Both in this case and in the lobster the division is attended by the dissolution of some of the chromatin.

The histology of the embryo during the invagination period is illustrated by figs. 246, 251, 254. At a very early stage a few cells break with the surface and migrate a short way into the egg. A depression about the point of ingrowth soon appears, and the cells, being bathed with nutriment, multiply rapidly until the condition illustrated in fig. 251 is reached. They here form at the surface a definite layer of prismatic elements, each containing a quantity of yolk with definite boundaries. It should be noticed also that the nuclei of the in-wandering cells are often inclosed in spherical masses of yolk.

The histological processes which occur at this period vary considerably in different embryos. Thus in fig. 246 we see a stage of development very similar to that of fig. 252, but a little earlier. In the former (fig. 246) the cells about the area of invagination have multiplied until they form a large cluster at the bottom of the pit. A syncytium is formed, and the protoplasm of the outermost cells lies at the surface, while the neighboring yolk is thrown into long, tapering segments. Some of these

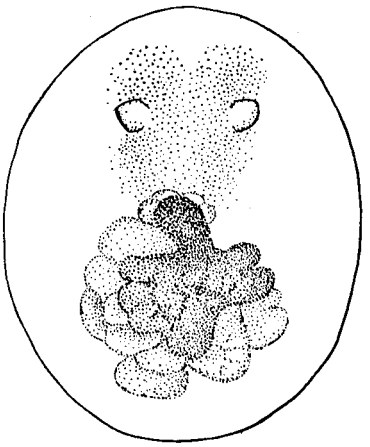
invaginated cells have wandered a short way only into the egg. Now, if we examine the peripheral cell envelope, we find abundant evidence of cell division over the side of the egg where the embryo proper is soon to be built up. Nests of nuclei, often surprisingly large and numerous, are now and then seen in the midst of a spherical mass of yolk either at the surface or just below it. Isolated cells, though few in number, also occur, scattered through the peripheral parts of the yolk at this stage. What is their origin? They can not be referred to invaginate cells, since none of these have yet wandered to remote parts. Furthermore, these cells tend, not to scatter, but to migrate in a body. They may be the descendants of the primary yolk cells or migrants from the peripheral cell envelope, or may originate in both these ways.

At the time of invagination the egg of Alpheus is very similar to that of the lobster in its histological relations. The main difference which is apparent to the eye is in the larger size or greater amount of food yolk in the latter. I have described and figured the invagination stage of Alpheus in some detail in my work on the embryology of this crustacean (*94*, p. 400, plate XXXI). In this species the primary yolk cells persist and mingle with the wandering cells derived from the invagination. An egg of *Alpheus saulcyi* in the invagination stage contains about 460 cells, of which 8 per cent—exactly 37 were found in two separate eggs—are primary yolk cells (*94*, p. 432, table 1). These yolk cells do not appear to be much more numerous in the larger egg of the lobster (see cuts 21 and 22, showing eggs with 15 and 28 yolk cells respectively), but in this animal they degenerate faster than in Alpheus, so that at the invagination period very few are left. On the other hand the occurrence in the lobster at this time of nests of nuclei within the yolk ball, which lies just below the surface or some times almost in contact with it, points to migration of cells from the surface after the invagination stage. In any case most, if not all, such cells degenerate and disappear.

In an older embryo, represented in fig. 254, the pit in the invagination area is considerably enlarged, and below this a solid wedge-shaped column of cells is seen advancing straight down into the yolk or bending slightly toward the hinder end of the embryo. This mass of cells forms what has been called the thoracic-abdominal plate. It here gives rise in part to a mass of cells which migrate into the yolk and eventually form mesodermic and endodermic structures. I shall call this cell-mass the *mesendoderm*. Regarding these cells we notice in particular the peculiar association of the cytoplasm with the yolk, the pseudopodia by which they worm their way among the yolk spherules like so many amœbæ, the evidence of cell multiplication and of the degeneration or breaking down of cells.

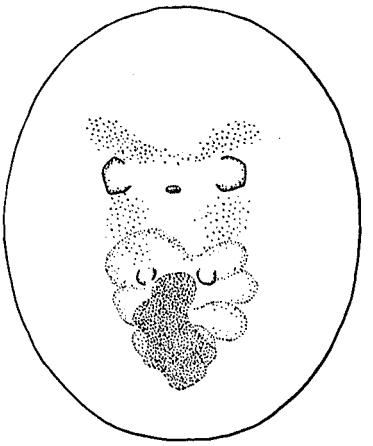
Signs of cell degeneration are also present in a striking degree over the embryonic area of the egg. The surface cells form a single tier of short prismatic elements loaded with yolk, while beneath them we see a thin cloud of fine chromatin particles. These are mostly the remains of cells which have migrated thither from the mesendodermic mass, and possibly in part also of cells which have wandered from the surface.

The embryo at a little later period has the appearance shown in plate 53. The ingrowing plug of cells has a rounded, somewhat pear-shaped outline when seen from above, the stem end of the pear pointing backward and downward into the yolk. The embryonic area of the egg presents a beautiful mosaic of cells, among which karyokinetic figures are abundant. The dividing planes of these cells are always radial—that is, parallel with a radius drawn from the center to the surface of the egg, but make any angle with a line drawn upon the surface of the egg, such as that

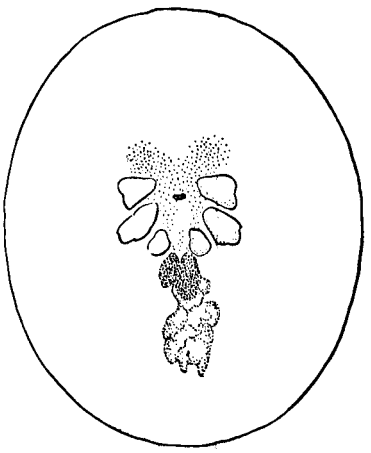


CUT 27.—Surface view of embryo, showing buds of first pair of antennæ and clouds of in-wandering cells. The latter extend in great cumulus-like folds and surround large masses of yolk with thin layers of cells. Embryo about 9 days old. August 6, 1891. 29 diameters.

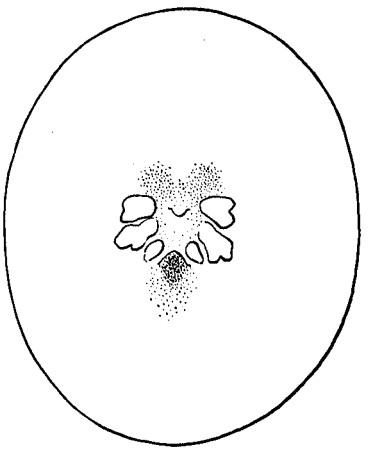
In cuts 25–33 the eggs were fixed with hot water and Mayer's picro-sulphuric acid, and stained in Kleinenberg's hæmotoxylon or Grenacher's borax-carmine.



CUT 28.—Surface view of embryo, showing buds of first pair of antennæ and of mandibles. The stomodæum is present in form of a small transverse pit, on the level of a line drawn through the posterior margins of the antennary buds. The outlines of the masses of yolk-cells appear much more circumscribed than in the earlier stage shown in cut 27. Embryo 9 to 10 days old. August 5, 1891. 29 diameters.



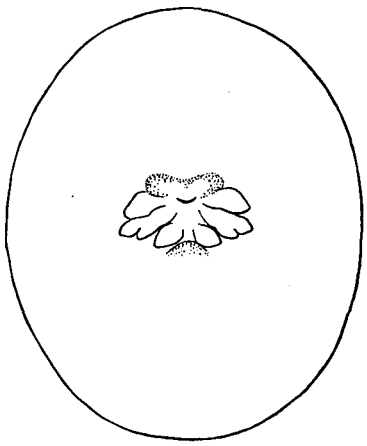
CUT 29.—Surface view of early egg-nauplius embryo, showing buds of the first and second antennæ and the mandibles. Mouth or opening of stomodæum distinct; in-wandering cells beneath the thoracic abdominal plate shaded dark. The yolk-cells are still further circumscribed to outward appearance, having wandered far into the egg. Optic disks more clearly defined. Embryo about 10 days old. 29 diameters.



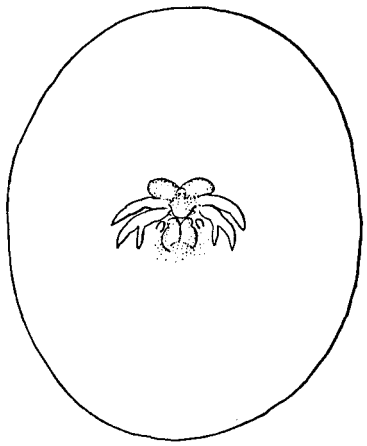
CUT 30.—Surface view of egg nauplius, slightly older than that shown in cut 29; second antennæ bifid; labrum and thoracic abdominal fold present; embryo about 11 days old. July 12. 29 diameters.

In cuts 25–30 surface-cells are roughly indicated only in the immediate region of the embryo.

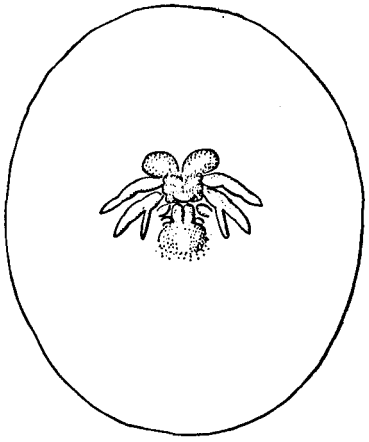
Drawn by F. H. Herrick.



CUT 31.—Surface view of egg nauplius, showing thoracic abdominal fold. The mouth, as in cut 30, is screened by the labrum, and the optic disks are more sharply defined; second antennæ forked; embryo about 12 days old. 29 diameters.

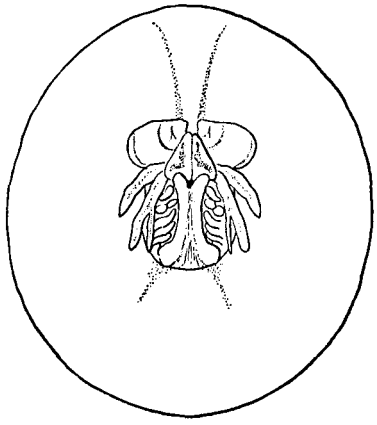


CUT 32.—Surface view of egg nauplius, showing parts much more concentrated than in earlier stages. Antennæ exhibit traces of segmentation, and the second antennæ have a slender inner branch. The abdomen is bifid at its extremity, which nearly touches the labrum; optic disk lobular; embryo 14 to 16 days old. August 14. 29 diameters.



CUT 33.—Surface view of embryo with first maxillæ budded; embryo 16 to 18 days old. August 5. 29 diameters.

In cuts 31-38 there is little attempt to show more than the form of the embryo. The series G to J represents the progressive development of the summer eggs. Compare the Rate of Development, pp. 55 to 57, and table 18.



CUT 34.—Surface view of embryo, showing 5 pairs of post-mandibular appendages. The antennæ have grown obliquely backward until they come to lie nearly parallel with the abdomen. The telson, which is now distinctly forked, partially overlaps the brain. Eye-pigment not yet apparent. Nearly same stage as 3 (5), table 18; about 21 days old. From egg killed in Perenyi fluid, August 15, 1893. 29 diameters.

Drawn by F. H. Herrick.

through the longitudinal median axis. There is no tendency to form radial strings or concentric circles of cells with reference to a given center at the surface, such as Reichenbach (*163*) has described in the crayfish, a fact already noticed by Bumpus (*30*). Diffused clouds or islands of chromatin particles, the wrecks of cell colonies, lie strewn over the embryonic area, particularly in its forward part. These are for the most part immediately below the ectoderm. The opposite side of this egg shows nothing particularly noteworthy and has not been figured. The nuclei are more scattered, cell division is less frequent, and clouds of chromatin granules are much less extensive.

The internal structure of a little older embryo is illustrated by fig. 255, plate 54. The most noticeable changes are the great spread of the mesendoderm which, like a cloud of dense smoke from an engine, rises up and trails backward into the depths of the yolk with many rounded summits; the columnar form of the ectodermic cells—most pronounced in the region of the optic disks—and the swarm of degenerating particles which underlie these regions. Sticking to the basal ends of the prismatic cells, numerous amœboid elements can also be seen. How do they originate? They must come either from the mesendoderm or from the ectoderm. That some of them migrate forward from the region of the thoracic-abdominal plate there can be no doubt, and it seems almost equally certain that some come from the surface cells. The position of the nuclei of the peripheral cells frequently points to the theory that some of them are crowded below the surface by mutual pressure. On the other hand it is sometimes, but not always, the case that the boundaries of the ectodermic cells are clearly defined. The ectoderm still consists of a single cell stratum. The ectodermic nucleus is suspended in the middle of the cell, cytoplasm filling the peripheral and deutoplasm the central ends. Mesendoderm cells also travel backward and sideways from the thoracic-abdominal plate and settle down upon the ectoderm. The cells which migrate into the depths of the egg and form the cumulus-like mass have this peculiarity—they form a connected syncytial mass; their nuclei are small and of irregular shapes. On the other hand amœboid cells below the embryonic area frequently possess large spherical nuclei.

LATER STAGES IN EMBRYONIC DEVELOPMENT.

The development of the external form of the embryo is illustrated by cuts 27 to 38 and by plate 51. The mesendoderm cells play an important rôle at the time the appendages are budding. In surface views they become less and less conspicuous, until in the late egg nauplius (cuts 31, 32) they have passed out of sight into the deeper parts of the egg.

The appendages make their appearance in the following order: (1) First antennæ, (2) mandibles, (3) second antennæ, (4) first maxillæ, and the remaining thoracic appendages in regular succession. They are all formed by the folding of the body wall or ectoderm, and contain solid yolk cores, until these are absorbed and replaced in part by the mesodermic cells which migrate into them. The second antenna soon becomes bifid and bilobed at its apex (cuts 30–32), the inner branch representing the future long flagellum of this appendage. The first antennæ remain single until just before the time of hatching, when the inner branch or flagellum begins to grow out from the inner lower surface of the primary stalk. The optic disks are flat areas of rapid cell division.

The relative position of the mouth and antennæ is illustrated by cuts 28 and 29. I will add the account given in my paper on the development of Alpheus, where the lobster was also included, since it applies to the higher crustacea generally:

Before the first antennæ are folded, when they are distinguished as dense patches of cells, some eggs show the primitive mouth as a minute circular pit, lying nearly on a line drawn between the centers of these proliferating cell areas, but, so far as my observation goes, never distinctly in front of them. The relative positions of the mouth and first pair of antennæ shift very rapidly during the early period of their growth, before the fully developed egg-nauplius stage. The pit elongates and becomes a transverse furrow, and by the time the first pair of antennæ are clearly marked off as rounded buds, and before the second pair are raised into folds, the mouth is on a line with the first of these appendages. When the second antennæ are elevated into folds the mouth is behind the buds of the first pair, or on a line drawn between their posterior margins (*94*, p. 442).

At a stage before the appearance of eye pigment, represented in fig. 232, plate 51, a diffuse but conspicuous patch of ectodermic cells is developed, similar to what I have already described in Alpheus (*94*, p. 414). In case the egg is oblong this patch lies at one pole about 90° behind the embryo.

A stage just previous to the appearance of eye-pigment is seen in fig. 234. The forked telson now covers the labrum and is reaching up in front of the brain.

The relation between the age and size of the embryo under normal conditions—the eggs having been laid in summer—may be seen by comparing cuts 23–38 with table 18. Most of these are from the same batch of eggs.

Eye pigment is developed in about four weeks, and the rate of growth of the embryo can thenceforward be gauged by the increase of the pigmented area (cuts 35–38).

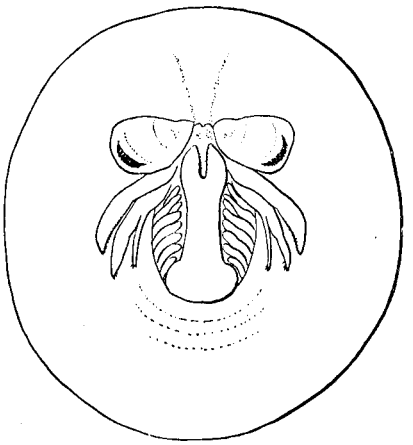
At a stage before the concentration of the embryo has begun, a little earlier than that shown in cut 29, Bumpus (*30*) has described and figured what has the appearance of a rudimentary pair of preoral appendages. These are elongated folds lying parallel with the convex border of the optic lobe, and separated from it by a slight furrow only. They are very transitory, disappearing completely after a brief interval. They can be seen in some of my preparations, but are not shown in the drawings.

HISTORY OF THE YOLK CELLS.

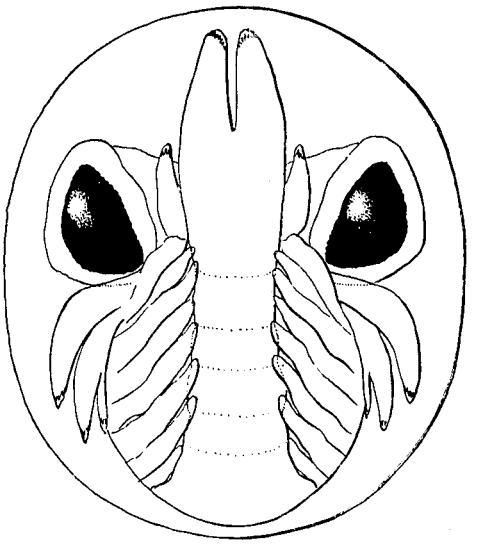
In my paper on the development of Alpheus I have devoted a chapter to the "Origin and history of wandering cells in Alpheus," and I have little doubt that what is said there of Alpheus is generally true of the lobster and of most decapoda.

In Alpheus, as in the lobster, a certain number of cells, 30 to 40, are budded off from the blastosphere, and form what I have called the primary yolk cells. Wandering cells, or those which enter the yolk and move about in it, have a triple origin, namely, from the *blastoderm*, the *invaginated cells*, and the *ventral plate*. It should also be added that both the process of multiplication by indirect cell division and that of dissolution or degeneration of protoplasm take place simultaneously in the wandering cells.

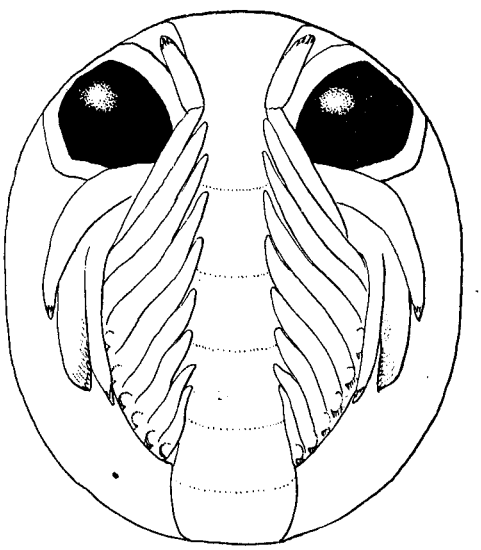
During the egg-nauplius period there is a rapid diminution of the wandering cells, due to cell disintegration and emigration to those parts of the embryo where mesoblastic organs are being laid down. The history of the wandering cells in Alpheus is largely the history of the early development of the mesoblast and entoblast. The endoderm makes its appearance as a distinct cell layer during the egg-nauplius period, and takes the form of a narrow sheet of rather large cells, between the yolk and the rudimentary heart, near the body wall. In the space corresponding to the heart, blood corpuscles can already be detected, besides scattered mesoblast cells. Both the latter and the entoblast are derived from the wandering cells which come out of the yolk (*94*, p. 408).



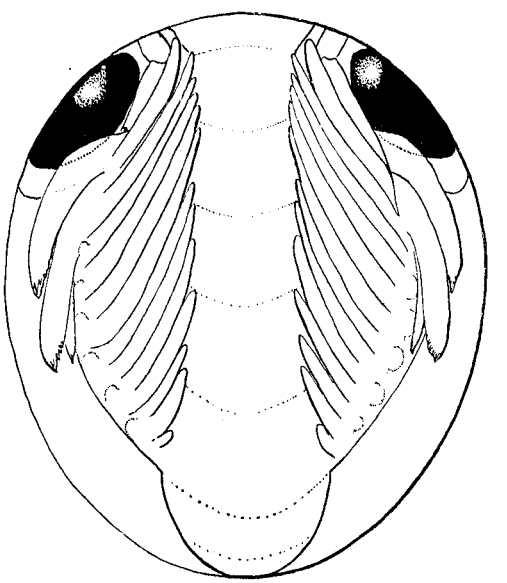
CUT 35.—Surface view of embryo with eye-pigment in form of crescent, as seen from the surface. Telson overlaps brain. Embryo about 26 days old. From series No. 3, table 18, July 26, 12 m. Cuts 35-38 drawn from eggs fixed with picro-sulphuric acid. Outline of egg a little under size. 29 diameters.



CUT 36.—Embryo 61 days old. Area of eye-pigment semicircular. Telson behind brain. From No. 3 (11), table 18, September 1. 29 diameters.



CUT 37.—Embryo 122 days old. Area of eye-pigment rounded or irregularly oval in outline. From No. 3 (13), table 18, November 1. 29 diameters.



CUT 38.—Embryo 211 days old. Area of eye-pigment irregular, somewhat oval or rounded in outline. From No. 3 (16), table 18, February 1. 29 diameters.

Drawn by F. H. Herrick.

In the lobster there appears to be this difference, in that the primary yolk cells are for the most part, if not wholly, disintegrated before invagination occurs, and take no part in development. This can not be shown to be the case in Alpheus.

I have spoken of the formation of the primary yolk cells by tangential division, in Alpheus and other forms, as a process of *delamination*, on the ground that they represented a primitive endoderm, and that the egg with primary yolk cells corresponds to the *planula* stage of cœlenterates. I first called attention to this mode of origin of yolk cells in decapod crustacea in my paper on Alpheus (*94*, p. 400), and found that in the lobster they arose by transverse division from the blastospheric cells or from the peripheral cell layer (since there is no true blastosphere in this egg). The budding of these cells, moreover, begins before the outwardly migrating cells have reached the surface and completely surrounded the yolk. The regularity with which this process occurs "in such typical forms as Alpheus and Homarus argues," as I remarked in an earlier paper, "for its presence in allied species where it has possibly been overlooked." A precisely similar origin and speedy dissolution of yolk cells has been recently described in Gebia by Butschinsky (*31*). It seems that there can be no doubt that the formation of yolk cells at this early period is the last trace of a process which was once of importance, but the rôle which they play now must be an exceedingly minor one. I have never found more than 28 of these cells in the large egg of the lobster (cut 22). Here, while it may be admitted that they are phagocytes or yolk digesters, the impression which they make upon this large mass of material is insignificant, and they are themselves soon disintegrated and become a part of the general food stock. It is possible that they are the remains of a primitive hypoblast, that they once played a more important part as digesters of the yolk than they do at present, and that this function was usurped by the mesendoderm formed at the time of invagination. The term transverse fission instead of *delamination* should, however, be used in speaking of this process (*94*, see pp. 400 and 419), since no true delamination occurs and nothing certain is known about the origin and meaning of this process in the decapod crustacea.

DEGENERATION OF CELLS.

I have discussed the subject of cell degeneration in my paper on Alpheus (*94*, pp. 425–431) and need not refer to the facts again in detail (see figs. 237, 240, 241, plate 52). The degeneration of cells in the ovary has already been mentioned (p. 152). In the embryo this breaking down and absorption of cells into the common yolk mass is first seen in the primary yolk cells, and afterwards in the mesendoderm, where it soon becomes one of the most striking, and at the same time most puzzling, of all the varied phenomena presented by the developing embryo. If we examine a longitudinal section of the egg nauplius of the lobster, we find not a few chromatin balls, but a meteoric swarm of granulated bodies and naked chromatin grains coextensive with the embryo and reaching a considerable distance into the yolk amid the scattered mesodermic cells, but perhaps most abundant, as in Alpheus, in the neighborhood of the stomodæum. A long, nebulous train of yolk spherules and granules extends forward a considerable distance in front of the mouth and is especially marked in the region of the optic disks. The labrum and the folds of the appendages which contain solid yolk cores abound also in these peculiar granulated bodies. They occur in less numbers in connection with the mesendoderm cells, which have at this stage traveled through the greater part of the egg and form a series of irregular sacs filled with yolk. These yolk masses, with their surrounding sheet or advancing column of cells, corre-

spond to the endoderm sac of the crayfish. In the latter the peculiar cell fragments also occur.

If one now examines very thin sections under high powers, he finds that the granules and the granulated bodies correspond in general to the structures found in Alpheus. The chromatin grains appear sometimes as naked masses in the yolk, and stain either very intensely or faintly. They are often vesiculated—that is, they appear as hollow shells (fig. 241). Under favorable conditions it is easy to demonstrate the fact that these bodies surround particles of yolk, and occasionally they have a crescentic shape, when they seem to be enwrapping a yolk spherule (fig. 240, plate 52) (*94*, p. 427). I have shown that the "secondary mesoderm cells" described in the crayfish by Reichenbach (*163*) are undoubtedly products of degeneration which are afterwards absorbed in the yolk. In this species the endodermic cells which are loaded with yolk probably divide by multiple karyokinesis, producing nuclear nests or clusters, some of which in time undergo degeneration. The naked balls of chromatin which are found in these cells are probably formed *in situ*, though they unquestionably shift their position in the egg.

In a species of Cambarus, which I studied at a stage when five pairs of appendages were present, the endodermal nucleus was surrounded by a thin layer of protoplasm, which worked its way amid the yolk so as to practically surround a pyramidal mass. This strongly recalls the serpentine manner in which the cells creep through the yolk in the egg of the lobster.

Later, when nine pairs of appendages are represented, the endodermal cells have nearly reached the ectoderm. The yolk within the confines of the ectoderm has an irregular, pyramidal, or radial cleavage. Centrally it blends with a serum-like fluid, in which occasional granules or balls of chromatin are suspended. Small spherical bodies containing a single chromatin ball, or several balls, occur not only in the yolk underneath the ectoderm and in the vicinity of the endodermal nuclei, *but also in the central yolk of the endoderm sac* at various levels below the endodermal nuclei. This is a point of some interest in connection with the fate of these bodies. They wander not only peripherally but centrally.[1] Rarely we meet one which is three or four times the average size, having a small chromatin spherule in its center. These latter become absorbed and gradually disappear (*94*, p. 428).

As I have already shown, the plasmic vesicles described by Bumpus (*30*) in the ovarian egg are mesodermic cells in the process of degeneration. (For the origin and history of these bodies see p. 152.)

Later, according to Bumpus, the plasmic vacuoles are represented by chromatin granules scattered about in the peripheral parts of the yolk.

In the early cleavage stages Bumpus says that the plasma cells are still represented by chromatin grains, which "are no longer confined to the periphery, however, but have advanced toward the center and formed an indefinite ring" (*30*). In the specimens of eggs in the early cleavage stages which I have studied—stained chiefly in Kleinenberg's hæmatoxylon solution—I have never been able to detect any degenerative products whatever. They appear to have been completely absorbed or converted into yolk before this time.

In a still later period, when the ∪-shaped embryonic area is differentiated, "the plasma vacuoles," according to Bumpus, "are represented by chromatin nebulæ, which

[1] The movement of these bodies is probably due wholly to extraneous mechanical causes

generally underlie the triangular and U-shaped areas" and are "found as small clouds between and also outside the limits of the embryonal tract." He says further that "chromatin grains, as was seen in the surface view, are most abundant where ectodermal cells are most numerous." No inference is drawn from this, but plainly the true one is not that the larger collection of endoderm cells are centers of cell degeneration, but that the mesoblastic cells attach themselves to those parts of the embryonic ectoblast which are growing the fastest, and by their own dissolution give rise to the "chromatin nebulæ."

Bumpus does not explain the origin and fate of the chromatin particles which he accurately figures, but remarks that "structures comparable with the chromatin grains of the plasma cells are neither mentioned nor figured by Reichenbach, though the so-called 'serum' may represent the region of their activity." Further on it is said that "future comparison may prove these," the "secondary mesoderm cells," of Reichenbach "to be the same as the plasma vacuoles and their chromatin grains;" and again, "I have been unable to find in Homarus preparations that throw any direct light on the so-called 'secondary mesoderm.'"

I have shown (*94*) that the "secondary mesoderm cells" are not cells at all, but the products of cell degeneration, and that in their origin and final destiny they bear the closest resemblance to the "chromatin nebulæ" of the lobster.

ABNORMAL DEVELOPMENT.

SEGMENTATION OF THE EGG.

In every batch of segmenting lobster eggs one is sure to meet with many irregular forms, and in some cases the greater number appear to be abnormal. Nuclei can be detected at the surface of many of the segments, and if the egg is treated with Perenyi's fluid or with an acid the dark-green segments and their nuclei contrast very strongly with a milk-white coagulable substance in which they seem to be embedded. Some eggs, which were laid by a lobster on August 23, after a captivity of eight weeks in a small aquarium, were light-colored, but were normally fixed to the abdomen, and were fertile, although the segmentation was exceptionally irregular. Sections of these eggs showed an irregular distribution of cells both at the surface and throughout the yolk. In some places cells appear to have been carried below the surface by overgrowth, and afterwards to have multiplied in the yolk.

Eggs which are otherwise regularly segmented may contain a large superficial mass of undivided yolk, as in fig. 226, plate 50. Here is a very large mass of yolk about the pole of the egg—a similar one lay near it on the opposite side—and a considerable number of smaller segments. When this egg is sectioned it is found that the large yolk masses are nearly devoid of protoplasm, while the smaller segments contain each a nucleus which shows traces of degeneration. There is no nuclear membrane, and the chromatin has assumed a very irregular form.

It is common to find eggs with yolk unsegmented with the exception of one or more small balls at the surface. Sometimes a single large segment is seen, looking as if it had been pinched off, and in this and in many other cases it is evident that the egg has in some way received harsh treatment.

In one egg, rather more anomalous than usual, there was a single small spherical segment at one of the poles of the elongated egg, while the remainder of the yolk was

undivided. A single nucleus was visible in the small segment, but the egg in reality contained six cells, five lying in the unsegmented yolk.

It would be interesting to know how many of the irregularly segmented cells eventually attain a normal condition. It seems probable that very many of them do, judging from the fact that the number of abnormal eggs which later appear when the nauplius stage is reached is much smaller, yet there is no evidence that any of the eggs are lost.

THE INVAGINATION AND EGG-NAUPLIUS STAGES.

I will now speak of some interesting variations which occur during the invagination period and immediately after it.

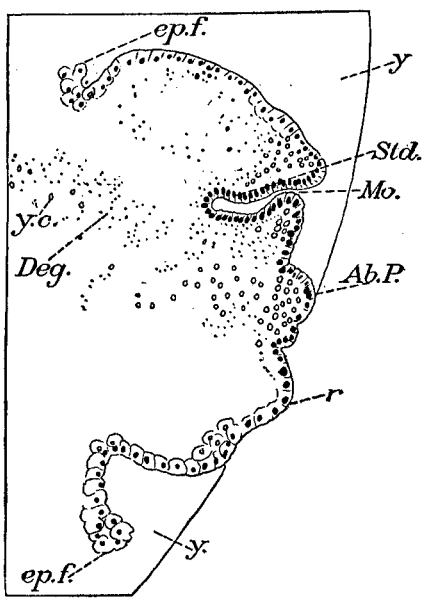
Instead of the normal ingrowth of cells from the surface into the yolk and the sinking in of others to form a small circular pit, there is what appears at the surface as a deep transverse invagination. This is sometimes a long crescent-shaped or irregular transverse fissure, as in the egg of which cut 40 represents a median longitudinal section.

In other cases, in which the processes of development have gone further, there is formed an irregular, oval, or circular disk of cells in connection with the invagination, as shown in fig. 229, plate 51. Here there is a well-defined rim on one side, while upon the other the structure seems to blend with the yolk. In a further-developed stage in the same process I find that the egg has often a well-defined, sometimes round, and very irregular circumvallate disk of cells. The cells within the vallum are densely crowded, and the presence of numerous karyokinetic figures shows that at times cell division may become rapid. Below the surface, both within and without the vallum, the granular masses of chromatin bear abundant testimony to the degeneration of living protoplasm which is taking place in the yolk. The columnar aspect of the marginal cells of the disk can be plainly seen. The way in which this condition is reached is illustrated by cuts 39 and 40. By the ingrowth (or infolding in consequence of unequal growth) of some of the superficial or ectoblastic cells into the massive ball of yolk, a tongue-shaped or island-like patch of cells is formed, on which the embryo proper is subsequently marked off (figs. 228 to 231).

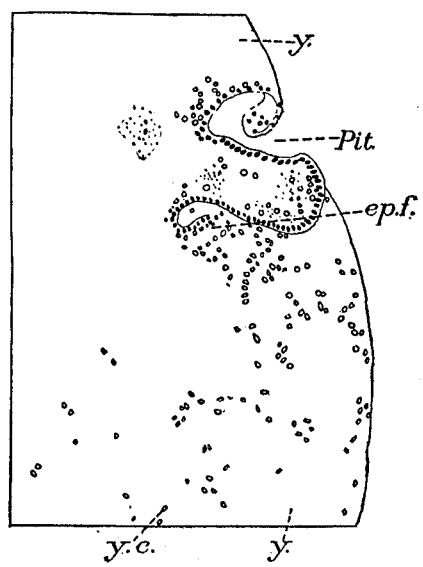
The egg-nauplius may arise in a depressed central part of the disk, as in fig. 231, or upon its margins, figs. 228, 230.

We will now glance at the histology of some of the abnormal embryos. Cut 40 shows a median longitudinal section through one of the earlier stages described. When the egg was examined from the surface a transverse irregular fissure was seen, corresponding to the pit (*Pit*) where the sheet of cells dips below the surface. We see from a study of this egg that a considerable stratum of cells, including the invaginate area, has grown into the yolk, and that its edges are folded upon themselves. In this case one side of the disk, corresponding to the anterior end of the embryo, is at the surface, while the opposite side is deeply embedded in the yolk. Numerous cells have budded off from this cell plate, particularly at its posterior end, where they multiply rapidly and move about freely in the yolk, like the normal mesendodermic cells. Like the latter, they move chiefly in a posterior direction into the deeper parts of the yolk. Many of these wandering cells are moreover already in process of degeneration. It looks as if there was a migration of cells from the surface behind the cell plate, but the appearances may be in this respect deceptive. The yolk flows over the engulfed cells, but I find in my preparations no new superficial layer of ectoderm established.

Cut 39 represents a median longitudinal section through the embryo shown in fig. 230, plate 51. Here the entire embryo is immersed in the yolk or in a thin coagulable fluid derived from it, through which it can be seen, while the cell plate touches the surface in a narrow, bow-shaped area, but dips below again at its peripheral margin. The cell plate beyond the confines of the thoracic-abdominal process and appendages of the embryo consists of a single layer of very large cubical or columnar elements gorged with yolk. In front and behind, the edges of this sheet unite to form a cul-de-sac, so that the whole structure resembles in form a flattened bag, which is partially buried in the yolk, with which it communicates by the opening or mouth of the sac below. The edges of the plate are curled over in the yolk, like one of the limbs of



Cut 39.—Median longitudinal section through abnormal embryo shown in fig. 230, plate 51. Fixed with picro-sulphuric acid, stained in Kleinenberg's hæmatoxylon, August 9, 1892.



Cut 40.—Sagittal section through abnormal embryo in early stage of development. Fixed in picro-sulphuric acid, stained in Kleinenberg's hæmatoxylon, August 9, 1892.

AbP, thoracic-abdominal process. *Deg.*, egenerating cells. *ep.f.*, ingrowing fold of surface-epithelium. *Mo*, mouth of stomodæum. *Pit*, pit formed by ingrowing fold. *r*, outward fold of surface epithelium. *y.c.*, scattered cells in yolk. *y.*, food-yolk, abnormally covering embryo in cut 39.

the letter S. In other respects the histology of this egg-nauplius embryo resembles that of a normal form, except in perhaps a great preponderance of degenerating cells. In the embryo, the surface view of which is shown in fig. 228, plate 51, essentially the same conditions are seen. These abnormal embryos which have just been described are due in all probability to a disturbance of the normal mechanical conditions under which the egg usually develops. It is quite probable that they could be artificially produced, but no experiments have yet been made in this direction.

I have noticed another interesting abnormal variation in the invagination stage. (See *91*). At a period nearly corresponding to that shown in fig. 255, plate 54, there is a large irregular cavity or several communicating cavities in the depths of the egg. This chamber contains very little yolk, and its wall is composed of cells which grasp the

yolk by long pseudopodia. The surface of the wall next the cavity is densely studded with nuclei. This irregular cavity is undoubtedly formed by a folding of the embryonic area, brought about by unequal growth, like the cases already described, and morphologically lies outside the embryo. This is probably the same as the structure referred to by Bumpus (*30*, p. 238). It has nothing to do primarily with either the endoderm or the alimentary tract.

It seems quite probable that many of the abnormal stages already described may eventually attain to a normal growth and development, but this is not certain.

DOUBLE MONSTERS IN OVUM AND LARVA.

Brightwell, who gave a description of the young of the European lobster (*Homarus gammarus*), in 1835, was the first to notice double monsters in this species. He says: "Two specimens of the young which appeared double were found, being strongly united in the head" (*24*). In 1886 the first particular account of these monstrosities was given by Ryder (*171*), who describes four types of fusion among the free-swimming stages. It is to his kindness that I am indebted for the opportunity of examining the six abnormal larvæ which he described, two of which I have figured.

It seemed worth while to trace, if possible, the history of these abnormal larvæ back to their early embryonic stages, but although I examined many eggs from many individuals, I found only three monstrosities of this kind. The earliest is in the invagination stage, corresponding to that shown on plate 53. It has the appearance of a normal egg, except that instead of a single invagination there are two areas of ingrowth. The axes of these two embryos appeared to be inclined to each other at an angle of about 135°, and they were separated by considerably more than one-third the circumference of the egg. The posterior ends of these embryos are the nearest together, as with the others which I have observed. There is no cellular union of the embryos in the yolk, but they meet in a common peripheral layer of cells, the nuclei of which are now widely scattered, except in the immediate embryonic areas.

The next youngest stage obtained was the egg-nauplius, which I have reproduced in fig. 235, plate 51. The two embryos are similar in every respect and lie almost exactly opposite each other. The thoracic-abdominal plate of one embryo is joined to that of the other by a long train of cells which extends through the yolk just below the surface. These have the general character of migrating mesendodermic cells, and some have already passed into the depths of the egg.

In a little older double egg-nauplius the long axes of the two embryos make an angle of about 160° with each other. Their posterior extremities are apposed and, as in the first instance, separated by about one-third the circumference of the egg. It is probable that had the two latter monsters been allowed to develop they would have appeared, when ready to hatch, as if fused, back to back, like the fourth type described by Ryder, in which four eyes were developed, two to each embryo, two distinct sets of mouth parts, and biramous locomotor appendages. As Ryder remarks: "This relation of two perfectly formed embryos in the same lobster egg is exactly the reverse of that which is observed in vertebrates" (*171*).

In the first type of larva described by Ryder there are no eyes; the cephalothoraces are fused completely, both laterally and anteriorly, and the separate abdomens diverge at a wide angle. In his second type (fig. 200) there is a single median eye on the line of fusion of the cephalo-thoraces. The abdomens diverge at a very wide angle, and, as seen in the drawing, there is a fusion of the first pair of antennæ.

This shows that parts of the embryo on the middle line, including the ocellus, have disappeared, and that the large median pigment spot is beyond question the last trace of the fused compound eyes.

In fig. 199, which illustrates the third type described by Ryder, the cephalothoraces are fused laterally and anteriorly; there is no median eye, but a pair of compound eyes, the right of which is the right eye of the right embryo and the left the left eye of the left. The stomachs are fused on the middle line, but there is no apparent union of the antennæ or mouth parts. Behind the stomach the parts are all double.

It is evident that the causes which have produced the monsters with a single pair of compound eyes (fig. 199) are of exactly the same nature as those which have produced the monster with a single median pigment spot. In the latter case their action has been more prolonged. It is also evident that these abnormal larvæ have been derived from embryos like those which I have described. There is, however, this noticeable distinction: In the abnormal embryos the posterior ends of the bodies are apposed and united, while in the larvæ the anterior ends are united, the posterior parts being widely divergent. It seems to me probable that the apposition and union of the tail ends of the embryo do not last long, and never involve anything more than the cells in the yolk; that two distinct thoracic-abdominal processes and two distinct tail folds are formed, which begin to diverge at an early period. Along with these changes a process of fusion apparently takes place between the anterior parts of the two embryos, which are at first *entirely separate and distinct*, excepting for the yolk and peripheral cells (ectoderm) which unite them.

The fusion of parts does not take "place coincidently with the process of gastrulation," as Ryder suggested, and does not begin to show practical results until after the egg-nauplius stage. In regard to the way in which the different degrees of fusion have been brought about, Ryder applies the rule adopted by Rauber for the interpretation of fish embryos—that the degree and manner of fusion is "determined by the width of the angle at which the embryonic axes were primarily inclined to each other." This principle probably applies to the double monsters produced from the lobster's egg, but the process of fusion seems to me to be something entirely distinct from the concrescence seen in the parts of the normal embryo. We have to do here with the fusion of two embryos which are practically distinct from the first.

NOTE ON THE DEVELOPMENT OF CAMBARUS.

I received through the kindness of Professor J. E. Reighard, in the fall of 1893, a large number of crayfish of the species *Cambarus immunis*. They were taken from a pond in Ann Arbor, Michigan, on the 16th of November, when ice was just beginning to form. Many of the females were already "in berry," and most of the eggs were in a very early stage of development, some, without segmentation of the yolk, having been recently laid. Several were in the egg-nauplius stage, and the oldest which I examined corresponded to Stage H of Reichenbach (*163*), having all the thoracic appendages, and the folded abdomen had grown forward so that it nearly touched the labrum.

The eggs carried by each female are relatively very large (1.5 mm. in diameter) and few in number. They are of a light or sometimes rather dark coffee-brown, and appear to be insecurely fixed to the swimmerets, being liable to drop off or become detached, especially when several animals are kept together. The species is hardy

and will thrive in confinement, although, as Professor Reighard remarks, the eggs do not fare so well.

The early phases of segmentation of the protoplasm and yolk correspond very closely to what has been described in the lobster. The protoplasm divides, and its products migrate toward a limited area of the surface of the egg, which becomes the animal pole. This lies usually, if not always, somewhere between the stalk of attachment and the opposite surface of the egg.

In one egg which I studied three small whitish spots could be seen glistening through the brown yolk. These, which were some distance apart, marked the first cells to reach the surface and initiate the segmentation of the yolk. In another egg, which had 27 cells visible at the surface, the shell was raised or distended over that hemisphere containing the animal pole. This distention of the membrane is not, however, so uniformly restricted to this part of the egg as is the case with the lobster, nor were the large yolk hillocks, so characteristic of the latter, discernible here. The cells are now visible to the naked eye as white dots.

Other eggs are seen in which 40 or more cells could be detected lying rather near together and covering nearly half the egg, while the rest of the surface is without trace of protoplasm.

The process of migration from depths of the yolk and division of those cells which have reached or nearly reached the surface continues until the whole superficies of the egg is dotted with cells, 80 or more in number. What corresponds to the animal pole can now be faintly distinguished where the cells are somewhat thicker or closer together. No segmentation of the superficial yolk has yet taken place, although the latter is apparently raised slightly about each cell.

As cell division proceeds, the number of surface cells becomes very greatly increased until 400 or more are visible. The egg then appears to be very nearly uniformly segmented at the surface, and in certain phases of "rest" has the usual beaded appearance. This is a late "yolk-pyramid" stage.

The invagination stage soon follows, and a very distinct round pit appears at the surface, very much in external appearance like the corresponding phase of the lobster's egg, excepting that the invaginate cavity is larger.

An invagination of a different character sometimes occurs which is probably abnormal. A round, very symmetrical depression is seen in the midst of the cells corresponding to the animal pole. The depression is shallow, and at its bottom three or more cells can be seen looking as if they had been pushed below the surface at this point. The cells bordering this depression are sometimes arranged very uniformly. A similar pit was seen in the midst of the cells of the animal pole before they had spread over the entire yolk. In this case it was plainly abnormal.

I have not yet studied all the phases of the external segmentation of Cambarus by means of sections, but from what has already been seen it is clear that it follows in all essential details the course of events which have been described in the lobster.

Chapter XIV.—SUMMARY OF OBSERVATIONS.

GENERAL REVIEW OF THE LIFE-HISTORY OF THE LOBSTER.

I will now give a brief summary of the most important observations which have been detailed in this work, emphasizing in particular those facts which bear upon the problem of the artificial propagation of the lobster.

(1) *Distribution.*—The geographical range of the lobster covers about 20 degrees of north latitude, from the thirty-fifth to the fifty-second parallel, and includes a strip of the Atlantic Ocean 1,300 miles long and from 30 to 50 miles wide. Its vertical distribution varies from 1 to upward of 100 fathoms. The most northern point at which its capture has been recorded is Henley Harbor, Labrador; the most southern point, the coast of North Carolina. The fishery was begun on the coast of Massachusetts and gradually extended northward. Consequently, at present the lobster is most abundant and attains the greatest size in the northerly part of its range, in eastern Maine, and in the northern maritime provinces of Canada.

(2) There is great diversity in the character of the environment which explains in some measure the many variations which occur in the habits of the animal, as in the time and frequency of molting, in egg-laying, in the hatching of the young, and in the rate of growth.

(3) The lobster displays a considerable degree of intelligence and possesses organs to which the various senses of the higher animals have been ascribed. The tactile sense is diffused over the whole body, and the dead shell is perforated by innumerable minute pores which are capable of transmitting stimuli to sensitive cells lying in the delicate skin below. It has the sense of smell and of taste, but it is doubtful if the so-called auditory organs are really ears.

(4) The sea-bottom is the natural abode of the lobster in the adult state, and it never leaves it and never forsakes the water unless obliged to do so.

(5) *Migrations.*—No coastwise migrations are known to occur, but large numbers of lobsters move to and from deep water in fall and spring. This bathic migration varies in accordance with the character of the coast and nature of the bottom. It is influenced by the temperature of the ocean, by the abundance of food, and to some extent by the molting and breeding habits.

(6) Many lobsters remain in the relatively shallow and cold waters of harbors throughout the winter, but at this season they are found only upon *rocky* bottoms, where food is most abundant. One may search for them in other situations, as on a weedy or muddy bottom, during the winter season in vain.

(7) *Influence of temperature.*—The optimum temperature of the lobster is about 55° F. When the temperature of the sea marks 50° to 55° in spring (May at Woods Hole) large numbers of lobsters begin to creep nearer the shores, and when again in the fall (October at Woods Hole) the temperature is near this point, they have already begun the outward movement.

(8) In severe winters lobsters are either driven into deeper water or, if living in harbors, seek protection by burrowing in the mud when this is available. This sometimes happens when a sudden lowering of the temperature arises from any cause, and always when the animals are confined in pounds. In such cases a prolonged cold spell may prove fatal (see p. 26). The lobster is practically excluded from the coast of Labrador east of the Straits of Belle Isle by the Arctic current and lingering ice.

(9) The adult lobster is essentially a nocturnal animal, being far more active by night than in the day. The reverse is true in the larval period, when the habits are entirely different.

(10) *Burrowing habits.*—The lobster is a great burrower in the sea-bottom. This habit is developed to an extraordinary degree in pounds or inclosures, at all seasons, and is practiced, though less regularly, under other circumstances. (Compare paragraph 8.) The holes, some of which are 2 to 3 feet long, are solely for protection and are never used while the animal is molting. In the construction of the holes the large claws are used, and possibly the tail-fan. The lobster almost always enters its burrow tail first.

(11) *Food.*—The adult lobster feeds chiefly upon fish, dead or alive, and upon invertebrates. It also takes a small quantity of vegetable food, such as algæ and eelgrass. Fragments of dead shells, coarse sand, and small gravelstones are also swallowed. The former yield lime, which is absorbed and finally laid down in the skeleton. Many small fish which inhabit the bottom fall a prey to the sharp cutting-claw of the lobster, which it uses with great skill and dispatch. The larger lobsters prey invariably upon the smaller or weaker ones when they can.

(12) The food is seized, torn, and crushed by the large claws, and then taken up by the appendages about the mouth (maxillipeds, maxillæ, and mandibles), by which it is successively torn and chopped fine, when this is possible. While the animal is eating, a stream of fine particles is passed into the mouth, thence to the gastric mill or masticatory stomach. Here the food is ground and the fluid or digestible parts are strained into the small delicate intestine from which they are absorbed. The indigestible refuse is regurgitated from the stomach-bag.

(13) *Impregnation.*—In copulation the female receives the sperm from the male in packets or spermatophores, which are deposited in an external chamber, the seminal receptacle. This is a blue, heart-shaped structure, situated on the under side of the body, between the bases of the fourth pair of legs counting from the large claw-bearing appendages. It opens to the exterior by a median slit with elastic edges, which can be easily pressed apart.

(14) The male does not discriminate the sexual condition of the female, which may be impregnated at any time. It is, however, probable that copulation takes place most commonly in spring. The sperm retains its vitality for a long time, in some cases for at least several months before it is used.

(15) *Egg laying.*—Much confusion has existed concerning the time when the eggs are laid. This has resulted chiefly from the fact that the eggs are carried by the females for the space of from ten to eleven months before they are hatched. About 80 per cent of the spawning females lay their eggs at a definite season in the summer months, chiefly July and August. The remainder, about 20 per cent of the whole number, extrude eggs at other seasons—in the fall and winter certainly, and possibly also in the spring.

(16) In the western end of Vineyard Sound and the region about Woods Hole the greater number of eggs are extruded during the latter part of July and the first half of August. The summer spawning of each year lasts about six weeks, and fluctuates from year to year backward and forward through an interval of about a fortnight.

(17) This variation in the time of the production of the eggs is due to the fact that the ovarian ova require at least two years of growth before they are ready for

extrusion. Anything which affects the vital condition of the adult female will thus affect the time of spawning.

(18) The spawning season in the middle and eastern districts of Maine is about two weeks later than in Vineyard Sound. In 1893, 71 per cent of the eggs which were examined from the coast of Maine were extruded during the first half of August.

(19) At Woods Hole, Massachusetts, 168 egg-bearing lobsters were captured from December 1, 1893, to June 30, 1894. Out of this number 44, or 25.6 per cent, bore eggs which had been laid outside of the summer months, chiefly in the fall. A lobster captured at Matinicus Island, Maine, February 4, 1893, with the yolk unsegmented, and therefore in a very early stage, is mentioned in table 13, No. 20. Similar captures recorded in tables 12 and 13 show that the laying of eggs in fall and winter is not rare.

(20) Lobsters laid eggs in confinement only twice during the six summers which I spent at Woods Hole, although ripe females were frequently placed in the aquaria. When kept under these conditions, or even in floating-boxes outside, the eggs are usually not laid, but are absorbed directly from the ovary.

(21) *Law of production of eggs.*—The law of the production of eggs may be expressed arithmetically as follows: *The numbers of eggs produced at each reproductive period vary in a geometrical series, while the lengths of the lobsters producing these eggs vary in an arithmetical series.* A lobster 8 inches long produces about 5,000 eggs. According to this law, a lobster 10 inches long would produce 10,000, a 12-inch lobster 20,000, a 14-inch lobster 40,000. An examination of table 15, in which the number of eggs borne by over 4,000 lobsters is tabulated, shows that this law holds good up to the fourth term. When a lobster attains a length of 14 to 16 inches this high standard of production ceases to be maintained. A 17-inch lobster produces about 63,000 eggs.

(22) The largest number of eggs recorded for a single lobster is 97,440. In one case the lobster was 15 inches long and in another 16 inches. In neither was the animal able to fold its tail on account of the large number of its eggs. This suggests that the rudimentary condition of the swimmerets on the first abdominal somite in the female is necessary for the protection of the eggs. The egg-bearing female goes about with the tail folded. This would be impossible if these appendages were of the usual size and carried the usual number of eggs.

(23) The average weight of a 10½-inch female lobster with eggs is 1¾ pounds, the eggs weighing about 2 ounces. A 15-inch lobster, which weighs upward of 4 pounds, sometimes carries a burden of a pound of eggs. The number of fresh eggs in a fluid-ounce is about 6,440, and they weigh about 1 ounce avoirdupois.

(24) *Incubation period.*—The period of incubation for the summer eggs at Woods Hole is from 10 to 11 months, in one case lasting 335 days, from July 1, 1890, to June 1, 1891, when the young were just beginning to hatch out.

(25) The general range of the hatching period of summer eggs at Woods Hole is from May 15 to July 15. The greater number are hatched in June.

(26) The hatching of a single brood lasts in some cases over a week, owing to the slightly unequal rate of development of individual eggs.

(27) The period of incubation of the summer eggs varies with the temperature of the water. In Newfoundland the hatching period is said to be from three to six weeks later than at Woods Hole (15th or 20th of July to the 20th of August).

(28) The hatching period also varies with the time of egg-laying. Thus the hatching of young lobsters has been observed in November in Newfoundland and Woods Hole, and in February at Gloucester, Massachusetts.

(29) *Time of sexual maturity.*—Female lobsters become sexually mature when from 8 to 12 inches long. The majority of all 10½-inch female lobsters are mature. In 100 dissections recorded in table 20, 25 females were found, from 9 5/16 to 12 inches long, which had never laid eggs, but in 8 of these the ovaries were nearly ripe. Of the 17 immature, 6 were 10½ inches or over in length, and in most cases the ovaries would not have become mature for two years.

(30) *Frequency of spawning.*—The lobster does not spawn oftener than once in two years. The spawning interval is probably a biennial one, one set of eggs (summer eggs) being laid in July or August (at Woods Hole), and the following set in two years from that time. One has only to examine the ovary of a lobster (see fig. 138, plate 38) which has just hatched a brood—that is, one year from the time of the last spawning—to be convinced that annual spawning is an anatomical impossibility. The conclusion reached from a study of the growth of the eggs is confirmed by the percentage of egg-bearing females captured during the fall and winter. I have shown that conclusions deduced from statistics of this kind are often erroneous, especially when observations have been made in a single locality. When the results of the catch in the harbor of Woods Hole and off No Mans Land were averaged it was found that about one-half of the adult females had external eggs, which accords with the view that the spawning interval is a biennial one.

(31) *Relative abundance of the sexes.*—The relative number of males and females varies considerably in certain localities, as at No Mans Land, May, 1894 (table 22), especially in places affected by the inshore migrations, where the males seem to take the lead. In other places the number of the sexes is about equally divided; this would always be true if our observations were extended over a sufficient period and area.

(32) *Molting.*—By far the greater number of lobsters molt during the months of June, July, August, and September, but there is no month in which soft lobsters may not be caught. The male probably molts oftener than the female, which would accord with the larger proportion of soft male lobsters captured and with the greater size attained by the male.

(33) Molting lobsters are more often taken on sandy or weedy than on rocky bottoms.

(34) In preparation for the molt organic matter is absorbed from the shell, making it very brittle. Mineral salts are also extracted from certain definite areas of the carapace and chelipeds, an essential condition for the safe passage of the molt.

(35) In molting, the carapace is raised up behind and the body is drawn out through the opening thus made between carapace and abdomen. Normally, the shell comes off entire, and there is no break in any of the membranes except that between the carapace and the rest of the body. The flesh of the large claws is drawn through the narrow openings of the joints of the limb by the elasticity of the muscles and previous removal of blood from the extremity. This difficult process is also aided by the absorption of lime from certain joints of the old shell.

(36) The lining of the alimentary tract is molted, and the gastroliths which are left in the stomach are eventually dissolved. The gastrolith is a specialized part of the lining of the stomach. It is formed in a gastrolithic sac, which is an organ of excretion. It agrees in chemical composition with the rest of the shell, excepting in the greater proportion of calcium salts. The view that the function of the gastroliths is to supply the molting lobster with an immediate supply of lime for the hardening of its soft shell must be abandoned. The gastroliths more probably represent a mass of lime which

has been excreted in the course of absorption of mineral salts from certain areas of the shell. The subsequent assimilation of these bodies thus becomes of secondary importance. It was found that small lobsters (3 to 4½ inches long) filled their stomachs with fragments of dead shells of mollusks and crustacea, probably for the purpose of obtaining an immediate and abundant supply of lime for hardening the skeleton.

(37) *Hardening of the new shell.*—From six to eight weeks are necessary under ordinary conditions to produce a shell which is as hard as the one cast off, and lobsters destined for the market are in better condition in from ten to twelve weeks after molting.

(38) *Rate of growth.*—From the data at hand we conclude that the rate of growth varies considerably with the individual and its surroundings. The length of the young lobster when it hatches from the egg is about 7.84 mm., and the increase in length at each molt is about 15.3 per cent. The lobster molts from 14 to 17 times during the first year. A 10½-inch lobster has molted from 25 to 26 times, and is about 5 years old.

(39) *Regeneration of parts.*—All the appendages are capable of regeneration, the time required for this process depending upon the time of the accident with respect to the molting period and on the temperature of the water and the abundance of food. Defensive mutilation or autotomy is perfectly developed only in the large chelipeds.

(40) *Size.*—The greatest size attained by lobsters is about 25 pounds. This conclusion is reached after the examination of skeletons of large lobsters in museums and comparing them with the measurements of large lobsters of known weight. Most accounts of the weights of these animals are unreliable.

(41) The weight does not bear a constant relation to the length, owing to the occasional loss of the appendages. The large chelipeds alone contribute from one-quarter to one-half the weight of the entire animal, and in giants like the Belfast lobster the weight of the large chelipeds is more than two-thirds that of the entire body. The weight is also subject to great variation in consequence of the molt, when a heavy shell is exchanged for a much lighter one.

(42) The adult male is as a rule heavier than the adult female of the same length, and this difference increases with age in favor of the male.

(43) The egg-bearing females with eggs removed weigh less than the female lobster of the same length without external eggs.

(44) *Enemies.*—Every predaceous fish which feeds upon the bottom may be an enemy of the lobster. The cod is one of the most destructive to small lobsters, after the larval stages are passed.

(45) *Tegumental glands.*—Besides the hair pores, the shell is perforated by innumerable minute pore canals which lead into tegumental glands situated in the soft skin. Each gland has a capillary duct of its own which opens by a pore canal at the surface of the shell, and each has one or two peculiar cells which resemble nerve or ganglion cells. These organs are found widely diffused over the surface of the body, and they also occur in the walls of the œsophagus and intestine. It is probable that those in the swimmerets of the female secrete the cement by which the eggs are glued to the body, and that in some parts of the body, as in the labrum, they have a secondary sensory function, and are the organs of taste, but this is uncertain.

(46) *Color.*—The color variations of the lobster, some of which, like the red, blue, and cream colored types, are nonadaptive, and this is also true of the remarkable color

variations in the larvæ and older stages. The normal coloration of the lobster has, however, a protective significance.

(47) *Abnormal variations.*—Normally the large claws are differentiated for either cutting or crushing the food, but a rare variation occurs in which the same type of claw is developed on both sides of the body. The large crushing-claw may be either upon the right or left side of the body, but this is a question of heredity, and it is probable that all the young of a brood have the larger claw developed on the same side.

(48) *Repetition of parts.*—The large chelipeds of the lobster are especially liable to secondary outgrowths, which undergo a peculiar fission, giving rise to what appears at first sight as a double claw. It is usually a double part rather than a double appendage, although duplicate limbs occasionally occur.

(49) *Structure of ovary.*—When the ovary is ripe it is of a dark-green color and can be dimly seen through the membrane between the carapace and "tail." If the wall of such an ovary is cut the eggs immediately flow out in a stream. The eggs if immature invariably adhere together or to the substance of the ovary.

(50) After ovulation the ovary is collapsed, of an opaque white color flecked with green spots, ripe eggs which were left behind—or yellow spots, the remains of similar eggs from the last reproductive period. The presence of degenerate eggs thus proves that the animal has already become sexually mature and has previously laid eggs. The ovaries of lobsters which have never before produced eggs have a uniform tint—yellow, pink, gray, or green—and are unmistakable. (For histology of the organs, see Chapter X.)

(51) *Development of ova.*—The eggs are developed from mesodermic cells of the ovarian stoma, and the massive food yolk is derived from three sources: (1) From the protoplasm of the cells destined to become eggs; (2) from the degeneration of follicle cells, and (3) from the ovarian glands.

(52) When the lobster hatches, its reproductive organ is a minute cluster of cells $\frac{1}{44}$ mm. in diameter, and in the case of the female it takes from four to five years for the organ to reach maturity.

(53) The sperm cells are probably motile in the final stage of their history, but nothing is known either as to how the spermatophores are conveyed to the seminal receptacles or how the spermatozoa reach the eggs and fertilize them.

(54) *Young.*—The lobster hatches from the egg as a pelagic free-swimming larva. It lives at the surface of the ocean from six to eight weeks, when, after having molted five or six times, it goes to the bottom and appears in habit and general structure like a very small adult animal. After reaching the bottom it travels toward the shore and establishes itself in rock piles in harbors and at the mouths of rivers, where it remains until driven out by ice. At very low tide they can be found by digging away the loose stones. The smallest, from 1 to 3 inches long, go down deep among the loose stones, where they are secure from every enemy. When they reach the length of $3\frac{1}{2}$ to 4 inches they become bolder, leave their burrows in the rock piles, and seek the shelter of stones, beneath which they excavate a shallow hole. Young lobsters are also found in eelgrass and on sandy bottom in shallow water.

(55) At the time of hatching, the egg membranes burst into two halves and are drawn off over the head. At about the same time the little lobster sheds its entire cuticle; the plumose hairs which garnish its appendages are evaginated and, leaving its mother, it swims up to the surface. The first larva has long rowing exopodites on its thoracic appendages, and a six-jointed abdomen with spatulate telson. At the second

molt rudimentary abdominal appendages appear on the second to fifth abdominal somites, inclusive, and the branchial formula is completed.

(56) At the fourth molt it loses the use of its larval swimming organs, but still remains at the surface, propelling itself forward by its swimmerets and backward by flexion of the abdomen. It is now from three to four weeks old, is half an inch long, and has characteristic colors.

(57) After the fifth molt is passed the young lobster still swims at the surface, though it is possible that some leave it during this stage. When the sixth stage is reached, age five to six or eight weeks, length about three-fourths of an inch, it remains at the surface for a time at least, but goes to the bottom to stay before the seventh molt is passed. At the sixth molt all trace of the larval swimming organs is lost.

(58) The molts follow each other at rather short intervals, and during the first year of life, supposing the animal to have been hatched in June, the lobster molts from fourteen to seventeen times and attains a length of from 2 to 3 inches. The main facts of the subsequent life-history need not be repeated.

(59) The problem of artificial propagation of the lobster will be solved when means are devised by which the larvæ after hatching can be reared in large inclosures until the fifth or sixth stage, when they are able to take care of themselves.

(60) *Food of larvæ.*—The food of the larval lobster consists of minute pelagic organisms of all kinds. They show little discrimination at this time, snapping up any floating objects not too large for them to manage.

(61) *Heliotropism of larvæ.*—In the pelagic stages the young lobsters are positively heliotropic, rising to the surface in the daytime and staying there, and going down at night. This habit is not invariable, but the capture of the young by day is the rule, by night the exception.

(62) *Survival of larvæ.*—Great destruction is wrought upon the free-swimming stages by both animate and inanimate enemies. A survival of 2 in every 10,000 larvæ hatched would maintain the species at an equilibrium, and the destruction of the young under the present conditions of the fishery is probably even greater than this implies. (For a discussion of this subject see No. *97* of Bibliography.)

(63) The general scarcity of the young in the hatching season in places known to abound in lobsters is due (1) to their wide horizontal distribution, and (2) to their destruction.

(64) The whole course of development and later growth is slow. The slow larval development secures the necessary transportation from the shores and wide horizontal distribution, which is absolutely necessary for the life of the species. An abbreviated metamorphosis such as is found in this animal appears to be a compromise between a still longer development which the animal would have to go through if the egg possessed less yolk, and the limitations to protoplasmic activity which are imposed by the temperature of the North Atlantic Ocean.

For the facts pertaining to the development of the embryo the reader must refer to Chapter XIII, and for details and the discussion of general questions to the body of the work.

Appendix I.—PREPARATION OF THE EGGS.

The eggs of the lobster may be easily prepared for the study of the external surface in the following way: The fresh eggs are to be placed in either fresh or salt water, which is heated to near the boiling point, until the green pigment coloring the yolk is permanently converted into bright red lipochrome (see p. 137). They should then be transferred to cold water and shelled under the dissecting microscope. The eggshell when distended slightly with water may be removed by means of very fine-pointed forceps, nipping the shell and holding it with one pair of forceps while the shell is ruptured and the egg carefully released with the other pair.

There are two periods in the course of development when it is difficult to remove the shell without injury to the embryo. These are at the close of segmentation, when the blastoderm secretes a fine membrane, which becomes soldered to the shell so that when the latter is removed the blastoderm itself is torn away; and, secondly, either during the egg-nauplius stage or shortly after it. In the early egg-nauplius two membranes can be removed, an outer thick one, the eggshell (composed of the primary and secondary egg membranes), and an inner cuticle, the secreted product of the embryo. This last usually sticks to the tips of the antennæ, the second pair in particular, and carries them with it when it is removed. It sometimes happens that the entire embryo is thus stripped off.

After shelling, the eggs should be placed at once in Mayer's concentrated picro-sulphuric acid, and left from two to three hours. They may be then transferred to 70 per cent and finally to 80 per cent alcohol, and the latter should of course be changed until all trace of the yellow salt is removed.

I have frequently made use of 70 per cent alcohol instead of water in making up the picro-sulphuric acid solution, and it is usually successful. I used it with excellent results ten years ago in studying the eggs of Alpheus, but the aqueous solution is perhaps better on the whole. I have tried a great variety of killing and fixing reagents, but none are to be compared for reliability with picro-sulphuric acid in the concentrated form.

The eggs are stained by placing them in a vial of borax-carmine for the space of two to three minutes or longer, just long enough to stain the surface cells only. The diffuse stain must then be thoroughly removed by acidulated alcohol until the eggs have a light-yellow color, the nuclei of surface cells only being stained red. Turpentine is one of the best clearing reagents, none of the essential oils in common use—oil of cloves, origanum, thyme, or bergamot—offering any appreciable advantage over it.

Clearing requires but a few minutes, and while it is in progress the eggs should be placed in a solid watch glass with turpentine, and examined under a dissecting microscope. With a very small and thin knife they may be cut into halves in any desired plane. It is better to roll the egg under the knife edge, and thus cut into the surface all the way round before pressing the knife through the egg. The eggs cut like cheese at first, but later become brittle and are very apt to break if left in turpentine for too long a time. It is thus best to place a few at a time in the clearing fluid, and cut them at once.

In the treatment of these eggs I have profited by the experience and advice of my friend Dr. William Patten, whose method of mounting the ova of Arthropods,[1] and orienting them for the microtome, which I have essentially followed, leaves little to be desired. A cell is made of strips of cardboard of the desired thickness, and the respective hemispheres of each egg are fixed in place by a small drop of concentrated Schallibaum's fixative. The cell may be flooded with turpentine while the process of fixation is going on, and when drained thick balsam is added and the cover glass is afterwards applied. In this way the most perfect and beautiful preparations can be made.

Eggs are hardened in the same way, when the object is to cut them into sections. They may be successfully embedded in either paraffin or celloidin. Bumpus has described his successful use of the latter reagent, which he heartily recommends.[2] This method is undoubtedly the surest although the most laborious to pursue. I have obtained excellent sections of the early and late stages of development by the paraffin method, and for the older embryos it is certainly preferable. Turpentine and all the essential oils soon harden the yolk so that it firmly resists the knife. The eggs should therefore be allowed to remain in the clearing fluid for the shortest possible time only, and then thoroughly saturated with paraffin. The method which Patten has given for orientation can hardly fail to meet with success.

Appendix II.—COMPOSITION OF THE SHELL AND GASTROLITHS OF THE LOBSTER.

[By ALBERT W. SMITH, Ph. D., *Associate Professor of Chemistry in the Case School of Applied Science.*]

The analyses of the shell of the lobster were made from four distinct individuals, taken at Woods Hole, Massachusetts (Nos. 1 to 4 in the table below), and were selected with reference to the molting period. The description of the shells and lobsters from which they were taken is as follows:

No. 1. Hard-shell female with external eggs, August 3, 1894.

No. 2. A hard-shell female lobster near the point of egg-laying; length, 11 inches; July 16, 1894. The ovarian eggs of this lobster were mostly absorbed. (See p. 48.)

No. 3. From a female near the point of molting; length, 10 inches; August 2, 1894. (The gastroliths of this "shedder" are described on p. 89, and their chemical analysis is given in No. 3*a* of the following table.)

No. 4. The molted shell of a male 11 inches long. (See No. 2, table 24, and p. 89.)

The gastroliths subjected to analysis have the following history:

No. 0*a* is taken fresh from the gastrolithic sac of a "shedder." (For drawing of this gastrolith separated into its constituent spicules see fig. 165, plate 42.)

No. 3*a* is from lobster No. 3 of this table, taken fresh from the gastrolithic sac of the animal shortly before it was ready to molt.

No. 4*a* is from the lobster which cast off shell No. 4 of this table, taken from the stomach of the animal when soft and preserved in alcohol. (For drawings of this gastrolith see cut 8, plate C; for description of lobster No. 2, table 24.)

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[1] Orienting Small Objects for Sectioning, and "Fixing" them, when Mounted in Cells. (American Naturalist, vol. 28, pp. 360–362, 1894.)

[2] American Naturalist, vol. 26, pp. 80–81, 1892.

Table showing composition of the shell and gastroliths of the lobster.

Composition—air dried.	Carapace.				Gastroliths.		
	1.	2.	3.	4.	0*a*.	3*a*.	4*a*.
Weight in grams	11.87	21.51	8.48	9.12	1.37	.....	3.96
Calculated as calcium oxide—CaO	22.87	23.11	24.94	30.41	45.85	49.14	50.82
Magnesium oxide—MgO	3.18	1.14	1.61	1.30	0.30	0.40	0.48
Aluminum oxide—Al_2O_3—(Fe_2O_3)	0.68	2.04	1.04	1.36	0.20	0.04	0.06
Sodium oxide—Na_2O	0.89	1.06	1.35	1.67	1.09	1.34	0.55
Silica—SiO_2	0.14	0.29	0.08	0.46	0.10	0.06	0.08
Phosphoric anhydride—P_2O_5	3.53	3.81	5.12	4.36	4.43	4.16	5.12
Sulphuric anhydride—SO_3	0.34	0.31	0.58	0.40	0.07	0.08	0.35
Carbonic dioxide—CO_2	21.20	17.05	17.70	23.00	37.00	37.10	35.00
Water at 100° C—H_2O	.....	7.40	.....	.....	.....	.....	3.50
Calculated as calcium carbonate—$CaCO_3$	43.68	32.83	32.93	44.60	72.44	78.87	78.46
Calcium phosphate—$Ca_3(PO_4)_2$	7.70	8.32	11.18	9.52	9.67	9.08	11.18
Calcium sulphate—$CaSO_4$	0.58	0.53	0.99	0.68	0.12	0.14	0.59
Magnesium carbonate—$MgCO_3$	3.50	2.39	3.38	2.73	0.63	0.84	1.01
Sodium carbonate—Na_2CO_3	1.51	1.80	2.31	2.85	1.87	2.28	0.93
Alumina, Al_2O_3—(Fe_2O_3)	0.68	2.04	1.04	1.36	0.20	0.04	0.06
Silica—SiO_2	0.14	0.29	0.08	0.46	0.10	0.06	0.08
Organic matter and water, by difference	42.21	51.80	48.09	37.80	14.97	8.69	7.69

As will be seen by reference to the table the principal part of the mineral structure in the carapace is made up of carbonate of calcium, with some considerable proportion of calcium phosphate and of magnesium compounds. The gastroliths differ in being much more largely mineral, and in consisting almost entirely of carbonate and phosphate of calcium. All of the specimens contained iron, its quantity being so small that it was not thought advisable to make a separation of it from the aluminum. A minute proportion of potassium also was present in every case, but its quantity was so small that it was detected with difficulty by the spectroscope in the separated alkali salts.

No successful determination of the quantity of chitin in the carapace was attained, and no separation of any of the other organic constituents was attempted. The total quantity of organic matter and water is reported as the difference between the sum of the calculated percentages of inorganic salts and 100.

The portion of the shell subjected to analysis was taken in each case from the carapace, from the part bounded by the cervical groove in front and the branchiocardiac groove above.

Appendix III.—BIBLIOGRAPHY.

In the following bibliography the literature of the lobster, especially that relating to its habits and development, will be found to be fairly complete. All papers possessing scientific or historical interest to which reference is made, though some of them are of minor importance, have been included.

Since, in my chapter on the embryology of this species, I have not entered into the comparative development of the crustacea, it has been necessary to refer to but few general works, and all physiological papers have been omitted when not in the direction of my studies.

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Appendix IV.—DESCRIPTION OF PLATES.

PLATE 1.

Fig. 1. The Belfast lobster. Dorsal view of male lobster, captured at Belfast, Maine, May 6, 1891. Living weight a little over 23 pounds. From photograph of skeleton. Original in possession of the author. For detailed measurements see table 30, No. 1. A little less than one-fourth natural size.

PLATE 2.

Fig. 2. Ventral view of large lobster shown in plate 1.

Fig. 3. Ventral view of small lobster for comparison with fig. 2. Egg-bearing female; length 9¾ inches; weight about 1¼ pounds. Most of the eggs which were attached to the abdomen have been removed.

Both figures reproduced from photograph. About one-fourth natural size.

PLATE 3.

Fig. 4. Profile view of living red lobster. Female, length 11⅝ inches; weight about 2 pounds. Captured near Mount Desert, Maine. From photograph from life, April 10, 1894. For colored drawing of this lobster see plate 16, fig. 21. A little over one-half natural size.

PLATE 4.

Fig. 5. Adult male lobster, dorsal view. Length $12\frac{1}{16}$ inches; weight 2 pounds 14 ounces. From photograph from life, December 8, 1893. A little under one-half natural size. Membrane between thorax and abdomen unnaturally distended.

This lobster, with those represented by the three following plates, figs. 5–8, was captured at Woods Hole, Massachusetts, December, 1893, and sent alive to Cleveland, Ohio.

PLATE 5.

Fig. 6. Adult male. Ventral view of lobster shown in plate 4. From photograph from life. A little under one-half natural size.

PLATE 6.

Fig. 7. Adult female lobster with external eggs, dorsal view. Length $11\frac{9}{16}$ inches; weight 1 pound 13 ounces. From photograph from life. A little over one-half natural size.

PLATE 7.

Fig. 8. Adult female. Ventral view of lobster shown in plate 6. The dark-green eggs attached to the swimmerets under the tail are very clearly seen. A colored sketch of one of these eggs, showing the contained embryo, and a cluster of eggs from the swimmerets are represented by *figs.* 25, 26, plate 17. One-half natural size.

A lobster of this size produces on the average about 19,000 eggs. The seminal receptacle is seen between the bases of the third and fourth pairs of walking legs. Compare this with the organ as it appears in the immature lobster shown in plate 11.

PLATE 8.

Fig. 9. Immature female lobster, dorsal view; length 44 mm. (1.73 inches). From photograph, life-size. Casco Bay, Maine, October, 1893. See table 32, No. 2, for further details.

This and the immature or adolescent lobsters represented by plates 8–13, figs. 9–18, were collected in Casco Bay, Maine, in Small Point Harbor and vicinity, from August 31 to October 19, 1893. The photographs were all made from the alcoholic specimens. They are described in table 32, pp. 163–165. All are life-size.

Fig. 10. Immature male lobster; length 40.3 mm. (1.59 inches). See No. 1, table 32. The right cutting-claw is smaller than is normal, due to the fact that it has been recently cast off and is now only partially restored. (See Chapter IV.)

Fig. 11. Immature female lobster; length 64 mm. (2.5 inches). No. 7, table 32.

Fig. 12. Immature male lobster; length 58 mm. (2.28 inches). No. 5, table 32.

PLATE 9.

Fig. 13. Immature female lobster; length 75.6 mm. (2.98 inches). No. 16, table 32. The right cutting-claw is smaller than normal. See fig. 10, pl. 8, with description given above. From photograph; life-size.

Fig. 14. Immature male lobster; length 67 mm. (2.64 inches). No. 8, table 32. From photograph; life-size.

PLATE 10.

Fig. 15. Immature female lobster; dorsal view; length 86.5 mm. (3.41 inches). No. 21, table 32. From photograph; life-size.

PLATE 11.

Fig. 16. Ventral view of immature female lobster shown in plate 10. Length 86.5 mm. (3.41 inches). No. 21, table 32. From photograph; life-size. The seminal receptacle is seen between the third pair of walking legs. The normal rudimentary condition of the first pair of swimmerets is also well shown. Compare with plate 7.

PLATE 12.

Fig. 17. Immature male lobster; length 92.3 mm. (3.64 inches). No. 23, table 32. From photograph; life-size.

PLATE 13.

Fig. 18. Immature male lobster; length 110 mm. (4.34 inches). No. 32, table 32. From photograph; life-size.

PLATE 14.

Fig. 19. Male lobster showing abnormal, symmetrical development in large claws. Instead of the usual differentiation of the great claws, one for crushing, the other for cutting (well shown in fig. 6, pl. 5), both are here similar and belong to the cutting type. Length 10 inches; taken at Woods Hole, Massachusetts. See p. 144. From photograph from alcoholic specimen; about four-fifths life size.

PLATE 15.

Fig. 20. Right crushing-claw of lobster, probably a male, preserved in the museum of the Peabody Academy of Science, Salem, Massachusetts: Estimated weight of live lobster, about 25 pounds; weight of skeleton of claw (including the fifth joint or carpus), the parts shown in the drawing, 16¾ ounces. Natural size.

Fig. 20*a*. Right crushing-claw of female lobster, of about average size; length 11 inches; weight 1¼ pounds; shell fairly hard. Captured at Woods Hole, Massachusetts, July 24, 1894. Natural size.

This drawing of the claw of a lobster of average size, placed by the side of the mammoth specimen for the sake of comparison, shows more forcibly than words or figures can the great difference in size which may exist between adults of the same species. Both drawings are life-size, and to insure accuracy their outlines were carefully traced from the objects themselves. The living weight of the smaller claw (including the entire limb) was about 10 ounces, that of the larger about 10 pounds. (See p. 115.)

PLATE 16.

Fig. 21. Red female lobster, colored from life. Length 11⅜ inches; weight about 2 pounds. Captured in the vicinity of Mount Desert, Maine, April, 1894. An examination of the reproductive organs showed that the lobster had not yet reached sexual maturity. For photograph of this lobster see plate 3. A trifle under one-half life-size.

Fig. 22. Adult male lobster, colored from life. Length 10 inches; weight about 1¼ pounds; shell moderately hard. Woods Hole, Massachusetts, August 14, 1891. About two-thirds life-size.

PLATE 17.

Fig. 23. Eggs of lobster showing an unusual color variation. Drawn from life. The embryo was somewhat past the egg-nauplius stage. The lobster, which was 12½ inches long and weighed 2 pounds 5 ounces, was captured at Woods Hole, Massachusetts, December 4, 1893, and sent to me alive. These eggs turned a very light salmon-color when boiled. Six times natural size.

Fig. 24. Cluster of fresh eggs of lobster, colored from life. Laid in aquarium at the United States Fish Commission station, Woods Hole, Massachusetts. Drawn August 11, 1893. When first examined the eggs were closely adherent, and the glue which bound them together was very soft. The ovary of the lobster was examined on August 17; it was of small size, and contained but few unextruded eggs, which were partially absorbed. About 6 times natural size.

Fig. 25. Cluster of egg embryos from swimmerets of female shown in plate 7. Drawn from life December 7, 1893 The entire mass of eggs are attached to each other and to the setæ or hairs of the swimming feet, as shown in the drawing. A single detached seta with a number of eggs glued to it is here represented. About 13 times natural size.

Fig. 26. Profile view of embryo released from eggshell; taken from a cluster like that in fig. 25. Drawing made December 12, 1893, after killing the embryos with hot water. Embryos from the same lobster (see fig. 8) lived eight days in damp seaweed, in a cool room, and could apparently have been kept alive under the same conditions for a much longer time. Enlarged 33 times.

Fig. 27. Side view of embryo, as seen through the transparent shell. Drawn and colored from life. Eggs from same batch as those shown in fig. 25; female represented by plate 7. The conspicuous green yolk, which is restricted to the upper half of the egg, fills the cavity of the mid-gut. This eventually forms the "liver" or gastric glands, the anterior lobes of which are clearly seen in fig. 28. The clear space to the right (on the lower side in fig. 28) represents the heart. Below it the intestine joins the mid-gut. The eye is shown as it appears in reflected light in fig. 27, as in transmitted light in fig. 28. (See p. 169.) Enlarged 33 times.

Fig. 28. Dorsal view of embryo shown in fig. 27. Enlarged 33 times.

PLATE 18.

Fig. 29. Lobster hatching. Drawn from life July 5, 1891. The membrane of attachment (secondary egg membrane) has split along the middle line and is being drawn off over the head. The inner part of the shell (primary egg membrane or "chorion") invested the embryo as an exceedingly delicate, transparent membrane, and was ruptured (above the eyes) by needles in order to show it. When the outer membrane is borne away it usually drags the delicate inner one with it. Enlarged 33 times.

Fig. 30. Lateral view of a lobster, teased from an egg which was about ready to hatch, to show the embryonic cuticle which must be shed before the first swimming larval stage is reached. The healthy embryo sheds this skin either at the time of its escape from the eggshell or very soon after it. The intestinal concretions are clearly seen in both this and the preceding figures. The pigment cells of the skin and other details are purposely omitted. Drawn from life. Enlarged about 33 times.

Fig. 31. Profile view of lobster in fifth stage. General color reddish-brown. Pigmentation of skin not represented. Rudimentary exopodites of thoracic appendages present. Length 16 mm. July 2, 1891. Enlarged 9 times.

PLATE 19.

Fig. 32. First swimming stage of the lobster, usually called the first larva or the first schizopod stage. Dorsal view. Drawn from life July 3, 1890. The bright vermilion pigment cells or chromatophores of the skin are here expanded under stimulation. Under some conditions they contract, and the animal becomes very pale-blue, in consequence of the blood pigment. The stomach-bag on the middle line behind the eyes, the lobes of the yellow "liver" on either side of this, the heart behind the stomach, and the intestine passing beneath this from the stomach to the hinder end of the body, are clearly discerned through the transparent shell. The yellow cast of color is rather too pronounced, especially in the abdomen. For color of eyes, see p. 169, and fig. 27. Length about 7.8 mm. ($\frac{3}{10}$ inch). Enlarged 22 times.

PLATE 20.

Fig. 33. Profile view of the first larva of the lobster. Length about 8 mm. July 22, 1891. The transparency of these larvæ is often very great, and many of the organs, such as the heart, gills, and alimentary tract, are seen with great clearness through the shell. (Compare fig. 32.) The "liver" or gastric gland, usually of a golden-yellow color and resembling a cluster of grapes, is the most voluminous and conspicuous of the internal organs. The shading by stipple in this and the two following plates is purely conventional, no attempt being made to represent the pigmented skin. Enlarged 30 times.

PLATE 21.

Fig. 34. Second larva; profile view; drawn to the same scale as fig. 33. The second larval stage is preceded by the second molt. Beside the striking increase in size in all the parts of the body, the most important changes are the growth of the antennæ and the appearance of rudimentary legs or swimmerets on the under side of the abdomen—upon the second to fifth somites, inclusive. Length about 9 mm. (0.35 inch). Enlarged 30 times.

PLATE 22.

Fig. 35. Third larva; lateral view. Drawn July 15, 1891. The principal changes which are emphasized at the third molt concern the antennæ, the growth of the thoracic appendages, chiefly seen in the large claws, and the acquisition of the last pair of abdominal appendages, which, with the telson, constitute a very important locomotor organ, the propeller or tail fan. Length 11.1 mm. (0.44 inch). Enlarged 22 times.

PLATE 23.

Fig. 36. Fourth larva; dorsal view. Length 14.6 mm. Drawn and colored from life August 7, 1891. This represents the average normal color of this stage, yet, as will be seen in Chapter XII, this is subject to considerable variation. The brilliant peacock-green or intense yellow-green spots upon the carapace and abdominal segments are characteristic of this period, but it is difficult to represent these pigments in their natural glow and purity. Enlarged 10½ times.

PLATE 24.

Fig. 37. Sixth stage; dorsal view. Outline from a young lobster 15.3 mm. long, July 14, 1891; coloring from lobster No. 3, table 34, in sixth stage raised from fourth larva; length 15.5 mm. Enlarged $8\frac{3}{10}$ times.

PLATE 25.

Fig. 38. Young lobster in sixth stage; profile view. Raised from the egg; lobster No. 36, table 34. Length 16 mm. Drawn and colored from life July 30, 1892. The white spots or tendon-marks on the carapace are very characteristic of this period. They are somewhat less prominent in the fifth stage. The fifth stage usually resembles the sixth very closely, particularly in color. Enlarged 11½ times.

PLATE 26.

Fig. 39. Young, immature lobster; male. Length 47 mm. Drawn and colored from nature July 18, 1891. This animal was injured and brought up by accident in a lobster pot in Woods Hole Harbor. (No. 22, table 33.) Enlarged 2⅞ times.

PLATE 27.

[The stage or molt to which each drawing belongs is shown by roman numerals on plates 27 to 35.]

Fig. 40. Right first antenna of first larva, from below. The inner branch or flagellum of this appendage is now present as a very small unsegmented rudiment, which grows out of the primary stalk from its under side toward the middle line. 36 times natural size.

Fig. 41. Left first antenna of second larva, from below. Segmentation of flagellum of exopodite not yet visible, or but faintly marked; endopodite tipped with one long and one or two short setæ; shows slight traces of segmentation. Nine bunches of olfactory setæ present, 4 to 6 in a bunch, distributed in two longitudinal rows. 36 times natural size.

Fig. 42. Left first antenna of third larva, from below. Segmentation of flagella more marked. Outer and inner branches separated by pressure. 36 times natural size.

Fig. 43. Left first antenna of fourth larva, from above. Masses of brown pigment are seen in the auditory chamber. Segmentation of parts very distinct. *au*, auditory organ. 36 times natural size.

Fig. 44. Left first antenna of fifth stage, from below. Lobster No. 3, table 34. Parts shown in natural position. 36 times natural size.

Fig. 45. Right first and second antennæ of first larva, from above. Inner edge of exopodite of first antenna bears a fringe of 22 to 23 plumose setæ. 36 times natural size.

Fig. 46. Right second antenna of second larva, from above. 36 times natural size.

Fig. 47. Left second antenna of third larva, from above. 36 times natural size.

Fig. 48. Left second antenna of fourth larva, from below. Flagellum divided into 40 segments. 36 times natural size.

Fig. 49. Proximal portion of left first and second antennæ of lobster in fifth stage, seen from below. Lobster No. 28, table 34. Drawn without pressure. *gr*, papilla on which green gland opens. 36 times natural size.

PLATE 28.

Fig. 50. Left first and second antennæ of fifth larva, as seen from above. From lobster No. 28, table 34. 36 times natural size.

Fig. 51. Right first maxilla of first larva, from anterior face. 153 times natural size.

Fig. 52. Terminal joint of left fifth pereiopod of first larva from anterior side. 50 times natural size.

Fig. 53. Tip of endopodite of first maxilla of first larva. 45 times natural size.

Fig. 54. Front view of mouth and surrounding parts—labrum, metastoma, and mandibles—of first larva. Dark-red chromatophores occur on the mandibles and labrum. The mandibular palp sometimes carries two setæ at its tip. 154 times natural size.

Fig. 55. Right mandible of fourth larva, from behind, showing groove and cutting edge. 36 times natural size.

Fig. 56. Left mandible of fourth larva, from outer side. Hard, chitinous part next to cutting edges, bluish steel color. 50 times natural size.

Fig. 57. Mandibles of fifth larva, from anterior side. Drawn from the molted shell of lobster No. 23, table 34, August 10, 1892. Length of larva before molt 13 mm. 36 times natural size.

PLATE 29.

Fig. 58. Left first maxilliped of first larva, from the inner side. 125 times natural size.

Fig. 59. Left first maxilliped of fourth larva, from outer side, showing tegumental glands in second segment (basis). 52 times natural size.

Fig. 60. Right second maxilla of first larva, from outer side. 153 times natural size.

Fig. 61. Right first maxilla of fourth larva, from inner side. 52 times natural size.

Fig. 62. Right first maxilla of fifth larva, from outer side, showing tegumental glands in second segment (basis). Drawn without pressure. From lobster No. 27, table 34. 50 times natural size.

PLATE 30.

Fig. 63. Left second maxilliped of first larva, from anterior face. Epipodite is developed on basis; no distinct podobranchia. 50 times natural size.

Fig. 64. Left second maxilliped of fourth larva, from anterior face. Podobranchia present, but rudimentary as in the adult. 36 times natural size.

Fig. 65. Right third maxilliped of fourth larva, from dorsal surface, natural position. 22 times natural size.

Fig. 66. Left first pereiopod of first larva, from below. The arthrobranchiæ which issue from the membranes between the body and appendage, and are sometimes torn off with the latter, are also shown in fig. 65. 52 times natural size.

Fig. 67. Left first pereiopod of fourth larva, from below. The small tubercles of the chelæ are scarcely visible in this position. The exopodite (compare fig. 66), now a short rudiment at the base of the appendage, does not entirely disappear until the fifth molt. 22 times natural size.

Fig. 68. Part of left third maxilliped of fourth larva, from below, showing serrated inner margin of third segment. 22 times natural size.

Fig. 69. Left third maxilliped of first larva, from above. 50 times natural size.

PLATE 31.

Fig. 70. Left fourth pereiopod of first larva, from above. 50 times natural size.

Fig. 71. Serrated spine from propodus of left second pereiopod of fourth larva. 153 times natural size.

Fig. 72. Telson of embryo with eye pigment, July 26. Picro-sulphuric acid preparation; teased from egg in glycerin. 22 times natural size.

Fig. 73. Right second pereiopod of first larva, from the side. 50 times natural size.

Fig. 74. Left second pereiopod of fourth larva, from above. 22 times natural size.

Fig. 75. Left fifth pereiopod of fourth larva, from above. 22 times natural size.

Fig. 76. Left fourth pereiopod of fifth larva, from above. The podobranchia with epipodite, the arthrobranchiæ and the pleurobranchia are here shown. 30 times natural size.

Fig. 77. Antennæ of embryo, the telson of which is shown in fig. 72. 22 times natural size.

PLATE 32.

Fig. 78. Bud of first left abdominal appendage of fifth larva; length of larva 14 mm. Drawn from molted shell of lobster No. 36, table 34. July 30, 1892. 63 times natural size.

Fig. 79. Seminal receptacle of female. Lobster No. 17, table 33. Length of lobster 35 mm. 14 times natural size.

Fig. 80. Left first abdominal appendage of lobster No. 37, table 34; eighth stage; length 19.75 mm. (0.78 inch); raised from egg. 63 times natural size.

Fig. 81. Ventral view of young female lobster; length 51.8 mm. (2.04 inches); No. 19, table 33. The seminal receptacle is here shown in process of development. Compare with plate 11. 5.3 times natural size.

Fig. 82. Left first abdominal appendage of the sixth stage of development. From lobster No. 34, table 34. Drawn from molted shell. Length of lobster in sixth stage 16.3 mm. 63 times natural size.

Fig. 83. Left first abdominal appendage of lobster No. 34, table 34, in seventh stage. Length of lobster 18 mm. (0.71 inch). 63 times natural size.

Fig. 84. Left first abdominal appendage of lobster in sixth stage. No. 36, table 34; length of lobster 16 mm. 63 times natural size.

Fig. 85. Left first abdominal appendage of female in eighth stage. Lobster No. 3, table 34. Length of lobster 21.2 mm. Appendage segmented into two parts. For ventral view of thorax of this lobster see fig. 89. 63 times natural size.

Fig. 86. Left first abdominal appendage of female. Lobster No. 17, table 33. Length of lobster 35 mm. (1.39 inches). 14 times natural size.

Fig. 87. Left first abdominal appendage of male. No. 18, table 33. Length of lobster 36.3 mm. (1.43 inches). 14 times natural size.

Fig. 88. Left first abdominal appendage of female. No. 19, table 33. Length of lobster 51.8 mm. (2.03 inches). For seminal receptacle of this lobster see fig. 81. 14 times natural size.

Fig. 89. Ventral view of female lobster in eighth stage. From lobster No. 3, table 34. Length of lobster 21.2 mm. (0.83 inch). For first abdominal appendage of this lobster, see fig. 85; for color in sixth stage, see pl. 24. 5.3 times natural size.

Fig. 90. Left first abdominal appendage of young male. Length of lobster 19.3 mm. (0.76 inch) eighth stage. August 14, 1892. 63 times natural size.

Fig. 91. Ventral view of young male. No. 1, table 32. Length of lobster 40.3 mm. (1.59 inches.) 3.5 times natural size.

PLATE 33.

Fig. 92. Left cheliped of fourth larva (No. 23, table 34) in process of regeneration from stump, seen from below. Length of larva 13 mm. Drawn from molted shell of fourth larval stage August 9, 1893. *X*, plane of fracture. *1–7*, segments of limb. 22 times natural size.

Fig. 93. Left fourth pleopod of second larva, from outer face. 95 times natural size.

Fig. 94. Left second pleopod of third larva, from outer face. 36 times natural size.

Fig. 95. First abdominal segment of shell of lobster No. 34, table 34, in sixth stage, seen from behind. Raised from egg, and followed from third larval stage. Length of lobster 16.3 mm. A colored drawing of this lobster is given in fig. 38, plate 25, and a drawing of the first abdominal appendage in fig. 82. 16 times natural size.

Fig. 96. Left cheliped of molted shell of fifth larva, seen from above. Regenerated from the condition shown in fig. 92 after the intervention of a single molt. *X*, plane of fracture. *1–4*, segments of limb. 22 times natural size.

Fig. 97. Left second pleopod of fourth larva, from anterior face. *end*, endopodite. 36 times natural size.

Fig. 98. Sterna of the last three thoracic somites of fifth larva. From No. 36, table 34. Length of lobster 14 mm.; sex doubtful. July 30, 1892. 47 times natural size.

Fig. 99. Left fourth pereiopod of fourth larva, in process of regeneration. No. 23, table 34. Length 13 mm. *1–7*, segments of limb. 22 times natural size.

Fig. 100. Right second antenna of lobster in seventh stage, in process of regeneration, seen from above. No. 34, table 34. Drawn from molted shell, August 8, 1892. 22 times natural size.

PLATE 34.

Fig. 101. Respiratory organs of second larva, from left side. 8–14, appendages of corresponding somites of body. 36 times natural size.

Fig. 102. Telson of second larva, from above. 36 times natural size.

Fig. 103. Telson of first larva, from above. 50 times natural size.

Fig. 104 Caudal fan of third larva, from below. 36 times natural size.

Fig. 105. Caudal fan of fourth larva, from above. Alcohol-glycerin preparation. Setæ all plumose. 30 times natural size.

Fig. 106. Podobranchia of left second pereiopod of lobster, probably in fourth stage, from inner side. The gill now carries four rows of branchial filaments. 36 times natural size.

PLATE 35.

Fig. 107. Left first antenna of the embryo shown in figs. 27, 28, plate 17. Frontal view. 63 times natural size.

Fig. 108. Right second antenna of the same embryo, from below. 63 times natural size.

Fig. 109. Rostrum of second larva, from above. 37 times natural size.

Fig. 110. Profile view of carapace of first larva. 13 times natural size.

Fig. 111. Profile view of carapace of second larva. 13 times natural size.

Fig. 112. Profile view of carapace of third larva. 13 times natural size.

Fig. 113. Profile view of carapace of fourth larva. From molt, July 15. Dorsal view of same given in fig. 115. The entire outer surface is now studded with short setæ. 13 times natural size.

Fig. 114. Profile view of carapace of fifth larva, showing tendon marks. General color of larva brownish-green; carapace brown. 6 times natural size.

Fig. 115. Dorsal view of carapace of fourth larva, from molted shell. Profile view of same is given in fig. 113. The median area of absorption is now a broad band which widens in the rostral regions and unites with the cervical groove on either side to form a cross-shaped figure. 13 times natural size.

PLATE 36.

Fig. 116. Section of reproductive organ of embryo near time of hatching. 513 times natural size.

Fig. 117. Section of right reproductive organ of first larva. *R. O.*, reproductive organ. 513 times natural size.

Fig. 118. Right second antenna of an adult female lobster, overgrown with algæ (chiefly *Ulva* and *Laminaria*), seen from above. Length of lobster about 10½ inches Taken from lobster pound at Vinal Haven Island, Maine, August 26, 1893. Two-thirds natural size.

Fig. 119. Oviduct and part of ovarian lobe from left side, showing a row of unextruded eggs in duct. Length of female about 10 inches. External eggs in yolk segmentation. Woods Hole, Massachusetts, August 3, 1894. *od*, oviduct. Two-thirds natural size.

Fig. 120. Reproductive organs of adult male lobster from above. Duct of testis in natural position on right side, dissected out on the left. Dotted lines (*1* to *5*) mark planes of section of the vas deferens and refer to figures on plate 37. *a*, proximal segment; *b*, glandular segment; *c*, ductus ejaculatorius; *in*, intestine; *gg*, gastric gland. Two-thirds natural size.

Fig. 121. Disk-shaped concretion, probably containing glycogen, from maxilla; cracked by pressure. 133 times natural size.

Fig. 122. Large granular cell from first maxilliped, probably glycogenous in function. August 17, 1893. 733 times natural size.

Fig. 123. Reproductive organs of adult female dissected out, viewed from above; ovary nearly ripe. Length of lobster 10⅝ inches. No. 77, table 20. August 21, 1890. *od*, oviduct. Two-thirds natural size.

PLATE 37.

Fig. 124. Transverse section of proximal end of vas deferens of adult lobster. Plane of section marked "1" in fig. 120. Duct filled with sperm; lining-epithelium consists of small flat cells. This and figs 125–128 are from the same organ and illustrate the anatomy of the different parts of the male duct. *sp*, sperm cells; *mb*, connective tissue sheath of duct. 36 times natural size.

Fig. 125. Transverse section of vas deferens of adult lobster. Plane of section marked "2" in fig. 120. *ep*, epithelial lining of duct. 36 times natural size.

Fig. 126. Transverse section of vas deferens of adult lobster, showing thick muscular walls. Plane of section marked "4" in fig. 120. *c. mu*, circular muscles; *l. mu*, longitudinal muscles; *Bl. S.*, blood sinus. 36 times natural size.

Fig. 127. Part of transverse section of vas deferens, in plane marked "5" in fig. 120. *bm*, basement membrane; *c. mu*, circular muscles; *ep*, epithelial lining constituting the spermatophoral glands; *l. mu*, longitudinal muscles; *mb*, membranous sheath. 190 times natural size.

Fig. 128. Part of transverse section of vas deferens through glandular portion, in plane marked "3," fig. 120, showing spermatophores, contained sperm and glandular lining-epithelium. The gelatinous spermatophore is a secretion of the latter. *a*, *b*, compartments of duct; *f*, inward fold of epithelium of duct; *Sp*, sperm; *Spr*, inner gelatinous substance of spermatophore. 36 times natural size.

Fig. 129. Ripe sperm cells: *b*, *c*, from the vas deferens of an adult male and *a*, from the seminal receptacle of a female. About 550 times natural size.

PLATE 38.

Fig. 130. Seminal receptacle of adult female, from above. Natural size.

Fig. 131. Ovaries of immature lobster, seen from above. Length of lobster 44 mm. (1.73 inches). Length of ovary 15 mm.; diameter of lobe ¼ mm. From No. 2, table 32. Color opaque white. Oviducts, though undoubtedly present, not seen in dissection. Natural size.

Fig. 132. Ovaries of immature lobster, seen from above. Length of lobster 74.5 mm. (2$\frac{1}{16}$ inches). Length of ovary 41 mm.; diameter of lobe 1 mm. From No. 98, table 20. Natural size.

Fig. 133. Egg teased from fresh ovary shown in fig. 138. Represents relative size of ovarian eggs one year older than those shown in fig. 134. 44 times natural size.

Fig. 134. Ova teased from fresh ovary shown in fig. 136. Drawn to same scale as fig. 133. This illustrates the size at the time of egg-laying of the immature eggs which are to form the next generation, and which will be ready for extrusion two years hence. One year later they attain the relative size shown in fig. 133. 44 times natural size.

Fig. 135. Ova teased from fresh ovary shown in fig. 137. The difference in relative size between these eggs and those shown in fig. 134 represents a growth of about six weeks in summer. 44 times natural size.

Fig. 136. Ovary immediately after egg laying, seen from below. From lobster No. 52, table 20. The oviducts are filled with unextruded eggs; a few of these ova are also seen in the ovaries. Immature eggs from this ovary are shown in fig. 134. The yellow flecks are the remains of unextruded eggs of a former egg generation; that is, they have been in the ovary two years at least. Drawn in natural size and color from life. July 28, 1891.

Fig. 137. Ovary of lobster No. 87, table 20, bearing external eggs. The latter have been laid about six weeks (date of laying about July 10). The ovarian eggs possess a dark-green core and lighter periphery. At the period of ovulation they are colorless, as shown in figs. 134 and 136. August 21, 1891. Drawn in natural size from life.

Fig. 138. Ovary of female which has recently hatched a brood. Taken July 30, 1891. For description of lobster see No. 95, table 20. The pea-green color is characteristic of the ovary at this time. The contained eggs, one of which is shown in fig. 133, are approximately one year old. The difference in relative size between the ova shown in figs. 133 and 134 thus represents a year's growth, while the relative difference in size between the ova shown in figs. 134 and 135 represents only six weeks of summer growth.

We thus see that a generation of ovarian ova grow very rapidly during the first summer following the last ovulation. They then enter upon a period of quiescence, growing but slowly, like the external embryos during the succeeding winter. The second summer following ovulation is marked by a second period of rapid growth, followed in turn by a second period of quiescence during the succeeding winter. At the beginning of the third summer after ovulation this generation of eggs is ready for extrusion. That the spawning periods are thus two years apart is a valid inference drawn from the study of the anatomy of the reproductive organs. Yellow spots mark as before the remains of degenerate eggs which failed of emission at the last reproductive period. The characteristic condition of the ovary shown in this drawing proves that annual breeding is an impossibility. Drawn in natural size and color from life.

PLATE 39.

Fig. 139. Part of transverse section of ovary of lobster, No. 52, table 20, with external eggs in early segmentation, the ova having been laid about thirty-six hours. The peculiar glandular organs are now seen in the peripheral parts of the lobes. *O. G.*, ovarian gland; *O. W.*, wall of ovary. 36 times natural size.

Fig. 140. Part of transverse section of ovary of lobster No. 94, table 20. Glands absent; ovaries approaching maturity. 36 times natural size.

Fig. 141. Part of transverse section of nearly ripe ovary, from lobster No. 75, table 20. August 19, 1890. The nucleus or germinal vesicle is shown in one of the nearly ripe eggs. (For more detailed drawing of nucleus, see fig. 160.) *Bl. S.*, blood sinus; *Ct*, nodule of connective tissue. *O. G.*, ovarian gland 22 times natural size.

Fig. 142. Part of transverse section of ovary of lobster No. 52, table 20, showing follicle cells which have wandered into the egg and are undergoing degeneration. *Dg*, vesiculated masses of chromatin, the fragments of degenerated cells; *Bl. S.*, blood sinus containing blood cells. 457 times natural size.

Fig. 143. Part of transverse section of ovary, the same as in fig. 141, showing the gland-like organs. *Bl. S.*, blood sinus (dotted line should be continued across gland). 211 times natural size.

PLATE 40.

Fig. 144. Right pleopod of adult female lobster, seen from posterior surface. Drawn from alcoholic preparation, with camera and dissecting microscope, the cuticle being removed from one side to show distribution of cement glands in swimmerets. 4 times natural size.

Fig. 145. Fold of glandular epithelium from transverse section of ovary of lobster No. 75, table 20. From same as fig. 141. *ys*, body resembling yolk spherule. 190 times natural size.

Fig. 146. Transverse section of lobe of ovary shown in fig. 131, plate 38. From No. 2, table 32. 67 times natural size.

Fig. 147. Part of transverse section of ovarian lobe from a lobster with external eggs near the point of hatching. The condition of this ovary closely corresponds to that shown in fig. 138. June 30, 1890. *Bl. S.*, blood sinus. 36 times natural size.

Fig. 148. Part of transverse section of ovary of lobster No. 51, table 20, showing the inner or primary egg membrane (shaded dark), and the follicular epithelium by which it is secreted. *Bl. S.*, blood sinus. 211 times natural size.

Fig. 149. Part of transverse section of ovary of lobster No. 52, table 20, showing part of an egg and follicular cells in contact with it. Those which have wandered into the yolk afterwards degenerate. The external eggs borne by this lobster were in an early stage of segmentation. *f. c.*, follicle cells immersed in the yolk. 211 times natural size.

PLATE 41.

Fig. 150. Degenerating cells from the ovary of lobster No. 76, table 20. The larger body to the left is the remains of what was once a mature egg, which having failed of emission at the time of egg-laying has suffered degeneration. The tough egg membrane seems to defy complete absorption. To the unaided eye such an egg appears as a yellow fleck, if visible at all (see fig. 136). 540 times natural size.

Fig. 151. Part of horizontal section of ovary from lobster No. 76, table 20, showing ova inclosed in folds of follicular epithelium. This ovary was slit open along the mid-dorsal line, pinned out, hardened, and sectioned in longitudinal, horizontal planes. 67 times natural size.

Fig. 152. Part of transverse section of ovary of lobster No. 52, table 20, showing the developing ovum and its relation to the folds of glandular epithelium. Remnants of degenerating cells can be detected in this egg. (See figs. 139 and 149.) *B. M.*, basement membrane; *Bl. S.*, blood sinus; *G. E.*, glandular epithelium. 281 times natural size.

Fig. 153. Glandular epithelium from transverse section of ovary of lobster No. 75, table 20. *F. G.*, vacuoles, probably representing fatty globules which have been removed in the process of preparing the tissue for sectioning; *ys*, bodies resembling yolk spherule. 253 times natural size.

PLATE 42.

Fig. 154. Ovum in early stage of growth, from ovary of lobster No. 52, table 20. Diameter of egg $\frac{1}{33}$ mm., of nucleus $\frac{1}{\text{?}}$ mm. 353 times natural size.

Fig. 155. Young ovum from same ovary as the last. Diameter of egg $\frac{1}{19}$ mm., of nucleus $\frac{1}{33}$ mm. 353 times natural size.

Fig. 156. Young ovum from same ovary as the last. This nucleus contains two nucleoli. Diameter of egg $\frac{1}{14}$ mm., of nucleus $\frac{1}{27}$ mm. 353 times natural size.

Fig. 157. Young ovum from same ovary as the last. Diameter of egg a little over $\frac{1}{14}$ mm., of nucleus $\frac{1}{18}$ mm. 353 times natural size.

Fig. 158. Nucleus of ovum from transverse section of ovary of lobster with external eggs about to hatch. From same as fig. 147. Diameter of egg $\frac{1}{76}$ mm., of nucleus $\frac{1}{11}$ mm. 353 times natural size.

Fig. 159. Nucleus of ovum from nearly ripe ovary of lobster No. 94, table 20. See fig. 140 for ovarian section. Diameter of egg $1\frac{1}{8}$ mm., of nucleus $\frac{1}{11}$ mm. 353 times natural size.

Fig. 160. Nucleus of ovum from ovary of lobster No. 75, table 20. For ovarian section and position of nucleus, see fig. 141. Ovary ripe. Diameter of egg $1\frac{7}{8}$ mm., of nucleus $\frac{1}{21}$ mm. 353 times natural size.

Fig. 161. Nucleus of egg in process of emitting polar cells. From section of unextruded egg taken from the oviduct. Diameter of egg 1.31 mm., of nucleus $\frac{1}{40}$ mm. The nucleus is in process of karyokinesis and lies close to the surface of the egg. The axis of the nuclear spindle appears somewhat oblique to the surface. July 28, 1891. 353 times natural size.

Fig. 162. Bifurcated rostrum of lobster taken at Woods Hole, Massachusetts. Dorsal view. Two-thirds natural size.

Fig. 163. Profile view of the same. Two-thirds natural size.

Fig. 164. Ovaries of lobster, from below, showing bifurcation in left anterior lobe. Ovary light golden-yellow color. Ova very immature. May 19, 1892. Two-thirds natural size.

Fig. 165. Part of gastrolith, separated into its constituent spicules, taken fresh from the wall of the stomach of a lobster nearly ready to molt. For chemical analysis, see No. *0a* of table, Appendix II. Compare cut 8, plate C. The broad flattened spicule at the lower right-hand corner of the drawing is from the peripheral convex margin of the gastrolith. 5.3 times natural size.

PLATE 43.

Fig. 166. Bud of right fourth pereiopod in process of regeneration from young lobster probably in fourth stage. August 3, 1893. 47 times natural size.

Fig. 167. Part of transverse section of oviduct of lobster, with ovary nearly ripe. July 25, 1893. 270 times natural size.

Fig. 168. Part of transverse section of oviduct of lobster, with external eggs in early yolk segmentation. For a drawing of this ovary see fig. 119, plate 36. August 3, 1894. 270 times natural size.

Fig. 169. Longitudinal section of first, second, and third segments of right first pereiopod of young lobster in sixth stage. Plane of section shown in cut 15. Length of lobster 18 mm. The right cheliped of this lobster was regenerated between the molts of the fifth and sixth stages. When the animal was preserved, August 17, 1893, the right regenerated cheliped was slightly smaller and more translucent than the left. No rudimentary tissue out of which the new limb is differentiated can be detected in the series of sections through plane of fracture. *x y*, plane of fracture; *1*, *2*, *3*, segments of limb. About 47 times natural size.

Fig. 170. Internal surface of cuticle of second joint (basis) of first maxilla macerated in Béla Haller's fluid, showing chitinous tubules of tegumental glands, and characteristic rosettes of what appears to be calcareous matter. From male lobster 10 inches long. July 31, 1893. 140 times natural size.

Fig. 171. Part of section of gastrolithic plate from female lobster with hard shell. August 10, 1893. Shown in its natural position in wall of stomach, in fig. 183. Fixed in picro-sulphuric acid; stained in borax-carmine; embedded in celloidin. *GP.*, cuticular portion of gastrolithic plate. The demarcation between the layers is not so sharp as shown in the drawing. 171 times natural size.

Fig. 172. Section of left first pereiopod of lobster 9 inches long, in process of regeneration. At *a* a mass of large disk-shaped concretions, probably of a glycogenous nature, is seen. Compare figs. 121 and 122. The blackened margins of cuticle on either side of appendage represent the remains of clotted blood on surface of the stump. About 6 times natural size.

Fig. 173. Section of bud of right first (crushing) cheliped of adult male lobster, showing the columnar epithelium, the new cuticle, blood sinuses, and connective tissue. Fixed in picro-sulphuric acid; stained in Ehrlich-Biondi mixture; embedded in celloidin. August 9, 1892. 47 times natural size.

Fig. 174. Part of longitudinal section of first larva through heart (*Ht.*) and right rudimentary reproductive organ (*ov*), cutting also intestine (*in*) and gastric glands (*gg*). 67 times natural size.

PLATE 44.

Fig. 175. Right fourth pereiopod of adult lobster in process of regeneration, from below. Color, bright coral red. Two-thirds natural size.

Fig. 176. Stump of right first pereiopod of adult lobster in course of regeneration, from below. Bud and surface of scar dull white. August 9, 1892. Two-thirds natural size.

Fig. 177. Surface view of membrane between old and new shells of molting lobster. This membrane is conspicuous at the time of shedding. It is noncellular, but is marked by the cell impressions of the chitinogenous epithelium. 733 times natural size.

Fig. 178. Right second pereiopod of adult male in process of regeneration, from below. New appendage reddish, tinged with blue at the joints. August 4, 1892. Two-thirds natural size.

Fig. 179. Left second antenna of adult lobster in process of regeneration, from above. June 30, 1892. Two-thirds natural size.

Fig. 180. Antennæ of the Isopod, *Ligea oceanica*, from above; that of the left side in the course of regeneration. Beaufort, North Carolina, June, 1885. 4.7 times natural size.

Fig. 181. Regenerating left antenna of the same, showing the new flagellum inclosed in the exoskeleton of the joint, which serves as a brood pouch. 16 times natural size.

Fig. 182. Left first cheliped of adult lobster in process of regeneration, seen from the inner and anterior side. Color, bright red, bluish at joints; cuticle thrown into thin creases. Longitudinal axis of body in direction of arrow. 5.3 times natural size.

Fig. 183. Profile view of masticatory stomach of lobster, showing gastrolithic plate, for the structure of which see fig. 171, plate 43. Lobster with hard shell, approaching the molting time August 10, 1893. Two-thirds natural size.

Fig. 184. Profile view of masticatory stomach of male lobster 7.5 inches long. Nearly ready to molt, showing gastrolith in place in the wall of stomach. For drawings of the gastrolith as it appears when it is dissected out and separates into its constituent spicules, see fig. 165, plate 42. Two-thirds natural size.

PLATES 45*a* and 45*b*.

Fig. 185. Molted shell of lobster shown in fig. 186. No. 1, table 24. This represents the size of the lobster before the molt. Length 5½ inches. Natural size.

Fig. 186. The soft lobster, shortly after the shell shown in fig. 185 was cast off. Length, 6½ inches. Natural size. These drawings show the average increase in size which is effected by a single molt (see Chapter III).

PLATE 46.

Fig. 187. Left cheliped of lobster, from below, showing budding and repetition of parts in propodus or sixth joint.

Fig. 188. Same as fig. 187, seen from above. Both figures from photographs, and both natural size.

PLATE 47.

Fig. 189. Part of right crushing-chela of female lobster, 11 inches long, seen from above, showing budding of dactyl. Woods Hole, Massachusetts, July 13, 1894. Two-thirds natural size.

Fig. 190. Propodus of left crushing-claw, from below. This and figs. 191–196 are from specimens in Peabody Academy of Science, Salem, Massachusetts, all from adult lobsters. Two-thirds natural size.

Fig. 191. Left crushing-claw, seen from above. Outgrowth from dactyl in horizontal plane; dactyl closes under propodus. Two-thirds natural size.

Fig. 192. Left crushing-chela, from above. Secondary dactyl bent downward slightly; no teeth; dactyl laterally compressed. *S*, spine of dactyl in primary symmetry; S^1, spine of dactyl in secondary symmetry. This supernumerary appendage probably represents two dactyls fused together. Two-thirds natural size.

Fig. 193. Right cutting-chela, from below. Fingers bent up; dactyls articulate at joint with propodus; primary dactyl and one of the adjacent secondary dactyl united. *S*, supernumerary dactyl in primary symmetry. Two-thirds natural size.

Fig. 194. Dactyl of left cutting-claw, seen from below. It is bent horizontally upon itself, into an angle of about 80°, this being probably due to irregular growth in the regeneration of a lost part. Two-thirds natural size.

Fig. 195. Chela of second or third pereiopod, from below, showing two supernumerary dactyls. Two-thirds natural size.

Fig. 196. Right dactyl of cutting-chela, seen from outer side. Bifurcating branches bear teeth, which are not, however, apposed. Two-thirds natural size.

PLATE 48.

Fig. 197. Deformed right cutting-claw. Accessory appendage bent downward from horizontal plane about 50°. The small terminal joint of the superadded part probably represents two dactyls fused together. *S*, spine of dactyl in primary symmetry; S^1, spine of dactyl in secondary symmetry. Two-thirds natural size.

Fig. 198. Right cutting-claw. Propodus apparently deformed by the irregular growth produced in the regeneration of a lost part. Two-thirds natural size.

Fig. 199. Double monster of first larva of lobster. Raised at Fish Commission station, Woods Hole, Massachusetts, by Professor J. A. Ryder; seen from above. 13 times natural size.

Fig. 200. Double monster of first larva of lobster, from Professor J. A. Ryder. Fusion of the organs at the anterior extremity has been carried to such a degree that the compound eyes are now represented by a small median spot of pigment. 13 times natural size.

PLATE 49.

Fig. 201. Gland-cell from tegumental gland of second maxilla. Macerated in Bćla Haller's fluid for several days, and stained in methyl green. 733 times natural size.

Fig. 202. Gland-cell from same preparation as fig. 201. 733 times natural size.

Fig. 203. Part of macerated tegumental gland from metastoma. Compare also fig. 214. From female with ripe ovaries. August 9, 1893. Stained in methyl green. Central cell takes on deepest stain. *gd.c*, gland-cell; *R*, central reticulated body; *s.c*, ganglion cell. 773 times natural size.

Fig. 204. Cell from macerated tegumental gland of first maxilla. Stained in methyl green. 773 times natural size.

Fig. 205. Gland-cell from same preparation as fig. 204. 773 times natural size.

Fig. 206. Cell from macerated tegumental gland of abdominal appendage of female before egg extrusion. Ovaries nearly ripe. Attenuated, central end of cell very refractive. Small bodies, apparently accessory nuclei, are present in cell. 773 times natural size.

Fig. 207. Same preparation as last, rolled under cover-slip and seen from opposite side. 773 times natural size.

Fig. 208. Tegumental gland from metastoma of female with ripe ovaries. Macerated three days in Béla Haller's fluid and stained in methyl green. The duct (*d*) of the gland could be seen to open directly into a small central chamber, as in fig. 212. 513 times natural size.

Fig. 209. Gland-cell from tegumental gland of abdominal appendage of female, which had recently laid eggs in an aquarium at the United States Fish Commission station, Woods Hole, Massachusetts. Macerated in Béla Haller's fluid. August 14, 1893. 773 times natural size.

Fig. 210. Tegumental gland from abdominal appendage of female lobster 10½ inches long, preparing to molt. Chromic acid preparation, stained in the Ehrlich-Biondi anilin mixture. Picro-sulphuric acid gives same result. Cells apparently shrunken, transparent, non-granular; nuclei clear. August 17, 1893. 513 times natural size.

Fig. 211. Tegumental gland from abdominal appendage of female after ovulation. External eggs in yolk segmentation. Central ends of gland-cells are filled with dark zymogen granules. Nucleus of gland-cell stains green, that of central cell always red, in the Ehrlich-Biondi mixture. August, 1893. *gd.c*, gland-cell; *s.c*, ganglion cell. 513 times natural size.

Fig. 212. Section of tegumental gland from abdominal appendage of female lobster with mature ovaries. Central part of gland has a bluish clouded appearance. Nuclei may be green or red according to the degree with which the stain is extracted. Stained in the Ehrlich-Biondi mixture. August 4, 1893. *d*, duct of gland; *n*, nerve-supplying gland; *R*, central reticulated body. 513 times natural size.

Fig. 213. Gland-cells from same preparation as figs. 204, 205. Central ends of cells attenuated, and strongly refractive. 773 times natural size.

Fig. 214. Macerated tegumental gland from metastoma of female, showing the central reticulated body, gland-cells, ganglion cell, and duct of gland. From female with ripe ovaries. *d*, duct of gland; *R*, reticulated body. 773 times natural size.

PLATE 50.

Fig. 215. Egg before yolk has segmented. The whitish spots are due to the presence of cells which are approaching the surface on one side of the egg. The yolk is later massed up about these in hillocks, as in fig. 218. 29 times natural size.

Fig. 216. Surface view of egg with 16 cells present near the surface, two double rows of eight cells each. The cells have just divided. This drawing was made at 10.30 p. m.; at 10.55 p. m. 20 cells could be discerned near the surface. 29 times natural size.

Fig. 217. Same egg as fig. 216; drawing made 1½ hours later (12 p. m.), showing the cells more diffused over the surface. 29 times natural size.

Fig. 218. Same egg as in figs. 216 and 217; rolled to show animal pole and yolk hillocks in profile. Drawing made at 10.55 p. m., when 20 yolk elevations had been formed. On the outskirts of these, other cells can be seen lying below the surface and destined soon to become the centers of new hillocks. 29 times natural size.

Fig. 219. Surface view of egg showing yolk segments in active division; 10.15 p. m., segmentation furrows complete. This side of egg corresponds to the side shown with yolk hillocks in profile, in fig. 218. Nuclei all dividing at 10 p. m.; at 10.10 p. m., furrows began to appear, separating cells. Same egg as shown in fig. 220. 29 times natural size.

Fig. 220. Reverse side of egg shown in fig. 219, corresponding to the right side of the egg shown in fig. 218, opposite the yolk hillocks. When drawn at 9.30 p. m., nuclei were invisible; at 10 p. m. they were very distinct and in diaster phase; at 10.15 p. m. segmentation furrows completed. 29 times natural size.

Fig. 221. Surface view of segmenting egg, under observation 5 hours (8 p. m. to 1 a. m.). At 12 o'clock the segments shown in the drawing were very convex at surface, standing far apart as if the egg were breaking up. At 1 a. m. the segments were closer together and nuclei were about to divide again. Drawing made at 11 p. m., after completion of division. 29 times natural size.

Fig. 222. Surface view of segmenting egg. Drawing begun at 11 a. m.; when completed, half an hour later, the nuclei had divided and segmentation furrows were making their appearance. 29 times natural size.

Fig. 223. Surface view of same egg, drawn at 12 m. Division of cells mostly completed. 29 times natural size.

Fig. 224. Surface view of same egg as in figs. 222 and 223, at 9 p. m., in advanced stage of segmentation. At 2.45 p. m. nuclei were dividing; at 6.45 p. m., when examined, division was completed. Drawing made at 9 p. m. 29 times natural size.

Fig. 225. Surface view of egg in advanced stage of yolk segmentation. Free-hand drawing. 29 times natural size.

Fig. 226. Surface view of egg in abnormal yolk segmentation, showing a larger yolk mass at the lower part of the figure and a number of smaller regular segments. A similar large yolk mass occurs on the opposite side of the egg next to the one shown in the drawing. 29 times natural size.

PLATE 51.

Fig. 227. Surface view of egg in invagination stage. August 3, 11.30 a. m. 29 times natural size.

Fig. 228. Surface view of abnormal embryo in egg-nauplius stage. August 10. 29 times natural size.

Fig. 229. Surface view of abnormal embryo. August 8. 29 times natural size.

Fig. 230. Surface view of abnormal embryo in egg-nauplius stage. *P*, cells approaching surface; *r*, outward fold of surface epithelium; *y*, yolk. August 9. 29 times natural size.

Fig. 231. Surface view of abnormal embryo in egg-nauplius stage. August 8. 29 times natural size.

Fig. 232. Lateral view of embryo, showing large white patch behind abdomen. August 5. 29 times natural size.

Fig. 233. Lateral view of embryo about 5 weeks old, showing lateral fold of carapace covering the antennæ, the heart (*Ht.*), the intestine containing characteristic concretions (*P*), the telson (*T*) overlapping brain and optic lobes, and the lateral indentations of the yolk corresponding to divisions of the midgut. July 29. 48 times natural size.

Fig. 234. Surface view of embryo about 25 days old, showing the large optic lobes of cephalo-thoracic appendages. The telson touches the brain, and the crescentic fold of the carapace extends forward as far as the first maxillipeds. August 3, 1892. 29 times natural size.

Fig. 235. Lateral view of double monster in egg-nauplius stage. August 13. 29 times natural size.

PLATE 52.

Fig. 236. Part of transverse section of egg in stage between that shown in figs. 224 and 225, yolk cells (*y c*) being formed by tangential division. About 70 times natural size.

Fig. 237. Part of longitudinal section of egg in egg-nauplius stage, showing degenerating cell (*Dg*). 457 times natural size.

Fig. 238. Part of section of segmenting egg, showing cell migrating from surface. July 31. 40 times natural size.

Fig. 239. Section of segmenting egg, showing yolk cell near center. July 31. 40 times natural size.

Fig. 240. Degenerating cells from same preparation as shown in fig. 237. *y s*, bodies resembling yolk spherules. 457 times natural size.

Fig. 241. Vesiculated masses of chromatin (*Dg*) undergoing degeneration in the yolk. From transverse section of early egg-embryo. July 18. 457 times natural size.

Fig. 242. Section of segmenting egg. Drawn July 31, 4 p. m.; 34 cells present. 40 times natural size.

Fig. 243. Section of egg in late segmentation, showing formation of yolk cells and division of these in yolk. August 1. *s c*, cell at surface undergoing tangential division; *y c*, yolk cell in process of division. 40 times natural size.

Fig. 244. Surface view of egg in late segmentation of yolk. July 11. Fixed in Perenyi's fluid. About 50 times natural size.

Fig. 245. Part of transverse section, showing multiple karyokinesis and formation of nests of nuclei. Stage like that shown in fig. 252. Part of section behind and to one side of invagination area. Same series as fig. 241. *c n*, cell nest at surface; *y n*, cell nest in yolk; *y n*^{1}, cell in multiple karyokinesis, situated in yolk ball. 457 times natural size.

Fig. 246. Part of transverse section through embryo in invagination stage. *in*, area of invagination. 211 times natural size.

Fig. 247. Part of section of egg to show nest of nuclei at surface. 211 times natural size.

Fig. 248. From section through embryo in invagination stage, showing multiple karyokinesis and formation of nuclear nests at surface, like that shown in fig. 247. 211 times natural size.

Fig. 249. Part of section of egg containing two nuclei, this one near surface. 285 times natural size.

PLATE 53.

Fig. 250. Surface view of embryo in invagination stage. The embryonic area of this egg lies in front of the shallow pit. Cells are most numerous immediately in front of this depression and about the extreme anterior margins of the exposed surface. The rapid proliferation of cells in these regions gives rise on the one hand to the thoracic-abdominal plate, and to the optic disks on the other. Karyokinetic figures of dividing cells are seen scattered over the entire surface of the egg. The equatorial plate is in each case vertical, and may make any angle with the longitudinal axis of the embryo, or with a line drawn through any proliferating center. Numerous granules, the products of cell degeneration, are commonly seen. The reverse side of this egg shows nothing peculiar. Nuclei are there less numerous, and the superficial cells are larger. Flecks or clouds of granules, floating in the yolk below the surface, are seen here and there with no regularity. The nuclei over most of the surface, excepting those at the extreme periphery, were drawn by aid of the camera lucida, as were the cell outlines in the more central parts. From a picro-sulphuric acid preparation, stained in borax carmine, the egg cut in two, and the hemispheres mounted in balsam. August 6, 1892. 500 times natural size.

PLATE 54.

Fig. 251. Part of transverse section through area of invagination (*in*), showing columnar surface cells (*ec*) filled with yolk and invaginate cells, lying between and within yolk masses. Some of the latter cells just below the surface are undergoing degeneration; some in the deepest parts of the egg are creeping with their long pseudopodia between the yolk spherules. These play the part of phagocytes and also contribute to the tissues of the embryo. 360 times natural size.

Fig. 252. Surface view of embryo in region of invaginate area, showing clusters of cells at surface, produced by multiple karyokinesis. *A*, anterior; *P*, posterior end of egg; *Deg*, degenerating cells; *e a*, embryonic area; *In*, area of invagination; *y n*, cell nest, produced by multiple karyokinesis. 89 times natural size.

Fig. 253. Part of longitudinal section of intestine of embryo in a late stage of development, showing concretions in the lumen of the organ. *b m*, basement membrane; *e p*, intestinal epithelium; *p*, intestinal concretion. 360 times natural size.

Fig. 254. Part of transverse section through invaginate area of an earlier stage than last, showing in-wandering masses of cells. *A*, anterior; *P*, posterior; *In*, pit of invagination; *y c*, invaginate cells. 89 times natural size.

Fig. 255. Part of longitudinal section through area of invagination, showing the advancing cumuli of cells, which are pressing into the deeper parts of the egg and investing large masses of yolk. The distinctly columnar superficial cells, gorged with yolk, are also shown. In the embryonic area these become very tall, and beneath them there are clouds of disorganized chromatin granules, the remains of degenerated cells. *A*, anterior; *P*, posterior; *Deg*, degenerating cells; *e c*, ectoderm; *Mes-ent*, mesendoderm; *In*, pit of invagination; *OD*, optic disc. 89 times natural size.

Fig. 256. Concretion from intestine of an embryo which was nearly ready to hatch. Teased from picro-sulphuric acid preparation and mounted in glycerin. 360 times natural size.

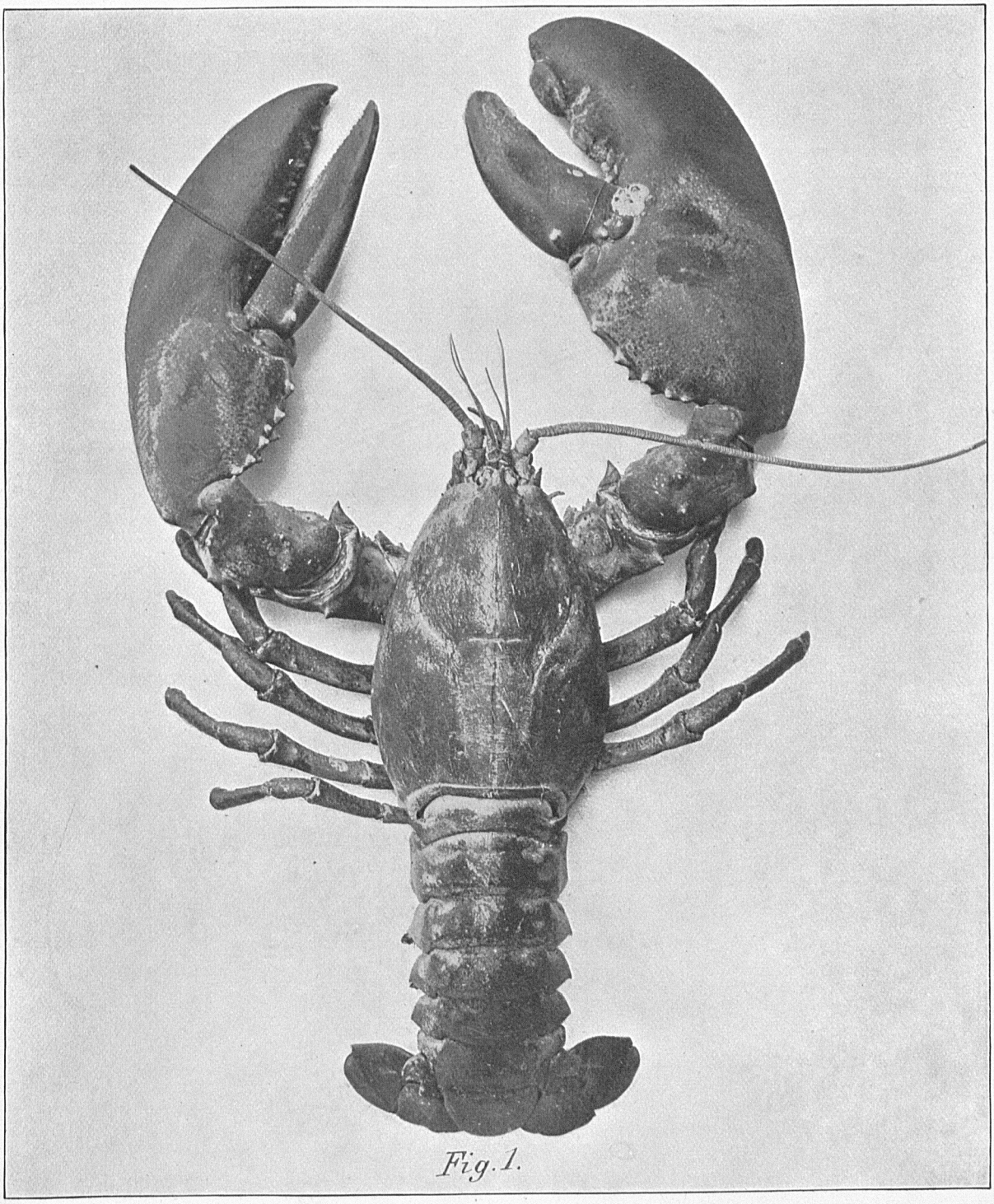


Fig. 1.

From photograph.

MALE LOBSTER. Weight, 23 pounds.

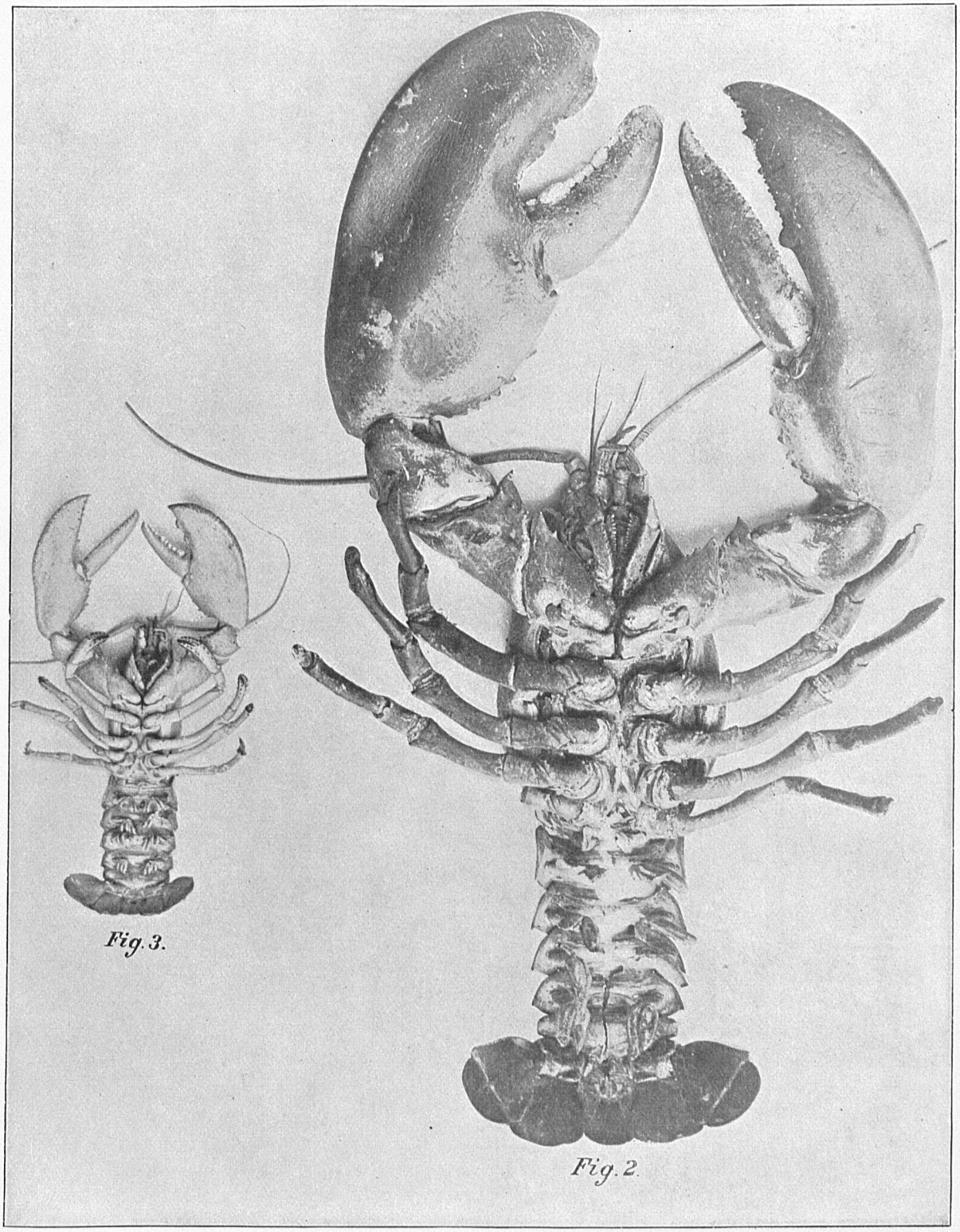


Fig. 3.

Fig. 2.

From photograph.

VENTRAL VIEW OF MALE LOBSTER. Weight, 23 pounds.
VENTRAL VIEW OF FEMALE LOBSTER. Weight, 1⅛ pounds.

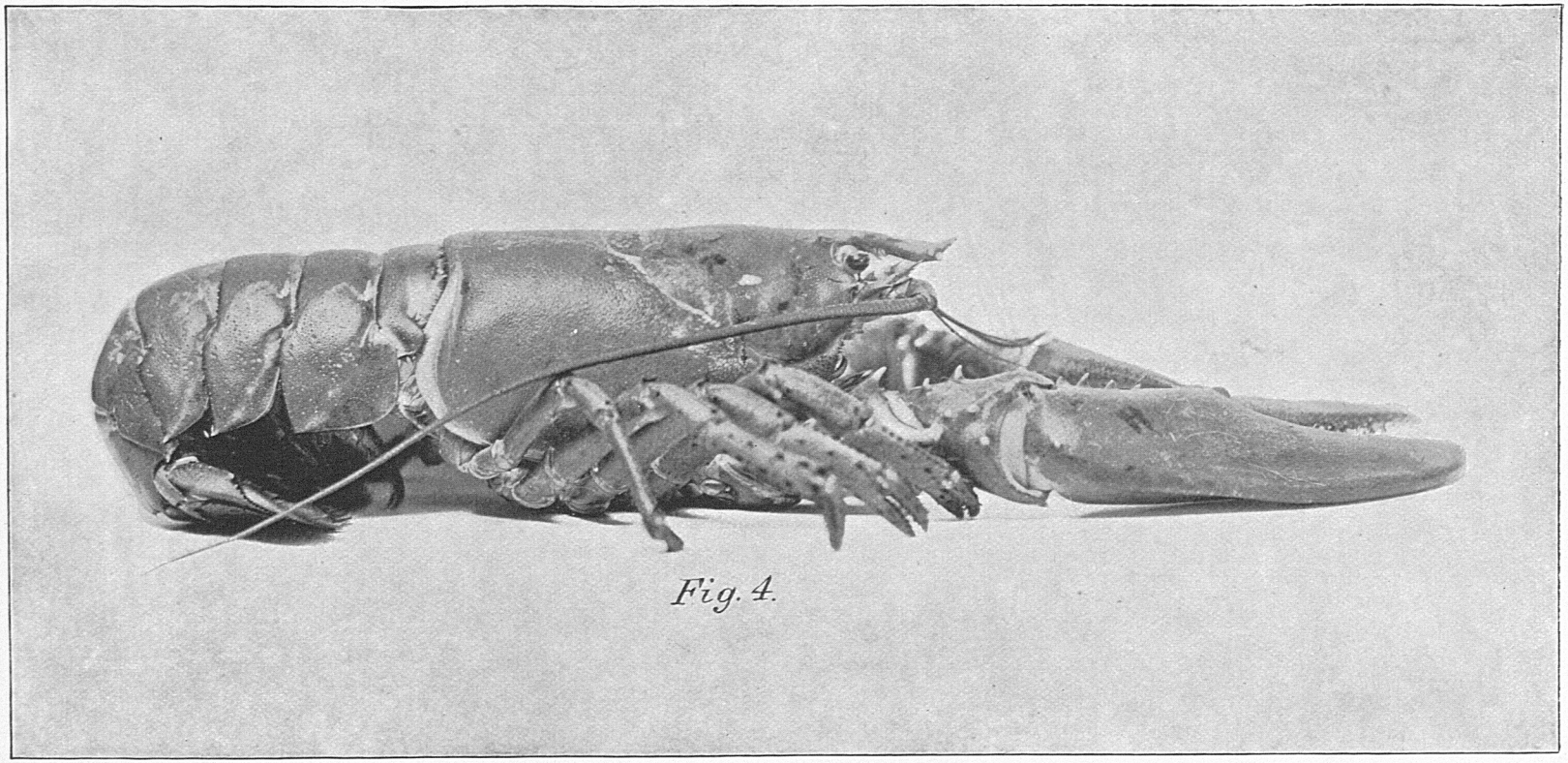


Fig. 4.

Photographed from life.

ADULT FEMALE LOBSTER.

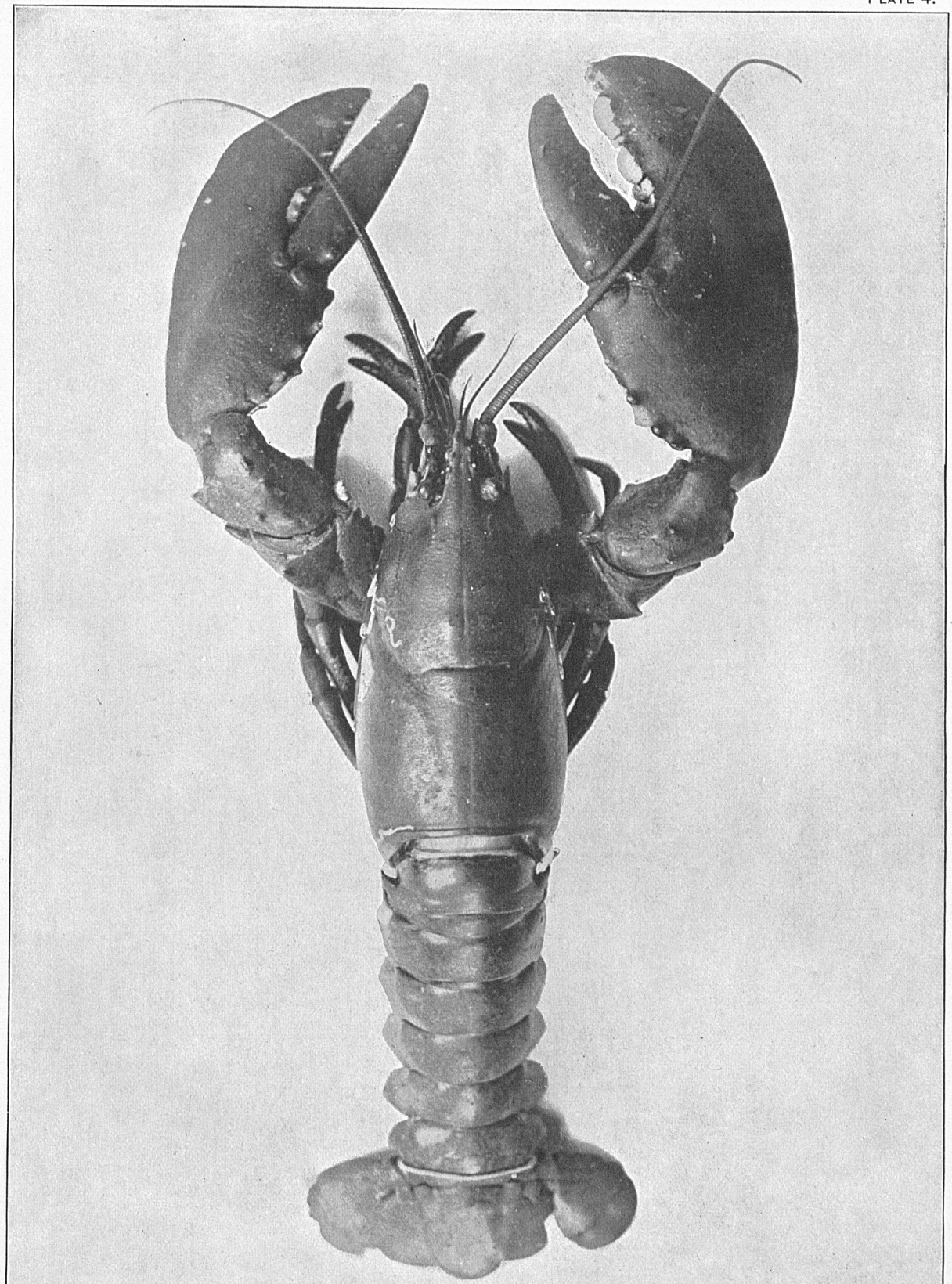


Fig. 5.

Photographed from life.

ADULT MALE LOBSTER. Dorsal view.

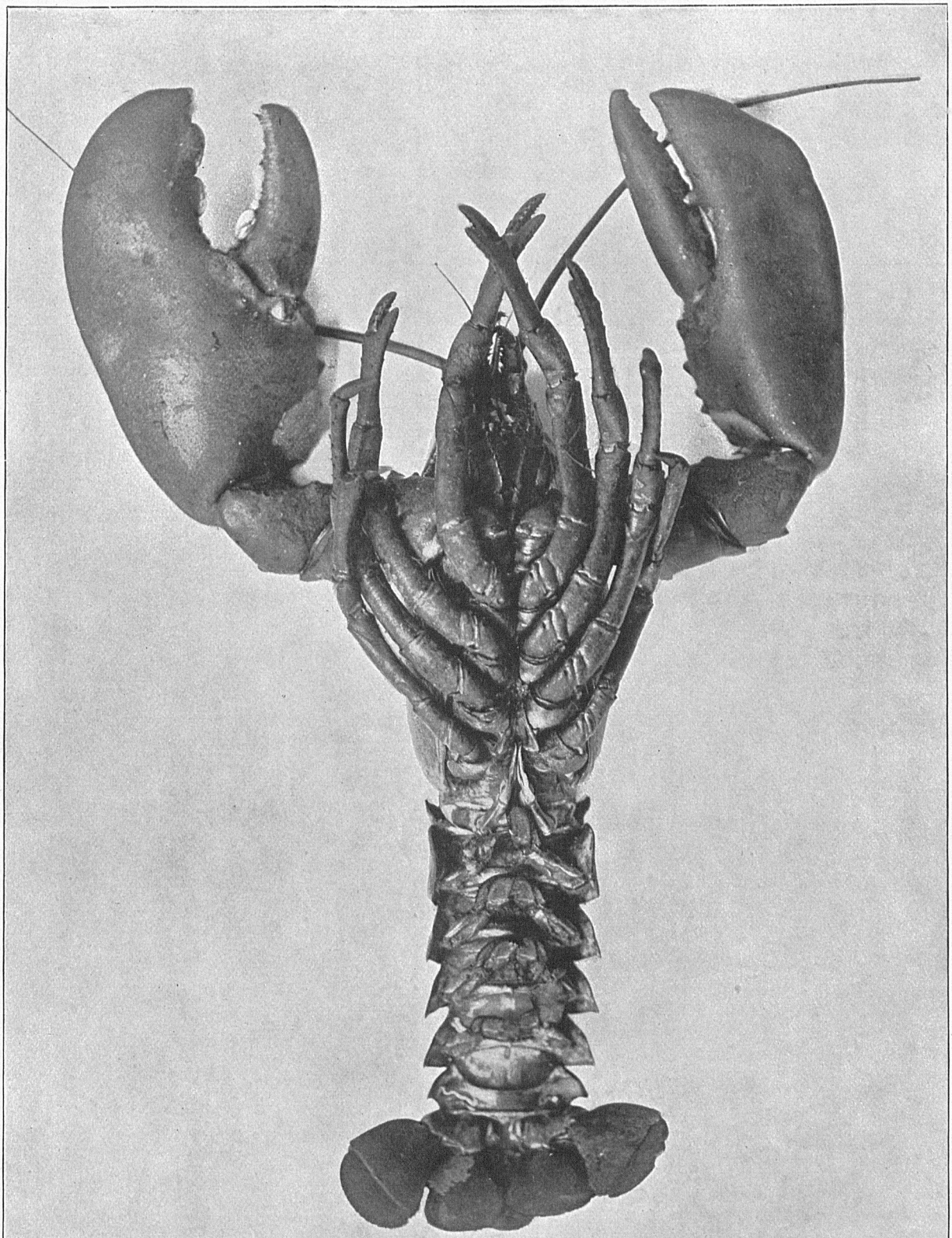


Fig. 6.

Photographed from life.

ADULT MALE LOBSTER. Ventral view.

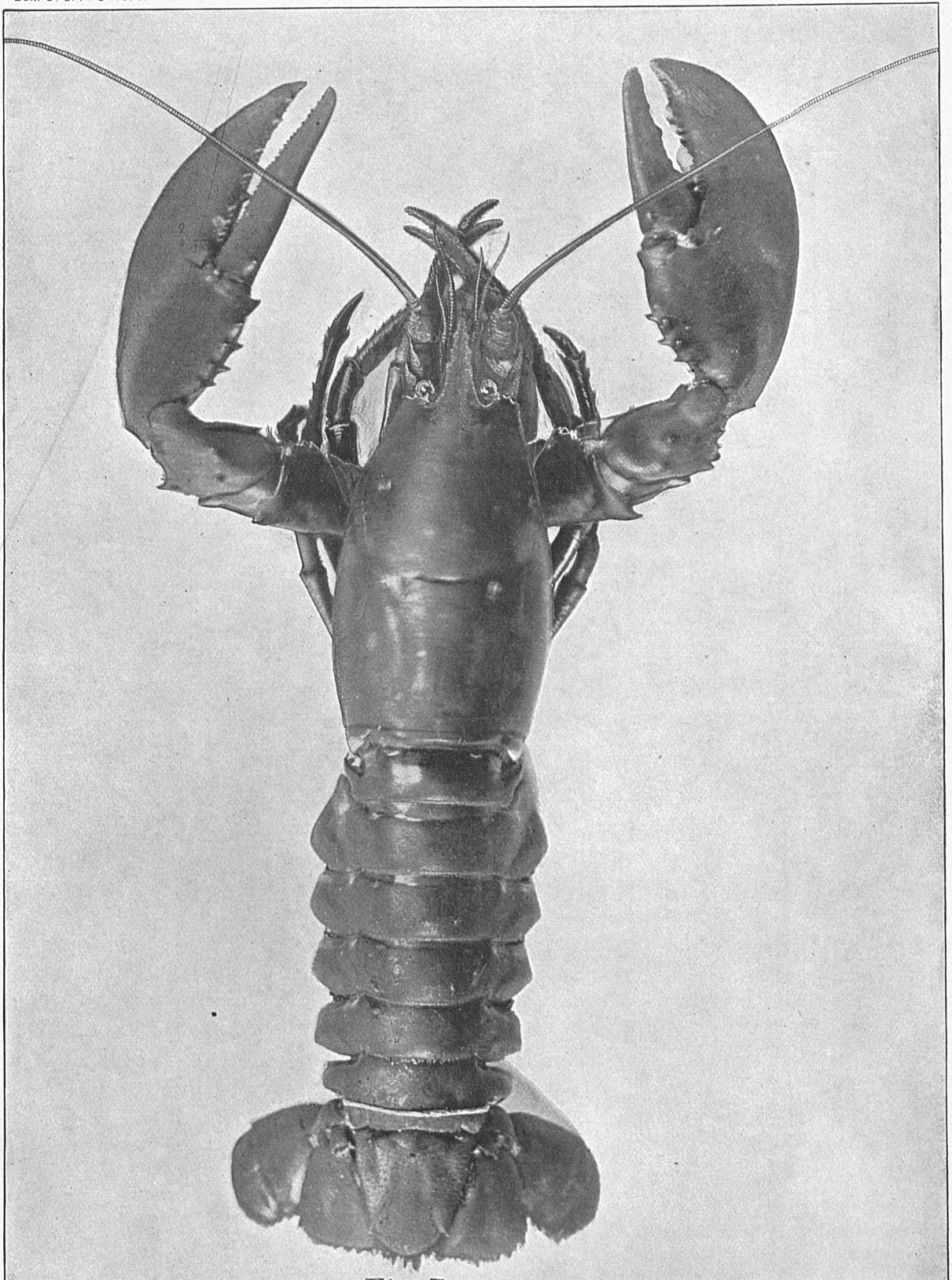


Fig. 7.

Photographed from life.

ADULT FEMALE LOBSTER WITH EXTERNAL EGGS. Dorsal view.

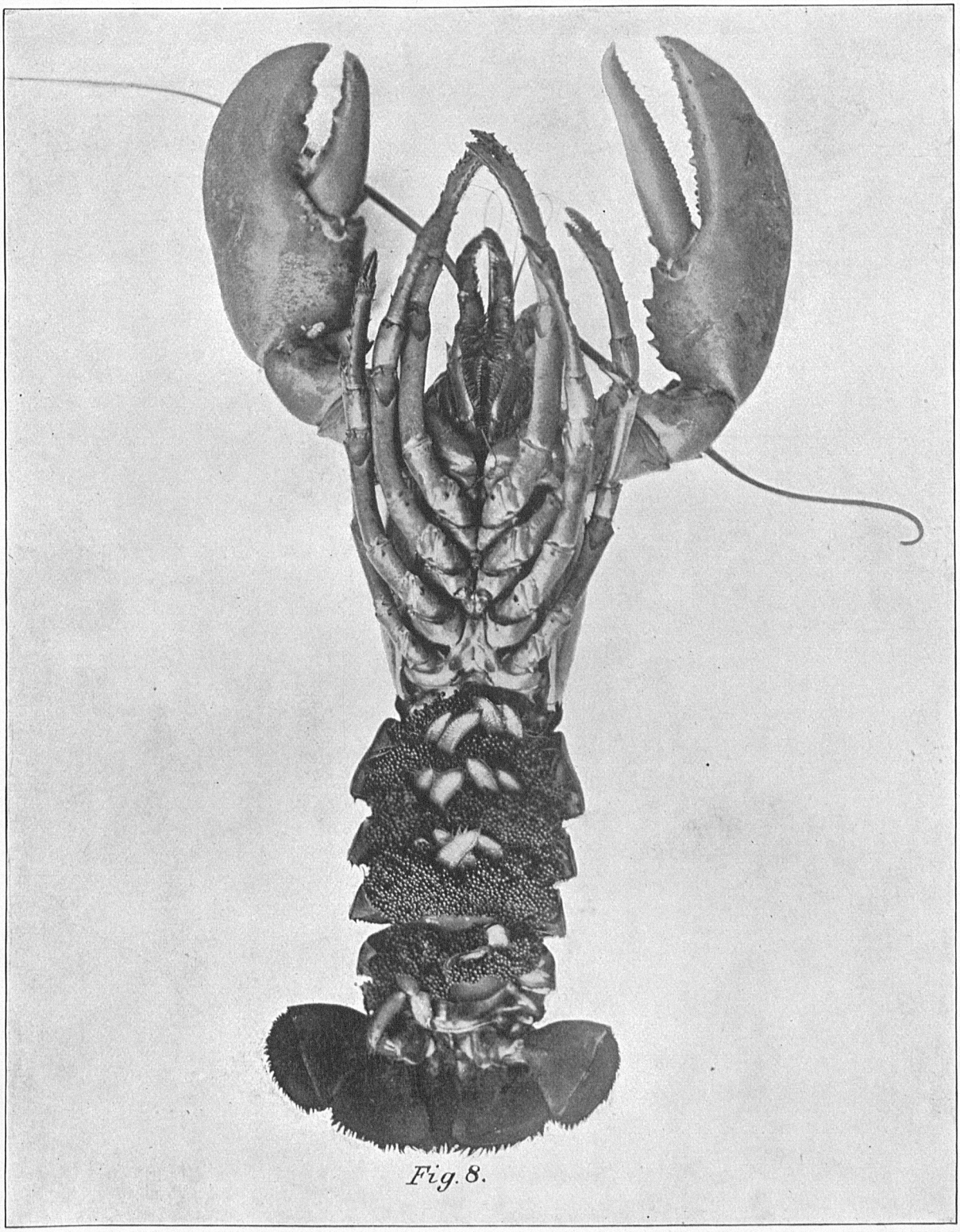


Fig. 8.

Photographed from life.

ADULT FEMALE LOBSTER WITH EXTERNAL EGGS. Ventral view.

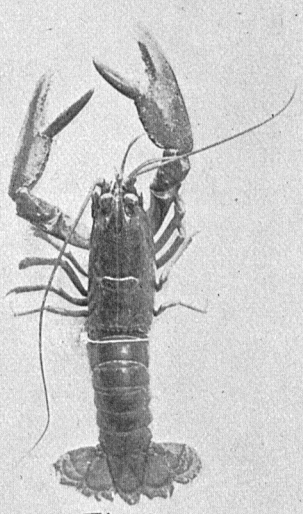


Fig. 9.

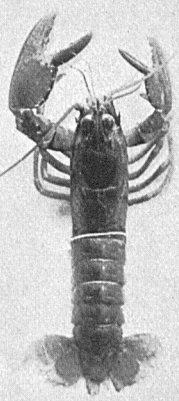


Fig. 10.

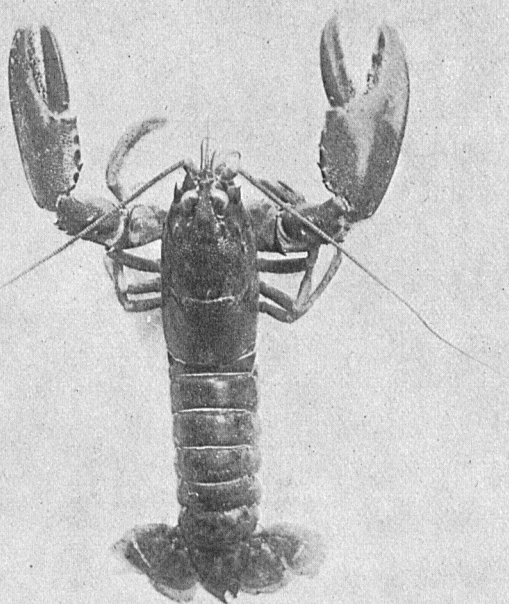


Fig. 11.

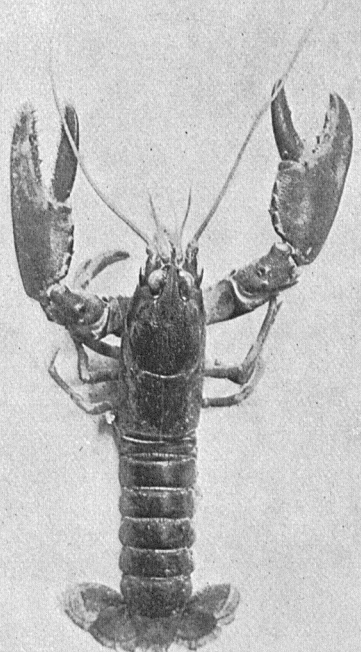


Fig. 12.

From photograph. Females. Males.

IMMATURE LOBSTERS. Natural size.

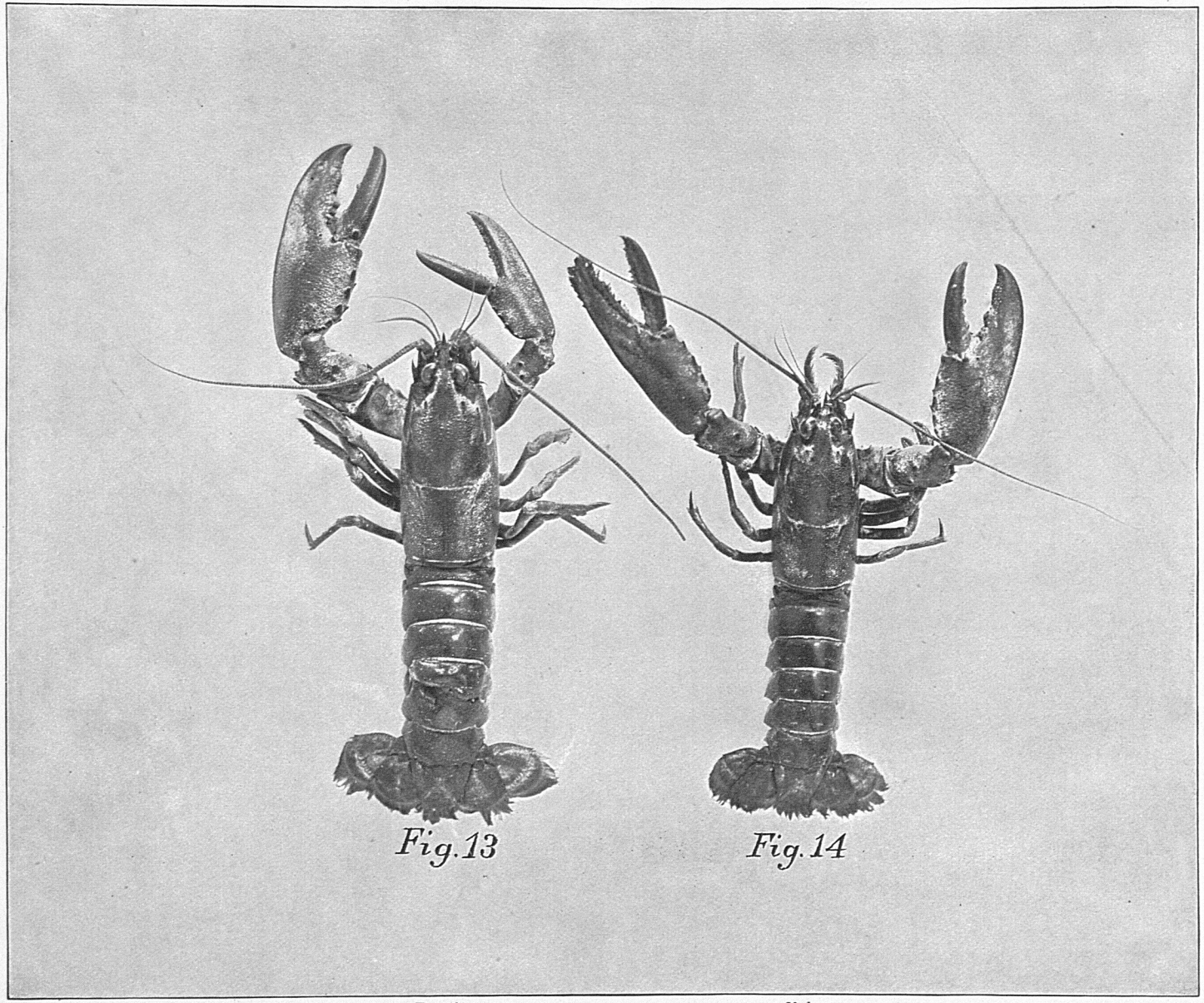


Fig. 13 *Fig. 14*

From photograph. Female. Male.

IMMATURE LOBSTERS. Natural size.

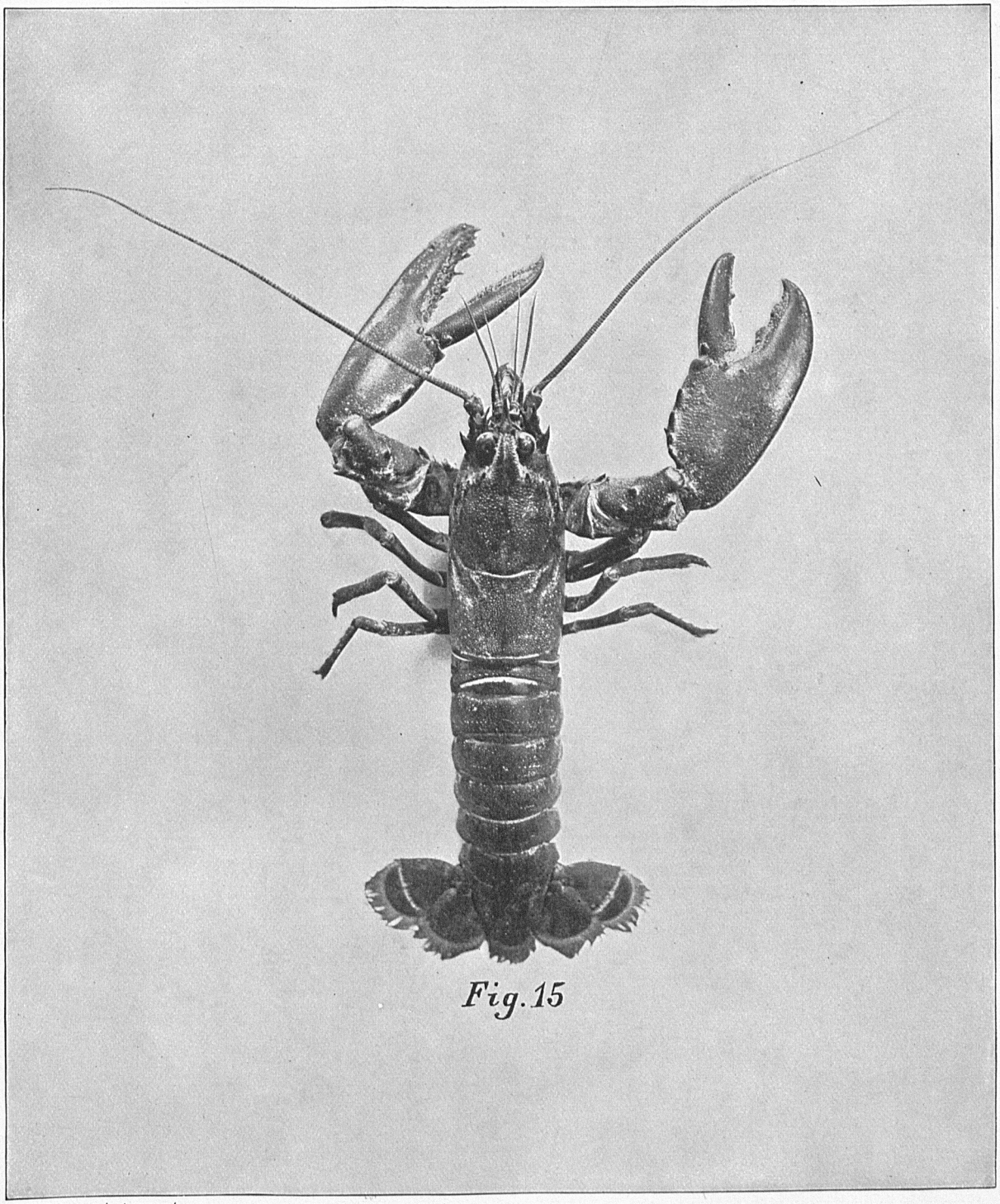


Fig. 15

From photograph.

IMMATURE FEMALE LOBSTER. Natural size. Dorsal view.

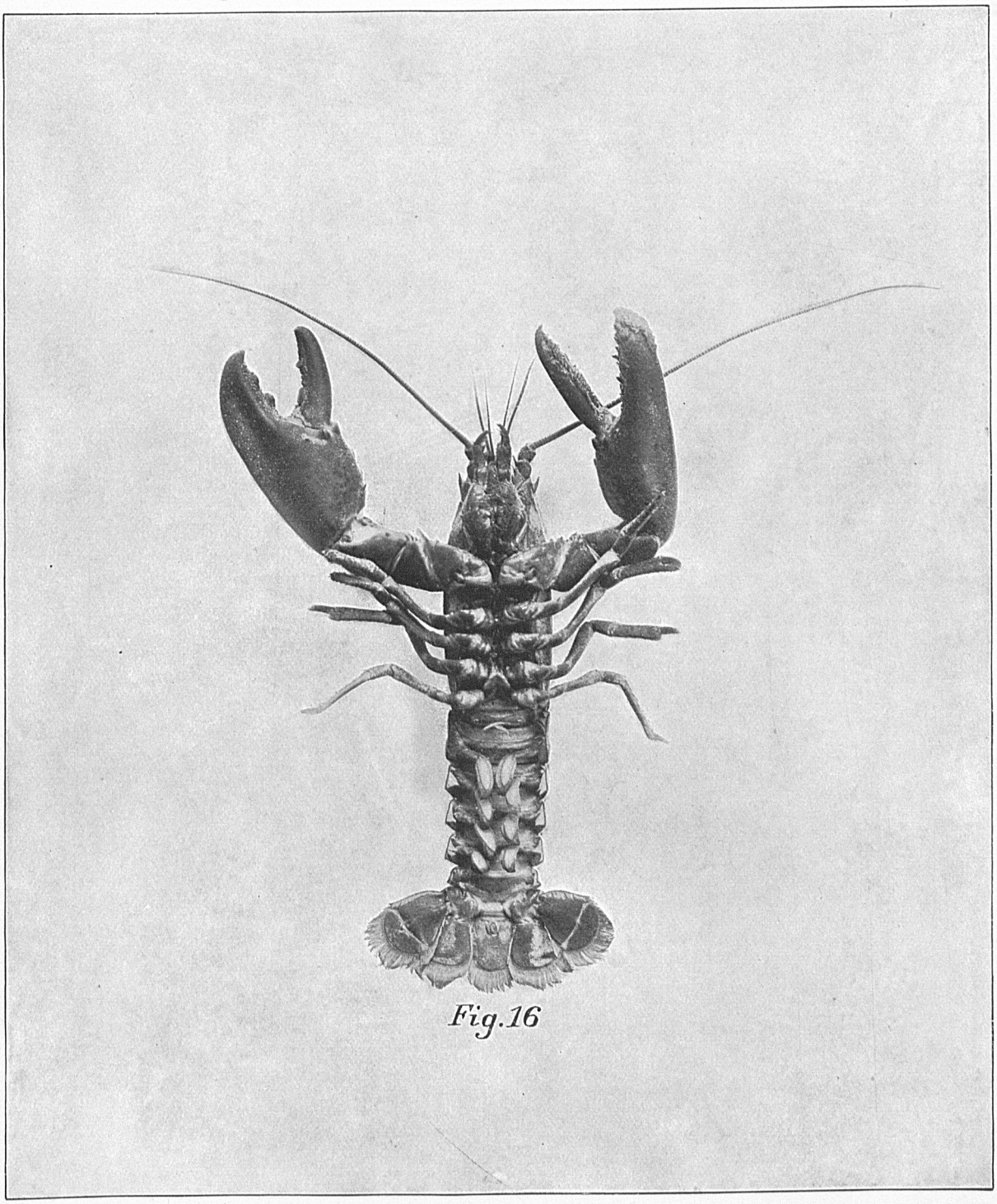


Fig. 16

From photograph.

IMMATURE FEMALE LOBSTER Natural size. Ventral view.

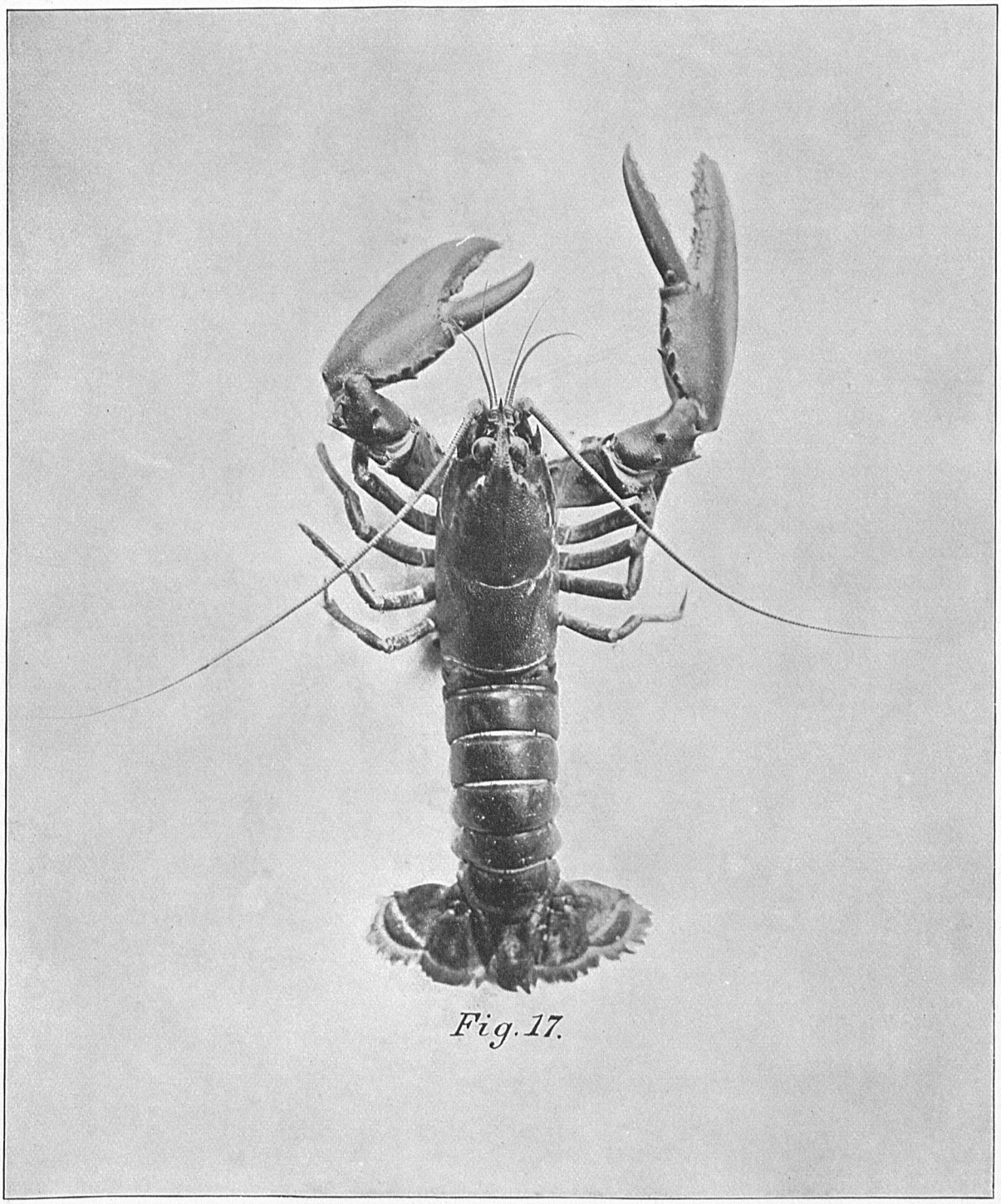


Fig. 17.

From photograph.

IMMATURE MALE LOBSTER. Natural size.

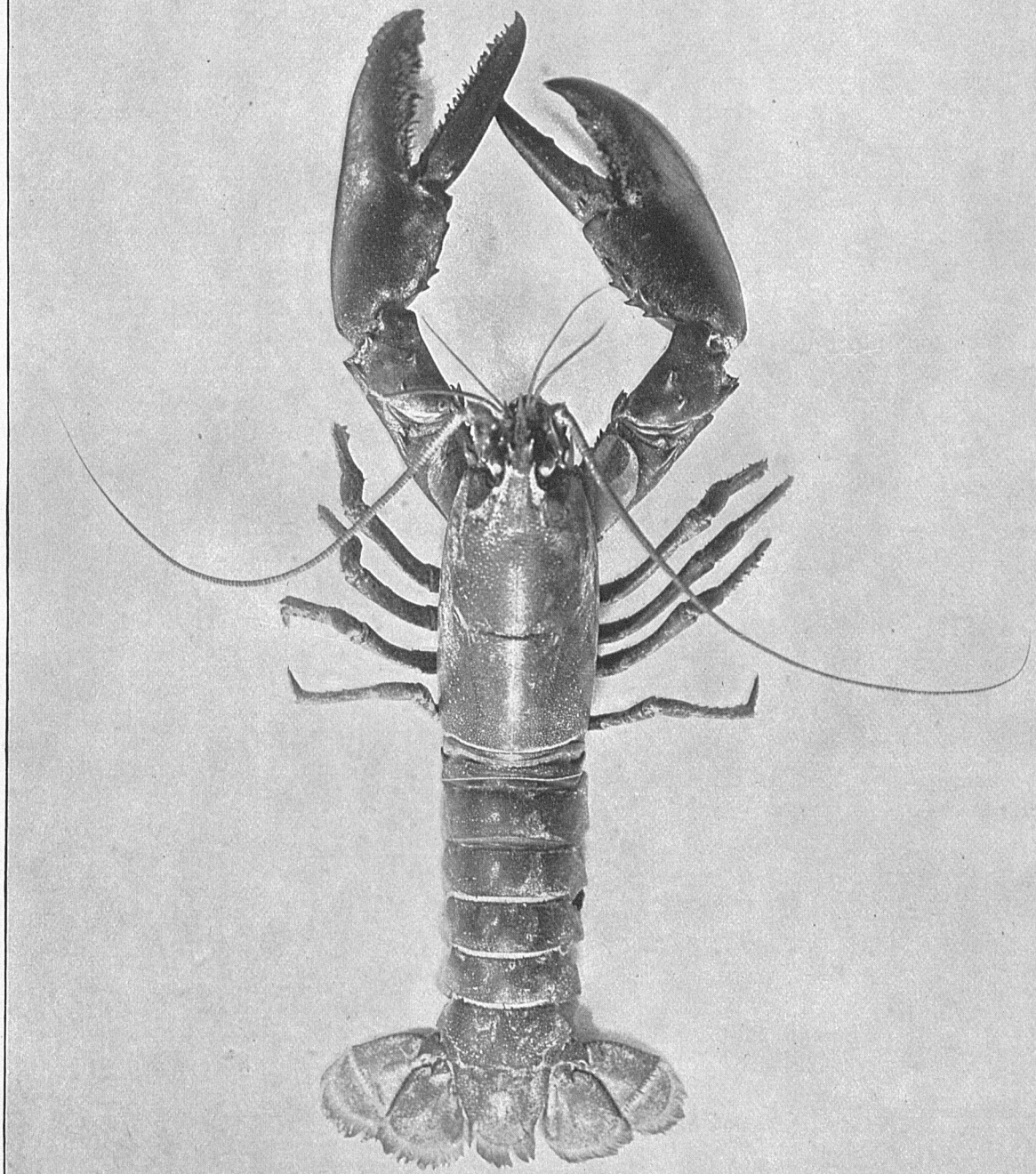


Fig. 18.

From photograph.

IMMATURE MALE LOBSTER. Natural size.

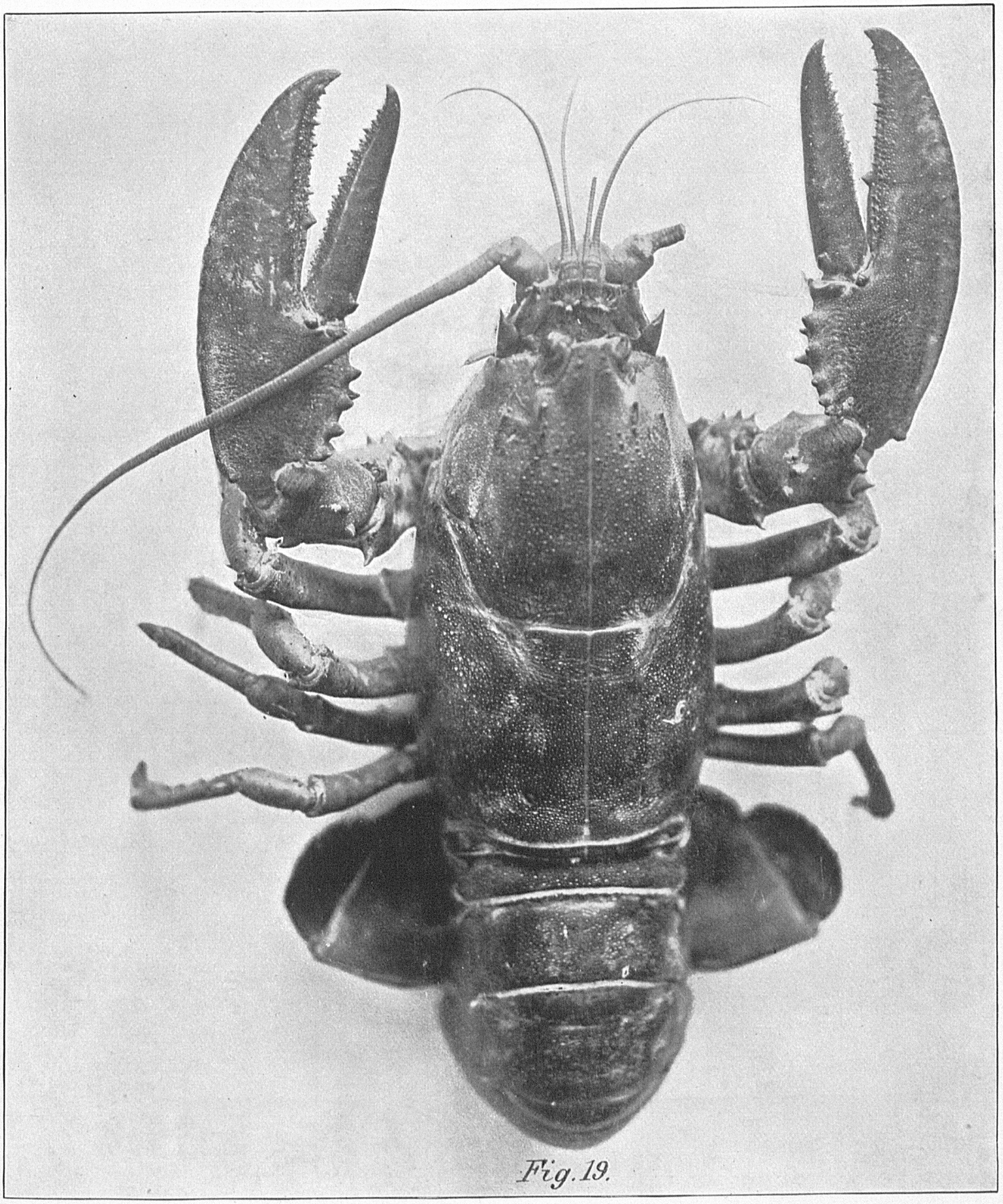


Fig. 19.

From photograph.

ADULT MALE LOBSTER WITH ABNORMAL SYMMETRY IN LARGE CLAWS.

Fig. 20.

Fig. 20a

F. H. Herrick ad nat. del.

RIGHT CRUSHING-CLAWS OF LOBSTERS WHICH WEIGHED 23 AND 1¼ POUNDS. Life size.

Fig. 21.

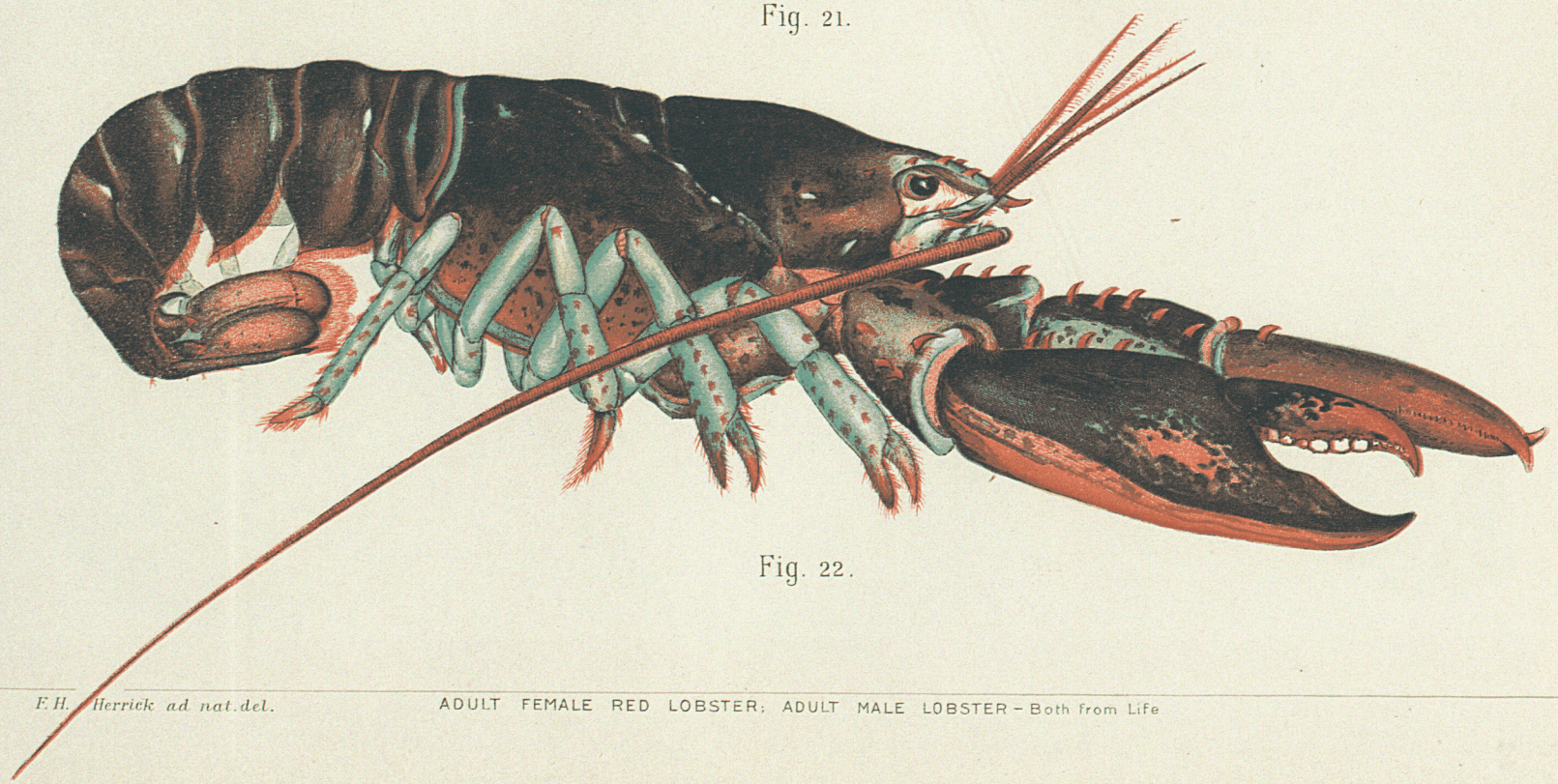


Fig. 22.

F. H. Herrick ad nat. del.

ADULT FEMALE RED LOBSTER; ADULT MALE LOBSTER – Both from Life

Fig. 23.

Fig. 24.

Fig. 25.

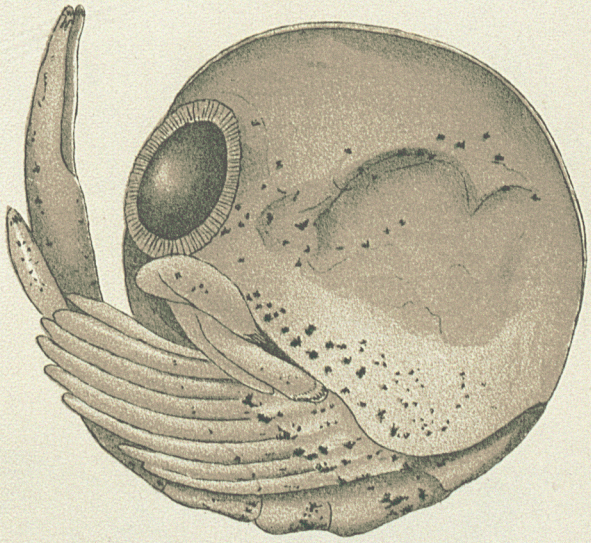


Fig. 26.

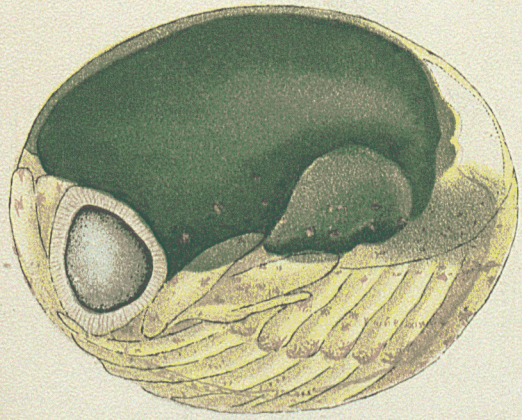
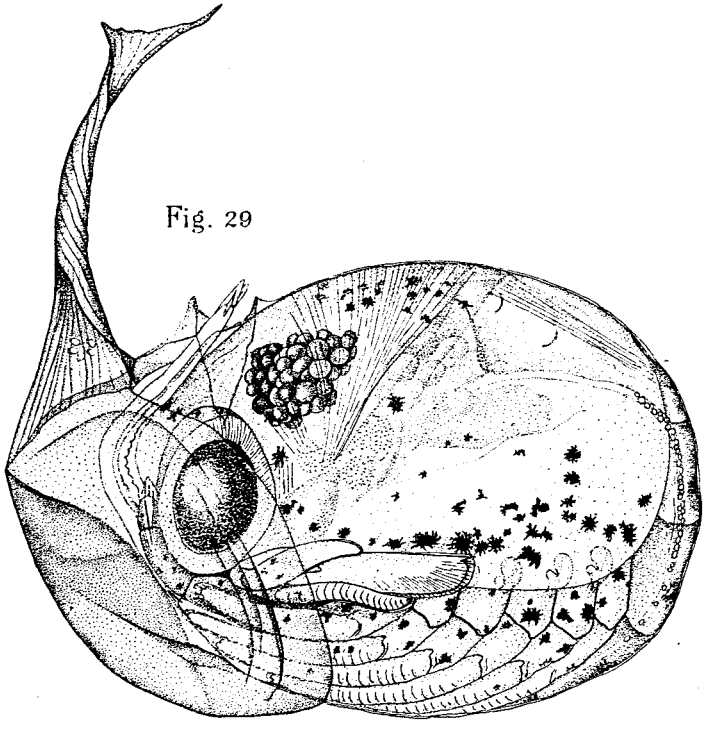


Fig. 27.

Fig. 28.

F. H. Herrick ad nat. del. FRESHLY LAID EGGS AND ADVANCED EMBRYOS.



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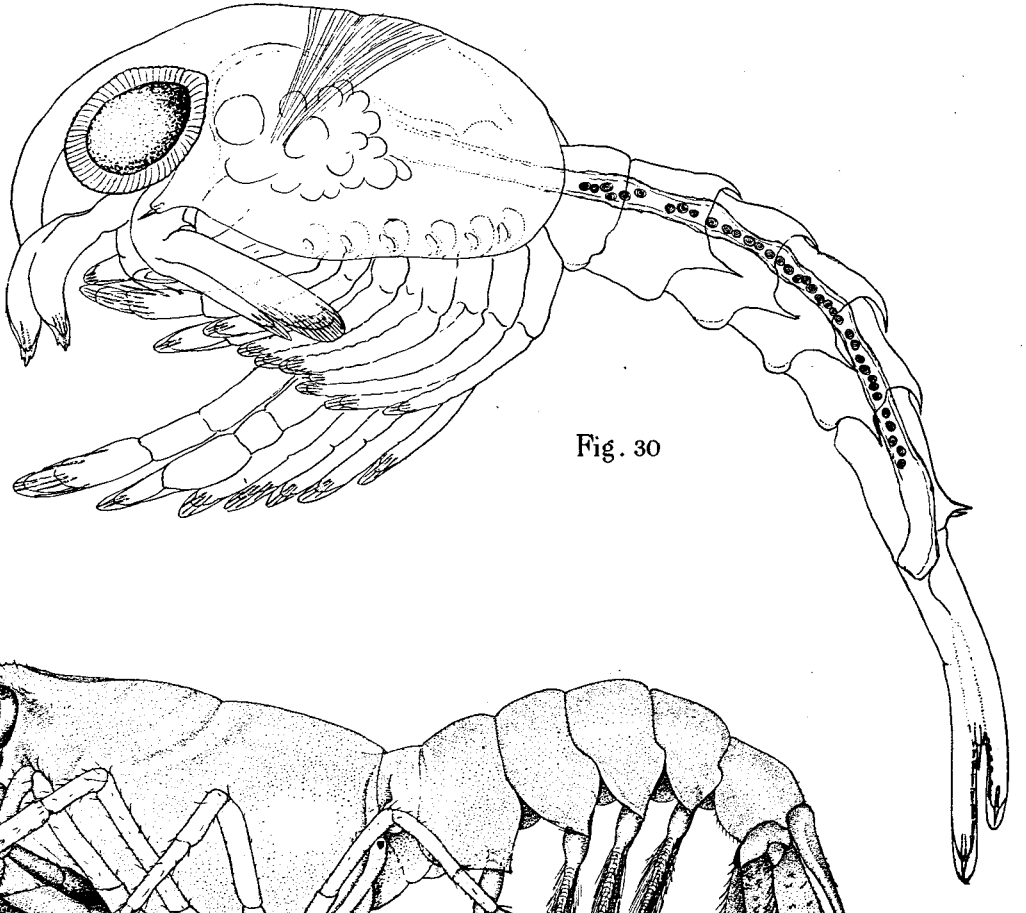


Fig. 30

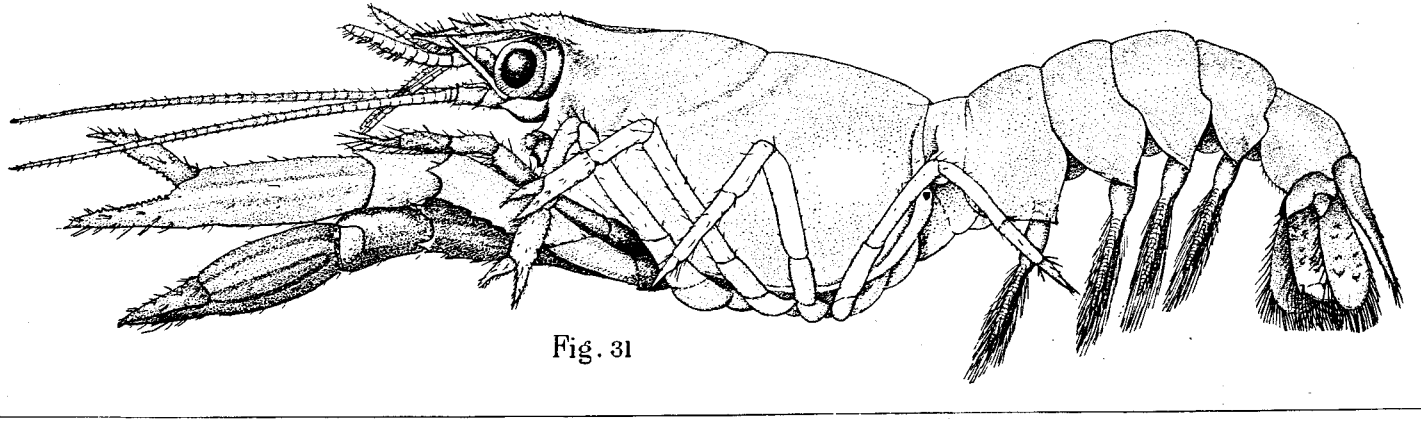


Fig. 31

F. H. Herrick ad nat. del.

LARVA HATCHING FROM EGG, LARVA REMOVED FROM EGG-SHELL, AND YOUNG IN FIFTH STAGE.

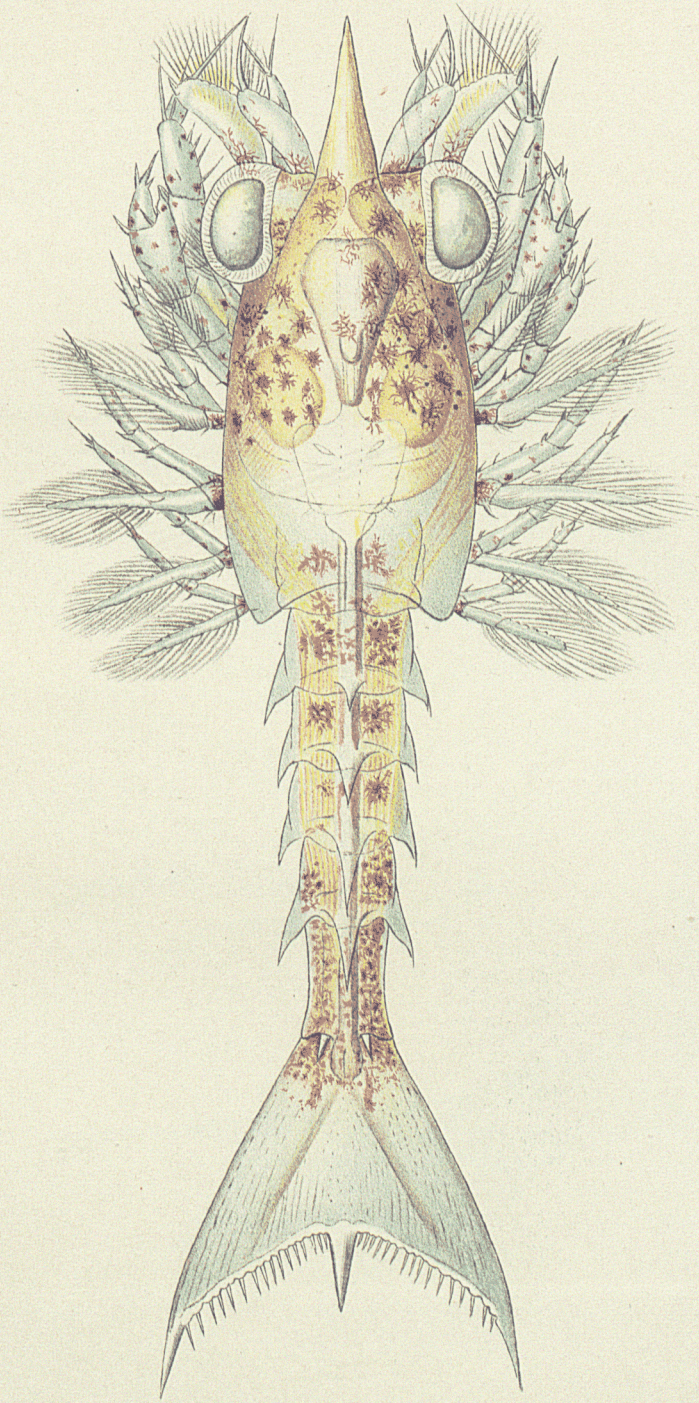


Fig. 32.

LENGTH.

F. H. Herrick ad. nat. del. THE FIRST LARVA; or First Free-Swimming Stage of the Lobster.

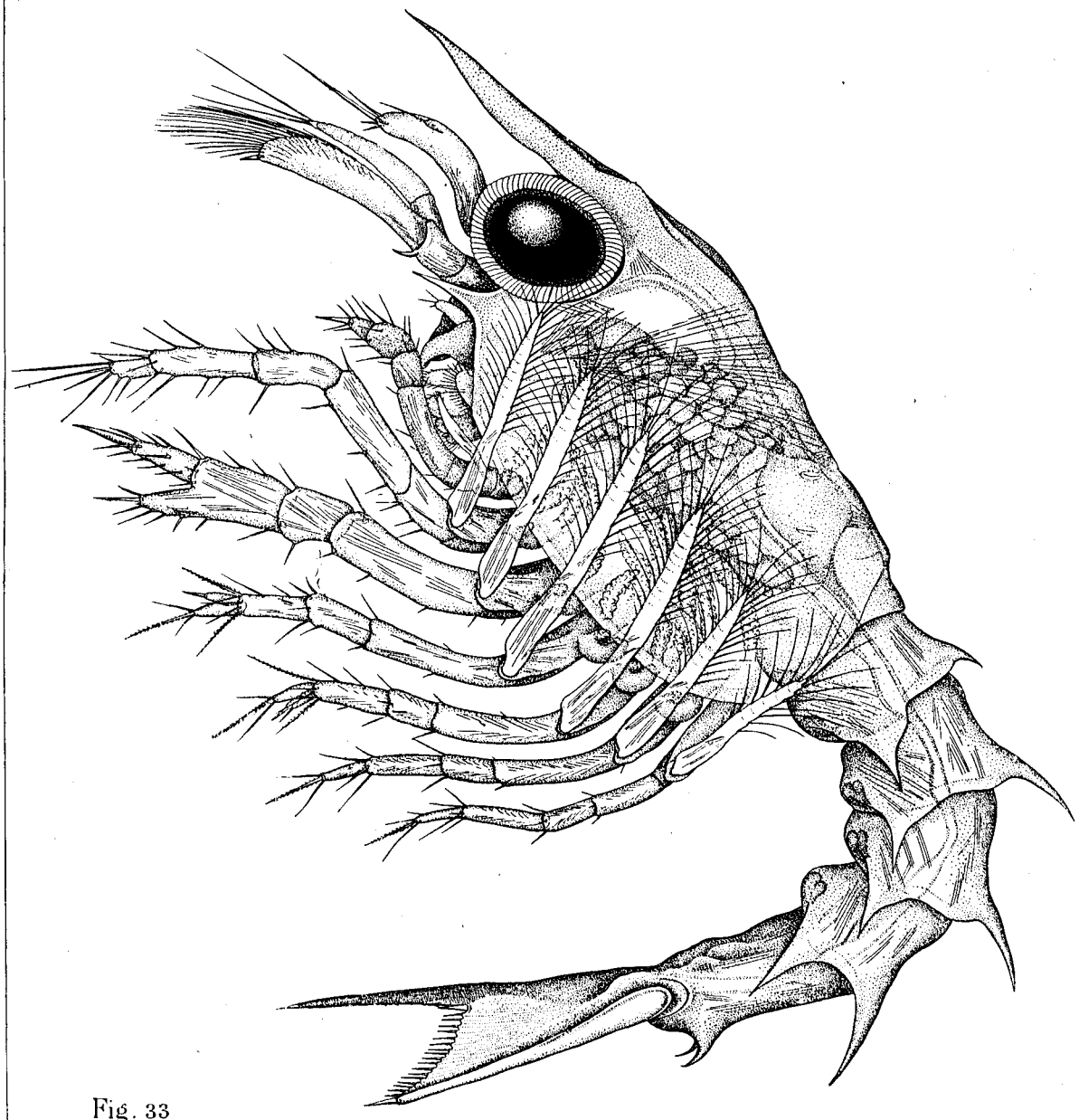


Fig. 33

F. H. Herrick ad nat. del.

FIRST LARVAL STAGE.

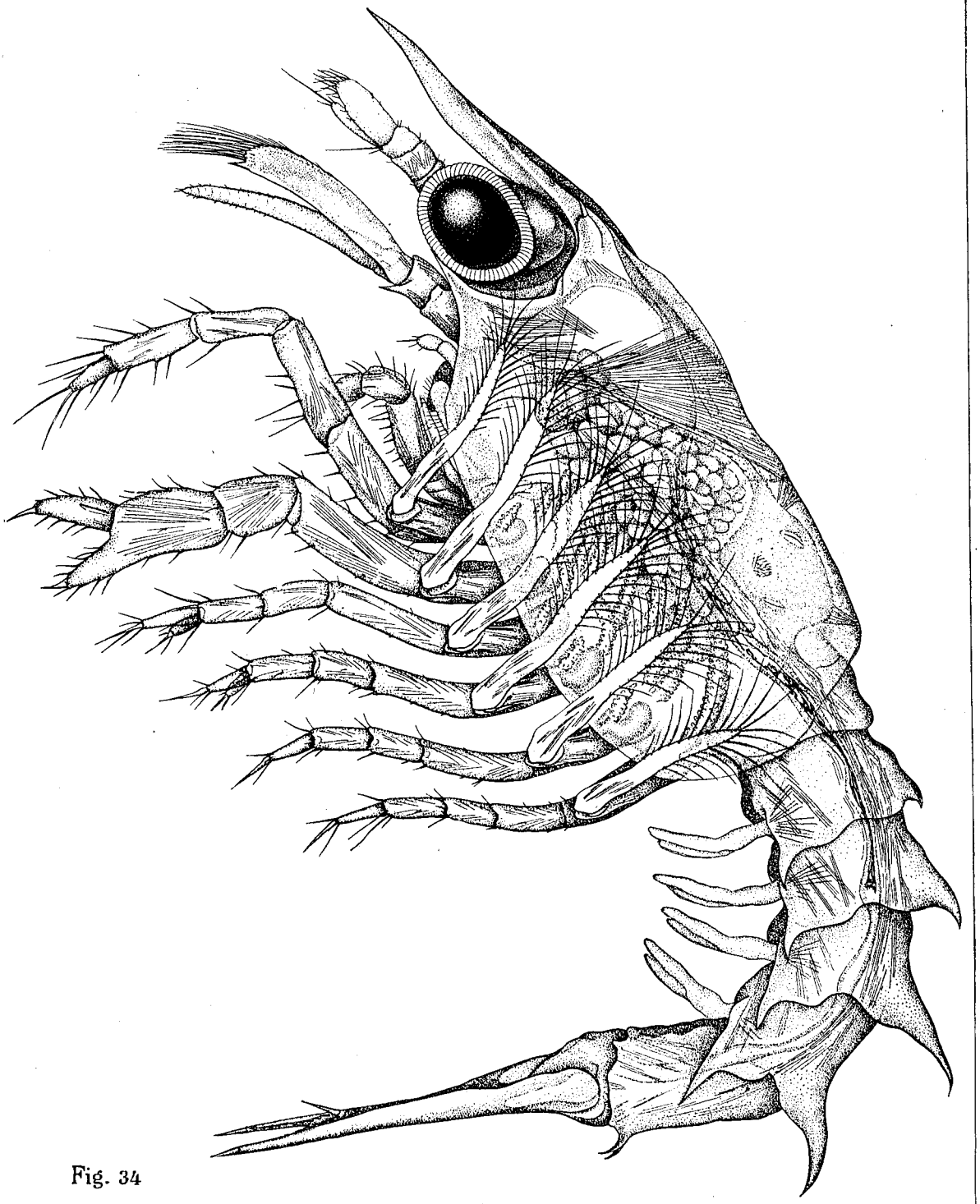


Fig. 34

F. H. Herrick ad nat del.

SECOND LARVAL STAGE.

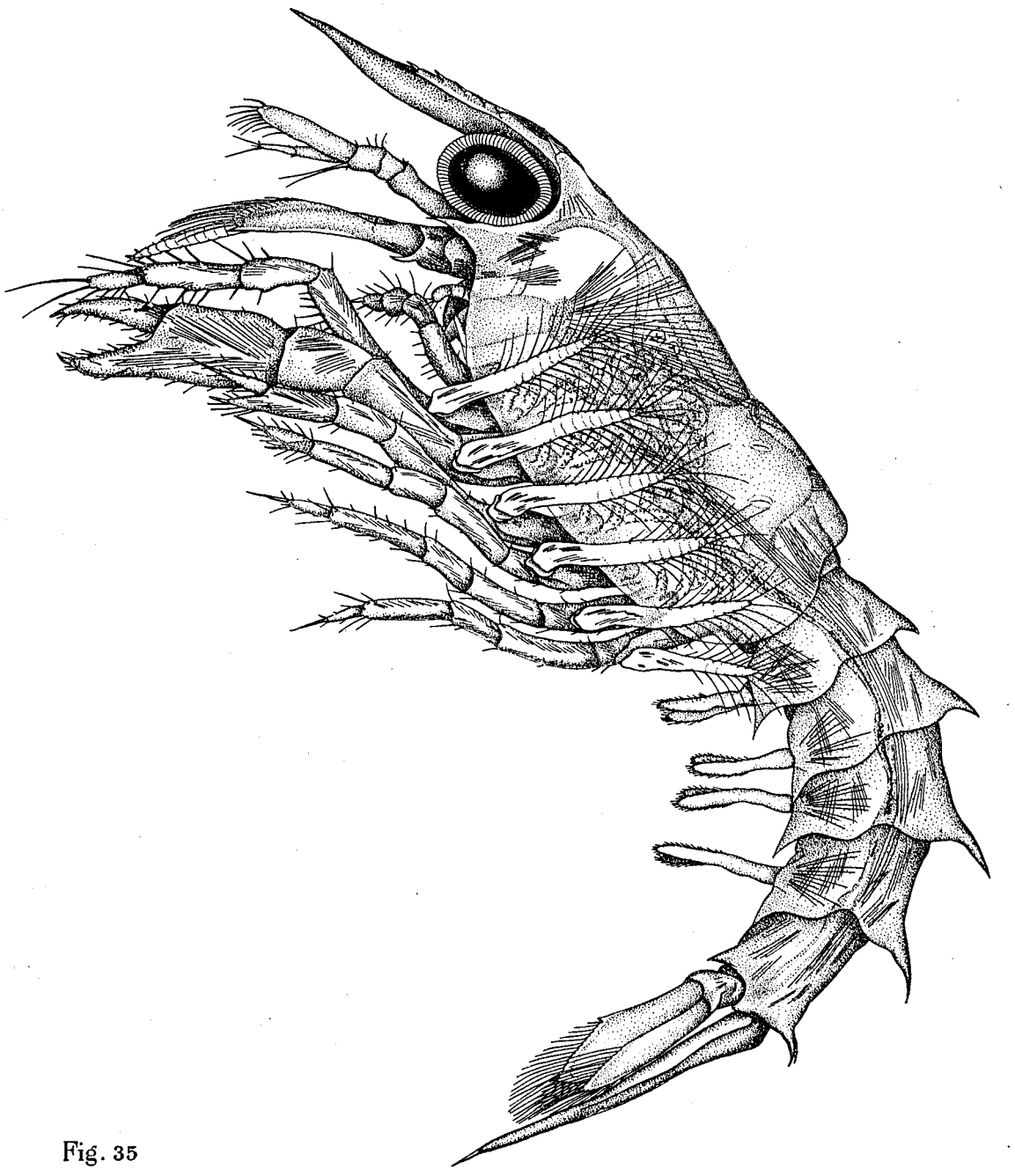
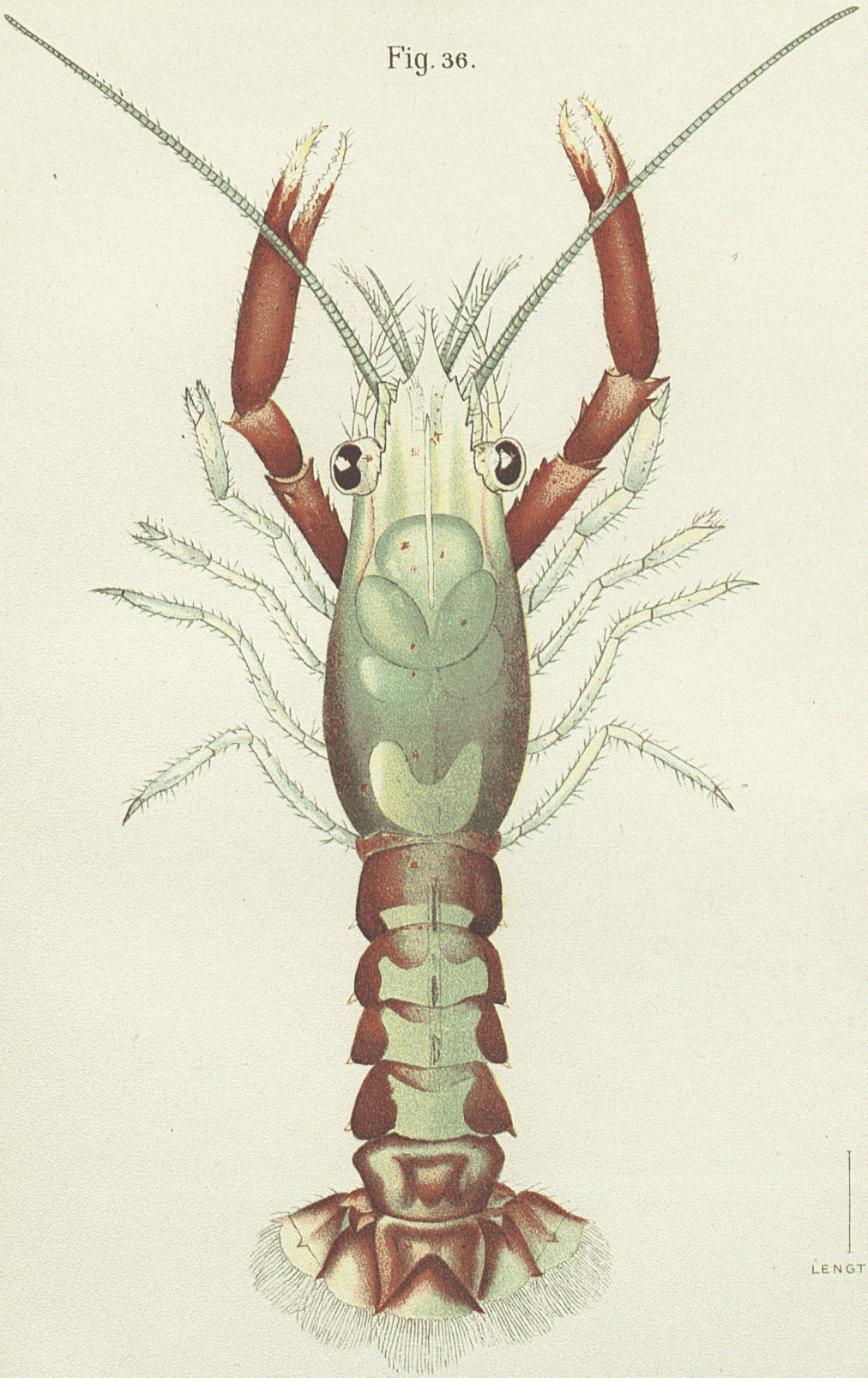


Fig. 35

F. H. Herrick ad nat. del.

THIRD LARVAL STAGE.

Fig. 36.

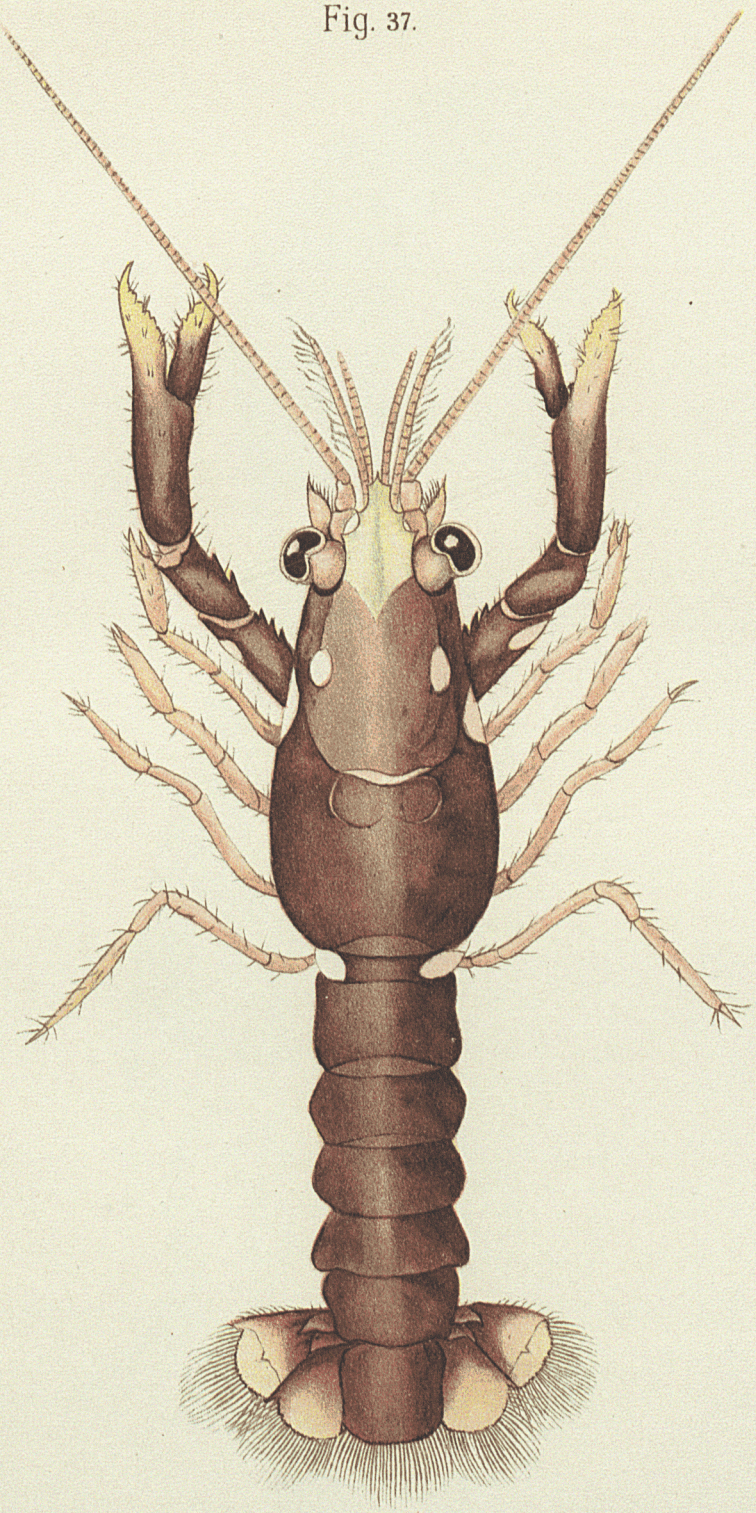


LENGTH.

F. H. Herrick ad nat. del.

FOURTH FREE-SWIMMING STAGE.

Fig. 37.



LENGTH.

F. H. Herrick ad nat. del.

SIXTH STAGE

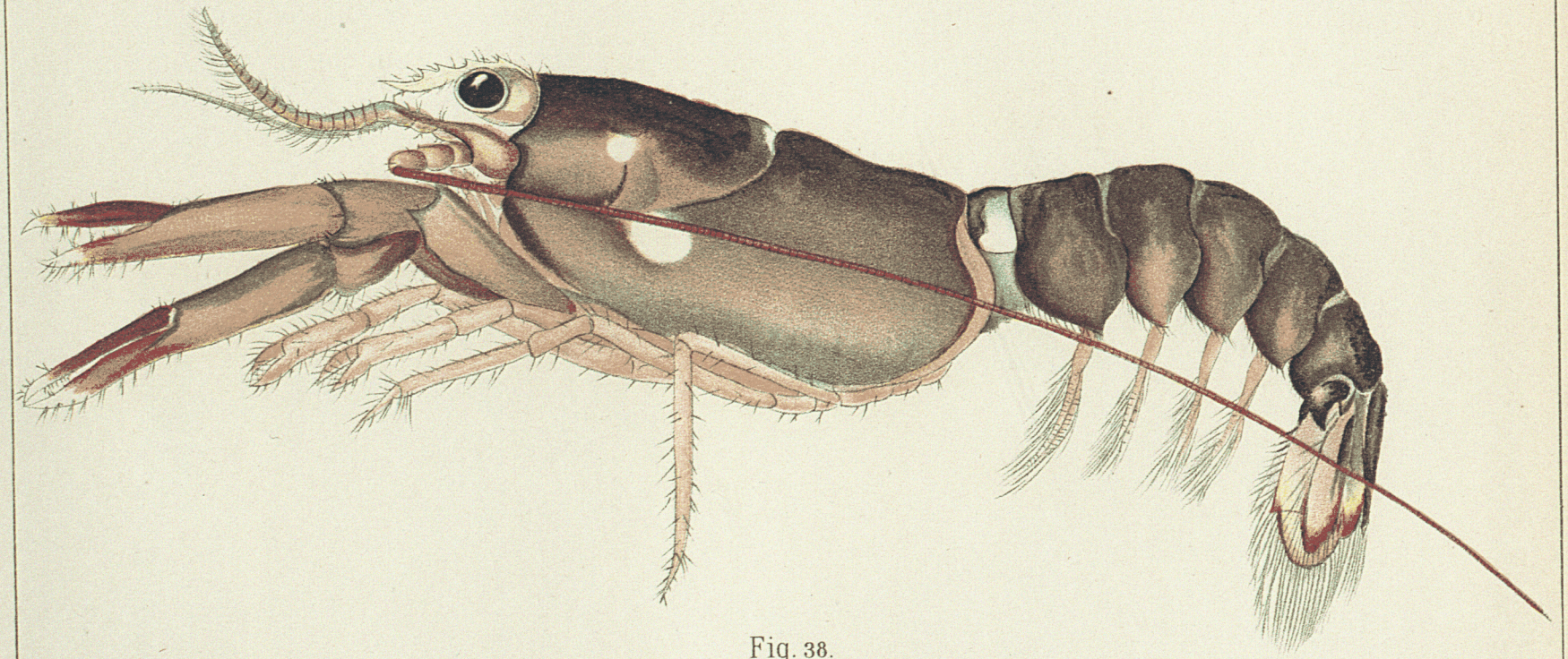


Fig. 38.

LENGTH.

F. H. Herrick ad nat. del.

SIXTH STAGE

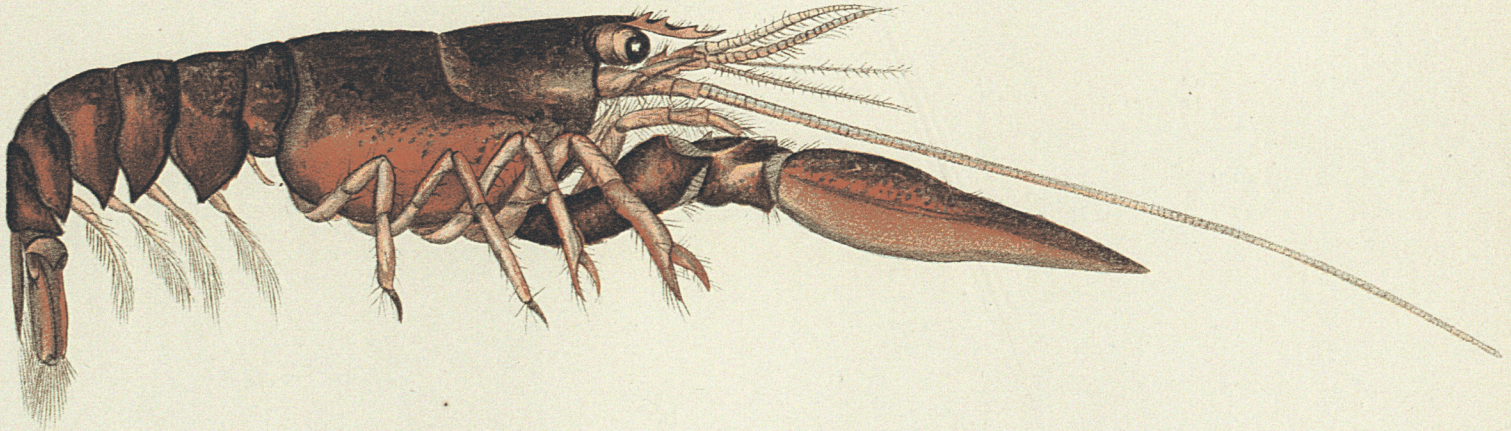


Fig. 39.

LENGTH.

F. H. Herrick ad. nat. del.

IMMATURE LOBSTER – One Year Old.

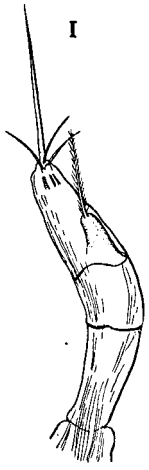
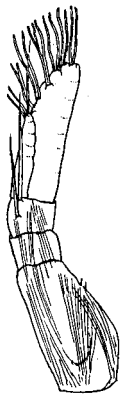


Fig. 40



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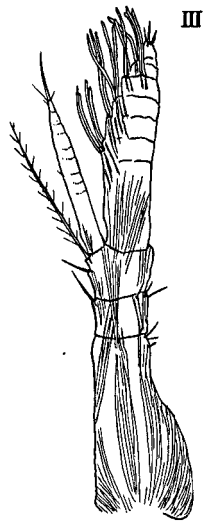

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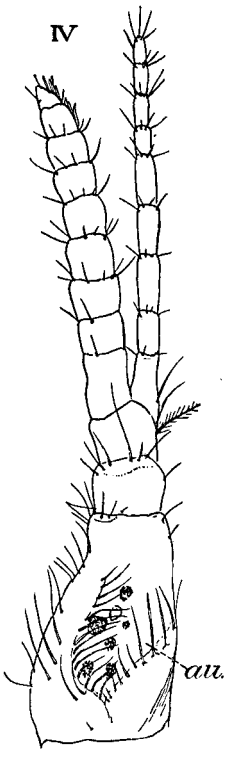

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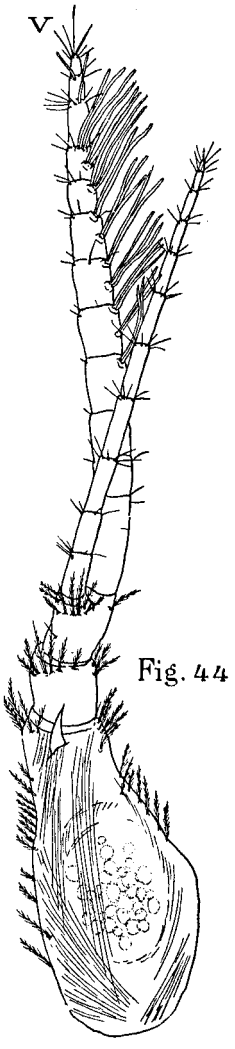

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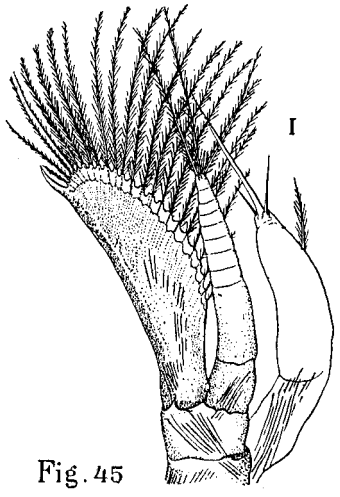

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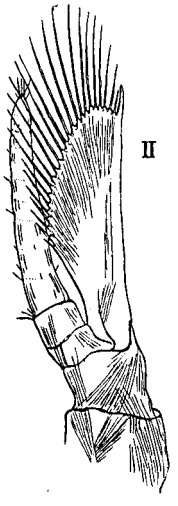

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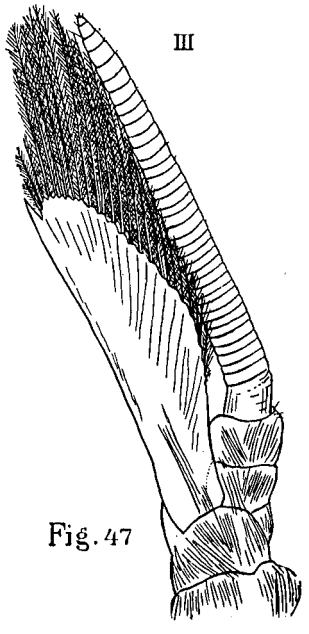

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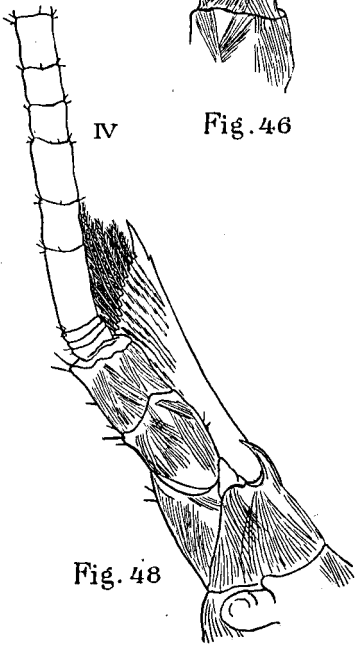

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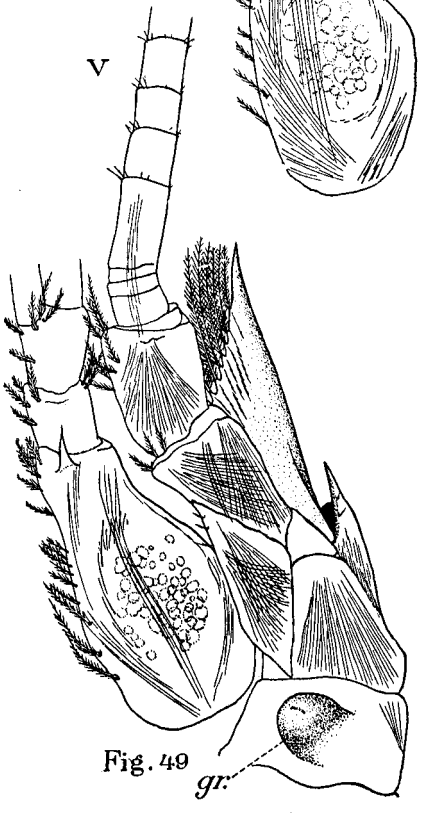


Fig. 49

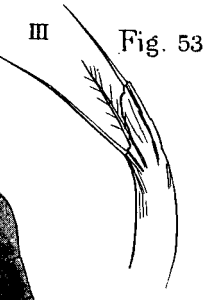
F. H. Herrick ad nat. del.

MORPHOLOGY OF APPENDAGES.

Fig. 50

Fig. 51

Fig. 52



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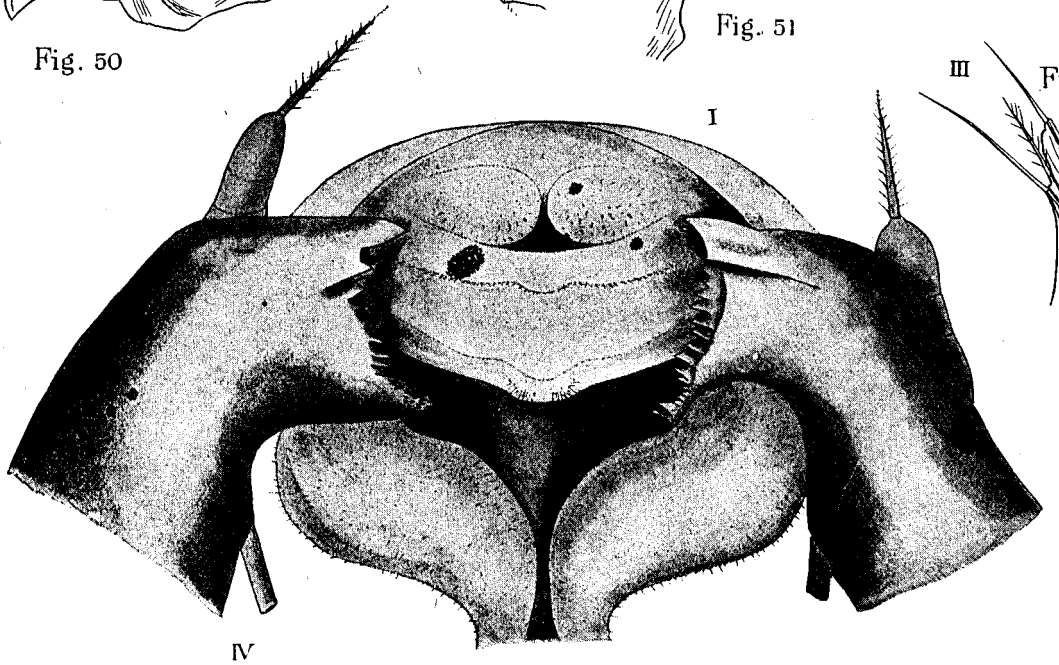
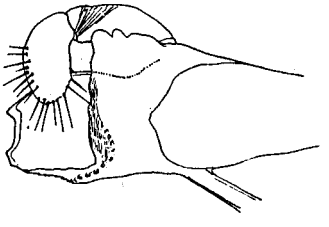


Fig. 54



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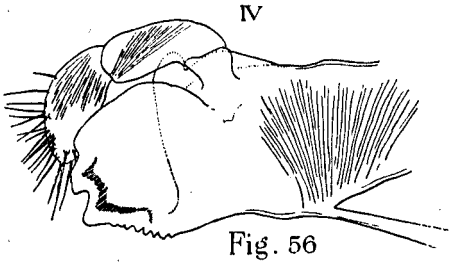


Fig. 56

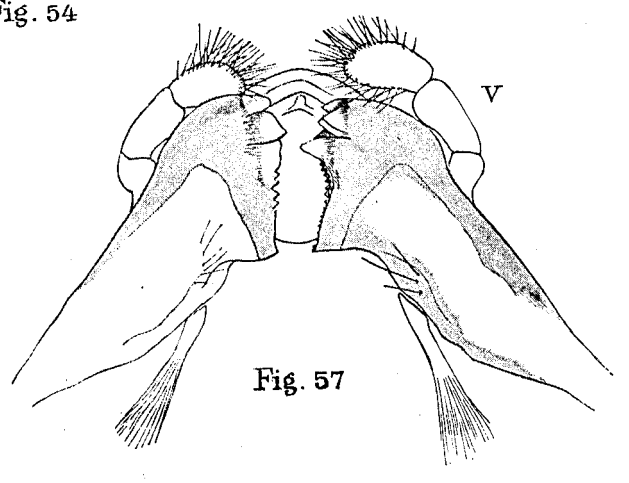


Fig. 57

F. H. Herrick ad nat. del.

MOUTH PARTS AND APPENDAGES OF THE YOUNG.

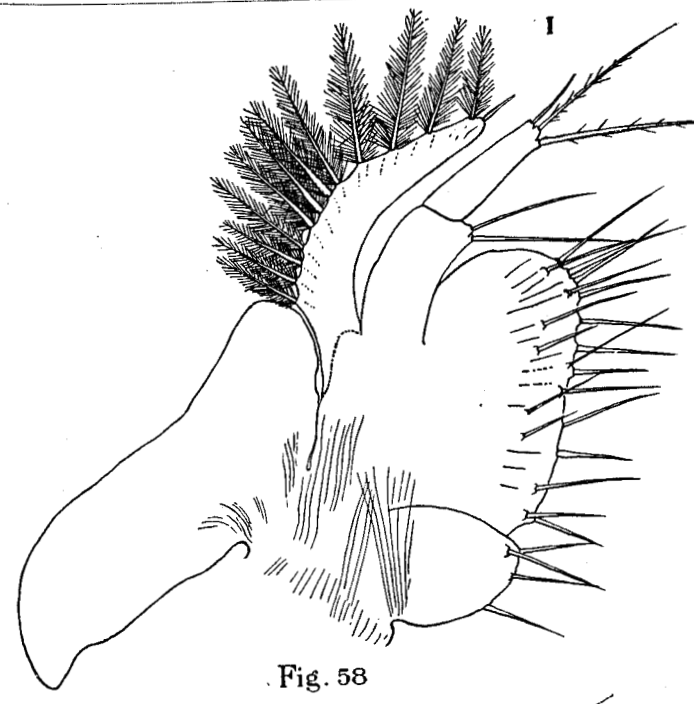


Fig. 58

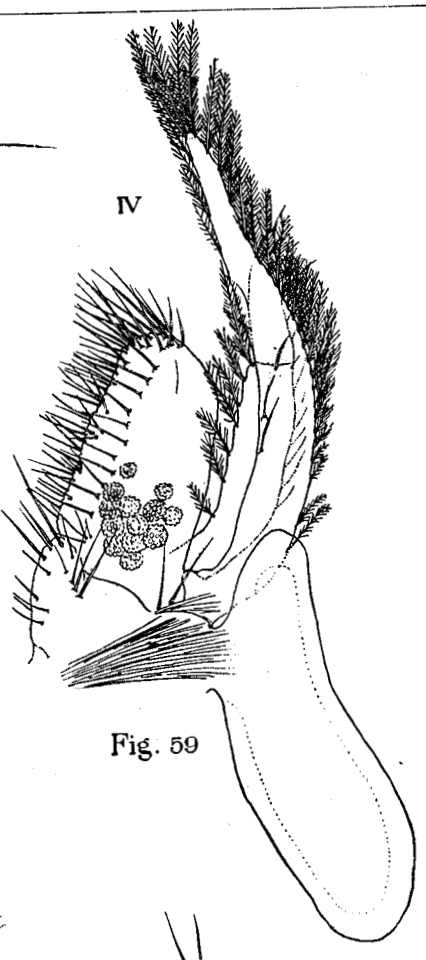


Fig. 59

Fig. 60

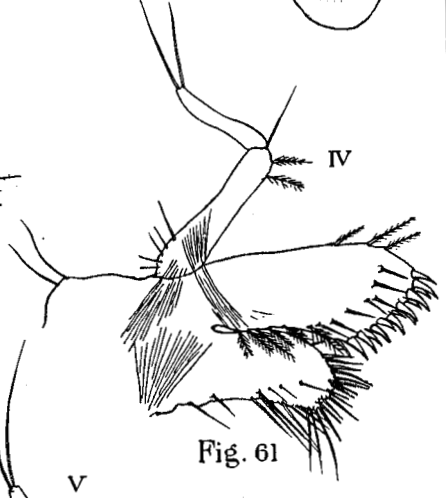


Fig. 61

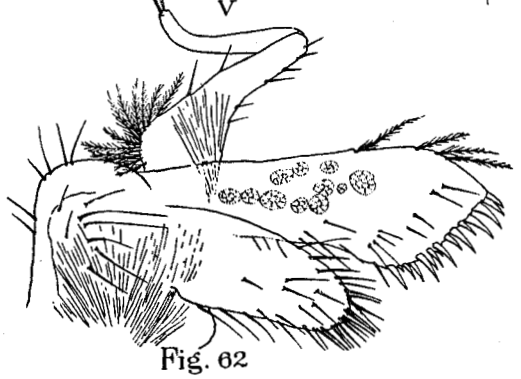
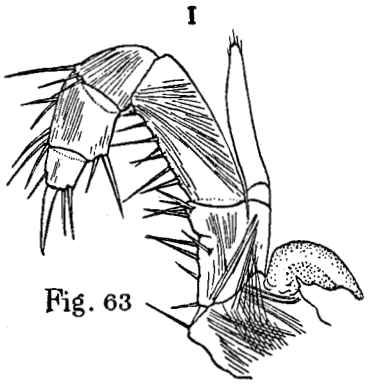


Fig. 62

F. H. Herrick ad nat. del.



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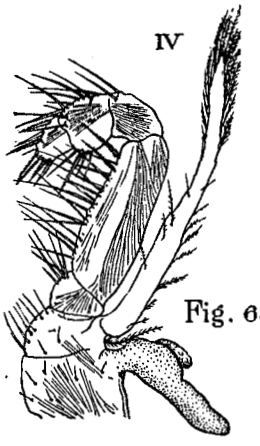

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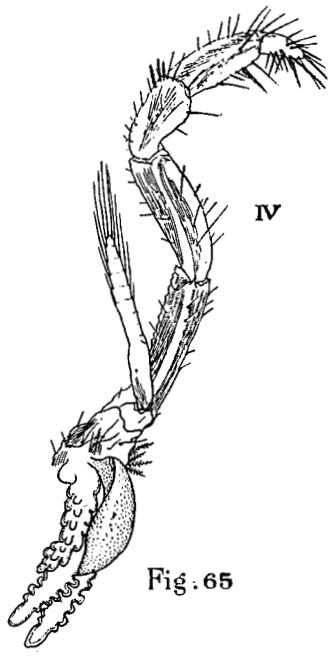


Fig. 65

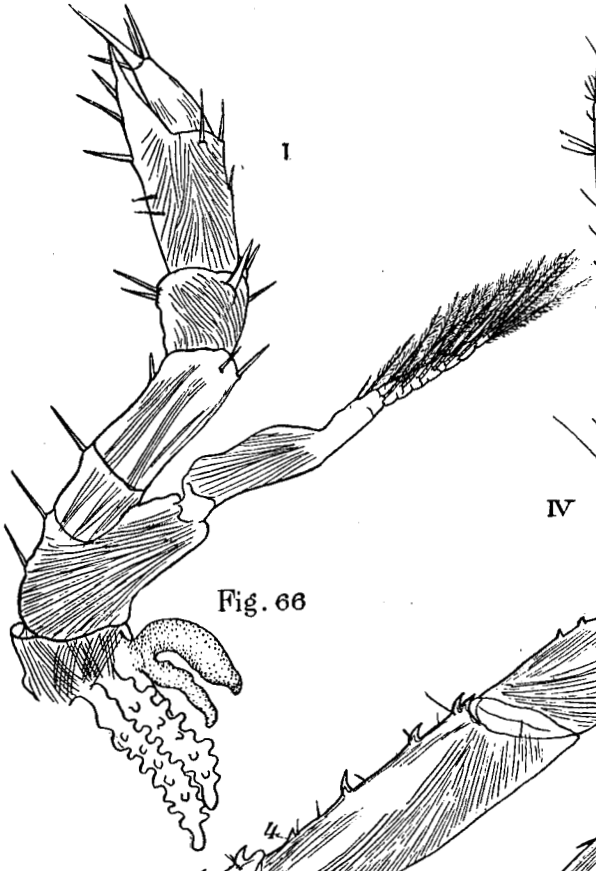
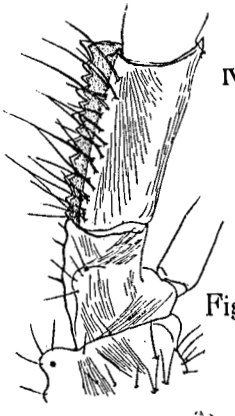


Fig. 66



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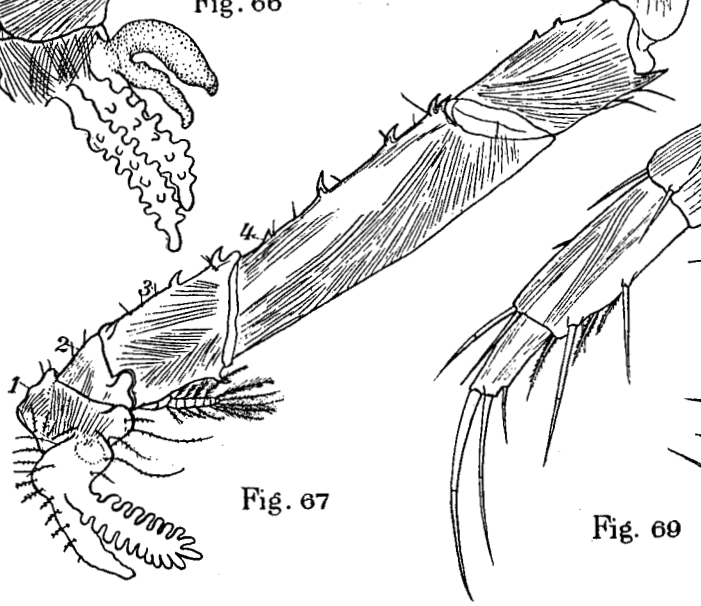


Fig. 67

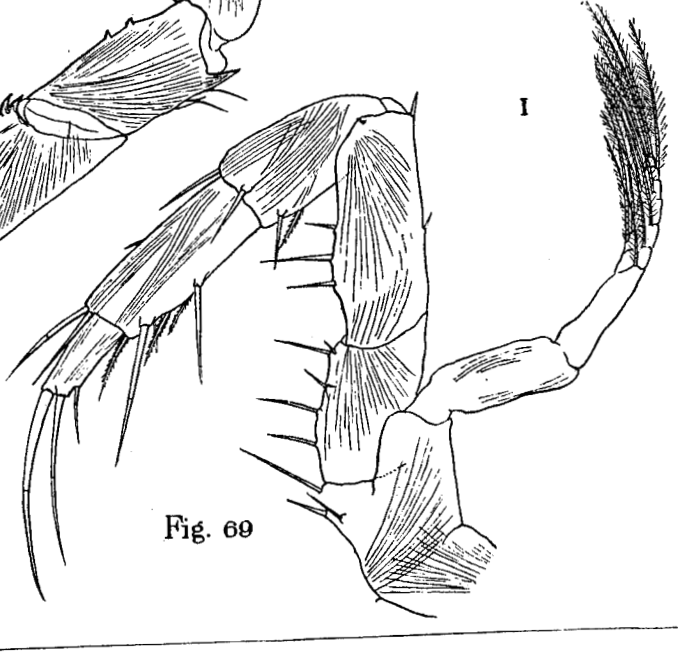


Fig. 69

F. H. Herrick ad nat. del.

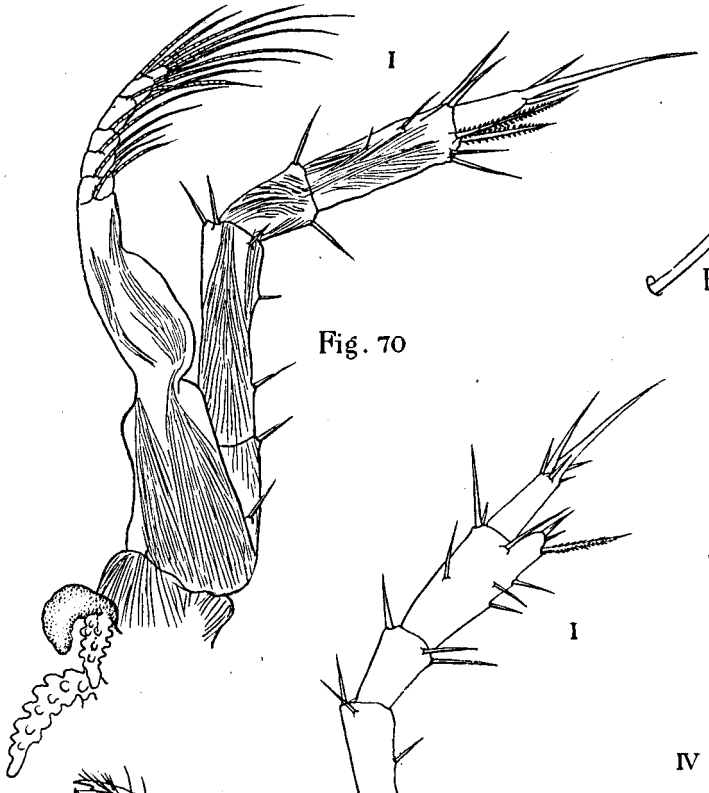


Fig. 70

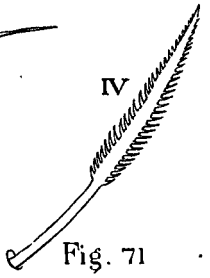
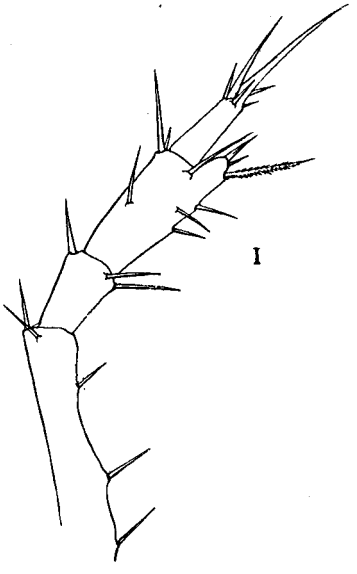


Fig. 71

Fig. 72



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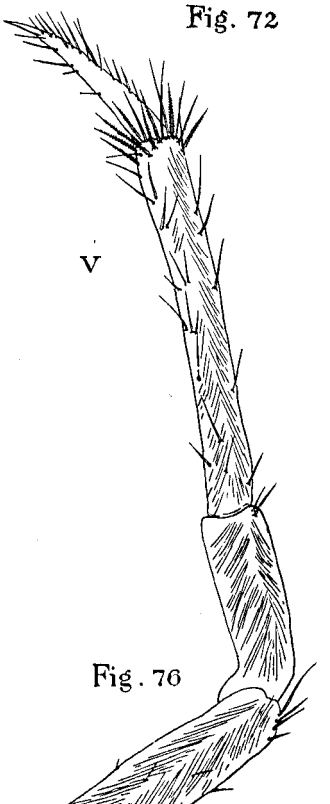

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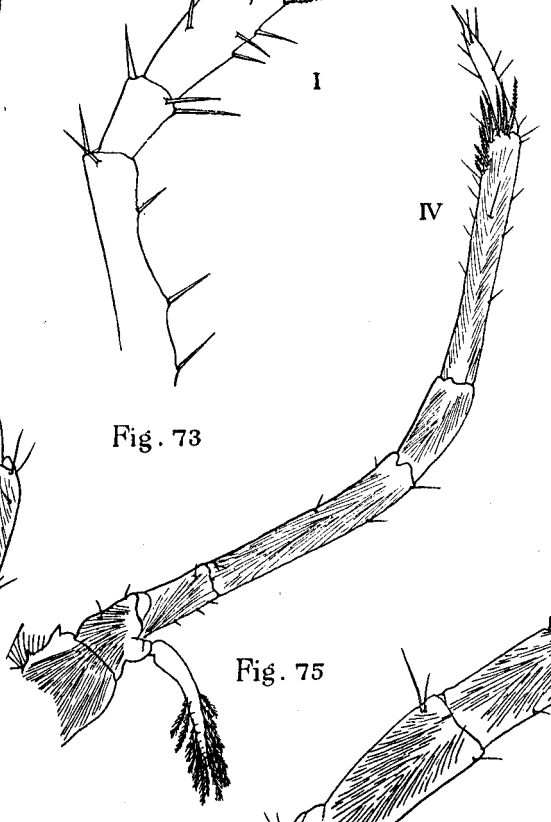


Fig. 75

Fig. 74

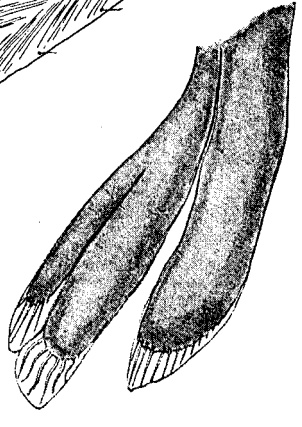


Fig. 77

F. H. Herrick ad nat. del.

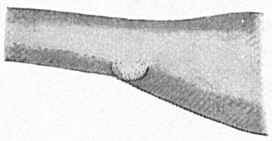
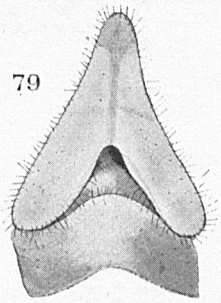


Fig. 78



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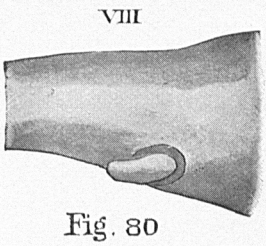

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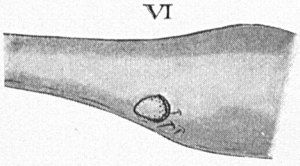

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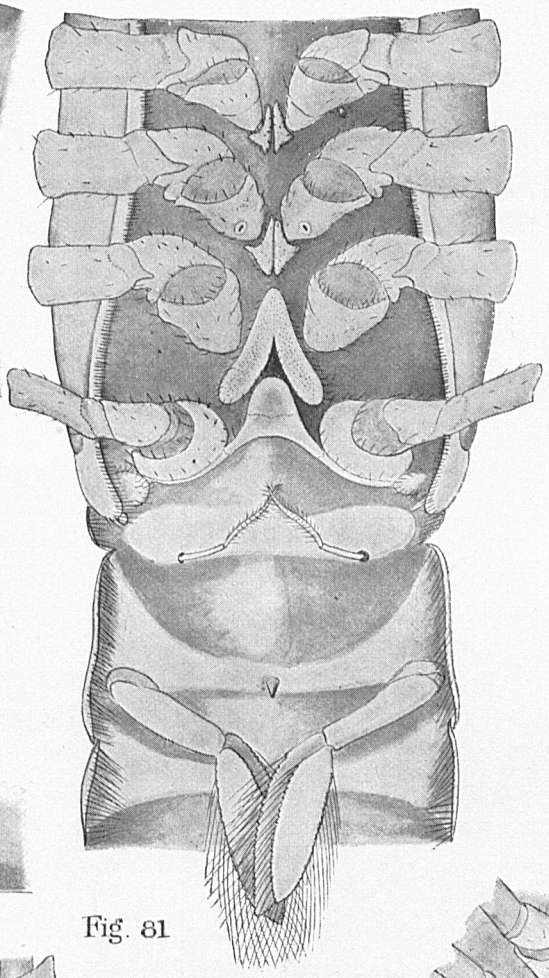


Fig. 81

Fig. 86

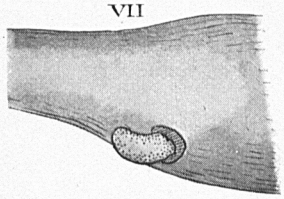


Fig. 83

Fig. 87

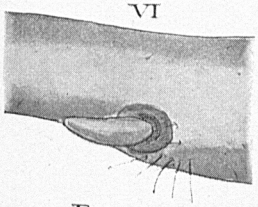


Fig. 84

Fig. 88

♀ VIII

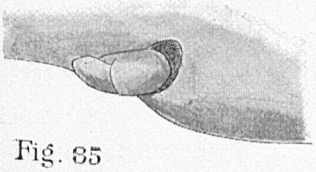


Fig. 85

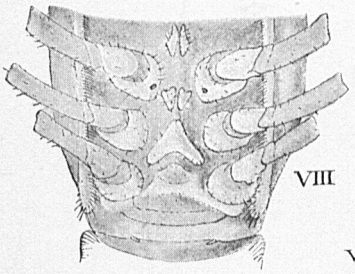


Fig. 89

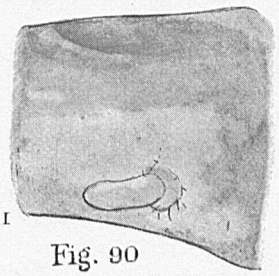


Fig. 90

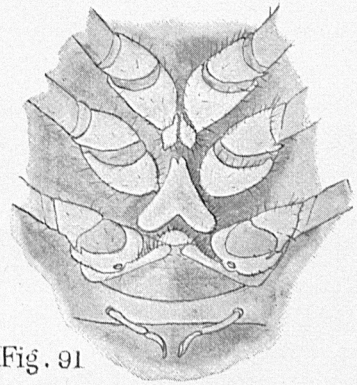
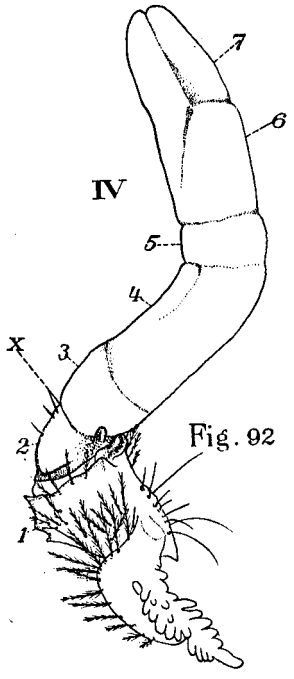


Fig. 91

F. H. Herrick ad nat. del.

DEVELOPMENT OF FIRST PAIR OF ABDOMINAL APPENDAGES AND SEMINAL RECEPTACLE.



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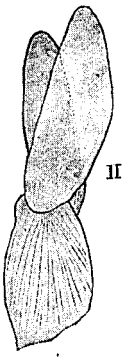


Fig. 93

Fig. 94

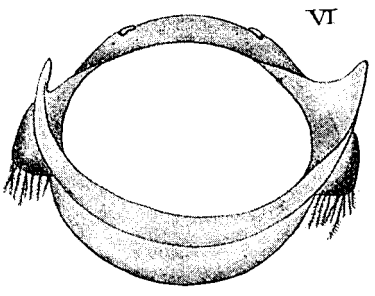


Fig. 95

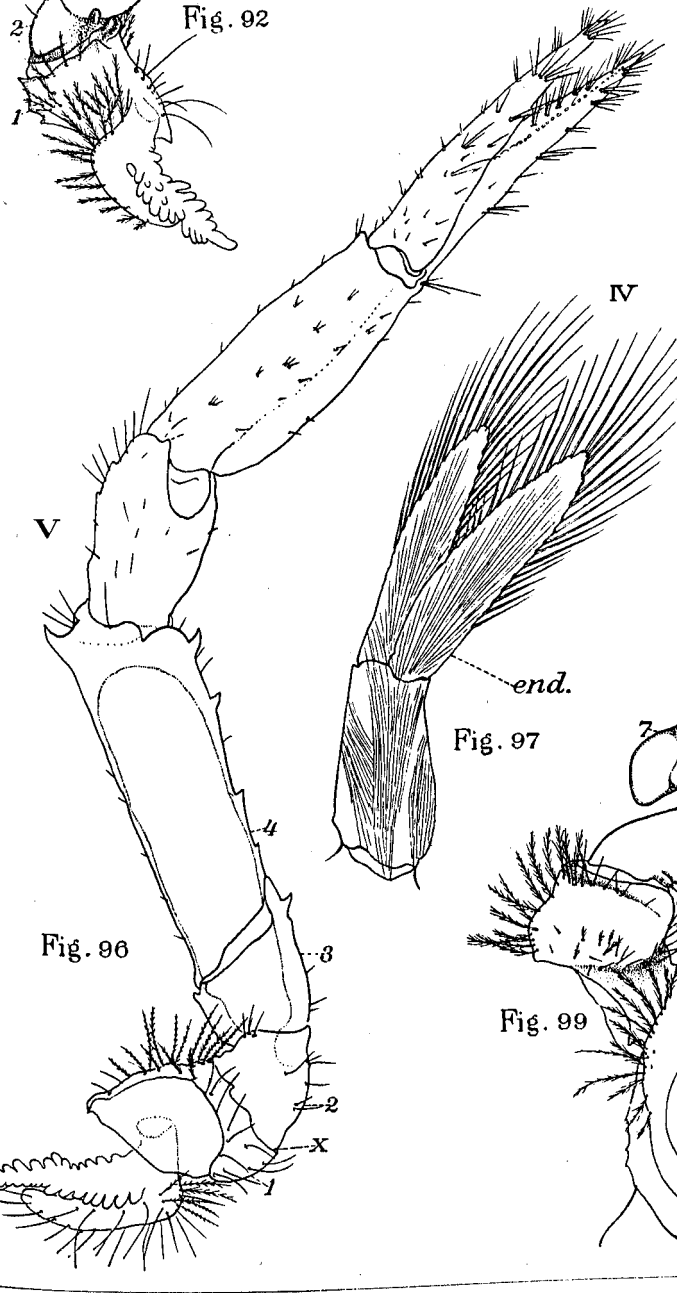
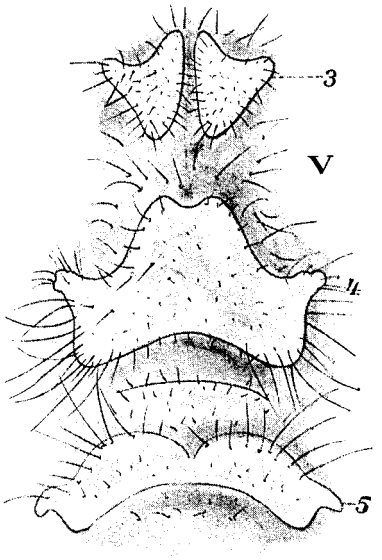


Fig. 96

Fig. 97



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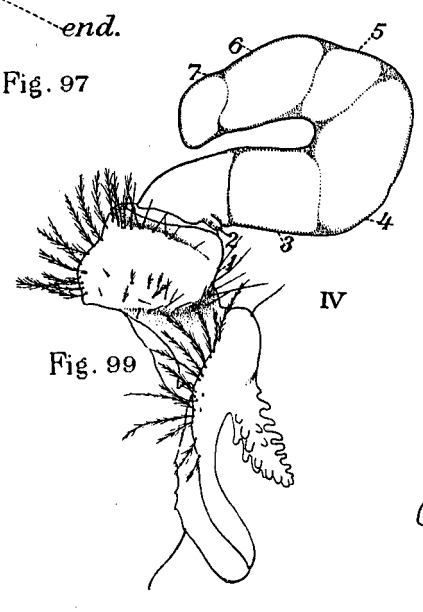

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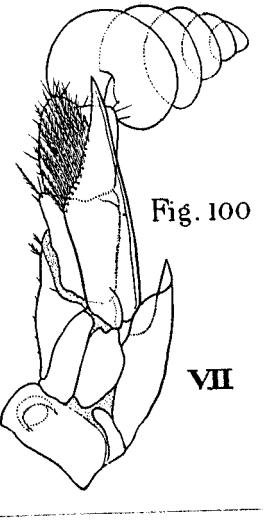


Fig. 100

F. H. Herrick ad nat. del.

REGENERATION AND DEVELOPMENT OF APPENDAGES.

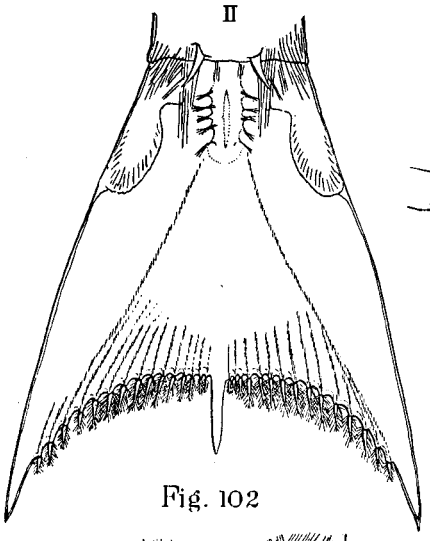


Fig. 102

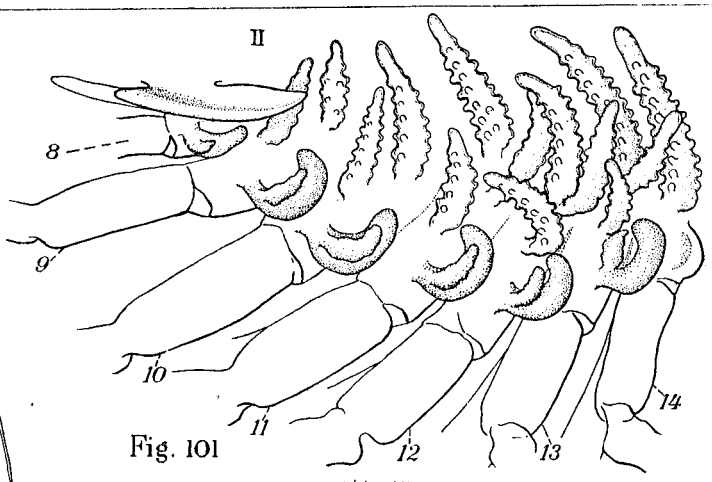
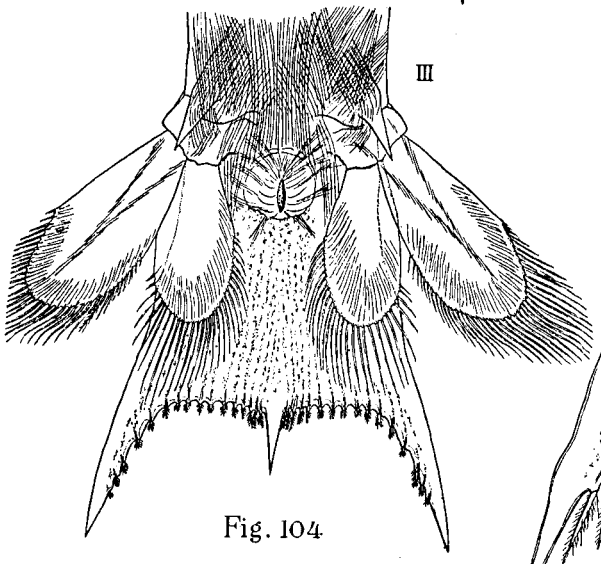


Fig. 101



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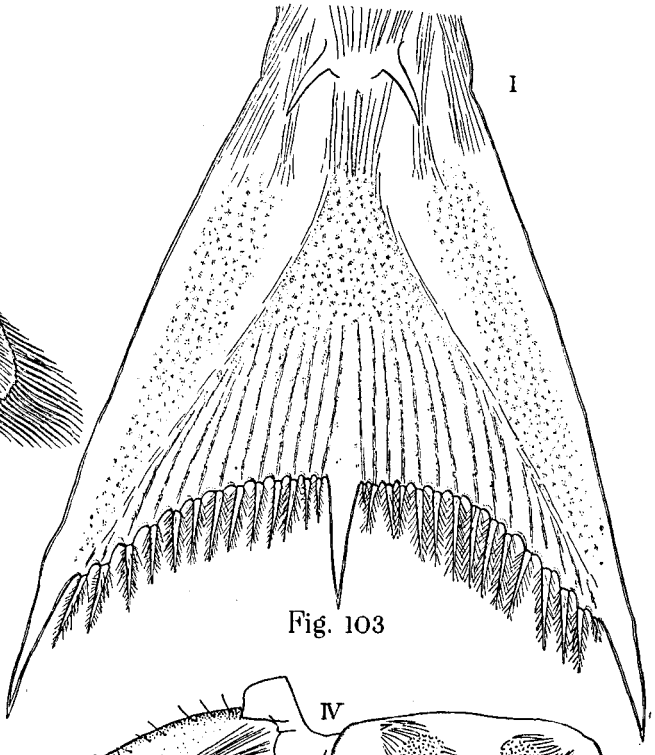

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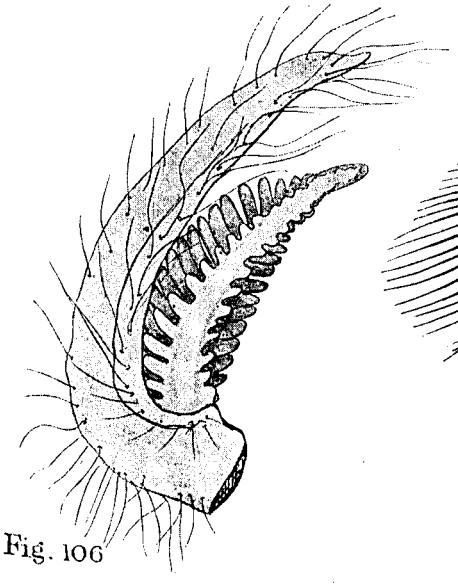

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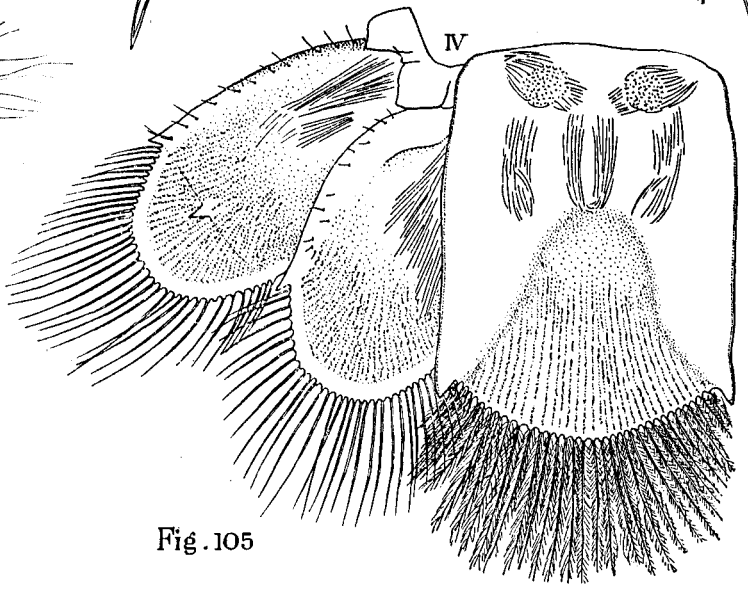


Fig. 105

F. H. Herrick ad nat. del.

MORPHOLOGY OF APPENDAGES AND BRANCHIÆ.

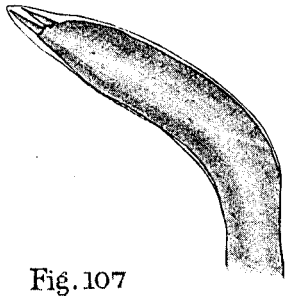


Fig. 107

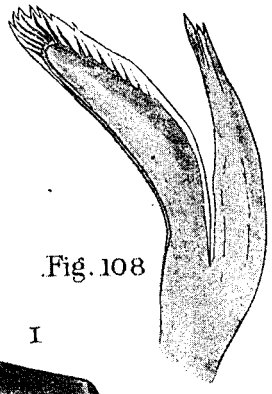


Fig. 108

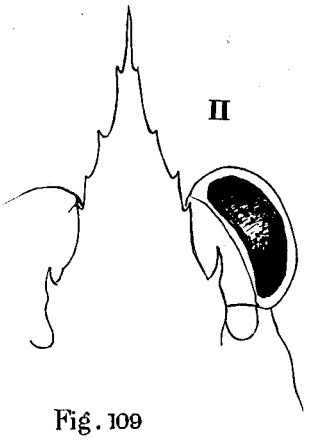
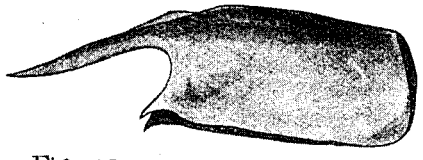


Fig. 109

I



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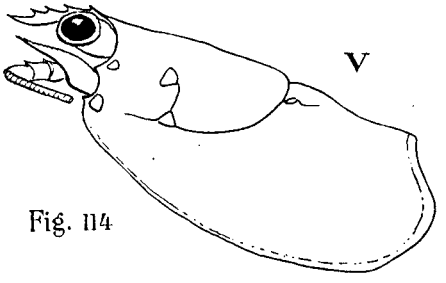

Fig. 114

II

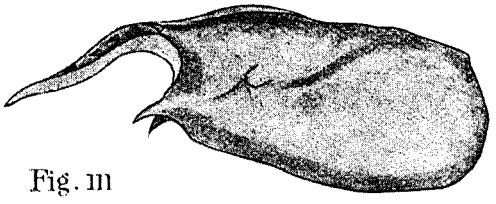

Fig. 111

III

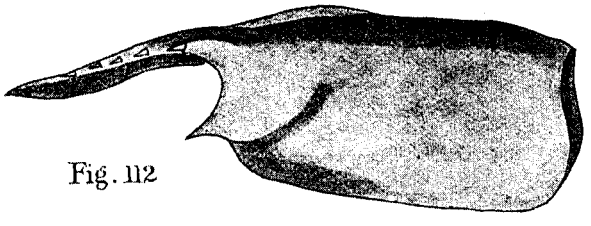

Fig. 112

IV

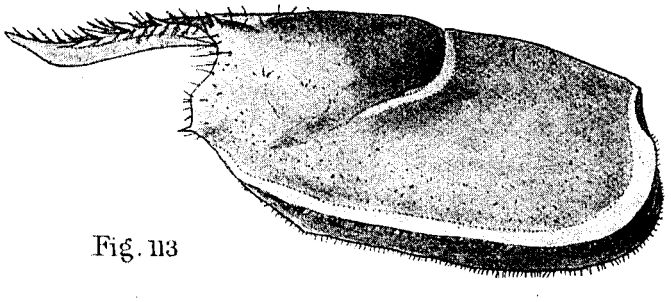

Fig. 113

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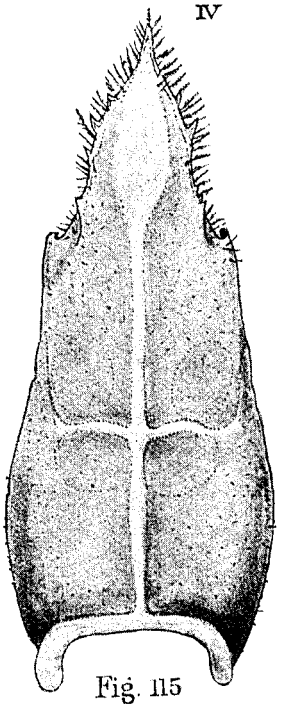


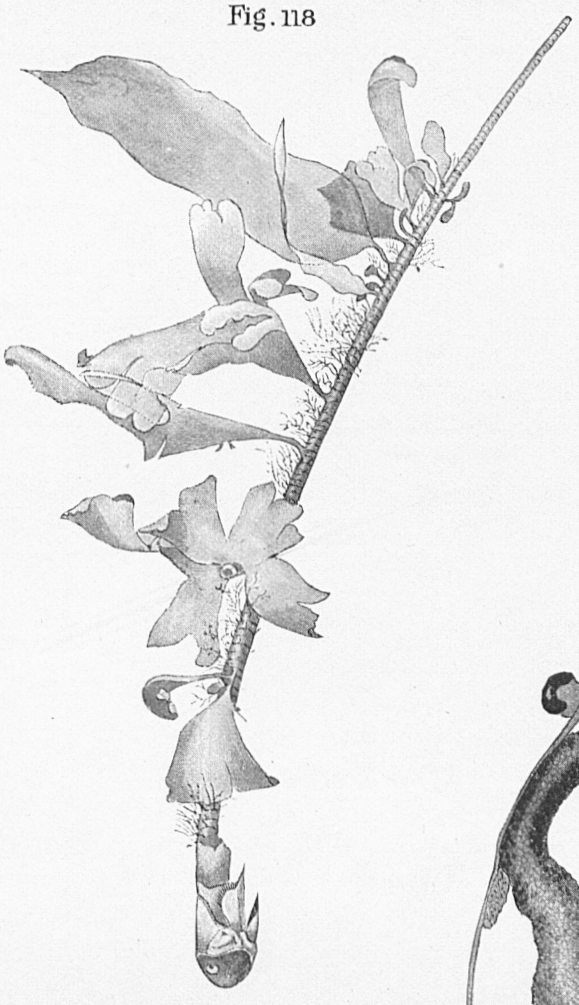
Fig. 115

F. H. Herrick ad nat. del.

THE CARAPACE AND ANTENNÆ.

Fig. 116

Fig. 118



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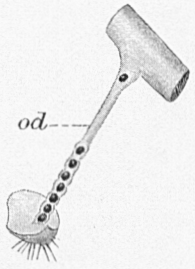
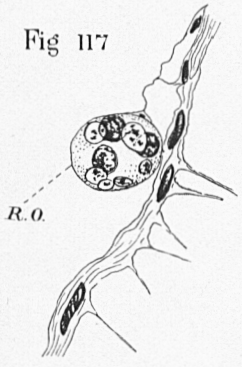


Fig 117



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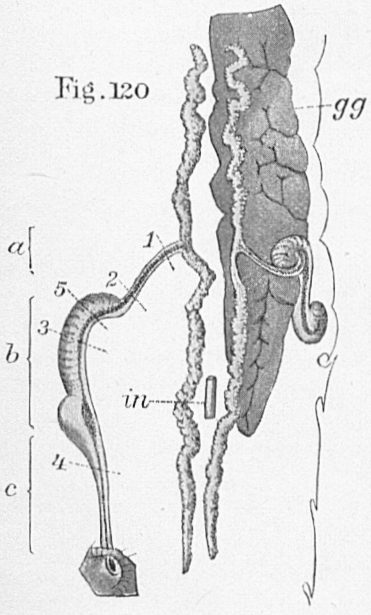

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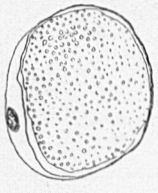

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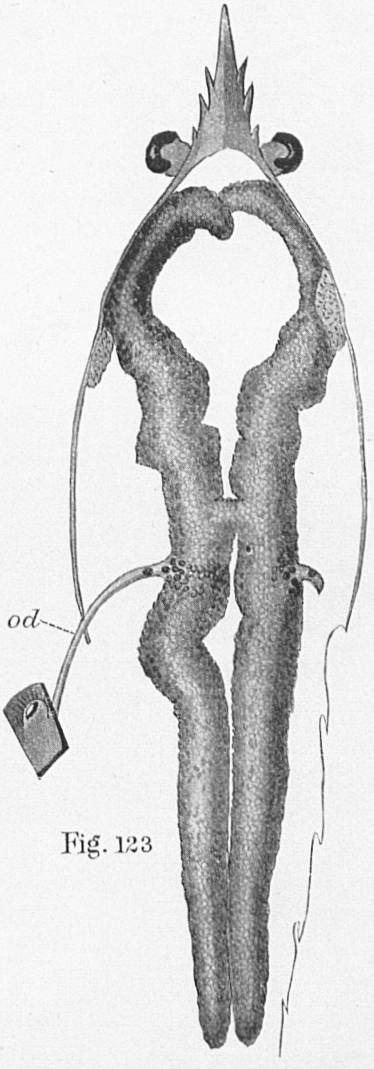
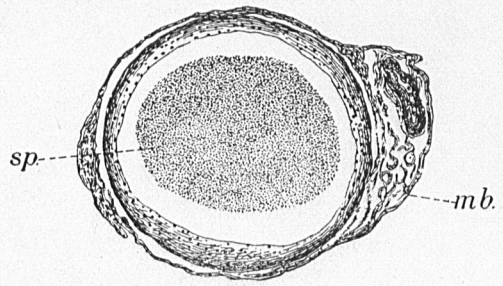


Fig. 123

F. H. Herrick ad nat. del.



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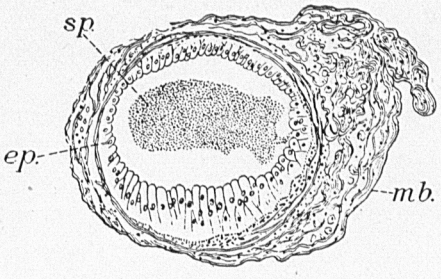

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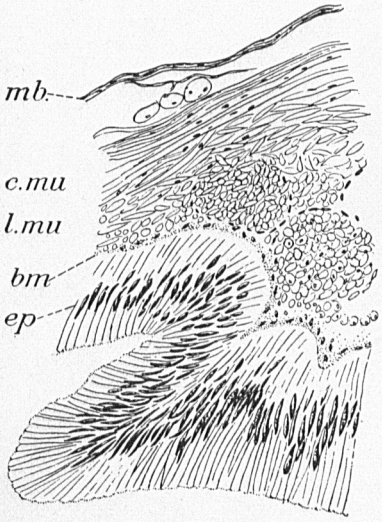

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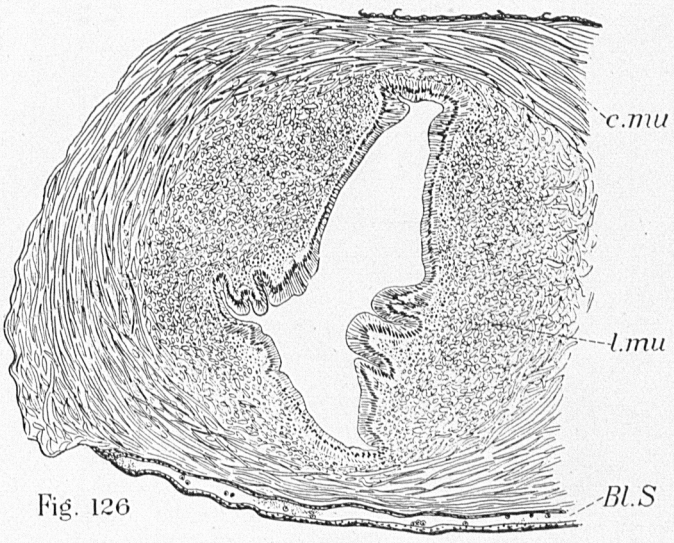


Fig. 126

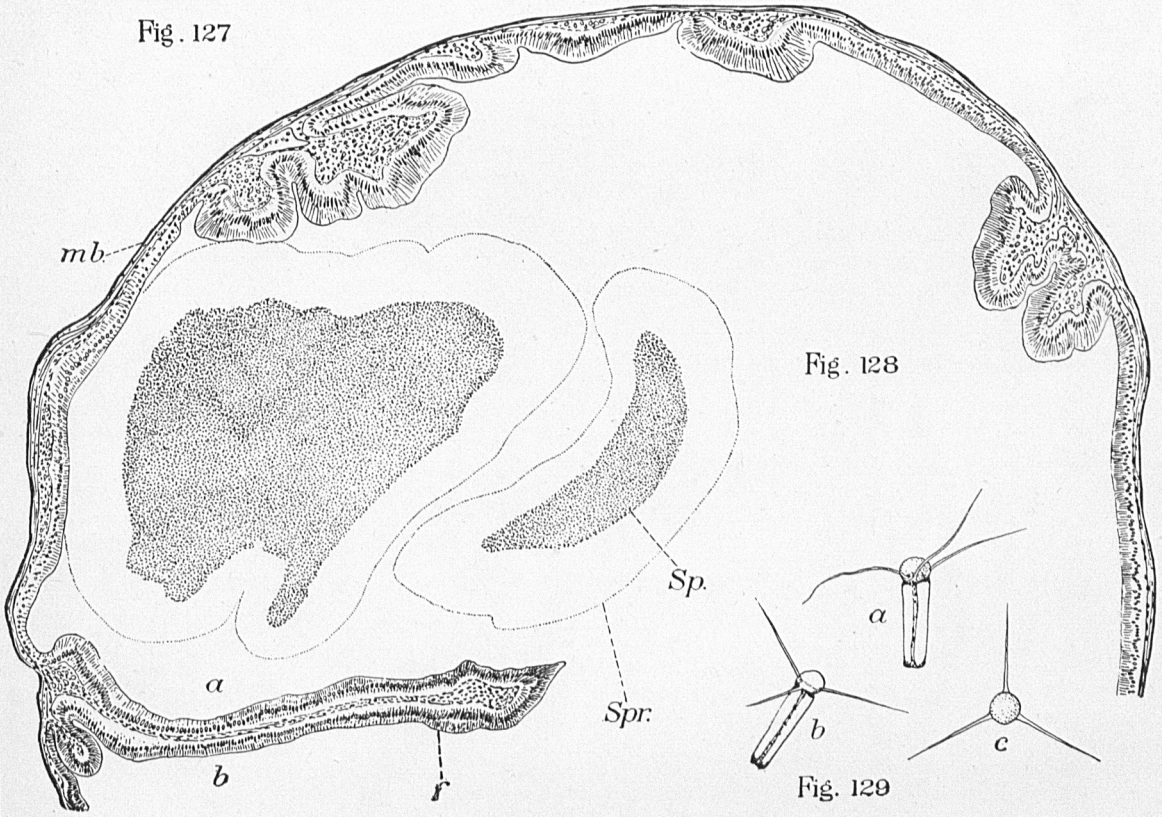


Fig. 128

Fig. 129

F. H. Herrick ad nat. del.

STRUCTURE OF VAS DEFERENS AND SPERM CELLS.

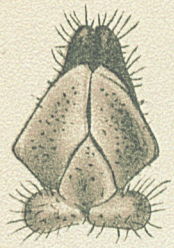
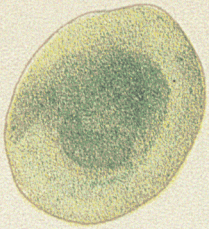


Fig. 130.

Fig. 131.

Fig. 132.



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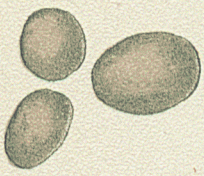
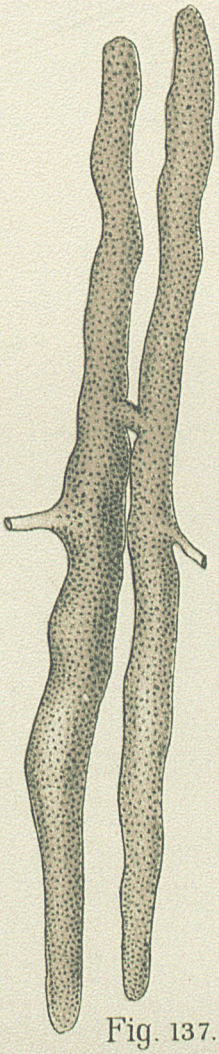


Fig. 134.

Fig. 135.

Fig. 136.



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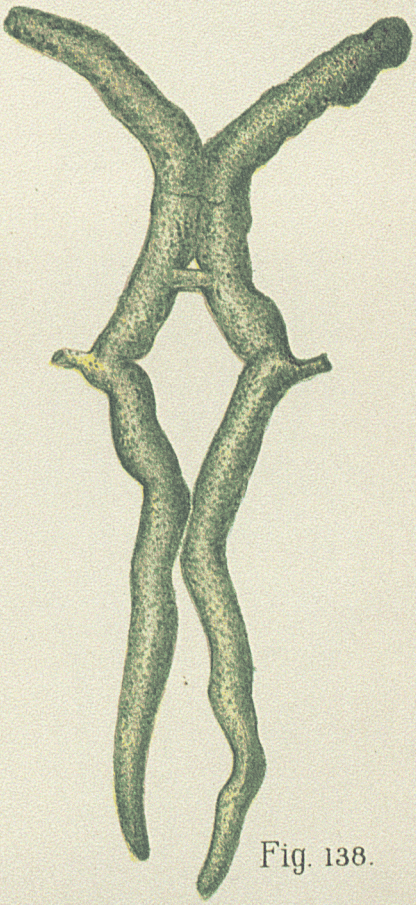


Fig. 138.

F. H. Herrick ad. nat. del.

THE OVARY AND SEMINAL RECEPTACLE.

Fig. 139

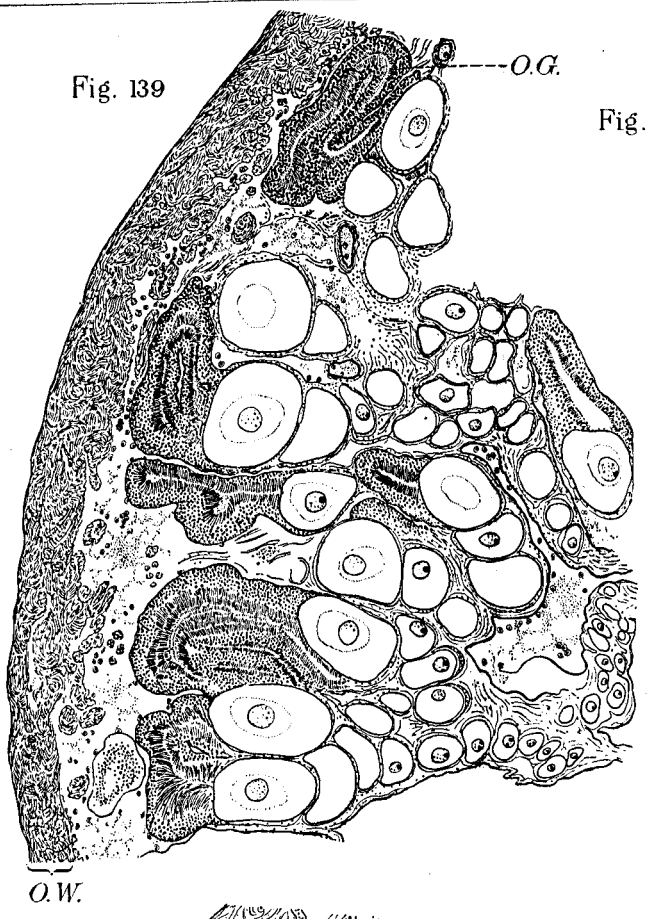


Fig. 140

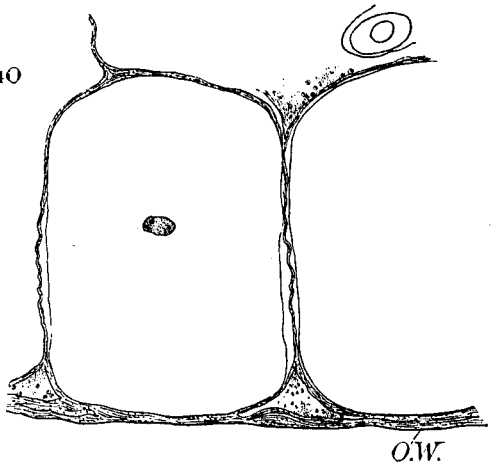
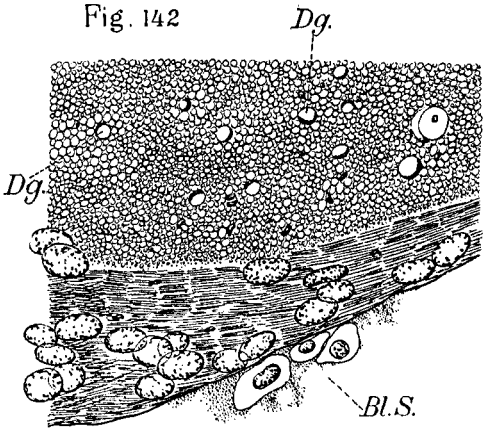


Fig. 142



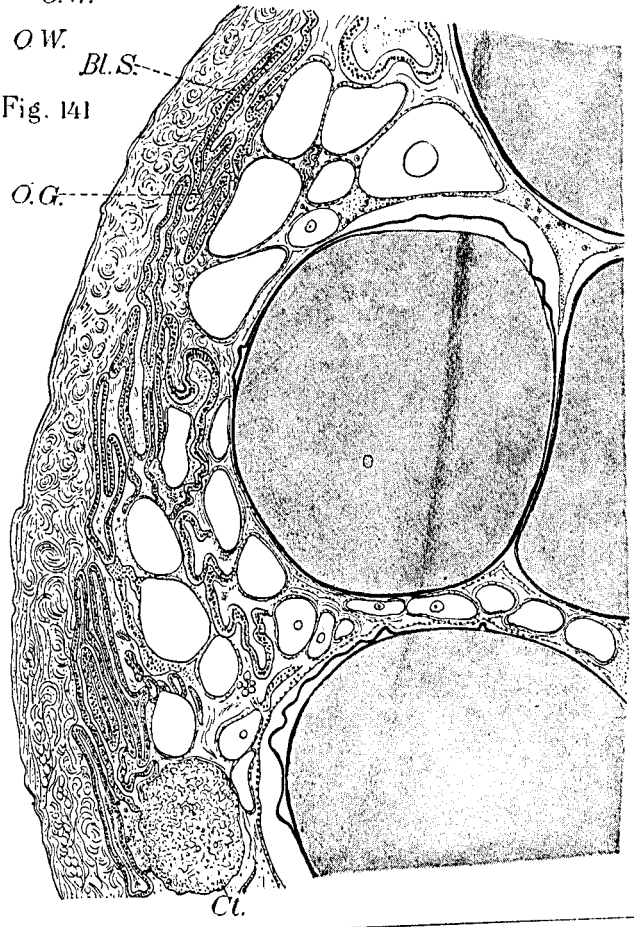
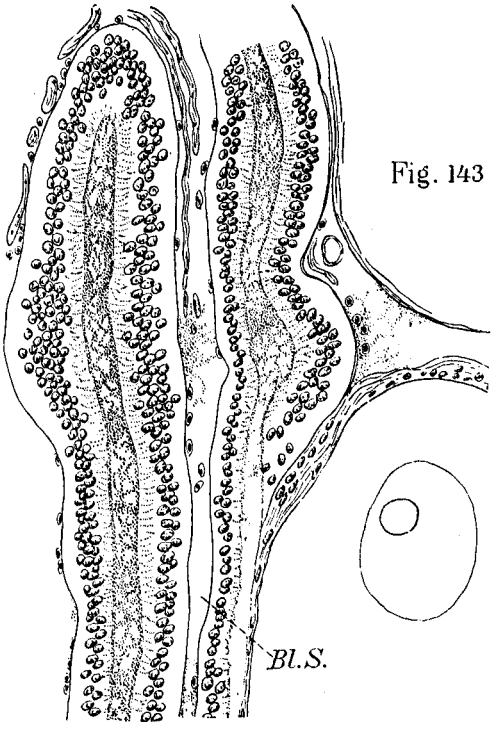


Fig. 141

Fig. 143



F. H. Herrick ad nat. del.

STRUCTURE OF THE OVARY.

Fig. 144

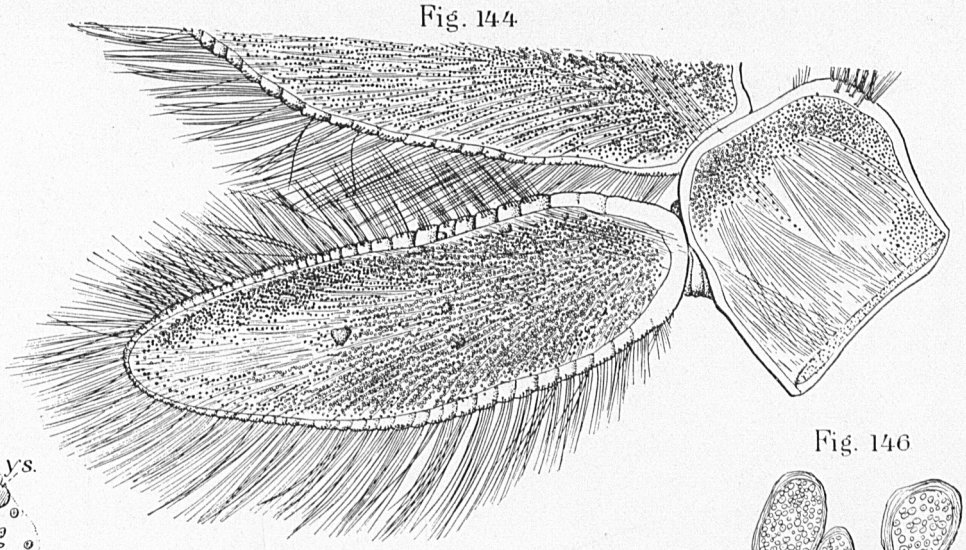
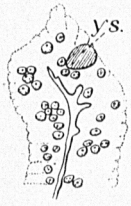


Fig. 145



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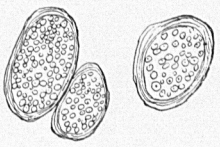


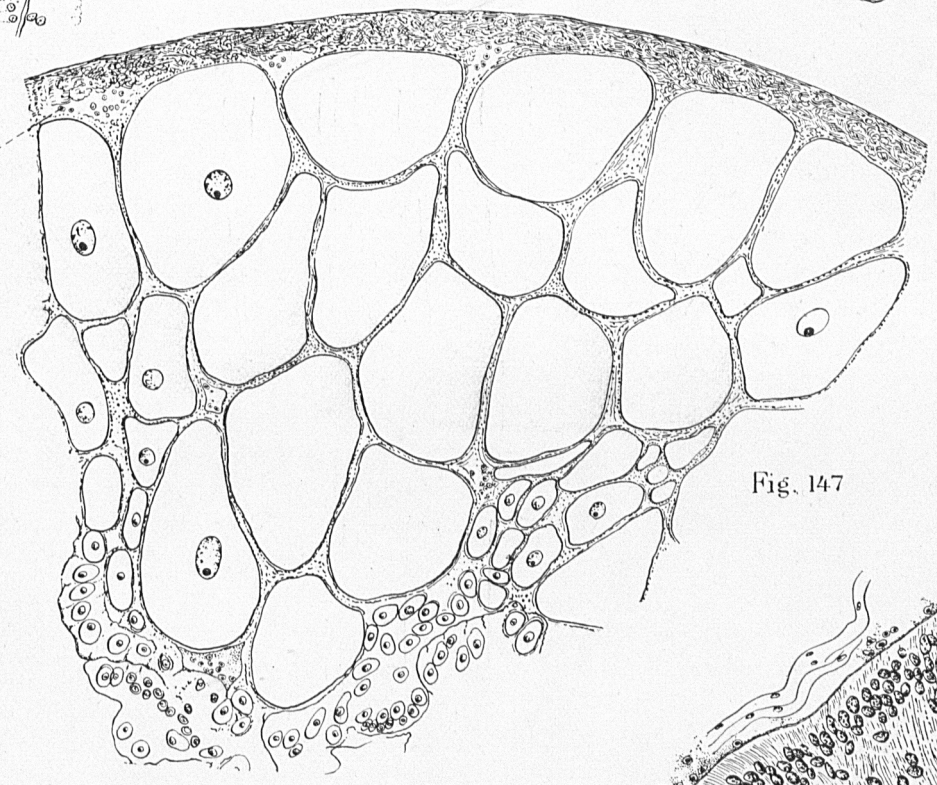


Fig. 147

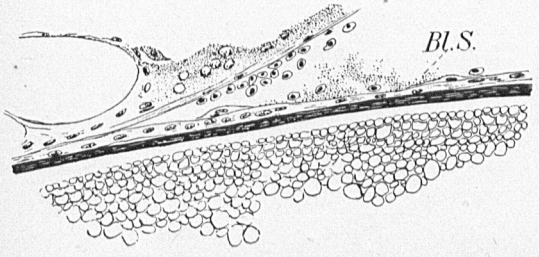


Fig. 148

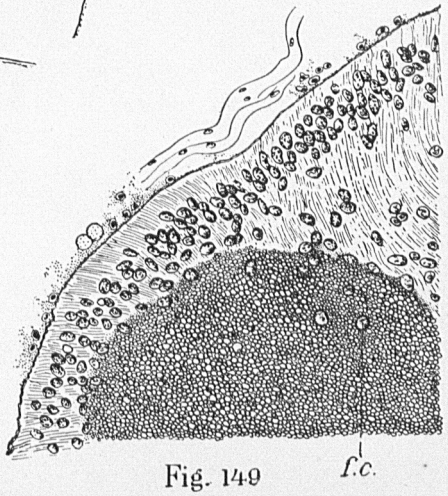


Fig. 149

F. H. Herrick ad nat. del.

OVARY AND TEGUMENTAL GLANDS.

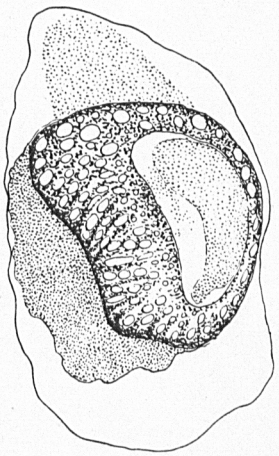
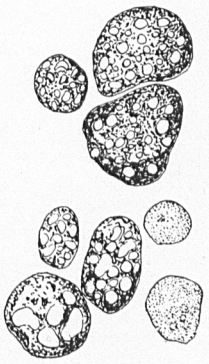


Fig. 150



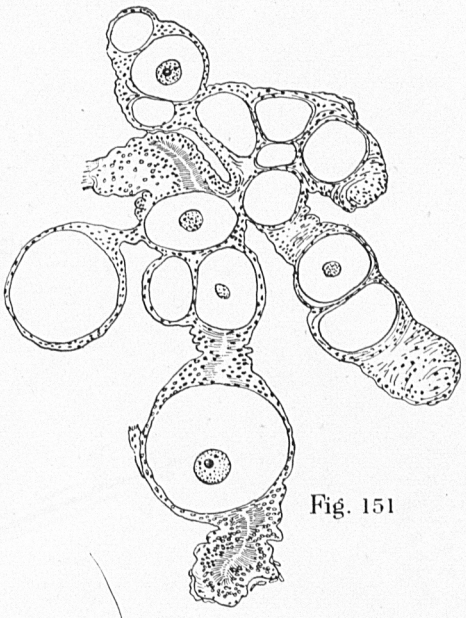
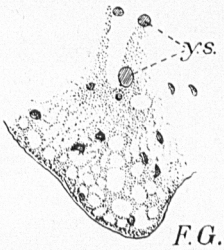


Fig. 151



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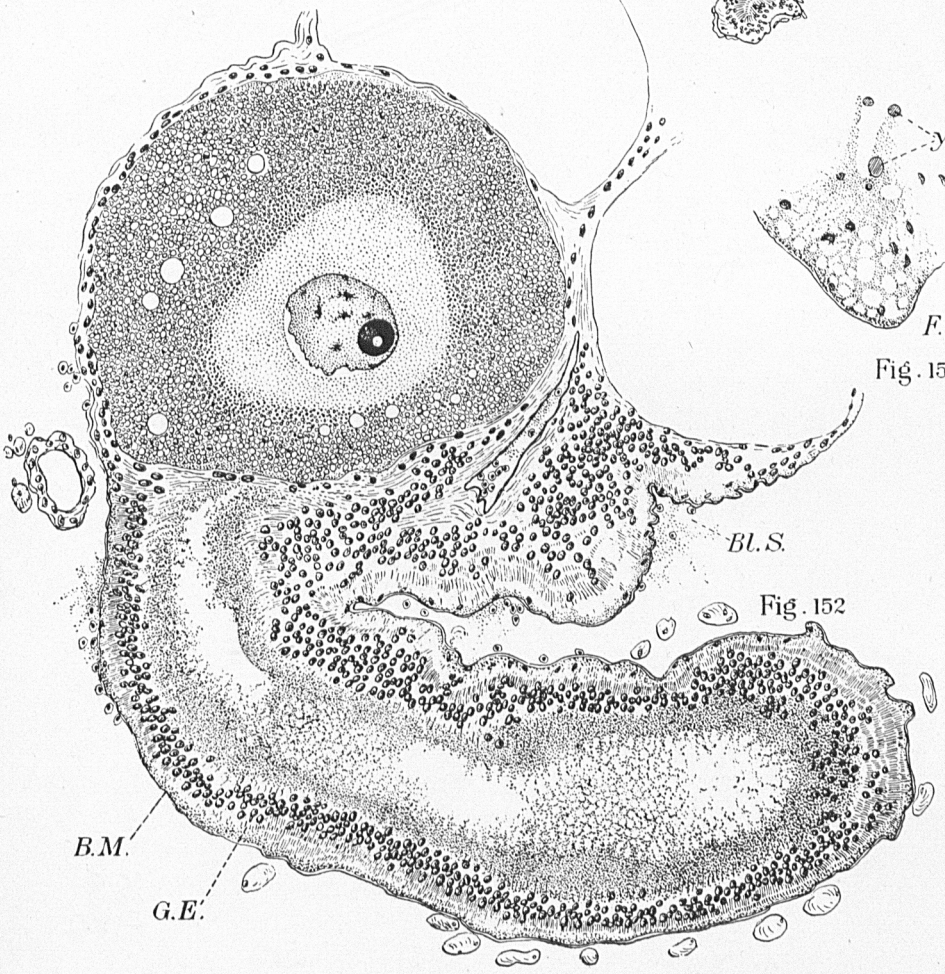


Fig. 152

F. H. Herrick ad nat. del.

STRUCTURE OF OVARY.

Fig. 154

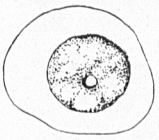


Fig. 155

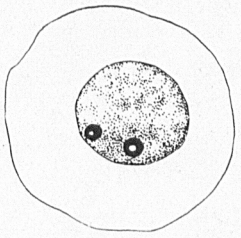


Fig. 156

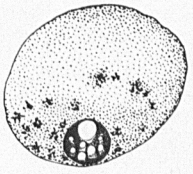
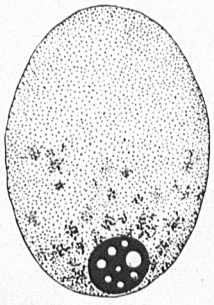


Fig. 157



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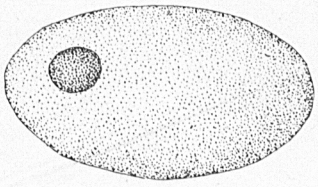

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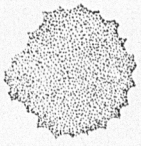


Fig. 160

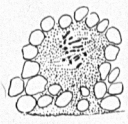


Fig. 161

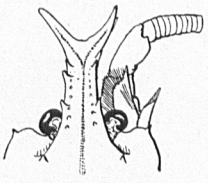


Fig 162

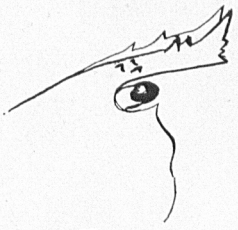


Fig. 163

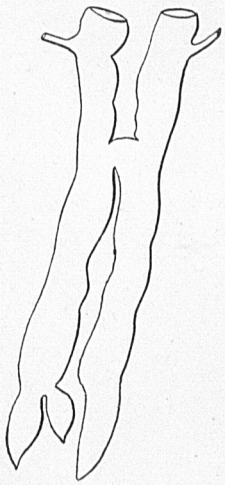


Fig. 164

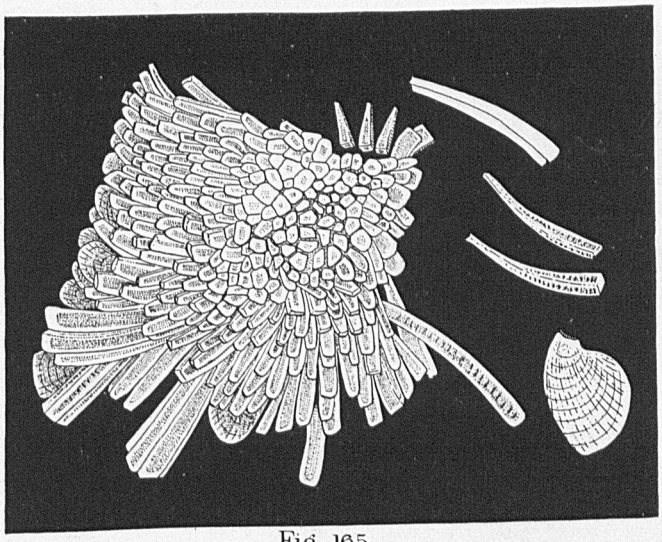


Fig. 165

F. H. Herrick ad nat. del.

METAMORPHOSIS OF GERMINAL VESICLE, SPICULES OF GASTROLITH, AND OTHER STRUCTURES

Fig. 166

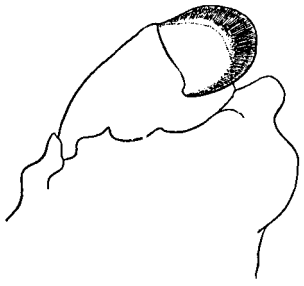


Fig. 167

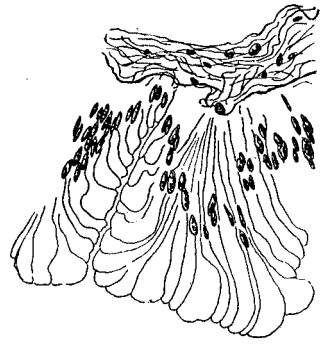


Fig. 168

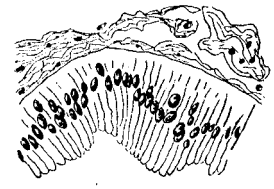


Fig. 169

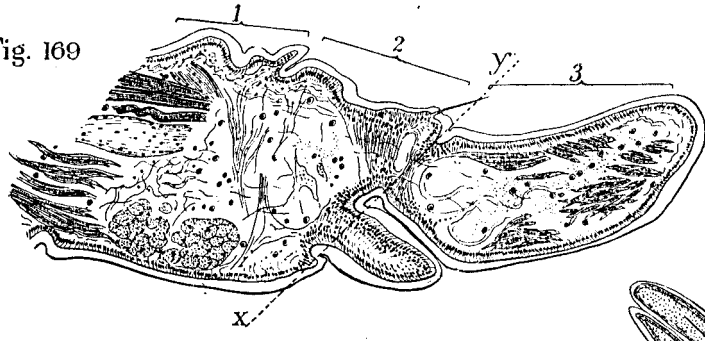
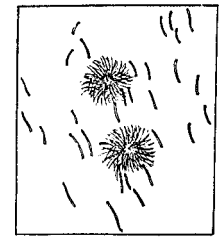


Fig. 170



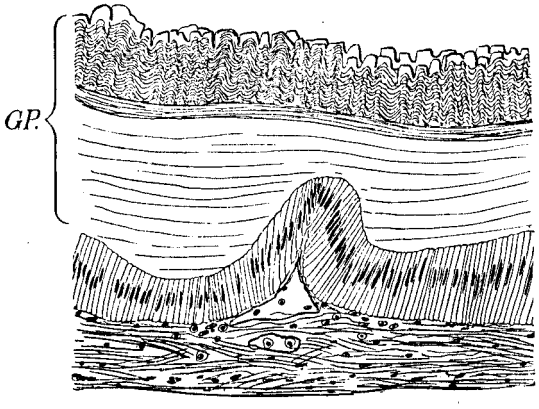


Fig. 171

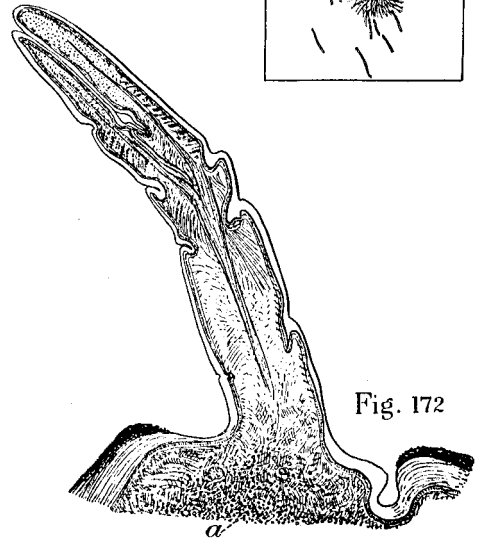


Fig. 172

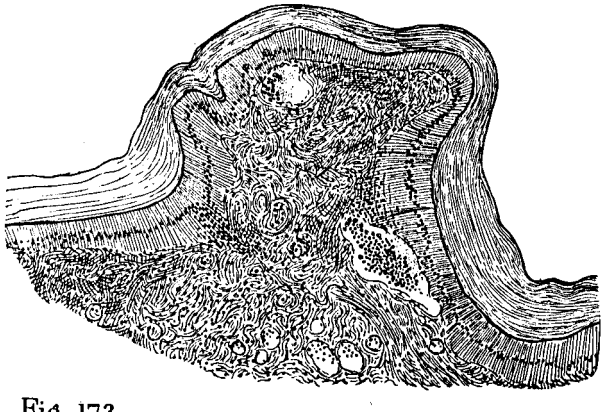


Fig. 173

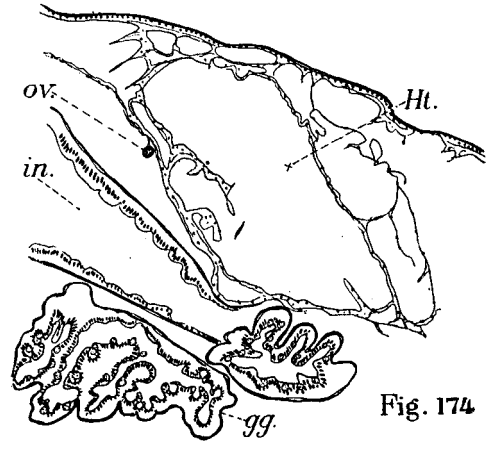


Fig. 174

F. H. Herrick ad nat. del.

REGENERATING LIMBS, THE OVIDUCT, AND OTHER ORGANS.

Fig. 175

Fig. 176

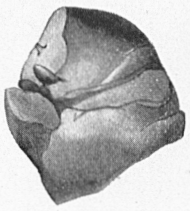


Fig. 177

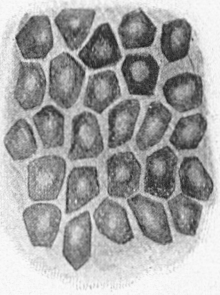


Fig. 178

Fig. 179

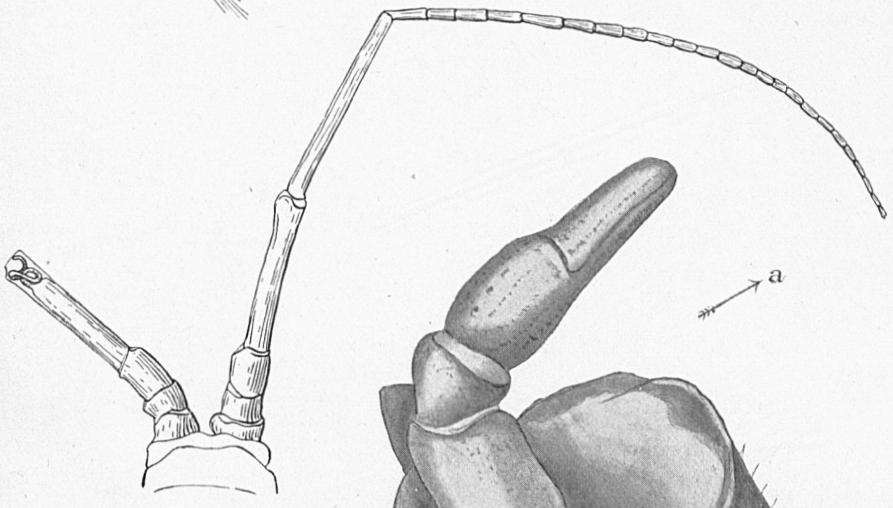
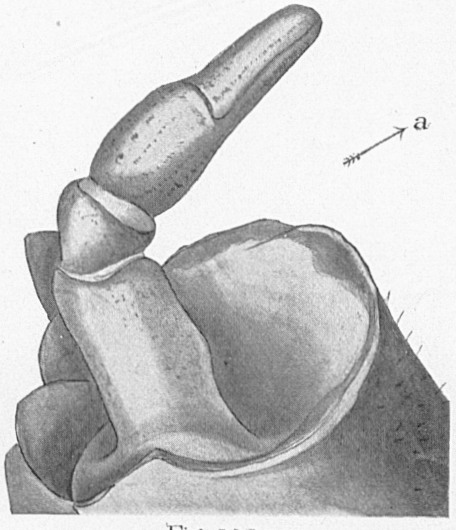


Fig. 180



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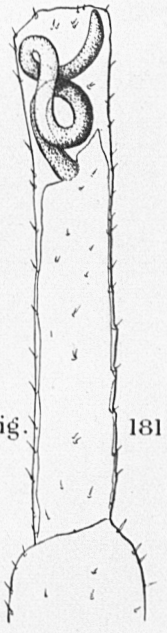

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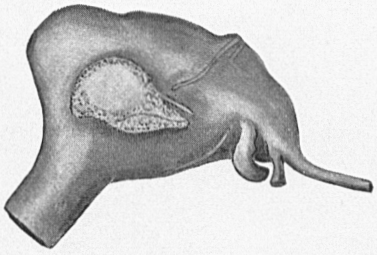

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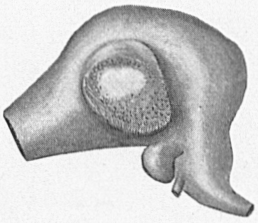
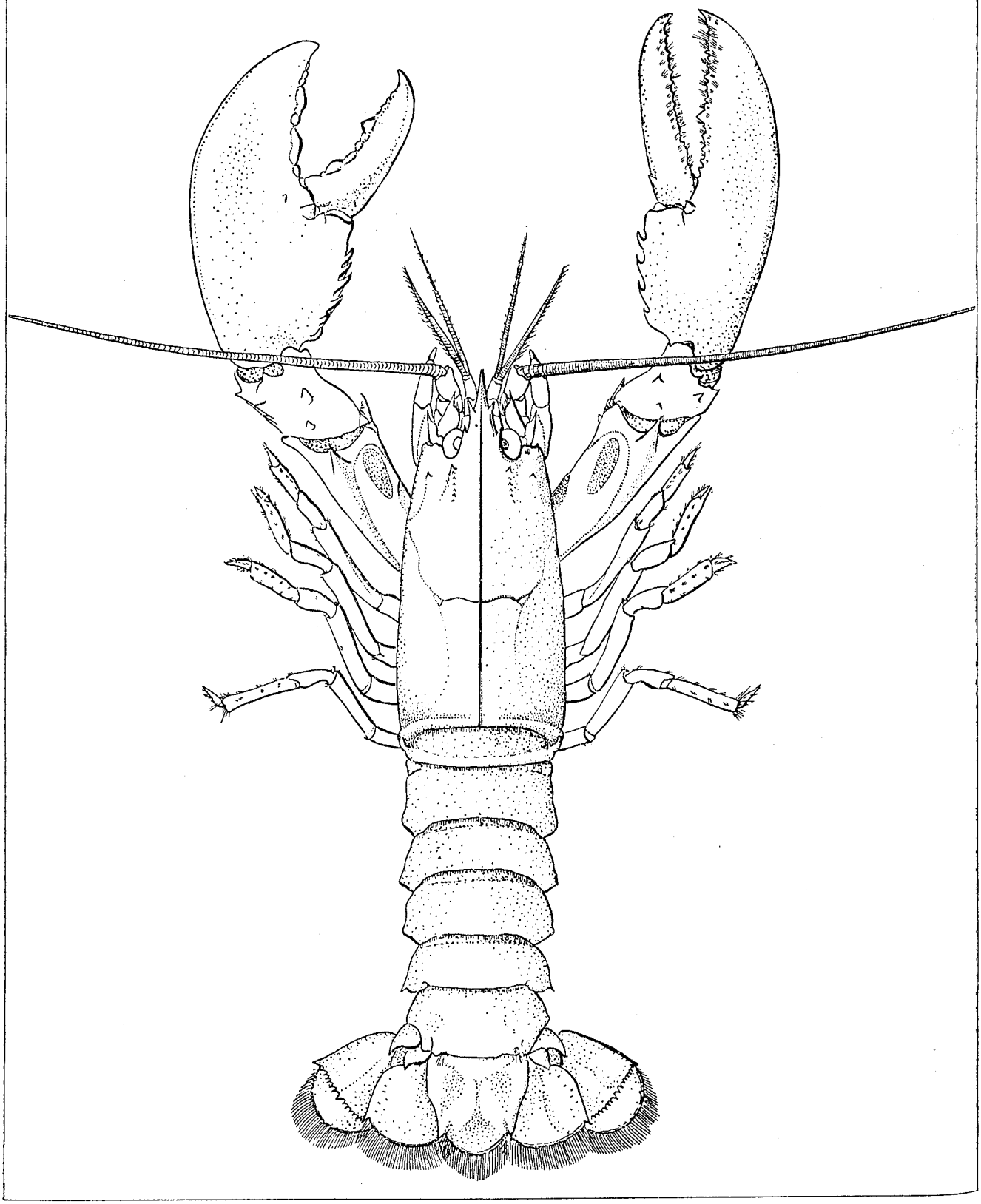


Fig. 184

F. H. Herrick ad nat. del.

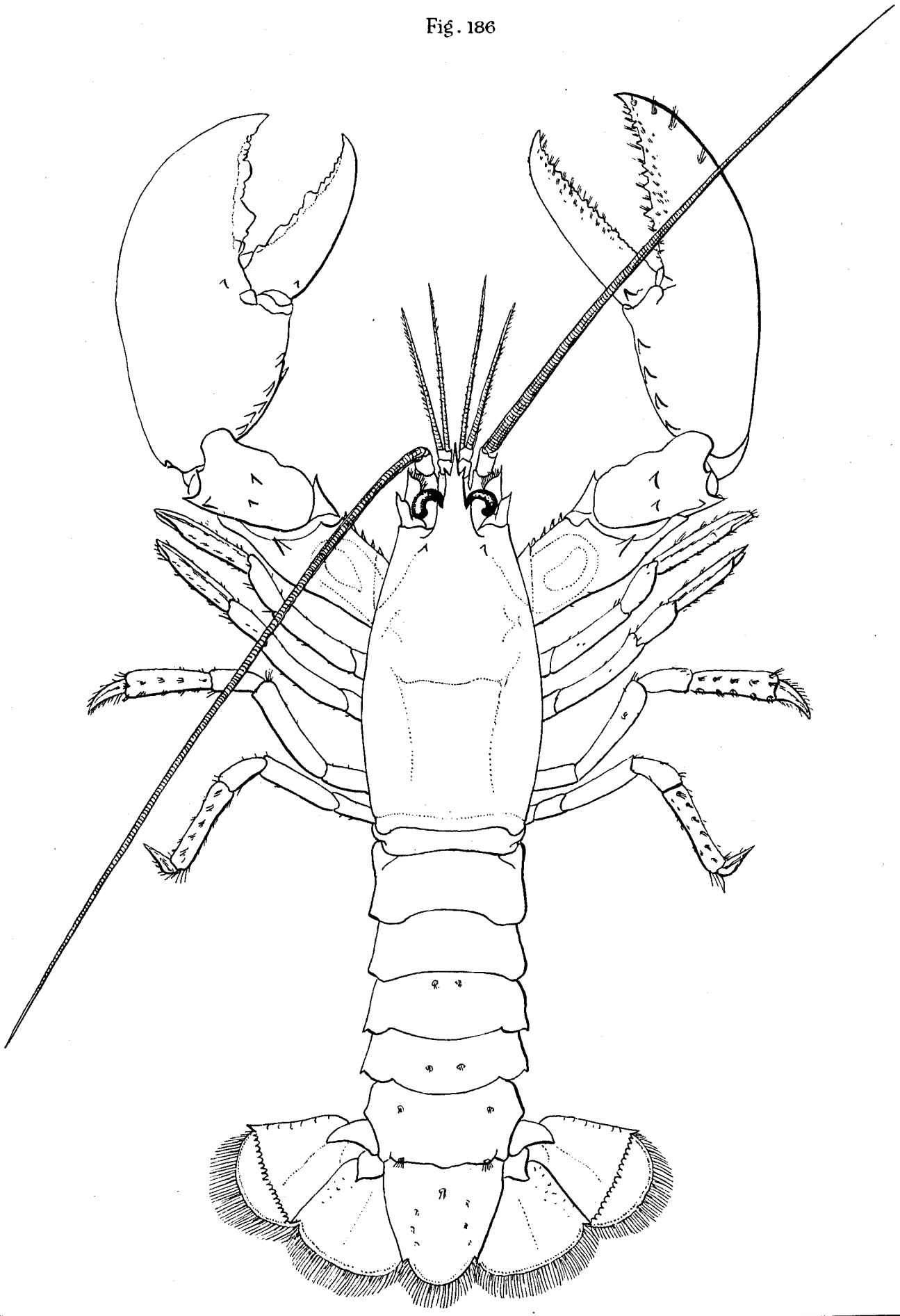
Fig. 185



F. H. Herrick ad nat. del.

CAST-OFF SHELL. Natural size.

Fig. 186



F. H. Herrick ad nat. del.

SOFT LOBSTER AFTER ESCAPE FROM SHELL SHOWN ON THE LEFT. Natural size.

Fig. 187.

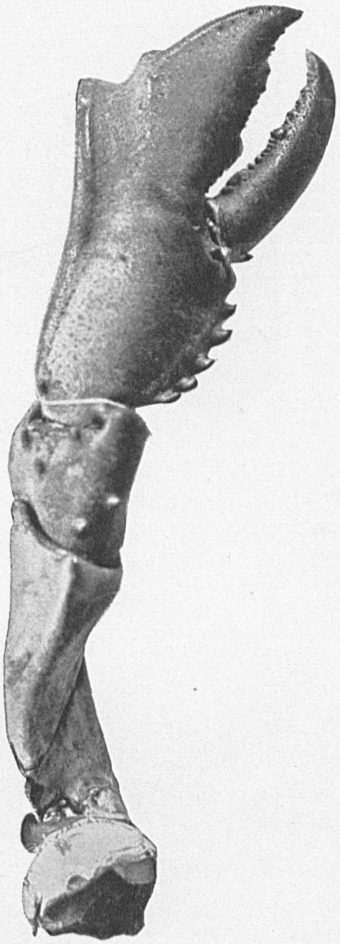


Fig. 188.

From photograph.

ABNORMAL CHELIPED. Natural size.

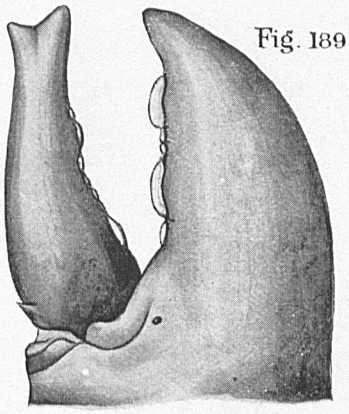


Fig. 189

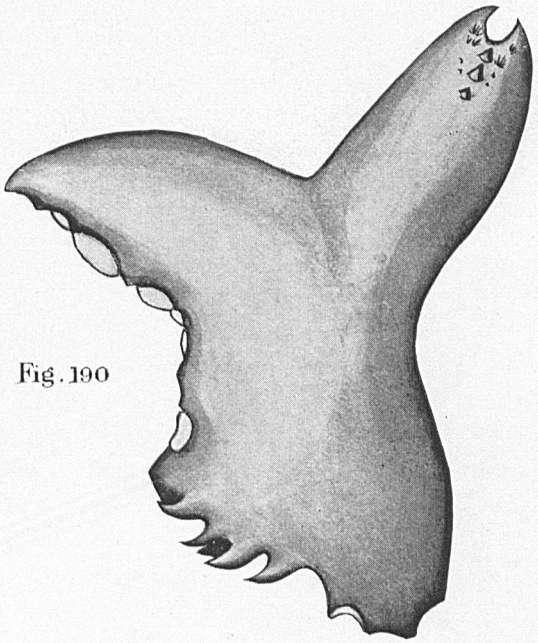
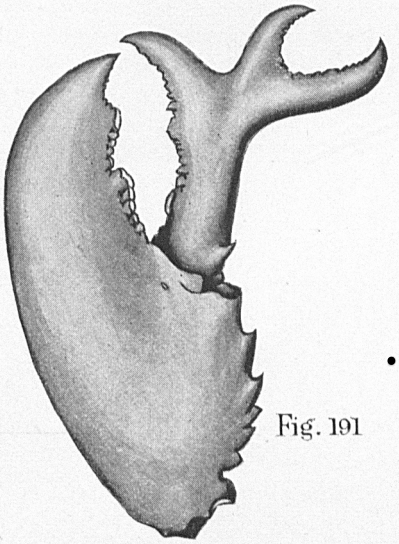


Fig. 190



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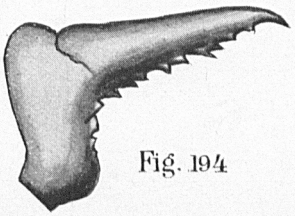


Fig. 194

Fig. 195

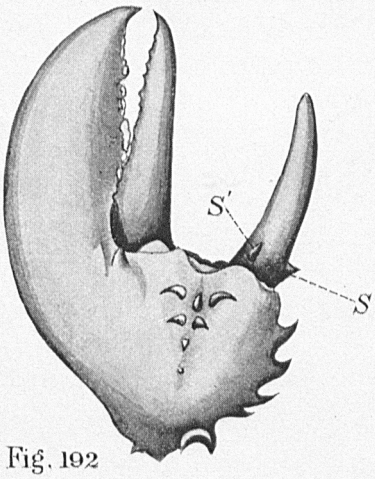
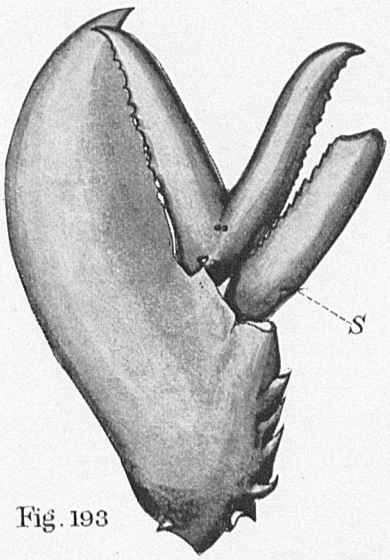


Fig. 192



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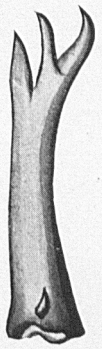


Fig. 196

F. H. Herrick ad nat. del.

DEFORMED CLAWS.

Fig. 196

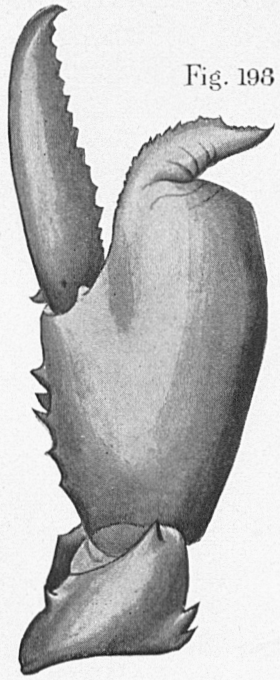
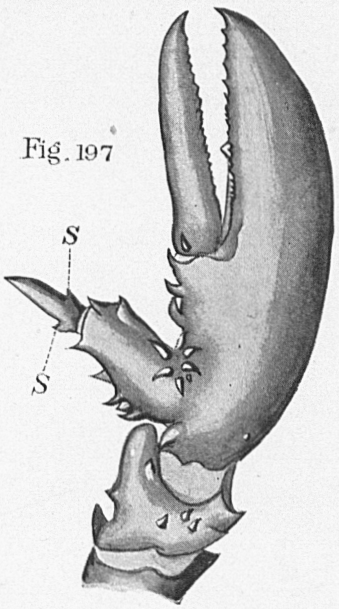


Fig. 197



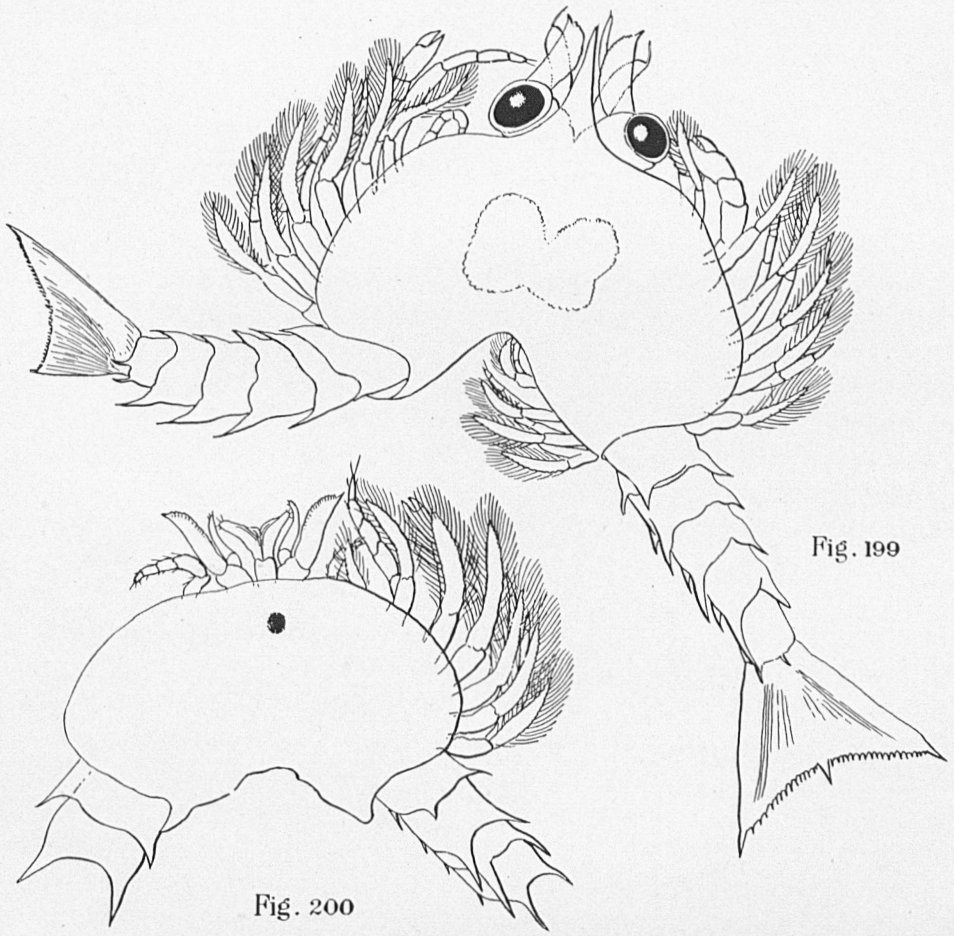
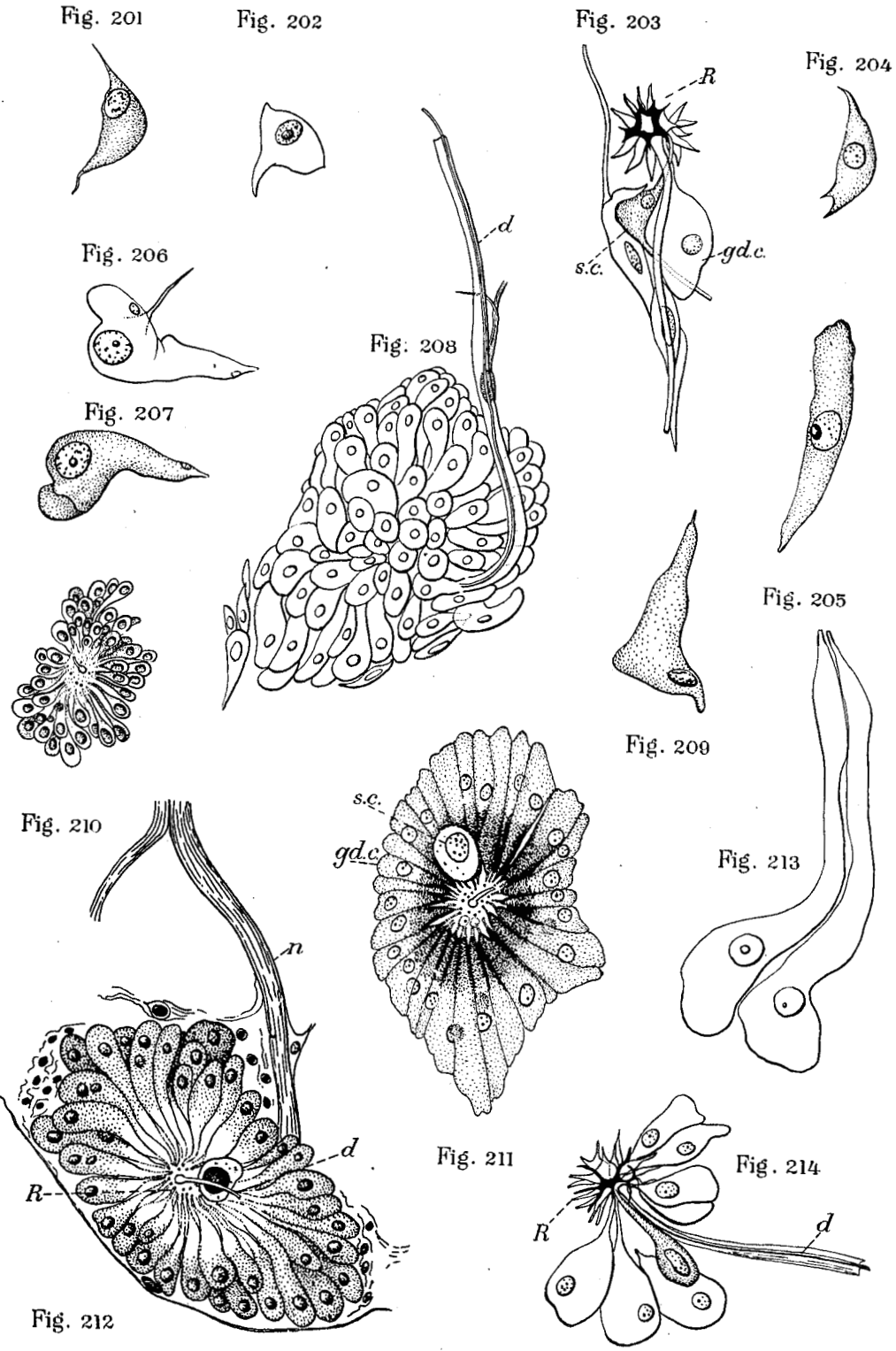


Fig. 199

Fig. 200

F. H. Herrick ad nat. del.

DEFORMED CLAWS IN ADULT AND DOUBLE MONSTERS IN FIRST LARVA,



F. H. Herrick ad nat. del.

STRUCTURE OF TEGUMENTAL GLANDS.

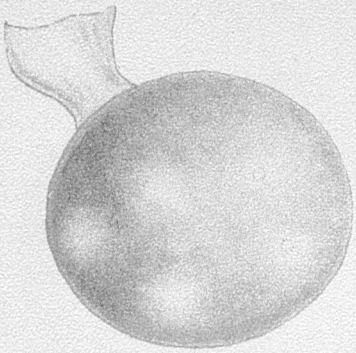
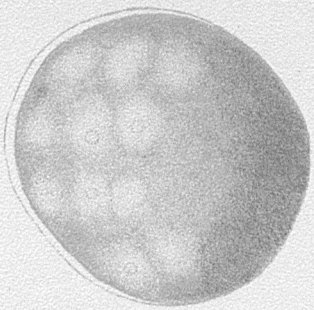


Fig. 215.



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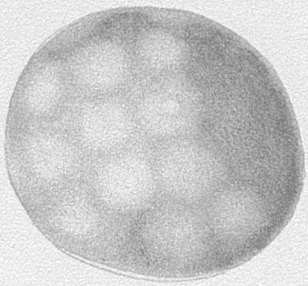
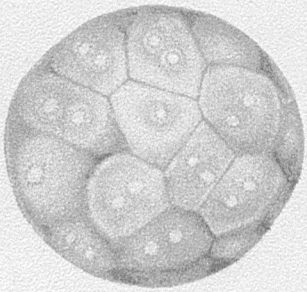


Fig. 217.

Fig. 218.



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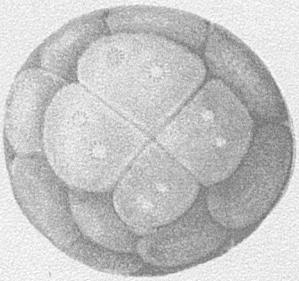

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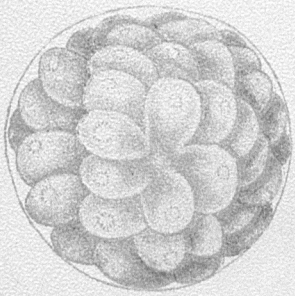

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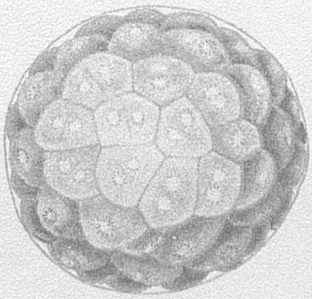

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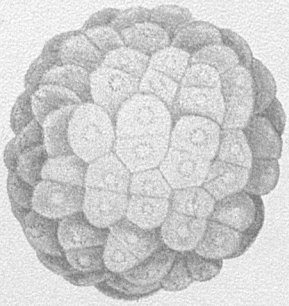

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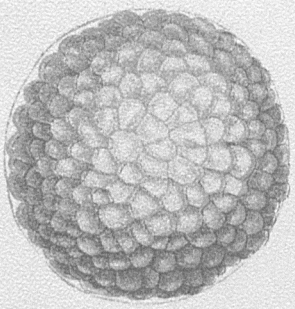

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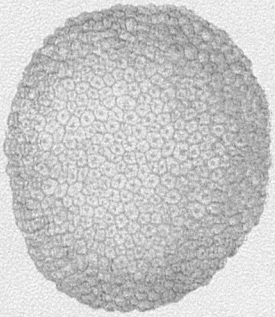

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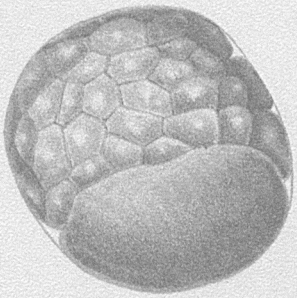

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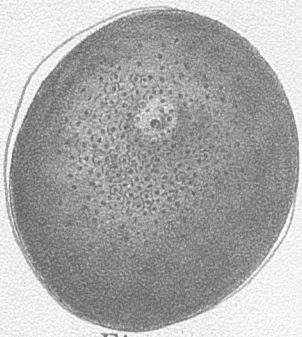

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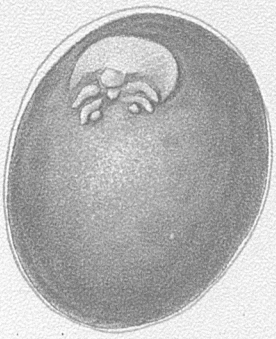

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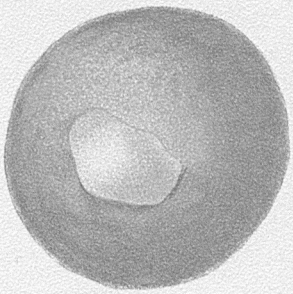

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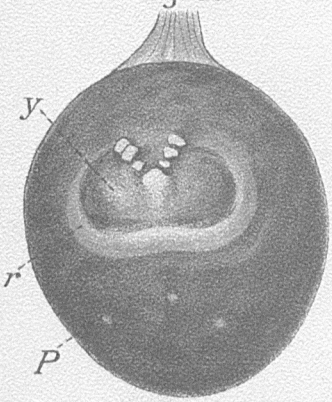
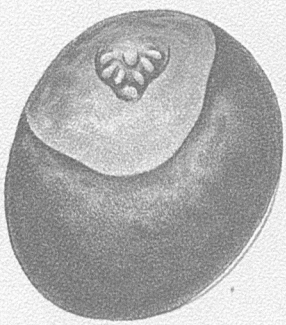


Fig. 230.



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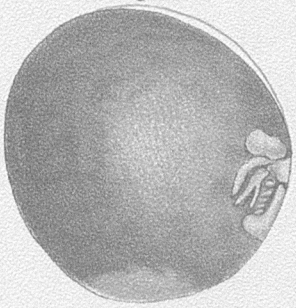

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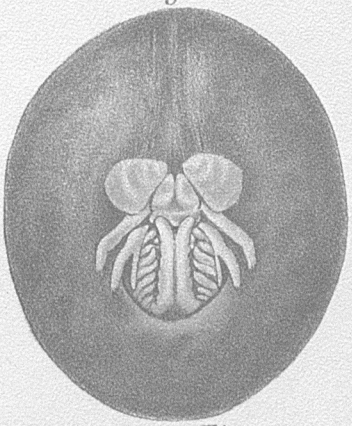

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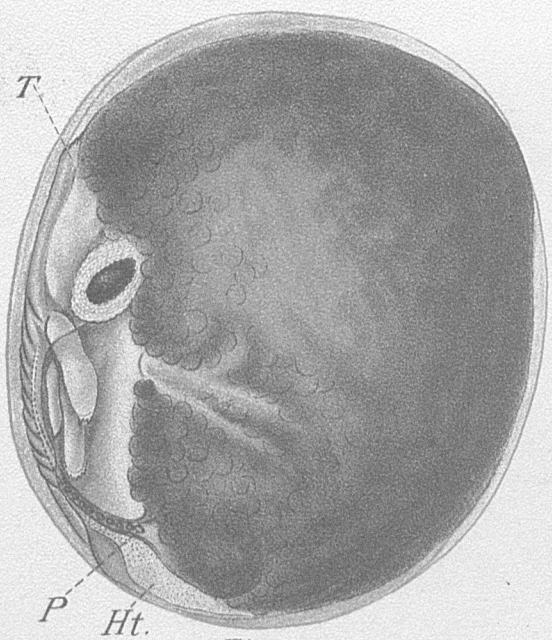

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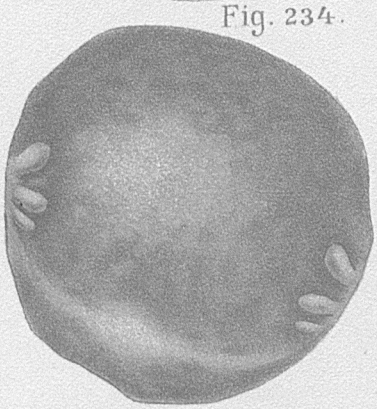

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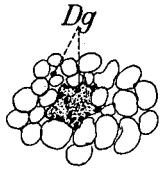

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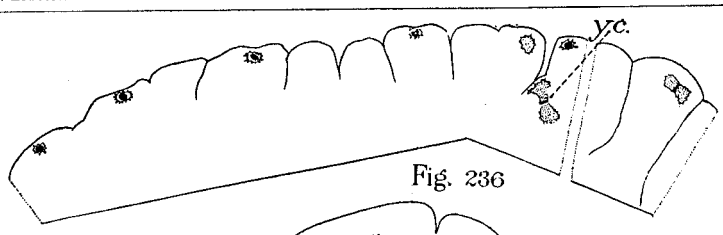

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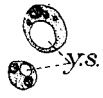

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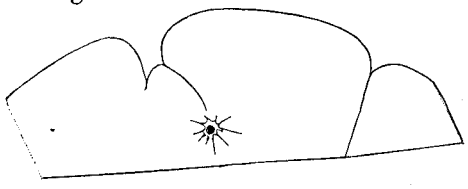

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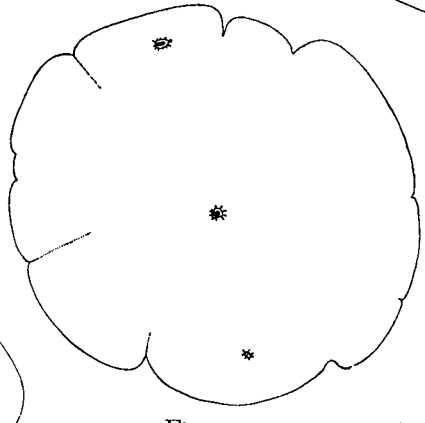

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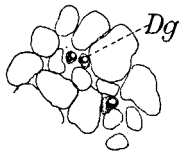

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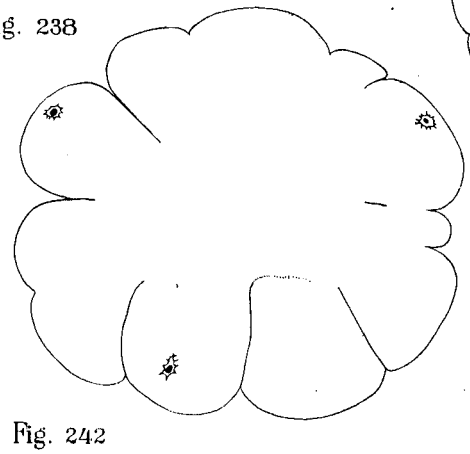

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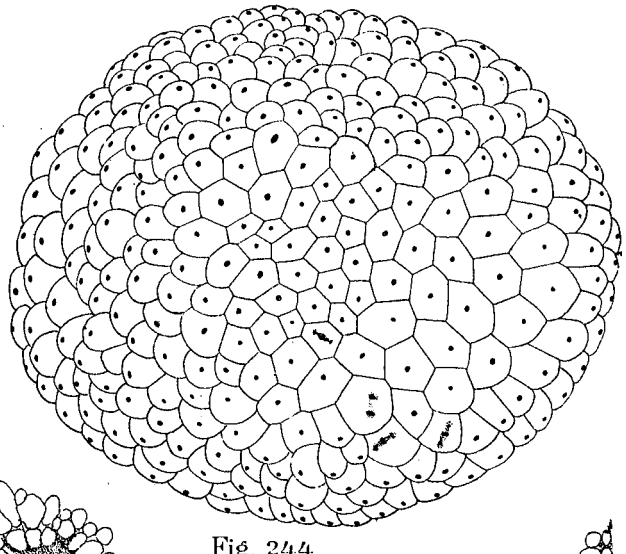

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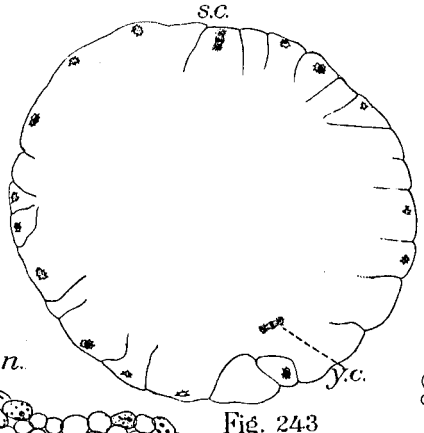

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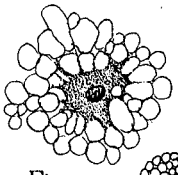

Fig. 249

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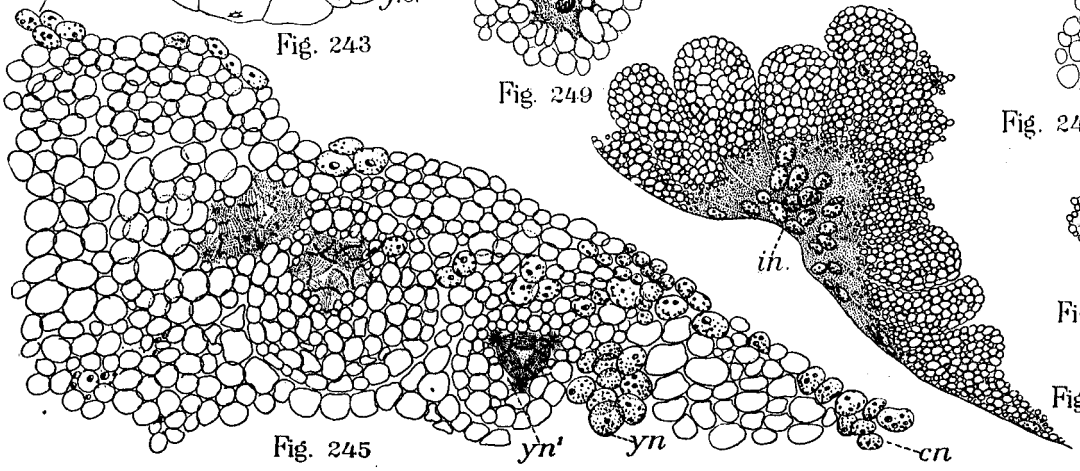


Fig. 245

Fig. 246

F. H. Herrick ad nat. del.

DEVELOPMENT OF EMBRYO.

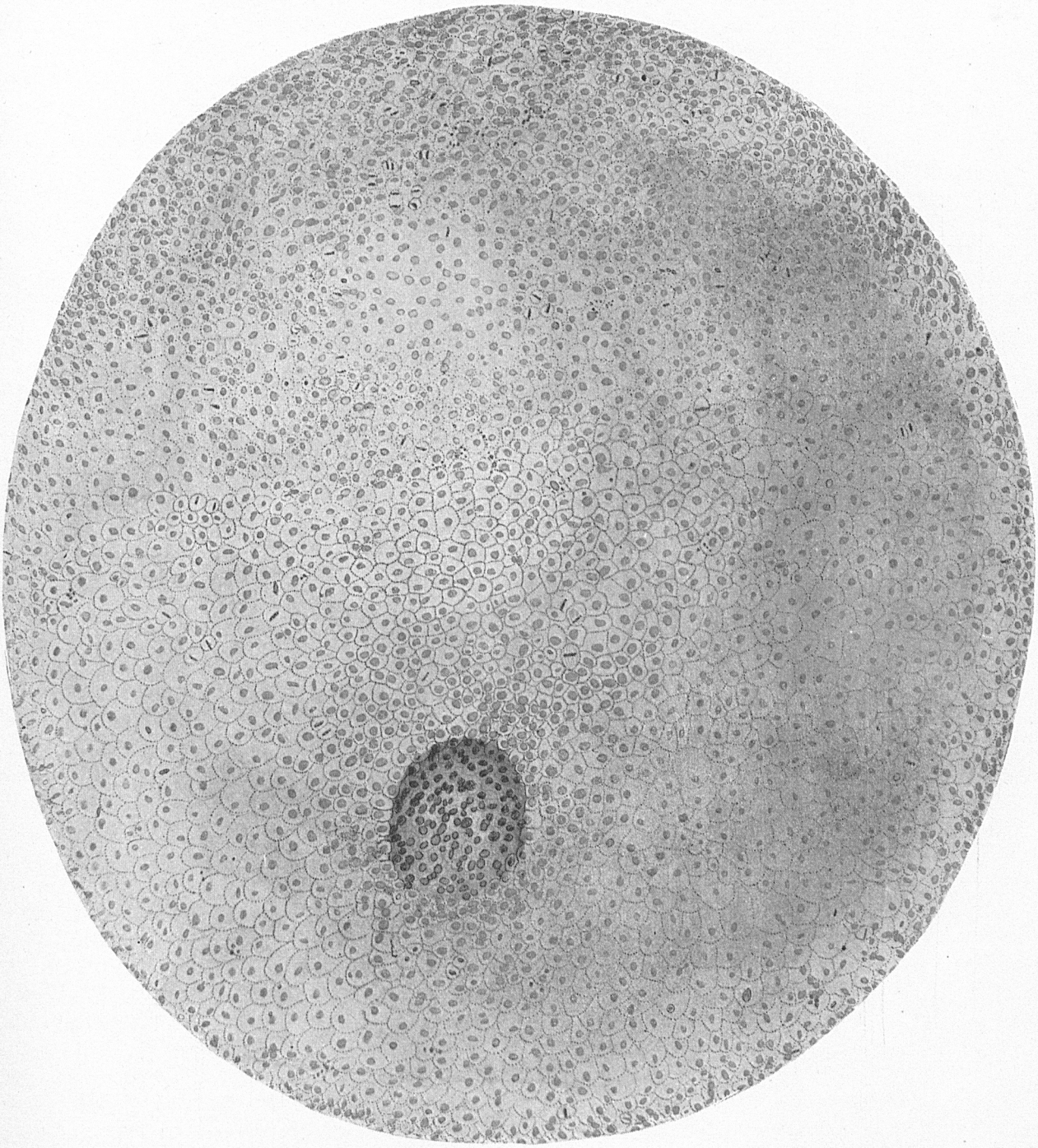


Fig. 250

F. H. Herrick ad nat. del.

EGG-EMBRYO. INVAGINATION STAGE.

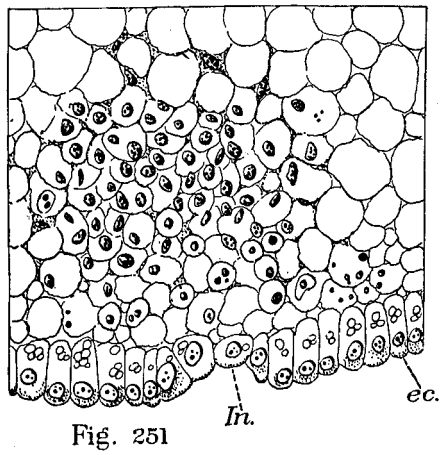
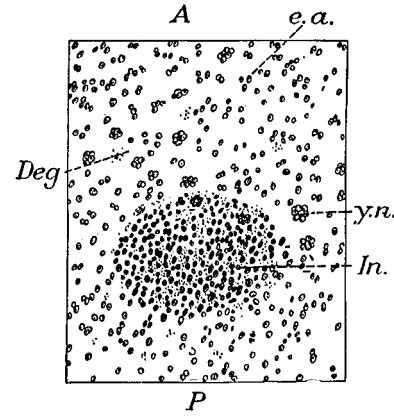


Fig. 251



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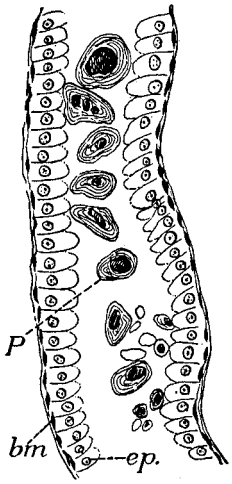

Fig. 253

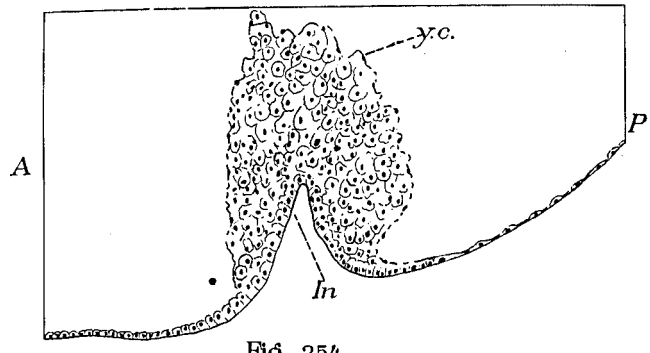

Fig. 254

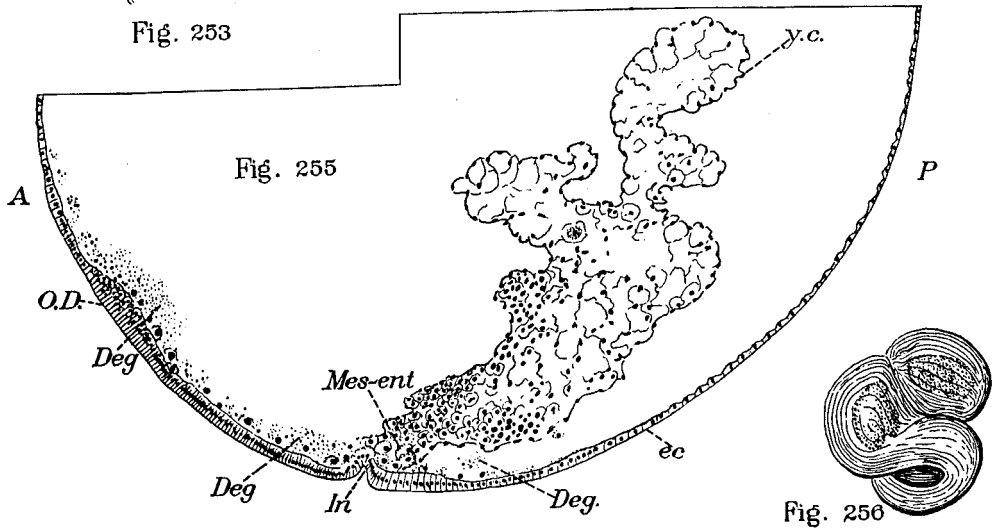

Fig. 255

Fig. 256

F. H. Herrick ad nat. del.

DEVELOPMENT OF EMBRYO.

2.—A PRELIMINARY REPORT UPON SALMON INVESTIGATIONS IN IDAHO IN 1894.

By BARTON W. EVERMANN, PH. D.,
Ichthyologist of the United States Fish Commission.

In this report are presented the results of certain investigations, carried on under instructions of the Commissioner of Fish and Fisheries, concerning the abundance, distribution, and spawning habits of the species of salmon which have spawning-grounds in the waters of the State of Idaho.

The alarming decrease in the salmon catch of the Columbia River within recent years, the importance of preventing the continuance of this decrease, and the desire and hope that the salmon industry may be rebuilt to its former importance, render imperative a most careful study of the natural history of the salmon and a more accurate knowledge of the location of their spawning-beds, their time of spawning, and the temperature and other physical conditions under which their spawning takes place.

These investigations were really begun in 1893, when the present writer, assisted by Dr. Charles H. Gilbert and Dr. Oliver P. Jenkins, both of Stanford University, made an examination of the obstructions in Snake River and in the Pend d'Oreille River, the report of which has been published.* During the spring and summer of 1894 they were continued on the Columbia and lower Snake River by Dr. Gilbert, whose report is now in preparation.

I left Washington September 1, 1894, and, being joined at Terre Haute, Ind., by Dr. J. T. Scovell, proceeded to Shoshone Falls, Idaho, where the work was begun. Our attention was directed chiefly to three localities: (1) The streams and lakes at the headwaters of the Salmon River; (2) the streams and lakes at the headwaters of Payette River; (3) that portion of Snake River lying between the Great Shoshone Falls and Huntington, Oreg.

In the following pages is given a somewhat detailed account of the physical features of the waters of each of these regions, and then follows what we have been able to learn regarding the three important species of Salmonidæ which ascend to the waters of Idaho for spawning purposes. These species are: (1) The chinook salmon (*Oncorhynchus tschawytscha*); (2) the blueback salmon or the redfish of Idaho (*Oncorhynchus nerka*); (3) the steelhead or salmon trout (*Salmo gairdneri*).

Although less than five weeks' time was given to this work, it is believed that new and very important facts were discovered regarding these three valuable food-fishes, and only the lateness of our arrival upon the spawning-grounds prevented our

*Report of the Commissioner of Fish and Fisheries on Investigations in the Columbia River Basin in regard to the Salmon Fisheries; issued as Senate Mis. Doc. No. 200, Fifty-third Congress, second session, 1894. This report contains "A report upon investigations in the Columbia River Basin, with descriptions of four new species of fishes, by Charles H. Gilbert and Barton W. Evermann."

making still further important observations. In addition to the definite information gained, the investigations are of great value in that they show us just what problems connected with these fishes can be studied with advantage in these waters and indicate when and how these problems may be best investigated.

The investigations show undoubtedly that very important spawning-grounds of the chinook salmon, redfish, and steelhead are found in Idaho, and that it is upon these grounds that we must depend in large measure for the natural increase necessary to the continuance of the salmon industry of Columbia River. The actual extent of these spawning-beds, the actual time of spawning in different streams, and several other questions of importance, can be learned only through a series of observations covering the entire breeding season of each species. For the redfish and the chinook salmon which ascend to the headwaters of Salmon, Payette, and Weiser rivers, this time apparently lies between July 1 and October 30; for the steelhead, observations should cover the time from April 1 to early summer, at least.

While making these inquiries and investigations in Idaho we were the recipients of many favors and courtesies from various citizens of that State. To all who rendered us assistance in any way I desire to express our appreciation of the kindness shown us. We are under especial obligations to Mr. Liberty Millet and Mr. Joseph McMeekin, of Upper Salmon Falls, who not only showed us every kindness during our week's stay with them but who were kind enough to keep an accurate record of their seining operations after we left. This record involved a large amount of work, in that it includes the weight, length, sex, and condition of every salmon which they caught, items of information of very great value to us in our investigations. To Mr. George H. Day, of Upper Salmon Falls, and Messrs. George W. Bell, Robert E. Conner, and Charles Harvey, of Lower Salmon Falls, we are under obligations for numerous favors shown us. Mr. William O'Brien, of Ontario, Oregon, not only furnished valuable information regarding his own fishery at Weiser, but he very kindly obtained for me as complete data as possible concerning the salmon and salmon-trout catch of all other fishermen between Huntington and Glenn Ferry.

I desire to mention also Messrs. Frank C. Parks, of Sawtooth; J. L. Fuller, of Bliss; Calvin White and William C. Jennings, of Salmon Meadows, and Thomas C. McCall, of Payette Lake, whose numerous kindnesses enabled us to accomplish much more than would otherwise have been possible.

SALMON RIVER BASIN.

The Salmon River is the largest and most important tributary of Snake River, in Idaho. It has its sources in Alturas and Custer counties, on the eastern slope of the Sawtooth Mountains, and, after a very crooked course for several hundred miles, it finally empties into Snake River near the northeast corner of Oregon in about latitude 46°. This river is said to be one of the most important salmon streams in the Columbia Basin. I know nothing about this stream, however, except at its headwaters in the vicinity of Alturas Lake, where we made observations September 11 to 14, inclusive.

Alturas Lake.—This small lake lies on the east side of the Sawtooth Mountains, about 45 miles northwest from Ketchum, the nearest railroad station. The elevation of the lake above sea level is about 7,335 feet, or 200 feet lower than the mining camp of Sawtooth, which is given as 7,536 feet by the United States Geological Survey. The lake is about a mile in average width, 3 miles in greatest length, and is estimated to be about 200 feet in greatest depth. The inlet is at the upper end and is called

Lake Creek. It is formed of two smaller streams, one coming down from Old Baldy Mountain on the right, the other from the Manly Creek summit of the Sawtooth Mountains. Lake Creek is about 8 miles long. Near its mouth it is about 30 feet wide. The upper portion of the stream is a rapid mountain creek with many falls and cascades, but the last 3 miles are through a relatively level meadow or wooded plain. The shores are usually covered with a dense growth of low bushes, chiefly willows. The bed of the stream is of fine white sand in the quiet reaches and of coarse granite gravel in the swifter portions. There are numerous gravel bars where the water is a foot or less in depth, and many quiet pools with a depth of several feet. The water is extremely clear and very cold, its temperature September 12 being 45° F., or less. There appears to be no vegetation of any kind growing in the water.

The outlet of Alturas Lake is a stream some 40 feet in width. About a quarter of a mile below Alturas Lake this stream flows through another very small lake and then, flowing 6 miles northward, joins Salmon River just below Stenton's ranch. From the left it receives two small tributary creeks, the outlets of Pettit and Twin lakes. These are two small lakes situated at the base of the mountains only a few miles below Alturas Lake.

Salmon River.—The main division of this river rises on the divide between Sawtooth and Ketchum, the divide which forms the watershed between the waters of Salmon River on the north and those of Wood River on the south. That portion of Salmon River above the mouth of Alturas Creek is about 12 to 15 miles long, but it carries less water than Alturas Creek does. Its course is through a narrow valley, free of trees in the main and meadow-like in character. Along its shores is usually a heavy growth of small bushes.

At the junction of Alturas Creek and Salmon River the former is perhaps 50 feet in average width and 3 feet in average depth, while the latter is somewhat smaller. The water in each is very clear and cold, the temperature September 13 being 47° F., at noon.

Above the mouth of Alturas Creek Salmon River receives a number of small tributary streams, the principal ones from the left being Beaver, Smiley, and Washington creeks, while those from the right are Pole, Lost, and Warm Spring creeks. Below the mouth of Alturas Creek, on the right, are two rather larger creeks, known as Champion and Fourth of July creeks, while from the opposite side, and about midway between these, Salmon River receives Roaring Creek. Still farther down are Big Redfish Lake and Stanley Lake, each of which pours its waters into the river through a short outlet. These lakes were not visited by us. Redfish Lake is said to be a long but narrow lake into which redfish come in large numbers. Stanley Lake is smaller, but a lake of considerable importance.

PAYETTE RIVER BASIN.

The Payette River is one of the important streams of Idaho. The main river rises on the southwest slopes of the Sawtooth Mountains in latitude about 44° 10′, and immediately west of the headwaters of Salmon River, the Redfish Lakes lying at the foot of the range on the east side. After flowing westward about 90 miles it is joined by a stream from the north known on the maps as North Fork of Payette River. It is this fork with which we are at present chiefly concerned. At the head of this fork are important spawning-grounds of the chinook salmon, the redfish, and the steelhead. The Payette Lakes are situated here.

Payette Lakes.—The group of small lakes known as the Payette Lakes is situated at the head of the North Fork of Payette River in the northern end of Boise County, Idaho, about 125 miles north of Boise. There are three or four of the Payette Lakes, but the only one in which the redfish certainly occur is Big Payette Lake, which is at the head of the North Fork proper. This lake is quite irregular in form. Its greatest length is about 6½ miles and its greatest width about 2 miles. Toward the upper or northern end there is a very narrow arm, about 2½ miles long, extending southeastward from the east side. The lake is surrounded by granite mountains, and its shores are for the most part precipitous and rocky. The water is clear and cold, the surface temperature at noon September 27 being 50°. In places where the bottom was of white sand we could easily see to a depth of 20 to 30 feet. Some soundings have been made, and the greatest depth found was 140 feet, though the depth is currently believed to be much greater.

About 9 miles above Big Payette Lake is Upper Payette Lake, the outlet of which is the inlet to the larger lake. We examined the last 5 miles of this stream September 27, and found it to average about 60 feet wide and 2 feet deep on the shallows, while in the numerous pools and quiet reaches depths from 5 to 20 feet are found. The water is exceedingly clear, and the bottom of coarse sand can be distinctly seen even in the deepest portions. The water is also very cold, the surface temperature from 10 a. m. to 3 p. m. September 27 being 45°.

The valley of this stream is apparently from 1 to 2 miles wide and is covered with a heavy evergreen forest, chiefly of Murray pine and Douglas fir. The immediate banks of the stream are covered in most places with a dense chaparral of willows, birch, cottonwood, and other low bushes. The stream is very tortuous in its course, and in many places is clogged by large amounts of logs and other drift material. The bottom in most places is of coarse white sand or fine white gravel. There are numerous shallows where the current is very swift, and usually below each is a deep, quiet pool.

North Fork Payette River.—The outlet of the Payette Lakes is North Fork of Payette River, which, flowing southward through Long Valley about 100 miles, joins the main river north of Boise; then, after flowing eastward for about 50 miles, it joins Snake River near the town of Payette. I examined this river through the first 4 miles of its course immediately below Big Payette Lake. The river here will average over 60 feet in width and 2 feet in depth. The current on the riffles was about 1 foot per second.

The water was, of course, very clear and cold. The temperature taken at four places September 26 when the air was 57° was 55°, 54.5°, 53°, and 53°, respectively. The bottom is of coarse sand in the deeper places, gravel where the current is swifter, and still coarser gravel and larger rocks where the current is swiftest. The banks are usually low and of gravel and sand. Murray pine is the principal tree in the valley, and there is a good deal of underbrush or chaparral.

About 20 miles below Big Payette Lake the North Fork is joined by two streams of nearly equal size, from the left or east, known as Lake Fork and Gold Fork. At the head of Lake Fork is Little Payette Lake, a small lake only a mile or so east of Big Payette Lake and separated from it by a low rocky mountain. Redfish are not known to enter this lake.

Gold Fork is a somewhat larger and colder stream coming down from the mountains farther east.

SNAKE RIVER.

During former investigations in the Columbia River Basin, particularly those of 1893, considerable information was gathered regarding the physical characters of Snake River, and something was learned about the salmon and other fishes occurring in that stream. This information has already been published.* In that report are given descriptions of the various falls in the Snake River, and a consideration of each as a barrier to the distribution of fishes in that river. The investigations upon which that report was based showed that salmon can not possibly ascend Snake River farther than the foot of Shoshone Falls; and it was also believed that certain falls below Shoshone Falls (Auger Falls, Upper Salmon Falls, and Lower Salmon Falls) interfere seriously with the ascent of salmon.

During my trip to Idaho in September and October, 1894, I made still further investigations along that portion of Snake River between Twin Falls and Weiser, Idaho, a distance of more than 200 miles. It was desired to determine more accurately: (1) The character of Auger Falls, Upper Salmon Falls, and Lower Salmon Falls, and the part each plays as a barrier to the free movement of fishes; (2) the abundance of salmon in that part of Snake River.

It was desirable not only to learn as much as possible regarding their abundance, but to locate their spawning-beds, determine their spawning time and habits, determine the location and importance of the salmon fisheries of the Snake River, and to make investigations with reference to locating a salmon-hatchery at some point on Snake River.

Twin Falls and Shoshone Falls.—Both of these falls were visited by us. At Twin Falls there is a vertical descent in a single plunge of about 180 feet, while at the Great Shoshone Falls, 4 miles farther down the river, the descent is 210 feet. Each of these is, of course, an absolute barrier to the ascent of fish. As already stated in the report referred to, the construction of fishways at either of these falls seems entirely impracticable.

Auger Falls.—About 10 miles below Shoshone Falls are Auger Falls. These are a long series of rapids and short falls, occupying 250 to 300 yards of the length of the river, as we have already described. It does not seem possible that many salmon would be able to sustain the long and continuous effort necessary to pass up through these turbulent rapids, though individual fish may occasionally succeed in doing so. One man with whom we talked at Shoshone Falls tells of a fisherman who claims to have seen some salmon at the foot of Shoshone Falls.

I visited Auger Falls September 9 and spent several hours examining that part of the river. Although it was at a time when we might expect to find fish there, we did not see a single salmon attempting the rapids or in the quieter water below. Immediately below these rapids a small stream known as Rock Creek flows into Snake River from the south or left bank, and it is claimed that salmon entered this stream formerly.

Mr. I. B. Perrine, of Blue Lakes, situated about 4 miles above Auger Falls, says he has killed salmon in this creek and that they used to run into it in considerable numbers.

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*A Report upon Investigations in the Columbia River Basin, with descriptions of Four New Species of Fishes, by Charles H. Gilbert and Barton W. Evermann, in Report of the Commissioner of Fish and Fisheries on Investigations in the Columbia River Basin in regard to the Salmon Fisheries.

Upper Salmon Falls.—These falls are situated about 25 miles below Auger Falls, and have been sufficiently described in the report of the investigation of 1893. Salmon pass over these falls in considerable numbers. A fishery has been maintained more or less regularly each year near Lewis's Ferry, about 4 miles above these falls. During last October, Mr. E. E. Sherman operated a seine at this place and caught about 300 salmon. He regarded this as very poor fishing, and finally abandoned this ground and went to Glenn Ferry, where he hoped for better success.

From Upper Salmon Falls down for more than a mile the river is, for the most part, full of short rapids and irregularities; about 2 miles below the falls is a considerable rapid at the head of a large island owned by Mr. Liberty Millet. At the head of this island, in the main stream, which flows to the left of the island, is the largest and most important salmon spawning-ground of which we know in Snake River. The spawning-bed is at the foot of the rapids and is on gravel bottom where the water is from 1 to 5 feet deep. From this island down for about 5 miles the river is comparatively quiet; there are a few very swift places, but nothing that would interfere with salmon until Lower Salmon Falls are reached.

Lower Salmon Falls.—These falls are very similar to the Upper Salmon Falls and are situated about 6 miles below them. Through most of their width these falls are 20 to 30 feet in vertical descent, but at about a third of their width from the right bank are two places where the lava ledge has become worn or broken down so as to materially decrease the vertical portion. At the top of each of these chutes the water takes a vertical drop of about 10 feet, and then descends 20 or 30 feet more in a boiling, seething rapid before reaching comparatively quiet water.

Toward the left bank of the river the ledge is broken up into benches resulting in irregular series of shorter falls, up which salmon are able to go, only, however, with more or less difficulty. The facilities for observing the salmon ascending the left portion of the falls were not good, as it was impossible to reach any point from which one might watch any portion where the salmon attempted the ascent. But by taking a boat below the falls on the right bank one can cross to some exposed portions of the ledge at the right side of the first of the chutes already mentioned, and from this point the entire length of the chute can be watched.

I first visited these falls September 16, and, crossing over to the ledge, spent some time watching the salmon jumping. We saw some thirty or thirty-five attempts made by salmon to ascend the falls, but all failed; these attempts likely represent only a few different fish, as each fish probably made more than one attempt. During the time we watched I never saw more than two fish in the air at the same time. The fish kept to the water until within 10 to 20 feet of the foot of the vertical portion. Our first sight of the fish would be when he shot out of the water like an arrow speeding toward the top of the falls; for 10, 15, and often 20 feet he sustains himself in the air, and then drops into the turbulent water at the foot of the falls, or strikes the column of falling water at some point below the lip of the ledge; occasionally he strikes near the top where the water is scarcely vertical, and then, with every muscle strung to its utmost tension, the body quivering in every inch of its length, he fights the descending torrent, retaining his position perhaps for several moments; but the contest is an unequal one and the salmon is finally carried down and into the pool below, perhaps to renew the fight after a period of rest. Often the leaping salmon would strike in the seething water at the foot of the fall and there he would sustain himself at the

top of the water for a longer time. Just under where we stood was a nook where the water was less turbulent, and there we could occasionally see salmon apparently resting before making another attempt.

We visited these falls at other times, on October 1, 2, and 7, and saw a few salmon jumping each time, but never saw one succeed. In years past this is said to have been a favorite place for the Indians to spear or gaff the salmon. A few salmon are still taken in that way by people living in the vicinity. The second chute can not be reached without considerable danger, nor can it be seen very well from any accessible point; it appears, however, to offer less difficulty than the first, and a good many salmon probably pass up the stream at that point. The large majority of salmon that make these falls, however, probably go up at some of the places nearer the left shore. Yet even these offer such serious obstruction that it is quite certain that many salmon which would otherwise reach the spawning-beds above are prevented from doing so by Lower Salmon Falls. There do not appear to be any suitable spawning-places below these falls in a distance of several miles. The river in this part of its course is usually quite deep and the bottom is said to be very rocky or else muddy. A little blasting at these falls would make it very much easier for the salmon to ascend. The expense would not exceed $100 to $300 and I believe it would result in a considerable increase in the salmon supply of Snake River.

Snake River below Lower Salmon Falls.—Immediately below Lower Salmon Falls, Snake River is quite deep and filled with large detached masses of lava. Even where the water is shallow these irregular, jagged lava rocks are so abundant as to render the use of the seine impossible.

Farther down, near the mouth of the Malade or Big Wood River and on to below Bliss, there are some gravel bars, but we could not learn that they have ever been used as spawning-beds. In the vicinity of King Hill, some 18 or 20 miles below Bliss, or 25 miles below the Lower Falls, are said to be some spawning-beds. King Hill was formerly resorted to by the Indians during the salmon run, and a few are said to visit there each year yet.

Five or six miles below King Hill is Glenn Ferry, in the vicinity of which some fishing is carried on. The railroad leaves the Snake River just below Glenn Ferry and does not return to it until below the mouth of the Boise River, more than 125 miles below Glenn Ferry. Very little is known concerning this portion of the river, and we do not know of any salmon fishing below Glenn Ferry until we reach the mouth of the Boise and Owyhee rivers. Beginning at that place there are fisheries scattered all along for about 60 to 75 miles, or from the mouth of the Boise to Huntington, and perhaps farther.

The time at our disposal did not permit us to visit all the fishermen in this part of the river, but we were able to get some figures regarding the number of salmon and steelhead which they caught during the past fishing season. These figures will be found farther on in this report. Several men whom we interviewed gave valuable information regarding the salmon and other fishes of Snake River.

In the following pages are brought together under each species all the important facts learned regarding it (1) at the headwaters of Salmon River, (2) at the headwaters of Payette River, and (3) in the Snake River.

THE CHINOOK OR QUINNAT SALMON.

Headwaters of Salmon River.—The headwaters of Salmon River have long been known as containing important spawning-grounds of the chinook salmon. All persons familiar with the region with whom we talked spoke of the salmon as spawning there in great numbers. Ten and fifteen years ago they were very abundant, but all agree that the number spawning there now are as nothing compared with former years.

Mr. F. C. Parks, postmaster at Sawtooth, has observed the fish of that region for several years, and he gives the following concerning the occurrence of chinook salmon in the headwaters of Salmon River:

The salmon (called dog salmon here) appear above the mouth of Alturas Creek about July 25. They are then in excellent condition, and people spear and shoot them for food. There is no regular shipping of fish from here; the fish are taken chiefly by miners and ranchers, and by tourists and campers, who often ship some home. They begin spawning about August 10 and keep it up until about September 1. On September 1, 1894, a Mr. Benson shot four near the mouth of Alturas Creek. About August 20 or 25, Mr. B. Carlo, of Sawtooth, shot and speared fourteen large salmon in Alturas Creek, half a mile above its mouth. [The writer saw the heads of most of these lying on the bank at Stenton's ranch, where the fish had been dressed.] These fish were ripe when taken. The best spawning-beds are in the last 1½ miles of Alturas Creek. There are other large spawning-beds in Salmon River immediately below the mouth of Alturas Creek and at various places on down the river, at least as far as the outlet of Redfish Lake. I have seen them as far up Salmon River as the mouth of Pole Creek, several miles above the mouth of Alturas Creek. Fully three times as many go up Alturas Creek as go up Salmon River above the mouth of Alturas Creek. I caught two in Pole Creek last August, and saw four dead ones there.

The salmon that come here will average about 15 pounds in weight. The largest I ever saw weighed 40 pounds, and the smallest about 8 pounds. The males are of a very dark lead-color, with some dirty red on the sides; the females are more silvery. When the spawning time arrives the male digs out a hole in the gravel with his nose; he sometimes turns on his side and may scoop out the gravel some with the hump on his back; he also seems to use his fins for this purpose. The female comes along and, passing over the hole scooped out by the male, lays her eggs, and the male comes and plunges around some, probably pouring out the milt at the same time. They always stand in the current with the head up stream. I think they all die after spawning; I do not believe any ever return to the sea; have seen many dead ones every year. I never knew one to take a hook, nor did I ever find any food in their stomachs. They spawn on the riffles in shallow water.

There were more salmon this year than for the past five or six years. More than six years ago they were much more abundant.

Thomas B. Mulky, of Stanley Basin, made the following statement:

The salmon come in July and their spawning is finished in September. Yesterday (September 12) I saw as many as 100 live "dog salmon" in Salmon River between Basin Creek and Valley Creek. Saw a good many dead ones, also. They spawn all along in that part of the river. I think all the salmon which spawn here die after spawning, none ever returning to the sea.

Mr. B. S. Brown, of Bliss, Idaho, gives the following information:

The dog salmon come into Upper Salmon River about August 1 and spawn very soon after. The largest spawning-bed that I know is in the river at the mouth of Roaring Creek. They go up Alturas Lake Creek about a mile above Stenton's ranch and up Salmon River to just above White's ranch. The height of their spawning here is between August 10 and 15. I think they all die after spawning. The largest I ever saw weighed 50 pounds; the smallest I have seen were about 18 inches long.

On September 13 I examined very carefully at least 2 miles of Salmon River next below the mouth of Alturas Creek; I also examined more than a mile of the river above the mouth of Alturas Creek and a mile or more of the lower portion of Alturas Creek. We walked along the shores or banks and counted all the salmon we saw. Only one live salmon was seen; it was covered with sores and would certainly die soon. Along the banks or in the water we counted 72 dead salmon; of these, 31 were

males, 36 females, and 5 too rotten to determine the sex. Five females which we examined measured 28, 32, 37, 39, and 44 inches, respectively, in total length. One male measured 53 inches long. All of these fish were much decayed, and we noticed that, as a rule, the males were more decayed than the females. The indications are that the spawning in this part of Salmon River is completed, and most of the salmon dead or gone early in September. The presence of salmon in the river in Stanley Basin as late as September 12, as noted by Mr. Mulky, probably indicates that the spawning takes place later there than it does farther up the river where the waters are colder.

Headwaters of Payette River.—This is also an important spawning region for the chinook salmon, as may be seen from the interviews given below. Mr. W. C. Jennings, who lives at the Meadows, about 10 miles from Big Payette Lake, says:

I have been familiar with Big Payette Lake and the surrounding country for twenty-five years. The salmon (the males of which we always call "dog salmon") come up Payette River into Long Valley about July 4; saw some on that day a few years ago in Gold Fork, about 15 or 20 miles above its mouth. They are most abundant about August 15 to September 15, when they are spawning. They spawn earlier in Gold Fork and a little later in North Fork and Lake Fork, the time for the last two being September 1 to 20. Gold Fork is a colder stream than either of the others, and I am confident the salmon run into it earlier and spawn there earlier because it is colder. I think that 75 per cent of all the salmon that come up Payette River spawn in Gold Fork. These three forks are nearly of the same size, and their mouths are very close together.

I have seen salmon up Gold Fork 10 to 12 miles, and as much as 15 miles up Lake Fork; have seen them in North Fork occasionally at the outlet of Big Payette Lake. These salmon will average 10 pounds or more. There are a good many small ones, weighing 4 to 8 pounds, but these are all males. They spawn on the riffles in Payette River, North Fork, Lake Fork, and Gold Fork, the principal spawning-grounds being in Gold Fork. They very rarely enter Big Payette Lake. I once killed one above the lake and heard of another.

I think all the salmon which come up here die after spawning; have seen thousands dead along the river. I think they come up from the sea, of course. I do not know when the young go down to the sea. A half-breed once told me that in Spokane River the young salmon go down stream in the mush ice in the spring. He says the Indians and French would catch them by the thousands in the mush ice. They would average 1½ inches long and were very good when fried. I do not know whether there is any truth in this or not. The salmon were much more abundant formerly than now.

Mr. Thomas McCall and his son, Dawson McCall, state:

We have lived at the lower end of Big Payette Lake several years; have not paid much attention to the salmon, but know that they come up the river within a mile or so of the lake; have an interest in a seine with which one haul was made about August 1, but only two salmon were caught. The other owners did a good deal of fishing in August and got a good many fish. At one haul they got thirty fish. The two gotten August 1 were females and weighed about 8 pounds each. One shot a few days ago was a male weighing about 8 pounds.

We think we saw one in the lake at the outlet, but it may have been a redfish. This is the only fish seen in the lake which we thought was a salmon. The Indians come in here in the early fall and camp along the river. They get a good many salmon which they cure for winter use.

My examination of Payette River (or North Fork, as the outlet of Big Payette Lake is called) did not result in the discovery of a single live chinook salmon. About 2½ miles below the lake we found one dead female, 28 inches long. A number of deserted wickiups along the stream showed that the Indians had been there recently.

Most of the people of whom we inquired stated that the salmon came somewhat earlier and in larger numbers than usual this year. Evidently the spawning season in this stream occurred much earlier this year than the last of September; not only were no live fish seen, but nearly all the dead ones had disappeared, either by decay or by having been eaten by coyotes or other animals.

Snake River.—The spawning-grounds of chinook salmon in Snake River between Huntington and Auger Falls have been, and perhaps still are, the most important in Idaho. Certain it is that more salmon fishing for commercial purposes is done here than in any of the other streams of the State. Owing to the interesting fact, not hitherto noted by anyone writing upon the salmon, that the spawning takes place in Snake River from six weeks to two months later than in the headwaters of Salmon and Payette rivers, we were able to learn more regarding it from personal observation in Snake River than elsewhere.

Mr. William O'Brien, of Weiser, Idaho, says:

I have been fishing for about sixteen years, off and on, principally for salmon trout, salmon, and sturgeon; also pay some attention to chubs, whitefish, and suckers.

I call these fish chinook salmon. They appear in this part of the river about the middle of August, but, as my fishery is on the Oregon side, I am prohibited by the law of that State from fishing until the 15th of September. We get our best salmon fishing between then and the 15th of October; they are most abundant, however, in latter part of August and early September. Up to the present time (September 21) have caught about 175 salmon. They will average 12 to 25 pounds, or about 15 pounds dressed. Have taken about 25 or 30 young ones this year; never saw any of these small ones until four or five years ago. All that I noticed were males. Some chinooks probably come up during the high water in July. They begin to get ripe about October 1 to 15; then they are not so good. I know of one large spawning-bed at Washoe near Ontario. This bed is of gravel in water 1 to 1½ feet deep. Have seen the old males turn on side and flip the tail as if scooping out the gravel. I think all the salmon that spawn here die after spawning. Have seen weak and dead ones floating down about last of October and early November, and some drifted up on shore. Have caught spent fish, but they were no account, so we threw them away. This, of course, would be late in the season.

While at Mr. O'Brien's fishery, September 21 and 22, the following additional information was gained: The fishery is 4 miles below Weiser and on the Oregon side of the river. Fishing began this year on September 18. The seine is 12 to 14 feet deep, about 350 feet long, and 2¼-inch bar. To operate it requires three men, a horse, and a boat, and the seine is hauled over the same ground each time. Starting at the upper end of the seining-ground, the man in the boat rows straight out from the shore as far as he can, the seine beginning to pay itself out when the boat is 150 to 200 feet from the shore; when he has gone as far out as he can, he rows downstream as fast as possible, the shore end being pulled downstream by the horse at the same time. When the boat is about two-thirds of the distance down to the landing-place it is pulled in toward the shore, and the oarsman, assisted by the third man, takes hold of the rope at the lower end of the seine and pulls it in to the shore, while the other man and the horse manage the other end.

When the area inclosed by the seine became small the fish would begin to dart from one end to the other; seldom would one get away, but most of them would soon become entangled in the seine. Then one of the men would hold a gunny sack into which another man would push the fish, and then they would be carried down to the live-boxes, where they are kept until ready to dress or sell. The place where the seine is hauled out is a long, broad gravel bar between which and the shore is a long, narrow, shallow strip of water. Mr. O'Brien has dammed this both at the lower and upper ends, thus making a pond into which he can put his fish and keep them alive indefinitely. He says he has had as many as 600 or 700 fish in this pond at one time.

He sells his fish (1) to farmers who come to his fishery for them, (2) to men who peddle them over the country, (3) some few to the hotels and others in Weiser, and (4) in the latter part of the season he ships a good many by express to various points, such

as Pocatello, Butte, etc. He lets the farmers have the fish at 25 cents a fish. For those which he ships or sells to the hotels he gets about 4 cents a pound. A few years ago he got 8 to 10 cents a pound. The fish he was getting while we were there were in excellent condition; the flesh was firm and of a good color, the nose of the males was not yet much hooked, the teeth not enlarged, and the body not covered with sores. The females examined were full of roe, but not yet ripe.

Mr. William Kinney fishes some on the Idaho side, about 3 miles below Mr. O'Brien's, but he was not doing any fishing at the time of our visit.

Through the kindness of Mr. O'Brien I have been furnished the figures given in the following table. These figures cover not only the catch of Mr. O'Brien for the season of 1894, but that of seven other fishermen operating between Huntington and the mouth of the Boise River.

Approximate number of chinook salmon and steelheads caught in Snake River between Huntington and Weiser in September and October, 1894.

Name of fisherman.	Location of fishery.	No. of chinook salmon caught.	No. of steelheeds caught.
Cole & Hopper	10 miles above Huntington	400	200
William Kinney & Co.	7 miles below Weiser	250	650
William O'Brien	4 miles below Weiser	*385	*1,516
Purcell & Co.	4 miles above Weiser	600	200
Pickler & Co.	5 miles above Weiser	400	400
Erricson & Co	8 miles above Weiser	200	100
Milton Hopper	10 miles above Weiser	500	300
Mr. Duncan	12 miles above Weiser	200	500
Hall & Reamy	Opposite Ontario	50	100
C. McDowell	At mouth of Boise River	(†)	(†)

*Of the 385 chinook salmon caught by Mr. O'Brien, 250 were males and 135 females; of the 1,516 steelheads, 834 were males and 682 females. Mr. O'Brien estimates that the male chinooks caught by him averaged 38 inches long and 25 pounds in weight; the females 34 inches long and 16 pounds in weight; the male steelheads 30 inches long and 12 pounds in weight, and the females 28 inches long and 12 pounds in weight. Not over 5 or 6 of the female chinooks were ripe.

† No figures obtained.

William Betz and Henry Oleson, of Glenn Ferry, Idaho, state:

We have fished more or less for three years, mostly for sturgeon, but catch some salmon. The salmon appear here about September 15 and are thickest about September 30. We see most dead ones during first half of November. We think most of them die, but some may get back to the sea. The first ones which come up we call "silver salmon," or, when the meat is very red, "salmon belly." Those which come later have hooked noses and are "dog salmon." They spawn on gravel beds in this part of the river, but we never noticed their spawning habits particularly.

Mr. Robert E. Conner, of Lower Salmon Falls, says:

I have lived here near these falls since 1882. For the first four or five years after my coming salmon were abundant; have seen the chute full of salmon; there must have been a thousand in sight at one time. But there has been a great decrease in the last four or five years. They used to come earlier than they do now, as early as August 1, I think. During the last few years I have not noticed them until September. Think they spawn upon all the riffles above the falls; have noticed them in shallow water along the shore. The Indians that come here say the salmon prefer the sandy beds, and that the coarse gravel which the miners have run into the river has caused the salmon to seek other spawning-beds. "Camas Jim" is sure this is the case.

No one has ever carried on salmon fishing here to any extent, but this used to be a famous Indian fishing-ground; they don't come here much now. The run usually begins about September 1 of late years and continues about a month. The salmon that I see here will average 15 to 20 pounds. Used to see many dead ones, but not many now; the coyotes pick them up. I think all the salmon that come here die. I never see any salmon except during the fall, and never saw any little ones.

Mr. E. E. Sherman, who lives 3 miles below Upper Salmon Falls, says:

The first salmon to run in the fall are what we call "silver salmon." They come about September 10 and continue until about October 15; occasionally catch them later, with "dog salmon." Last year I caught perhaps a ton at Mr. Millet's fishery. They would average about 8 pounds; the largest weigh about 15 pounds, and the smallest about 3 pounds. They spawn on the bars in the river, where the dog salmon spawn a little later. I never saw a dead silver salmon. Can tell them from the dog salmon by the difference in color, shape of head, shorter nose, and smaller teeth. I never see them at any time except early in the fall.

The "dog salmon" arrive about September 30, and are most abundant about October 10, but continue until the last of October. They are ripe when they first come. The smallest weigh about 5 pounds, the largest probably 60 pounds, or 49 pounds dressed; they average about 15 pounds. Last year I caught about 6 tons, which I sold at 3 cents a pound to people who would come to the fishery for the fish, then peddle them out, chiefly at Oakley, Goose Creek, Raft River, etc., getting 6 to 8 cents a pound.

The dog salmon spawn on coarse gravel bars. There is a good-sized spawning-ground at Millet's Island, and a large one about 8 miles above Millet's at Lewis's Ferry. They get sore late in the fall, especially the males. Have seen a good many dead dog salmon, and have seen them fighting a good deal.

It is scarcely necessary to state that the names "dog salmon," "silver salmon," "silversides," "salmon belly," "chinook salmon," and "quinnat salmon," as used in Idaho, all refer to the single species *Oncorhynchus tschawytscha*. The individuals which arrive earliest in the season are in the best condition and are known as silver salmon, silversides, or salmon bellies, while the distorted, disfigured, and dying individuals seen late in the season are generally known as dog salmon. "Chinook" and "quinnat" are not often heard among the Snake River fishermen.

Since my return home from Idaho Mr. Sherman has kindly sent me the following information regarding his fishing during the season of 1894:

From October 1 to October 15 I fished about 2½ miles above Upper Salmon Falls. I did not keep any record of my catch, but it amounted to about 3,200 pounds. The fish were not numerous, but were about as thick when I quit as at any time. About one-third of those caught were females and about half were ripe. They would average about 10 pounds each. Our seining-ground here was on a spawning-bed, and there are still other spawning-beds above the upper falls. Thinking I might do better I went to Glenn Ferry, and from October 20 to 26, inclusive, I fished at a point about 2 miles below the ferry. I caught about 5 tons of salmon, but they were in bad condition and I saved only about 1 ton. The run at that place was said to have been about October 10. The fish that I got were all spent fish and about a third of them were females.

Charles Harvey, Duret, Idaho, gives the following:

I am mining just below Lower Salmon Falls; have been here only one year. Caught a few salmon for my own use last year. Dog salmon came up last year about the last of September. Two weeks ago (about September 2) there were a great many salmon here at the falls. Most of the fish which get over the falls do so near the left shore and the left one of the two middle chutes. On Monday, September 17, caught a 20-pound female "silver salmon" with a grab hook at the chute. It was in excellent condition; the eggs were not yet ripe and the flesh was firm and of fine flavor.

Mr. George W. Bell, also living at Duret, says:

I have lived here near Lower Salmon Falls since 1889; have paid some attention to the salmon. Think they formerly came up earlier than they do now—as early as last of July. They used to be more abundant than now. Indians used to get a good many. There is only one run, lasting about a month. Camas Jim, an Indian who fishes a good deal, says there are not many fish this year.

Mr. Liberty Millet, Salmon Falls, Idaho, gave us the following information:

Have lived here on this island below Upper Salmon Falls for ten years, and have fished for eight years. Salmon were formerly much more abundant than now. They usually appear about September 1, but I have caught some in August. The early ones we call "silversides." The ones we call "chinooks" do not come until later, say about September 15 to October 1, and continue until the last of October.

The first, i. e., the "silversides," are not ripe. The males will average 15 to 20 pounds, the females about 10 pounds. The "chinooks" will average, leaving out the small males, about 15 pounds. The largest will weigh 40 pounds. The smallest ones are always little males weighing about 3 pounds, and they are nearly all ripe. Do not think I ever saw a female weighing under 8 pounds.

The height of the spawning season is about the middle of October. They spawn on rather coarse gravel with some sand in it, in 1 to 12 feet of water. The principal spawning-ground here is at the head of the island. The area covered is about 1,000 feet up and down the river and about 600 feet in width. On the other side of the bar is another small spawning-bed. When the spawning time arrives the salmon throw the gravel about a good deal; they throw it up into ridges crosswise with the stream, like windrows of hay. The tops of the ridges are sometimes so near the surface of the water that a boat drags in passing over them, while between the ridges the water may be 4 or 5 feet deep. Both the male and the female probably work the gravel about; they appear to turn more or less on their sides and work the gravel up with their fins. I think they cover the eggs pretty deep, for the small trout, whitefish, chubs, and other small fish that eat salmon spawn are there in great numbers. Small trout which we often catch in our seine are so gorged with salmon eggs that the eggs fall out of their mouths in great numbers when we hold them by the tail. The children bait their hooks with salmon spawn and catch great numbers of what we call young trout [they are not trout, but the Columbia River chub, *Mylocheilus caurinus*], which bite very quickly, and when they take them off the hook they find their stomachs full of salmon eggs.

I do not know when the eggs hatch. Have seen myriads of very little fish, 1 to 1½ inches long, in the shallow water in the spring, but I do not know whether they are salmon fry or not. I think the young salmon must start down stream soon after hatching. I never noticed any, or many, of these little fry after high water in May and June.

I do my fishing from about October 1 to October 25. Last year (1893) I leased my fishery to Mr. E. E. Sherman. In 1892 my season's catch amounted to between 7 and 8 tons, dressed. This included a few salmon trout. Most of the early catch are males, but later there are a good many females. We sometimes fish for a week or ten days without getting a single female.

My seine is 300 feet long, 10 feet deep in the wings, and 14 feet deep in the center; the mesh is 4 inches, or 2-inch bar. I haul the seine in 10 to 15 feet of water and right over the spawning-ground. Have caught as many as 200 at a single haul. I sell my fish principally here on the ground to farmers and others who come for them. They get them for their own use or to peddle over the country, chiefly down in the Raft River and Goose Creek country. I get 3 cents a pound, dressed.

A good many salmon die late in the fall, but I do not think all die. Have sometimes seen old males with scars healed up. I have always thought these were fish which had spawned at least once before, but it may be the wounds were received in some other way.

Dr. Scovell and I spent the week from October 1 to 7, inclusive, at Mr. Millet's, which afforded us good opportunities for observing the salmon at that place. Although the fish had not yet come in numbers sufficient to justify operating the seine, Mr. Millet and his brother-in-law, Mr. Joseph P. McMeekin, at our request, made several hauls each day during our stay. This enabled us to see the method upon which their fishery is conducted, as well as to note the abundance and condition of the salmon.

As already stated, Mr. Millet lives upon a large island in Snake River, below Upper Salmon Falls. Immediately above the island is a considerable rapid. Only a small portion of the river flows to the right of the island. The width of that portion flowing to the left of the island is 428 feet, measured at the lower end of Mr. Millet's hauling ground. At this place there is a gravel bar or island, 44 feet wide, separated from the main island by a shallow channel 59 feet wide. This leaves only 325 feet as the distance across the main channel between the small gravel bar and the left bank of the river. The depth in this portion of the river was found to be 14 to 20 feet near the left bank and less and less toward the gravel bar. The bottom temperature at 9 a.m. October 6 was 52°.

The seining is carried on about as follows: From a point about 300 yards above the gravel bar, and as near the rapids as the current will permit, the boat is rowed rapidly across the stream until most of the seine is paid out. Then, at a distance of

about 300 to 350 feet from the shore, the boat is headed downstream, while the man at the other end of the seine walks down the shore rapidly enough to keep approximately even with the boat, being careful at the same time not to let out so much rope as to allow the seine to get so far from the shore as to permit any salmon to run around at his end of the seine. At the upper end of the gravel bar the narrow channel separating it from the main island is quite shallow, permitting him to wade across to the bar. By the time he has reached the upper end of the bar the boat is at the lower end, both ends of the seine are now brought up to the land, and pulling in begins. This requires only a few minutes. The salmon caught are thrown out upon the bar and knocked on the head so as to keep them from floundering back into the water, the seine is loaded into the boat, and everything is ready for another haul.

The upper ground hauled over comprises a considerable portion of the principal spawning-bed. The depth of water there is 3 to 10 feet, while lower down the depth is as much as 15 feet. In the upper part the bottom is of coarse gravel, while below it is of finer gravel, with some sand.

In the following table are given important data regarding the catch of salmon at this place during the fishing season of 1894:

Table showing catch of chinook salmon at Liberty Millet's Fishery on Snake River, at Upper Salmon Falls, Idaho, September 29 to November 1, 1894.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Sept. 29	*a* 1	.....	.....	.....	.....	.....	
Oct. 1	*b* 6	.....	.....	.....	.....	.....	
Oct. 2	1	34	.....	Nearly ripe	.....	.....	
.....		32	.....	Not ripe	.....	.....	
.....	2	23	.....	Ripe	38	20	Not ripe.
.....		29	.....	....do	.....	.....	
.....		23	.....	....do	.....	.....	
	c 3	.....	.....	.....	.....	.....	
	4	44	30½	Nearly ripe	.....	.....	
.....		35	14¼	Not ripe	.....	.....	
.....		30	10¾	....do	.....	.....	
.....		31	11¾	Ripe	.....	.....	
.....		31	11	....do	.....	.....	
	5	32	11¾	Not ripe	.....	.....	
.....		25 }	12½	{Ripe	.....	.....	
.....		29 }		{Not ripe	.....	.....	
.....		37	19	....do	.....	.....	
.....		43	30½	....do	.....	.....	
	6	28	8½	....do	.....	.....	
.....		31	11¼	Ripe	.....	.....	
	7	21	4	Not ripe	.....	.....	
Oct. 3	1	40	20¼	....do	.....	.....	
	2	21	4	Nearly ripe	.....	.....	
	3	21	4	....do	.....	.....	
	4	21	4	Ripe	.....	.....	
Oct. 4	1	21	3¼	Nearly ripe	.....	.....	
.....		30	8	....do	.....	.....	
	2	22	3½	....do	.....	.....	
	3	43	29	Not ripe	.....	.....	
.....		32	11¾	Ripe	.....	.....	
.....		33½	11¾	....do	.....	.....	
.....		32	11	Not ripe	.....	.....	
.....		30	9½	Ripe	.....	.....	
	4	41	27¾	Not ripe	.....	.....	
.....		30	9	Nearly ripe	.....	.....	
.....		27	7	Partly ripe	.....	.....	
Oct. 5 A. M.	1	28	9½	Not ripe	.....	.....	
	....	32	12½	Ripe	.....	.....	
	....	23	5	....do	.....	.....	
	....	30	9½	....do	.....	.....	
	....	32½	13¼	....do	.....	.....	
	c 2	.....	.....	.....	.....	.....	
	3	31½	10½	Ripe	32½	14¾	Ripe.
	4	40	23½	Not ripe	.....	.....	

a One nearly ripe female caught but not measured nor weighed.
b These were not weighed; four of them measured 30, 30½, 21, and 19 inches, respectively.
c Caught nothing.

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
	5	30	10½	Not ripe			
	....	35	17½	....do			
	....	28	9½	....do			
Oct. 5 P. M.	....	20½	4	Ripe			
	6	21½	4	Nearly ripe			
	....	26	6½	Ripe			
	....	26	6½	Not ripe			
	....	28	7½	Ripe			
	....	31	13¼	Nearly ripe			
	1	32½	14	Ripe			
	...	30	9½	....do			
	....	30½	10	Not ripe			
	....	22	4	Ripe			
	....	22	3½	....do			
Oct. 6 P. M.	....	20½	3¾	....do			
	2	29½	10	Nearly ripe			
	....	28	9	....do			
	2	28½	9	Nearly ripe			
	....	30	12½	Ripe			
	....	23	4½	Scarcely ripe			
	....	21	4	....do			
Oct. 10 *a*	*b* 1	39	.....	Ripe	20	.....	Spent.
	.....	33	.....	....do	20	.....	Do.
	.....	30	.....	....do	.....	.....	
	.....	27½	.....	....do	.....	.....	
	c 2	33½	.....	....do	21	.....	Ripe.
	.....	22	.....	....do	.....	.....	
	.....	21	.....	....do	.....	.....	
	d 3	39½	.....	....do	29	.....	Not ripe.
	.....	30	.....	....do	.....	.....	
	.....	43	.....	....do	.....	.....	
	.....	42½	.....	....do	.....	.....	
	.....	41	.....	....do	.....	.....	
	.....	43	.....	....do	.....	.....	
	.....	33	.....	....do	.....	.....	
	.....	34	.....	....do	.....	.....	
	.....	32	.....	....do	.....	.....	
	.....	31	.....	....do	.....	.....	
	e 4	31½	.....	....do	29	.....	Spent.
	.....	.....	.....	.....	26	.....	Ripe.
	f 5	22	.....	Ripe	20	.....	Do.
	.....	26	.....	....do	.....	.....	
Oct. 11	1	21	3	....do	.....	.....	
	.....	24	6	....do	.....	.....	
	.....	23	3½	....do	.....	.....	
	.....	32	13	....do	.....	.....	
	.....	22	3½	....do	.....	.....	
	.....	31	11	....do	34	12	Spent.
	2	31	11	....do	.....	.....	
	.....	20	3½	....do	.....	.....	
	.....	21	4	....do	.....	.....	
	3	23	6½	....do	.....	.....	
	.....	27	14	....do	.....	.....	
	.....	22	5½	....do	.....	.....	
	.....	33	14½	....do	.....	.....	
	.....	33	16	....do	.....	.....	
	.....	38	22	....do	.....	.....	
	4	33	14	....do	32	12	Spent.
	.....	28	10½	....do	29	10	Ripe.
	.....	29	13	....do	.....	.....	
	.....	26	10	....do	.....	.....	
	.....	22	3	....do	.....	.....	
	.....	25	3½	....do	.....	.....	
	.....	21	2½	....do	.....	.....	
	.....	19	2	....do	.....	.....	
	5	39	26	....do	.....	.....	
	.....	37	24½	....do	.....	.....	
	.....	32	22	....do	.....	.....	
	.....	21	4	....do	.....	.....	
	.....	30	7	....do	.....	.....	
Oct. 12	1	31	10	....do	36	15	Ripe.
	.....	21	4	....do	35	13	Do.
	.....	23	4½	....do	.....	.....	
	.....	28	10½	....do	.....	.....	
	.....	23	4	....do	.....	.....	
	.....	40	24	....do	.....	.....	

a No fishing done from October 7 until October 10.
b Total catch, 6; total weight, 73¼ pounds.
c Total catch, 4; total weight, 37 pounds.
d Total catch, 11; total weight, 197½ pounds.
e Total catch, 3; total weight, 23½ pounds.
f Total catch, 3; total weight, 48¼ pounds.

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 12	2	28	8	Ripe	30	14	Ripe.
		32	12	do			
		36	14	do			
		18	2½	do			
		26	6	do			
	3	32	14	do			
		28	10	do			
		34	15	do			
		26	10	do			
		26	9	do			
		27	10	do			
Oct. 13	1	40	25	do	37	16	Spent.
		28	8½	do			
		32	12½	do			
		34	12	do	30	10	Ripe.
		28	8½	do	30	12	Do.
		23	8	do	31	9½	Do.
		20	3	do			
		21	3½	do			
	2	20	5	do			
		31	13	do			
		20	4½	do			
		40	29	do			
		21	7	do			
		23	10	do			
		40	26½	do			
		38	25	do			
		20	4	do			
		21	10	do			
	3	34	18	do			
		29	16	do			
		42	24	do			
		25	6	do			
		19	3	do			
		22	3½	do			
		29	13½	do	37	18	Ripe.
		30	12½	do	36	15	Do.
Oct. 14	1	32	10½	do	22	7	Do.
		30	11	do	21	12	Not ripe.
		31	13	do			
		28	9	do			
		24	6	do			
	2	39	26	do	35	18	Ripe.
		30	14	do	28	13	Do.
		28	12	do			
		30	13	do			
		31	14	do			
	3	42	31	do			
		37	24	do			
		20	4½	do			
	4	42	29	do	38	21	Ripe.
		30	10	do	32	17	Do.
		41	25	do			
		34	15	do			
		40	28½	do			
		29	9	do			
		20	5	do			
		29	9½	do			
	5	30	12½	do			
		30	12	do			
		19	2½	do			
		40	25	do			
		42	32	do			
		38	21	do			
		34	12	do			
		20	3	do			
		22	3½	do			
		20	3	do			
	6	39	23	do			
		32	21	do			
		41	31	do			
		39	23	do			
		38	24	do			
		32	22	do			
		34	23½	do			
		30	12	do			
		29	8½	do			
		29	9	do			
		28	10	do			
		22	7	do			
		20	6½	do			
		20	5	do			

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 14	7	36	13	Ripe			
.....		31	10	....do			
.....		38	15	....do			
.....		28	10	....do			
Oct. 15	1	38	20	....do	36	16	Ripe.
.....		30	11	....do			
.....		23	8	....do			
	2	34	17	No record			
.....		30	15	....do			
.....		24	10	....do			
.....		27	10	....do			
.....		20	5	....do			
.....		34	15	....do			
.....		20	4	Ripe	34	13	Ripe.
.....		20	5	....do			
.....		18	3	....do			
.....		15	2½	....do			
	3	40	25	....do	30	12	Ripe.
.....		30	12	....do			
.....		32	14	....do			
.....		36	19	....do			
.....		37	20	....do			
	3	24	8	....do			
.....		28	10	....do			
	4	33	13½	....do	32	17	Not ripe.
.....		30	12	....do	32	12	Spent.
.....		42	35	....do			
.....		32	14	....do			
.....		30	13	....do			
.....		18	3½	....do			
Oct. 16	1	30	11	....do	36	14	Ripe.
.....		41	25	....do	26	7	Spent.
.....		43	29	....do			
.....		26	9½	....do	36	15	Ripe.
.....		28	10	....do	32	7	Spent.
.....		31	12	....do			
.....		27	9½	....do			
.....		32	14	....do			
.....		30	14	....do			
.....		26	10½	....do			
.....		22	7	....do			
.....		22	7½	....do			
.....		39	23½	....do			
.....		40	26	....do			
	2	42	34	....do	33	15	Ripe.
.....		30	12½	....do	35	16	Do.
.....		32	15	....do	35	14	Do.
.....		32	15½	....do	34	17	Do.
.....		41	32½	....do	36	13	Spent.
.....		34	18	....do	33	14	Ripe.
.....		32	15	....do	30	8	Spent.
.....		21	7½	....do			
.....		42	27	....do			
.....		32	14	....do			
.....		33	16	....do			
.....		32	14½	....do			
.....		30	11	....do			
.....		41	27	....do			
.....		36	10	....do			
.....		41	26½	....do			
	3	31	13	....do	30	10	Spent.
.....		21	7½	....do	33	17	Not ripe.
.....		26	9½	....do	30	11	Spent.
.....		24	6½	....do			
.....		26	10	....do			
Oct. 17	1	30	11½	....do			
.....		39	23	....do			
.....		43	26½	....do			
.....		39	23	....do			
.....		30	12	....do			
.....		28	10½	....do			
.....		30	12	....do			
.....		28	11	....do			
.....		32	15	....do			
.....		31	14	....do			
.....		32	14½	....do			
	2	44	30	....do	38	28	Not ripe.
.....		42	29	....do	32	14	Spent.
.....		43	29	....do	31	10	Do.

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 17	2	40	26½	Ripe			
.....		29	10¾	....do			
.....		30	12	....do			
.....		29	9½	....do			
.....		22	6	....do			
.....		30	10	....do			
.....		24	5	....do			
.....		21	5	....do			
.....		22	6½	....do			
	3	38	25	....do	36	20	Not ripe.
.....		45	32	....do	35	16	Ripe.
.....		36	20	....do			
.....		24	8½	....do			
.....		26	9	....do			
.....		22	4¾	....do			
Oct. 18	1	42	28	....do	38	15¾	Ripe.
.....		31	12	....do	30	10	Spent.
.....		34	16	....do	39	17	Ripe.
.....		20	4	....do	31	15	Do.
.....		20	4½	....do	29	9½	Spent.
.....		41	25	....do	38	17½	Ripe.
.....		27	9½	....do	38	17	Not ripe.
.....		40	26	....do	40	19	Do.
.....		28	10¾	....do			
.....		26	10	....do			
.....		26	8¾	....do			
.....		30	12	....do			
.....		30	12	....do			
.....		28	19	....do			
.....		38	20½	....do			
.....		27	9	....do			
.....		42	28	....do			
.....		40	26½	....do			
.....		40	24	....do			
.....		38	25	....do			
.....		38	25	....do			
.....		36	20	....do			
.....		34	18¾	....do			
.....		37	19	....do			
.....		28	10	....do			
.....		29	9½	....do			
.....		26	7	....do			
.....		18	3	....do			
Oct. 19	1	30	11	....do	36	18	Spent.
.....		31	12½	....do	34	15½	Ripe.
.....		30	12	....do	30	11	Do.
.....		38	19½	....do			
.....		30	14	....do			
.....		42	28	....do			
.....		40	26	....do			
.....		40	24½	....do			
	2	32	15¾	....do	36	13	Spent.
.....		40	33	....do	34	14	Do.
.....		24	4½	....do	38	14	Do.
.....		20	4	....do	39	17	Do.
.....		40	32½	....do	34	17	Not ripe.
.....		31	8¾	....do	30	10	Ripe.
.....		24	6	....do	36	23	Do.
.....		41	24½	....do	32	14	Do.
.....		24	8	....do	34	16	Do.
.....		40	26	....do			
.....		31	12	....do			
.....		30	11½	....do			
.....		31	12	....do			
.....		30	11¾	....do			
.....		31	14	....do			
.....		22	7	....do			
.....		38	10	....do			
.....		36	20	....do			
.....		30	11	....do			
.....		36	18½	....do			
.....		28	10	....do			
.....		28	9¾	....do			
.....		40	29	....do			
.....		39	24	....do			
.....		27	10½	....do			
.....		32	15	....do			
.....		34	16	....do			
.....		26	8½	....do			
.....		28	9	....do			
.....		42	27	....do			
.....		36	20½	....do			

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 19	2	38	24	Ripe			
	.....	40	26	....do			
	.....	28	10	....do			
	.....	25	7	....do			
	.....	25	6½	....do			
	.....	30	15	....do			
	.....	44	28	....do			
	.....	20	3	....do			
	.....	25	7	....do			
	.....	33	20	....do			
	.....	31	16	....do			
	.....	28	9½	....do			
	.....	24	6½	....do			
	.....	28	10½	....do			
	.....	29	10¾	....do			
	.....	35	22	....do			
	.....	20	4	....do			
Oct. 20	1	40	20½	....do	28	11	Ripe.
	.....	35	16½	....do	38	18	Spent.
	.....	37	16	....do	35	16½	Ripe.
	.....	26	10	....do	29	11½	Do.
	.....	25	8	....do	30	11	Spent.
	.....	27	10	....do	35	15	Ripe.
	.....	28	11¾	....do			
	.....	22	5	....do			
	.....	25	7	....do			
	.....	42	25	....do			
	.....	38	23	....do			
	.....	27	20	....do			
	.....	27	20	....do			
	.....	41	24	....do			
	.....	26	9½	Spent			
	.....	42	25	Ripe			
	.....	26	7½	Spent			
	.....	39	17	Ripe			
	.....	41	26	....do			
	.....	40	24½	....do			
	.....	20	3½	....do			
	.....	21	4½	....do			
	.....	34	14	....do			
	.....	26	6	....do			
	.....	25	8	....do			
	.....	28	11	....do			
	.....	22	7	....do			
	.....	30	12¾	....do			
	.....	40	25	....do			
	.....	20	3	....do			
	2	43	26	....do	36	18	Ripe.
	.....	40	23	....do	34	16	Spent.
	.....	44	30	....do	34	17	Ripe.
	.....	29	12	....do	30	10¾	Do.
	.....	33	10¾	....do	38	20	Do.
	.....	30	9	....do	40	23	Do.
	.....	20	4	....do	33	15	Spent.
	.....	28	9½	....do	30	11	Do.
	.....	42	24	....do			
	.....	43	29	....do			
	.....	28	9½	....do			
	.....	34	16	....do			
	.....	40	29	....do			
	.....	40	28	....do			
	.....	28	10	....do			
	.....	30	14	....do			
	.....	20	3	....do			
	.....	20	3	....do			
	.....	26	9	....do			
	.....	41	23½	....do			
	.....	30	15	....do			
	.....	22	6	....do			
	.....	28	8½	....do			
	.....	40	22	....do			
	.....	40	24	....do			
	.....	40	22	....do			
	.....	36	18½	....do			
	.....	22	5	....do			
	.....	31	14	....do			
	.....	25	9	....do			
	.....	26	9	....do			
	.....	44	30	....do			
	.....	25	10	....do			
	.....	32	11½	....do			
	.....	20	3	....do			

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 20	2	31	11	Ripe			
	.....	36	20	....do			
Oct. 22	.....	40	24	....do	35	16	Ripe.
	.....	30	12½	....do	36	17	Spent.
	.....	28	10	....do	40	24	Ripe.
	.....	26	9	....do	32	13½	Spent.
	.....	46	39	....do	36	17	Do.
	.....	44	26	....do	35	14	Do.
	.....	41	25	....do	35	15½	Do.
	.....	43	27	....do			
	.....	30	11¾	....do			
	.....	25	8	....do			
	.....	42	27	....do			
	.....	38	19	....do			
	.....	40	29	....do			
	.....	25	7	....do			
	.....	40	23½	....do			
	.....	26	9½	....do			
	.....	40	23	....do			
	.....	40	23	....do			
	.....	26	8	....do			
	.....	26	9	....do			
	.....	25	7	....do			
	.....	25	7½	....do			
	.....	30	12	....do			
	.....	24	6½	....do			
	.....	30	11½	....do			
	.....	29	10¾	....do			
	.....	25	9½	....do			
	.....	24	7	....do			
	.....	30	10	....do			
	.....	25	8	....do			
	.....	30	10½	....do			
	.....	36	18	....do			
	.....	29	12	....do			
	.....	26	8	....do			
	.....	41	22¾	....do			
	.....	25	9	....do			
	.....	26	9	....do			
	1	26	10	....do			
	.....	42	26	....do			
	.....	25	9	....do			
	.....	41	25	....do			
	.....	36	19	....do			
	.....	22	6	....do			
	.....	24	4	....do			
	.....	41	22½	....do			
	.....	32	12½	....do			
	.....	28	10	....do			
	.....	24	8½	....do			
	.....	33	14	....do			
	.....	25	10	....do			
	.....	40	20¾	....do			
	.....	44	27¾	....do			
	.....	41	23½	....do			
	2	30	12	....do			
	.....	37	18½	....do			
	.....	43	27	....do			
	.....	26	9	....do			
	.....	21	8	....do			
	.....	21	5	....do			
	.....	23	7	....do			
	.....	22	7	....do			
	.....	22	7½	....do			
Oct. 23	1	41	23¾	....do	37	22	Ripe.
	.....	43	26	....do	29	10	Spent.
	.....	33	13	....do	33	16	Do.
	.....	37	18½	....do	26	9	Do.
	.....	40	20	....do	40	20	Ripe.
	.....	20	4	....do			
	.....	24	8	....do			
	.....	41	24	....do			
	.....	42	22	....do			
	.....	26	18	....do			
	.....	26	10	....do			
	.....	41	24	....do			
	.....	26	10½	....do			
	.....	33	16	....do			
	.....	41	25	....do			
	.....	27	18	....do			
	.....	40	22	....do	32	14	Spent.
	.....	24	8	....do	28	10	Do.
	.....	34	16¾	....do	30	14	Do.

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 23	1	22	4¾	Ripe	28	12½	Ripe.
		20	3	....do	39	23	Do.
		21	7	....do	30	12	Spent.
		20	3⅛	....do	38	16	Ripe.
		40	25	....do	37	15½	Do.
		23	4¾	....do	32	12½	Do.
		26	9⅛	....do			
		42	25	....do			
		18	3	....do			
		19	5	....do			
		40	26	....do			
		45	32	....do			
		41	26	....do			
		25	8⅛	....do			
		43	27	....do			
		40	24⅛	....do			
		24	8	....do			
		25	8⅛	....do			
		22	7	....do			
		40	23	....do			
		25	6	....do			
		34	18	....do			
		26	8⅛	....do			
		26	9	....do			
		32	14⅛	....do			
		39	22	....do			
		35	23	....do			
		31	12⅛	....do			
		25	8¼	....do			
		24	7	....do			
		30	12	....do			
		32	14	....do			
		38	20	....do			
		38	18¾	....do			
		25	7	....do			
		34	7	....do			
	2	26	8⅛	....do	29	10½	Spent.
		25	10	....do	28	9	Do.
		32	15	....do	37	14	Do.
		20	6	....do	38	18	Ripe.
		33	16	....do	29	10⅛	Do.
		30	10	....do	28	9	Spent.
		44	30	....do	30	18½	Ripe.
	3	36	19⅛	....do	34	18	Do.
		29	9	....do	26	10	Do.
		29	9	....do	35	18	Do.
		37	21	....do	33	16	Do.
		18	3	....do	36	15	Spent.
		15	2⅛	....do	30	12	Do.
		19	3⅛	....do	37	15½	Do.
		20	5	....do	30	12¾	Do.
		22	6⅛	....do	40	23	Ripe.
		40	23	....do	35	18⅛	Do.
		29	10	....do	32	15	Spent.
		30	11	....do			
	4	32	14	No record			
		31	14⅛	....do			
		41	23⅛	....do			
		36	24	....do			
		26	20	....do			
		26	20⅛	....do			
		24	7⅛	Ripe	34	18	Ripe.
		41	25⅛	....do	26	10½	Do.
		44	30	....do	35	22	Do.
		33	19	....do	33	17	Do.
		33	17	....do	38	23	Do.
		18	2⅛	....do	34	16⅛	Do.
		42	27	....do			
		44	28⅛	....do			
		26	10¾	....do			
		42	28	....do			
		25	8¾	....do			
		40	26	....do			
		26	9	....do			
Oct. 24	1	39	23	....do	31	12	Ripe
		22	7⅛	....do			
		24	8	....do			
		21	6¾	....do			
		30	12	....do			
		30	12⅛	....do			
		20	7	....do			

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 24	1	38	23	Ripe			
.....		28	10	....do			
.....		24	6½	....do			
.....		26	10	....do			
.....		25	8	....do			
.....		24	6	....do			
.....		22	7	....do			
Oct. 25	1	18	3	....do	25	7	Ripe.
.....		37	20	....do	36	14	Spent.
.....		26	9	....do	30	11½	Do.
.....		31	13¾	....do	39	18	Ripe.
.....		46	34	....do	39	19	Do.
.....		30	13	....do			
.....		19	4½	....do			
.....		17	3	....do			
.....		32	14	....do			
.....		31	14	....do			
.....		42	29	....do			
.....		26	9	....do			
.....		42	26	....do			
.....		18	3	....do	38	19	Spent.
.....		23	8	....do	34	12½	Do.
.....		19	4½	....do	39	19	Ripe.
.....		34	18	....do	40	22½	Do.
.....		34	17¾	....do	35	17	Do.
.....		28	10	....do	35	17¾	Do.
.....		27	10	....do			
.....		29	10	....do			
.....		30	11¾	....do			
.....		40	26	....do			
.....		43	27	....do			
.....		35	17	....do			
.....		36	18½	....do			
Oct. 26	1	38	22	No record			
.....		40	26	....do			
.....		26	10	....do			
.....		27	12	....do			
.....		25	8	....do			
.....		25	9	....do			
.....		22	7	....do			
.....		24	8	....do			
.....		37	20	Ripe	30	12	Ripe.
.....		31	10½	....do	30	11½	Do.
.....		26	7¾	....do	32	14	Do.
.....		28	8	....do	32	15	
.....		18	3	....do	30	12½	
.....	2	33	14	....do	38	18	Spent.
.....		29	9¾	....do	34	16	Ripe.
.....		30	12	No record			
.....		18	3	....do			
.....		26	10	....do			
.....		27	7½	....do			
.....		27	8¾	....do			
.....		34	18	....do			
.....		27	8	....do			
.....		32	12	....do			
.....		32	13¾	....do			
.....		28	8½	....do			
.....		26	7¾	....do			
.....		24	6	....do			
.....		27	8	....do			
.....		24	8	....do			
.....		40	23	....do	33	15	Spent.
.....		32	15	....do	34	21	Ripe.
.....		33	16½	....do	32	14¾	Do.
.....		35	17	....do			
.....		30	11	....do			
.....		32	19	....do			
.....		44	27	....do			
.....		24	5	....do			
.....		24	5	....do			
.....		32	14	....do			
.....		24	5½	....do			
.....		25	6½	....do			
Oct. 27	1	28	11	Ripe	30	12	Spent.
.....		26	8	....do	32	13	Do.
.....		38	24	....do	37	23	Ripe.
.....		25	7½	....do	30	12	Do.
.....		30	14	....do			
.....		36	22½	....do			
.....		40	26	....do			
.....		39	22	....do			

Table showing catch of chinook salmon at Millet's Fishery—Continued.

Date.	Haul No.	Males.			Females.		
		Length.	Weight.	Condition.	Length.	Weight.	Condition.
1894.		*Inches.*	*Pounds.*		*Inches.*	*Pounds.*	
Oct. 27	1	28	10⅛	Ripe	36	19	Ripe.
.....	.....	26	8	....do	32	14	Spent.
.....	.....	25	7	....do	28	9	Do.
.....	.....	31	15⅛	....do	30	12½	Do.
.....	.....	30	16	....do	34	16	Do.
.....	.....	42	31½	....do	.....	.....	
.....	.....	42	30	....do	.....	.....	
.....	.....	25	7⅜	....do	.....	.....	
.....	.....	26	7	....do	.....	.....	
.....	.....	24	6	....do	.....	.....	
.....	.....	26	8	....do	.....	.....	
.....	.....	31	16	....do	.....	.....	
.....	.....	28	10	....do	.....	.....	
.....	.....	36	22	....do	.....	.....	
.....	.....	24	6½	....do	.....	.....	
.....	.....	20	4	....do	.....	.....	
.....	.....	25	9	....do	.....	.....	
.....	.....	40	26	....do	.....	.....	
.....	.....	19	2	....do	.....	.....	
.....	.....	39	24	....do	.....	.....	
.....	.....	26	8½	....do	.....	.....	
.....	*	25	10	....do	.....	.....	
.....	.....	25	8	....do	.....	.....	
.....	.....	24	6	....do	.....	.....	
.....	.....	38	22	....do	.....	.....	
.....	.....	36	21	....do	.....	.....	
.....	.....	38	20	....do	.....	.....	
.....	.....	28	12½	....do	.....	.....	
Oct. 31	.....	42	26	....do	36	15	Spent.
.....	.....	44	29¾	No record	30	10⅛	Do.
.....	.....	41	26	....do	33	13	Do.
.....	.....	44	28	....do	36	14	Do.
.....	.....	40	26	....do	36	18	Ripe.
.....	.....	24	3½	....do	28	9	Spent.
.....	.....	18	2	....do	32	12	Do.
.....	.....	28	7¾	....do	34	14	Do.
Nov. 1	.....	45	30	Ripe	.....	.....	
.....	.....	38	23	....do	.....	.....	
.....	.....	34	18½	....do	.....	.....	
.....	.....	38	22	....do	.....	.....	

Summary of catch of chinook salmon at Upper Salmon Falls, Snake River, from September 29 to November 1, 1894, inclusive.

Date.	Males.	Females.	Date.	Males.	Females.
Sept. 29	.....	1	Oct. 17	29	5
Oct. 1	6	.....	Oct. 18	28	8
Oct. 2	18	1	Oct. 19	56	12
Oct. 3	4	.....	Oct. 20	67	14
Oct. 4	11	.....	Oct. 22	62	7
Oct. 5	16	1	Oct. 23	93	38
Oct. 6	12	.....	Oct. 24	14	1
Oct. 10	20	7	Oct. 25	26	11
Oct. 11	28	3	Oct. 26	41	10
Oct. 12	17	3	Oct. 27	36	9
Oct. 13	26	6	Oct. 31	8	8
Oct. 14	49	6	Nov. 1	4	.....
Oct. 15	26	5			
Oct. 16	35	14	Total	732	170

Summary of catch of chinook salmon in Snake River between Huntington and Auger Falls, September to November, 1894.

Fishermen.	Place.	Males.	Females.	Total.
Cole & Hopper	10 miles above Huntington			400
William Kinney & Co	7 miles below Weiser			250
William O'Brien	4 miles below Weiser	250	135	385
Purcell & Co	4 miles above Weiser			600
Pickler & Co	5 miles above Weiser			400
Erricson & Co	8 miles above Weiser			200
Milton Hopper	10 miles above Weiser			500
William Duncan	12 miles above Weiser			200
Hall & Reamy	Opposite Ontario			50
Liberty Millet	Near Upper Salmon Falls	732	170	902
E. E. Sherman	....do			320
Grand total				4,207

Headwaters of Weiser River.—In order to reach the Payette Lakes we traveled by wagon from Weiser, a distance of about 120 miles, chiefly through the valley of Weiser River and its upper tributaries. This afforded us some opportunity to learn of the occurrence of salmon in that region.

The Little Weiser River flows through Indian Valley, 50 miles north of Weiser, and we were informed that a few "dog salmon" are seen in that stream each fall. They come there to spawn in September. The stage-driver says he saw three or four at the ford above Indian Valley post-office about September 19. People in the vicinity spear them to some extent.

Just above Council Valley we examined Weiser River for about a mile of its course (September 25), but saw no fish. Persons living in the neighborhood told us that they caught four salmon about September 2, and saw a good many others. Those caught weighed 9 pounds or less each and were not ripe. They are said to be more common this year than usual; none were seen last year. One man says there were ten times as many this year as in any recent year, but there are scarcely any now compared with ten years ago. They go 5 to 8 miles above Council Valley to spawn. Most of the men with whom we talked think that late in September is the spawning time, but our observation indicated that it is somewhat earlier.

Mr. Oscar Ferguson, of Council Valley, says:

> The fish here now are all regular salmon, though some call the earlier ones "salmon trout" and the late ones "dog salmon." The regular salmon trout come in the spring. The salmon are spawning now; saw them 2 miles above the stage station at Seavey's ten days ago; saw twenty-five or thirty and killed three fine ones, each 2 to 3 feet long. Found a recently dead female a few days ago above Seavey's. She was full of eggs and had not begun spawning.

The stage-driver says he saw three or four salmon at the ford of Weiser River below Price Meadow about September 15.

It seems probable that a good many salmon still spawn in this river. The upper portion of Weiser River and its tributaries appear to have excellent water and all suitable conditions for salmon spawning-grounds.

THE REDFISH OR BLUEBACK SALMON.

Headwaters of Salmon River.—The redfish or blueback salmon (*Oncorhynchus nerka*) is the most important of all the salmon of Alaska, where it is known as the red salmon. In the Lower Columbia, where it is known as the blueback salmon, it is exceeded in importance only by the chinook salmon, the catch of bluebacks in the Columbia River in 1892 amounting to 873,106 fish, or 4,365,530 pounds. That this species spawns in large numbers in the Columbia basin is certain, but we know very little regarding its spawning habits or the location of its spawning-grounds. Dr. Bean has studied it in Alaska, but not until now has any naturalist studied it at any of its spawning-grounds in the Columbia basin.

So far as is yet known, the lake region at the headwaters of Salmon River contains some of the most important spawning-grounds of this species. I observed it at Alturas and Pettit lakes, and it is known to occur in Redfish Lake, Stanley Lake, and perhaps in one or two other small lakes of this group. They are also known from the headwaters of Payette River (Big Payette Lake), from Wallowa Lake in Oregon, and from Okanagan Lake in Washington.

Redfish at Alturas Lake.—Mr. F. C. Parks gives the following information:

The redfish appear at Alturas Lake usually about August 1, and reach the inlet of the lake about August 5, when some are nearly ready to spawn; others are tight and the flesh firm and without sores. They are then more wild and active than later. There are two distinct sizes, those of one size weighing 3 or 4 pounds, while those of the other size are very much smaller, weighing less than half a pound each. The small and large ones nearly always school separately. Have seen no big ones for three years until this year. Four years and more ago the large ones were common. About 1881 a prospector took 2,600 pounds fresh from Alturas Lake to Atlanta and Rocky Bar, where he sold them to the miners. Formerly many were salted and barreled. At one time there was talk of starting a cannery here or at Redfish Lake, but the passage of a law prohibiting traps stopped the matter.

Most of the fish seem to be males. We get them when they first come in, with grab hooks and spears. They spawn only in the inlet; do not believe they ever spawn in the lake. The small ones run up the inlet at least 3 miles, where the water is so shallow that their backs stick out. The large ones spawn in the lower part of the inlet. The spawning habits of the large and small ones are essentially the same. They spawn upon the gravel bars in shallow water. While on the spawning-beds the males fight a good deal; they bite each other upon the back and hold on for quite a while.

The spawning begins early in August and is usually over by the first of September. Finding them still spawning to-day (September 12) was a great surprise to me. When we started out this morning I did not believe we would find any redfish.

I think they come up from the sea each year; have never seen any in the lake in the winter and do not believe any stay there. I have never seen them in or about the lake except from about the last of July to late in September. I think they practically all die after spawning; a few may get back to the sea. The little ones I have always regarded as the same as the big ones, size being the only difference. I never found any food in their stomach, and never knew them to take a hook.

The ones we got to-day (September 12) will average in size with those of former years, both the large ones and the small ones. Have seen some weighing probably 6 pounds. Mr. Ferris, an old fisherman here, says he has caught them weighing 6 pounds.

There is not much variation in their time of arrival. They seem to have come a little later and in greater numbers this year than for several years; the large ones especially were more abundant this year than usual. The greater abundance this year may be due to the unusually high water of last spring, which may affect fish in two ways: (1) By reaching farther out to sea; (2) by enabling fish to get over falls, which prove a barrier in lower water.

Mr. B. S. Brown, of Bliss, Idaho, says:

I was at Alturas Lake about August 15, 1893, and saw 400 or 500 small redfish, but no large ones. They were in the inlet about 2 miles above the lake and were spawning. Have seen these little redfish fight just like dogfish (chinook salmon). The little redfish I have never seen in any of the lakes up there except Alturas Lake. Have seen the large ones in Big Redfish Lake, Stanley Lake, and Pettit Lake. Saw them spawning in Big Redfish Lake about August 18, 1893, and about August 15, in 1887, 1888, and 1889. I was there in each of those years and salted quite a lot of them. Have seen them in Salmon River about 3 miles below Stenton's ranch, and never saw any in Salmon River above the mouth of Alturas Creek. I am sure they come up Salmon River and I believe they all die after spawning. The large ones will average 3 to 4 pounds. There appear to be more males than females.

On September 12 we visited Alturas Lake and examined the inlet for about 3 miles in the lower part of its course. We started at the lake and followed all the windings of the stream, and then returned to the lake, keeping in sight of the creek all the way. By thus examining every foot of the stream we probably saw every redfish in that part of its course. In this distance I counted 114 small redfish and 14 large ones. Twelve of the large ones were on a shallow gravel bar near the mouth of the stream, and the other 2 were about a mile farther up, and on the same riffle with 29 small ones. Other bunches of small ones of 23, 13, 9, 6, and fewer, were seen. These were all on the riffles in shallow water and engaged in spawning. They were invariably in the current with head up stream. We noticed that they scooped up the gravel into piles or ridges, using the nose, pectoral fins, tail, and sometimes the back. These piles of gravel were not large, however, and could not be noticed at a very great distance. Frequently we noticed the fish in pairs, a male and a female, the female being usually a little in advance of the male. We supposed that they were spawning when in such position.

Sometimes there was considerable fighting among the males. They would catch each other by the pectoral fin or by the nose, and hang on quite tenaciously, meantime slowly floating down stream. Then they would release their hold and return to the shallow water, perhaps to renew the fight in a few moments. Immediately below each riffle, sometimes above, was a deep hole into which the fish would go when disturbed. By retiring into the bushes where they could not see us, we usually had to wait only a few minutes when they would again return to the riffle. After having been disturbed once, however, they became more timid and more easily frightened.

I have spoken of "small redfish" and "large redfish." The small redfish is what has been known as Kennerly's salmon (*Oncorhynchus kennerlyi*), and it has by some been regarded as a species distinct from the large redfish (*Oncorhynchus nerka*), while others have regarded it as a landlocked variety of the large redfish. The structural differences upon which the separation has been made do not appear upon an examination of a large number of specimens of each size. At present I am inclined to regard them as being specifically identical, though a fuller knowledge of the migrations of each may justify their specific separation.

In the water, both males and females of the large fish were quite red, the males but little more intense than the females. The small males are of a dirty red on the back, and much brighter red on middle of side; on the back are about thirty small, round black spots, not greatly unlike those on the cut-throat trout. The under parts were a dirty white; dorsal and anal fins, pale or dirty red; other fins smoky. The females were darker and less red; the spots were plainer, and the general resemblance to the cut-throat or black-speckled trout was more marked. By the use of a small seine we caught 29 small ones and 6 large ones.

The sex, weight, and condition of each are given in the following table:

Sex, weight, and condition of redfish caught in the inlet to Alturas Lake, Idaho, September 12, 1894.

Sex.	Weight.	Condition.	Sex.	Weight.	Condition.
	Lbs. oz.			*Lbs. oz.*	
Male	9	Scarcely ripe.	Male	7	Ripe.
Do	7½	Ripe.	Do	6½	Do.
Female	7	Do.	Do	5	Partly spent.
Male	8	Do.	Do	6	Do.
Female	7		Do	5	Spent.
Do	5½	Partly spent.	Do	5½	Partly Spent.
Do	5½	Do.	Do	5	Spent.
Male	7½	Ripe.	Do	5½	Do.
Do	6½	Do.	Female	7	Ripe.
Do	6½	Do.	Male	Not weighed.	Do.
Do	5½	Partly spent.			
Do	6½	Ripe.			
Do	6½	Do.			
Do	8	Do.	Male	3 10½	Ripe.
Female	6½	Do.	Do	3 2½	Partly spent.
Do	5½	Partly spent.	Do	3 5½	Do.
Do	4½	Spent.	Do	3 7½	Do.
Male	5½	Partly spent.	Female	3 10½	Ripe.
Do	8	Ripe.	Do	2 5	Spent.

Average weight of 28 small redfish, 6½ ounces. Average weight of 6 large redfish, 3 pounds 4½ ounces.

Of the 29 small redfish, only 4 (2 males and 2 females) were without sores or mutilations. The fraying out of the fins seems to begin first with the caudal, then on the front of the dorsal and anal, and later upon front of ventrals, and to some extent upon the front of pectorals. Besides the fraying out of fins, there are sores sometimes upon the body in different places. Whether these mutilations are due to the wear and tear incident to the long journey from the sea (if they really come up from the sea), to the wearing incident to spawning, to their fighting, or to general physiological collapse, is not certainly known. I am inclined to think it is chiefly due to the wear and tear of the journey up from the sea, but am not at all certain that this is the correct explanation.

Besides the 128 redfish which we saw in the stream, we counted 6 dead ones along the creek. We examined the inlet of Pettit Lake, also, but we saw no live fish; on the bank we found one large fish which had been partly devoured by some animal. And this suggests a reasonable explanation of the scarcity of dead fish. If all or nearly all the redfish die soon after spawning, as is generally believed, and as seems probable, more dead fish ought to be seen. But the dead fish are eaten by various animals, as we have observed, and many of them are no doubt eaten or carried away soon after dying.

Headwaters of Payette River.—At the head of the North Fork of Payette River are the small lakes already described. In the inlet of Big Payette Lake, the principal one of the group, important spawning grounds have existed and the evidence given below shows that considerable numbers of redfish still come there.

Concerning the fish of the Payette Lakes, Mr. W. C. Jennings gives the following:

Have lived near Payette Lakes 25 years. Heard of the redfish in these lakes even before I came here. For many years I put up a good many for use. Two fisheries were run here for seven or eight years, between 1870 and 1880, by Hughes & Bodily and Louis Fouchet. They put up great quantities of redfish. Hughes & Bodily put up about 75,000 fish one year. They quit fishing in 1876; no one fished in 1877, but in 1878 Fouchet came back and fished one or two years. Fish were not abundant enough to make it pay, so he quit, and there has been no commercial fishing here for over ten years.

Formerly the redfish were very abundant; the water was literally full of them; there were millions of them. Very few during recent years. They appear about August 10th to 15th each year, and continue to be seen up to the last of October, or until snow comes; have seen them in great numbers late in October. They appear a week or two before they are ready to spawn. They come from the lake

into the inlet and lie in the deep holes until ready to spawn. The height of the spawning season is throughout September. Then they come upon the gravel beds in the shallow water. Their spawning habits are very much the same as those of the dog (chinook) salmon—usually see a male and a female together. The males fight a good deal; bite each other, especially on the back. Have seen them fighting very often. Both male and female scoop out the gravel with their tails.

The principal spawning-beds were in the inlet 2 to 3 miles above the lake; they go up 5 or 6 miles, however. When they were so abundant many used to spawn around the edges of the lake on sandy places where there are springs which make the water colder. This spawning in the lake took place at same time as that in the inlet. I never knew but few to go up as far as the Upper Lake, which is 9 miles above the Big Payette Lake; they rarely go farther than 5 or 6 miles up. I never saw any in the outlet of the lake. Have never seen them in any of the lakes about here except Big Payette Lake. Some say they have seen them in Little Lake, which is about three-fourths of a mile east of Big Payette Lake, but I never saw any there, though I have noticed a few in the outlet (Lake Fork) of that lake.

I do not believe the redfish come up from the sea or return to the sea, but believe they remain right here in this lake and its inlet during the entire year. I have seen them in the lake at all times of the year. They are not red except in the fall; at all other times they look like trout, but the shape of the head is different. They will not bite a hook during the spawning season, but at any other time they take the hook readily; can catch them with hook baited with meat of any kind.

I wish to repeat that I am confident the redfish do not return to the sea. They belong in the lake. The thing that bothers me is this: If they come up from the sea, why is it that, on their way up, a million will come up the North Fork while few or none go up Lake Fork into Little Lake, and not one goes up Gold Fork? All three of these streams come together less than half a mile apart and they are all of about the same size and general character. Gold Fork is probably some colder than either of the others, but, aside from this, the streams are essentially alike. It may be that these redfish do come up from the sea and that, when they come to these three forks, every one of the thousands knows which of the three roads to take in order to reach the spawning-beds in and above Big Payette Lake, *but I don't believe it.*

There are both large and small redfish here; the large ones run 4 to 5 pounds undressed, or about 2½ pounds dressed. In putting them up we always counted 40 fish to the 100 pounds. The males are heavier than the females.

There used to be millions of them here. So thick were they that often, in riding a horse across at the ford, I have been compelled to get off and drive them away before my horse would go across. Thousands of dead ones would be seen along the shores and in the deep holes.

Mr. N. B. Robertson, of Weiser, Idaho, says:

I came down from Big Payette Lake last Friday (September 14); was at the head of the lake on Thursday (13th instant), and looked for redfish, but saw none; examined about a mile of the inlet. People up there say they have seen none this year, and few if any for five years. The last time I saw any there was in 1888—in September—when there were a good many, some of which I caught. One man put up 800 pounds, and Jennings, Folsom & White had about 600 pounds. This must have been about September 10. The fish were ripe at that time. The large ones averaged about 2½ pounds dressed. Have seen small ones 6 to 8 inches, which were said to be redfish, but they were not ripe and not much red. They were called young redfish at the lake, and probably were such.

I think the redfish stay in the lake and run up into the inlet to spawn. But they are never seen in the lake except right at spawning time, and then only at the bar at the mouth of the inlet. They spawn in shallow water where there is not much current, and where the bottom is sandy or of gravel. They used to begin spawning about the last of July.

Louis Fouchet used to come in about the first of July to get ready for fishing. Fifteen or twenty years ago he would salt down 30,000 to 40,000 pounds every year, and ship them out to the mining camps. William C. Jennings, of Salmon Meadows, knows more about the redfish of Payette Lake than anyone else.

Mr. John W. Smith, of Council Valley, Idaho, has observed the redfish at Payette Lake. He says:

I saw redfish in the inlet to Big Payette Lake some time early in September. They were 4 or 5 miles above the lake; there were 20 or 30 in one place and several in other places. All of these were large ones. Also saw a good many small ones, usually schooling by themselves; in one bunch of

small ones I saw one large fish. Have not seen many during the last few years; saw none in 1890, 1891, or 1892. They may have been there in 1893, but I did not notice any; other parties said there were none last year. During the spawning they fight a good deal.

I have heard it claimed that a few years ago the redfish spawned at the head of Crazy Woman Island, in Payette River, 2 miles above Emmettsville, or about 20 to 25 miles above Payette. This was a year when the water was so low that the fish were unable to reach the lake. They go up the inlet of Payette Lake 5 or 6 miles. I never saw nor heard of redfish in any of the Payette lakes except Big Payette Lake. They have been reported from Weiser River, about 75 miles above Weiser, but I do not know if they were really redfish.

They are reported more abundant than usual at Payette Lake this year. I have seen them coming up into the lake in great numbers, and they were then all *blue*, there being very little red upon them. I am sure they come into the lake from below. They are rarely seen upon the spawning-beds until in September. I think they all die after spawning.

At Council Valley, Idaho, we saw Mr. Alexander Kessler, who had recently returned from a trip to Payette Lake. He gave us the following important information:

At the end of the first week in September of this year I visited the inlet to Big Payette Lake, and while there spent two days catching redfish. This was on September 8 and 9, and we got about 175 fish. At least half of them were of the small form, less than a foot in length. Most of them were females [this is probably a mistake. E.] and nearly all were spawning or ready to spawn; some were about spent. We caught them with grab hooks in the inlet about 3 miles above the lake. They were very abundant; we saw one bunch in which there seemed to be as many as a thousand. We must have seen 2,000 to 3,000 altogether. We noticed that most of them lay in deep water during the day and came upon the riffles to spawn chiefly at night. We camped by the stream and at night could hear them splashing about in the shallow water. The small ones were not much red outside, but their meat was redder than that of the large ones. Most of the small ones and some of the large ones were blue like trout. This is the only year I ever paid any attention to these fish.

My own observations on the redfish of Big Payette Lake were made September 26 and 27, 1894. On September 27 I took a sailboat and Dr. Scovell a rowboat at the lower end of the lake and crossed the lake to the head, making such observations en route as we could to determine the presence of fish. Dr. Scovell followed up the east (left) shore, examining the shoal water as he went. We saw no redfish in the lake, though trout were very abundant. At the mouth of the inlet is a considerable bar, over which we had to drag our boats. After getting into the inlet we were able to ascend it about 2 miles, when a drift of logs prevented further progress with the boats. Leaving the boats at this place and carrying our seining outfit with us we followed on up the stream about 3 miles farther. The thick chaparral along the stream made it very difficult to get down to the water at many places. We put in the entire day, however, and succeeded in examining nearly every rod of the last 5 miles of the stream.

About 4 miles above the mouth of the inlet we found six large redfish spawning on a gravel bar in shallow water just below a deep hole filled with logs and brush. When disturbed the fish would run up into this deep hole and remain concealed some time before returning to the riffle. The temperature of the water on the riffle at 2 p. m. was 45°, and the depth about 18 inches. We watched these fish quite a while and saw them fighting some. Whenever two males came near each other, one would swim rapidly up to the other and catch him by one of the fins, usually the pectoral, or by the back. He would keep his hold quite a little while, the two meanwhile slowly drifting down with the current. At least two of the six were males, and two or three of them were covered with sores. After repeated attempts we caught one of the six, which proved to be a spent female 1 foot 8 inches long, and weighing 2 pounds 2

ounces. This fish was very thin and weak, and its fins were very much worn. Every time we attempted to get any of the others they would run under the brush in the deep pool above. These six are the only live redfish we saw in this stream.

As we were crossing the bar at the mouth of the inlet we saw a large fish which may have been a redfish, but we did not see it plainly enough to enable us to be certain as to the species. At various places along the stream we saw dead redfish in various stages of decay. We counted at least fifteen small ones and four or five large ones. Fragments here and there indicated that the dead fish were being eaten by animals of some kind, probably fishers, wolverines, wolves, etc., which occur here. One female redfish, 11 inches long, was found full of eggs; whether she got killed in some way we could not determine. All the small ones we examined were females.

There may have been a few other live fish lying in the deep holes under the drift, but there could not have been many. The clearness of the water and the care with which we examined the stream precluded the possibility of many escaping detection. Evidently the spawning season of the redfish in this stream was practically over at this time, and nearly all the fish had gone or had died and disappeared.

THE SALMON TROUT OR STEELHEAD SALMON.

One of the most interesting and important results of our work in Idaho was the discovery of the fact that large numbers of steelheads spawn in the streams of that State, and that the catch of steelheads in the Snake River is almost as important as that of the chinook salmon. During our stay at Weiser and Upper Salmon Falls we saw a number of steelheads caught. An examination of these specimens shows them to be *Salmo gairdneri*. We saw no specimens in Salmon, Weiser, and Payette rivers, but the evidence that this species breeds in all these streams is quite trustworthy. The name by which this fish is usually known in these Idaho localities is "salmon trout," although "steelhead" is occasionally heard along Snake River.

Headwaters of Salmon River.—Mr. F. C. Parks, Sawtooth, Idaho, says:

The salmon trout come to the Alturas Lake region about May 5, and are seen up to about June 10. Some spawn in Salmon River and Alturas Lake outlet, while others go up into the inlets where they probably spawn on the same gravel bars used later by the redfish. Their spawning habits are about the same as those of the redfish. Their noses get hooked and some sores appear later. Have seen some dead ones, but do not think many die. They are of various sizes, not in *two* sizes as the redfish are. The largest I have seen would weigh about 14 pounds, the smallest about 2 pounds, while the average weight is probably nearly 8 pounds. They are becoming less abundant each year. The small ones are very scarce.

We catch them with spears and grab hooks. They will sometimes take a hook baited with their own spawn tied up in mosquito bar. About one-third of those we get are females. Their eggs are about the size of those of the redfish.

Color: Along middle of side as red as the redfish; back, steel-color; the female has less red and is more silvery.

We saw no salmon trout here at the time of our visit, unless the fry which we found in little pools along Salmon River were salmon trout. The little pools and ditches in the vicinity of Stenton's ranch and elsewhere contained large numbers of young trout. We caught 50 or more of these fry which measure 1½ to 2¼ inches in length. We have no means of telling certainly whether they are young *Salmo gairdneri* or *Salmo mykiss*, but are inclined to believe them the former.

Mr. B. S. Brown, Bliss, Idaho, says:

The salmon trout arrive April 1 or earlier. They spawn in April, going up into the outlets of the lakes and sometimes using the same spawning-beds which the dog salmon use in the fall. They stay here at least until May 15. The largest I ever saw weighed perhaps 12 pounds, the smallest 4 or 5 pounds. I never saw many dead ones; they probably all go back to the sea.

Headwaters of Payette River.—Mr. W. C. Jennings states:

The salmon trout come up Payette River about April when the water is high. Never saw any above the lake. They will bite a hook occasionally. They will weigh from 5 to 30 pounds; have heard of them weighing as much as 40 pounds, but they probably do not average more than 10 pounds. I think they come up from the sea and that they do not die, but return to the sea or at least go down stream when the water gets low.

Snake River.—Mr. William O'Brien, Weiser, Idaho, says:

I first noticed these fish here about 18 years ago, but they are now more abundant than the chinook salmon. They come up early in September and remain in Snake River until about April 10, when they run up into the smaller streams to spawn. Do not think they spawn in Snake River. I think they spawn from April 15 to about May 10. Never caught any ripe salmon trout in the river. Six years ago my catch of salmon trout was about 18,000 pounds, or about 2,250 fish, the average weight being about 8 pounds. Since then they have decreased, so that last year I got only about 8,000 pounds, or 1,000 fish. But there are more fisheries now than there were a few years ago, so that the decrease in salmon trout is more apparent than real. We get them in the river from September 1 to December 1, and again in April. I expect to try for them about the first of next February, and believe I shall find some.

The catch of Mr. O'Brien and of the other fishermen interviewed will be found in the tables of this report.

According to Mr. R. E. Conner:

The salmon trout appear at Lower Salmon Falls as early as February, March, and April. Never saw any except in those three months. The fish which we call "steelheads" are the first salmon that come up in September.

Mr. E. E. Sherman says:

The salmon trout come chiefly in April; not so many in the fall. They are pretty common in the spring, but hard to catch. I never got any in the spring, but others sometimes get them with spears or grab hooks. They are said to run up Salmon and Cedar creeks, above Upper Salmon Falls.

Mr. Charles Harvey caught a 15-pound male "steelhead" at Lower Salmon Falls about the last of August, 1894. He thinks they spawn in the spring.

Mr. Liberty Millet says:

I catch salmon trout at same time with the chinook salmon, but they are not very common. They seem to be here all year. People catch them with hook and line sometimes. They weigh as much as 15 pounds, and probably spawn in the spring. I think they eat the salmon spawn in the fall. During the entire fishing season of 1894 caught only 10 salmon trout.*

CONCLUSIONS.

From the investigations detailed in this report it appears:

(1) That the chinook salmon, the redfish, and the salmon trout all occur in considerable numbers in the headwaters of Salmon and Payette rivers.

(2) That the chinook salmon and the salmon trout still ascend Weiser River in limited numbers, and that the chinook salmon and salmon trout are found in large numbers in Snake River, which they ascend as far as Auger Falls.

*Two which were caught October 5, and which I saw, were both females, 27 and 28 inches long, and weighing 6¾ and 7½ pounds, respectively. They were unripe. The 8 others were caught later. They were all unripe females, and weighed about 8 pounds each.

(3) While the number of fish of these three species now ascending the streams is very few compared with former years, important spawning-beds of the chinook salmon and salmon trout are still found in all these streams, and of the redfish in the inlets to Alturas, Redfish, Pettit, Stanley, and Big Payette lakes.

Many questions concerning these species, however, are still unsettled, and it is important that the investigations be continued. What has already been done is valuable chiefly for the reason that we now understand more clearly the nature of the problems that require solution and are better able to pursue the investigations in such ways as will lead to definite and practical results.

Among the problems which require further investigation may be mentioned the following:

(1) The migrations of the blueback salmon or redfish should be definitely made out. We should be able to settle the question whether the large redfish or the little redfish, or both, come up from the sea; and its spawning habits should be more carefully studied. Observations should begin in July at the outlet and inlet of one or more of the lakes in which they are found, and should continue until in October. Observations should be made on each of the lakes at the head of Salmon River, at the head of Payette River, and on Wallowa Lake, in Oregon. In addition to these localities, investigations should be made to determine the location of other spawning-beds in Washington and elsewhere in the Columbia Basin. This would include Lake Washington and the lakes on the Upper Columbia and the Okanagan rivers. The spawning-beds at present known do not account for the immense annual catch of blueback salmon in the lower Columbia; there must be other important spawning-grounds of this species in the Columbia Basin.

(2) The chinook salmon and the steelhead should be studied through at least one entire spawning season at their spawning-beds in Idaho, and the relation of temperature of water to time of spawning should be made out.

As to the artificial hatching of redfish, I have no doubt it could be carried on very successfully and profitably either at Big Payette Lake or Alturas Lake. The number of spawning redfish that could be obtained at either of these places would supply eggs sufficient for considerable fish-cultural operations; and the number of chinook salmon eggs that could be gotten in the same waters would still further increase the value of these places as desirable hatchery-sites. The distance from railroads is the only difficulty. A temporary station, however, could be established and conducted profitably at either of these places.

For the hatchery of chinook salmon the vicinity of Upper or Lower Salmon Falls offers many advantages. Near Lower Salmon Falls an abundant gravity supply of water can be obtained from the river or from creeks and springs, as may be desired. At the Upper Falls, or at Millet Island, an abundance of what I suppose would be excellent water can be obtained by gravity from the river or from springs, or both. The distance from Bliss, the nearest railroad station, would be 5 to 10 miles over a fairly good road.

The supply of salmon eggs that could be obtained here would be sufficient to guarantee a fair output for the station. Additional supplies of eggs could be obtained at Weiser and other points between Huntington and Glenn Ferry. At O'Brien's fishery, near Weiser, the salmon could be held in a pond until ripe.

3.—NOTES ON AN INVESTIGATION OF THE MENHADEN FISHERY IN 1894, WITH SPECIAL REFERENCE TO THE FOOD-FISHES TAKEN.

By HUGH M. SMITH, M. D.,
Assistant in charge of Division of Statistics and Methods of the Fisheries.

GENERAL IMPORTANCE OF THE MENHADEN INDUSTRY.

The taking of menhaden (*Brevoortia tyrannus*), for the purpose of converting them into oil and guano, is one of the most prominent fisheries prosecuted with vessels on the eastern coast of the United States. The fishery is carried on in every coast State from Maine to North Carolina, inclusive, with the exceptions of Massachusetts and New Hampshire, and is very extensive in Rhode Island, Connecticut, New York, New Jersey, and Virginia. Purse seines, operated from steam and sail vessels, are used in taking the fish. In the more northern States steamers predominate, while south of New Jersey sail vessels are more numerous. The shore industry dependent on the fishery is very important, affording employment to many persons and representing large investments.

At present between 50 and 55 menhaden factories are in operation annually; the value of the plants is about $925,000, and the additional cash capital is $700,000. The number of persons employed as factory hands and in other capacities about the factories is about 1,600. The vessels engaged in taking the menhaden and in transporting the catch number about 135, worth, with their apparatus and outfit, over $950,000. The fishermen number about 1,800. The total investment in this industry amounts to fully $2,580,000.

The number of fish taken and the quantity of oil and fertilizer prepared annually vary considerably from year to year. Some years over 700,000,000 fish have been handled by the factories. The fish are much fatter some seasons than others, and similar quantities will yield very different quantities of oil. During the past three or four years, between 400,000,000 and 600,000,000 menhaden have been utilized each season, the value of the fish in a crude state being from $1 to $4 per 1,000, depending on their fatness. The average value of the manufactured products has been over $1,000,000.

At the meeting of the United States Menhaden Association in New York in January, 1895, the report of the secretary showed that 44 factories were in operation during the season of 1894, employing 1,055 men on shore and 1,301 on vessels; the fishing fleet consisted of 28 sailing vessels and 56 steamers; the total number of fish utilized was 533,361,900, which yielded 1,999,505 gallons of oil and 47,639 tons of scrap. These figures apply only to menhaden firms who are members of the association.

OBJECT AND METHODS OF THE INQUIRY.

The menhaden fishery has received much attention from Congress, the legislatures of most of the States whose citizens are engaged therein, and several Federal and State courts. The fishery has encountered great opposition on account of its supposed injurious influence on the abundance of other fishes, especially those species which prey upon the menhaden and are taken by anglers and in the professional line fisheries. In recent years, probably no fishery on the Atlantic coast has attracted more attention, occasioned more discussion, and been the object of such marked opposition.

The contention is made by sportsmen and others, and very generally accepted by the newspapers and the public, that in menhaden fishing large quantities of game and other food-fish are taken; that these are usually landed at the factories, where they serve the same purpose as menhaden; that on account of the extensive menhaden fishing along the coast the supply of food-fish has been greatly reduced; that important fishing-grounds for game fishes have been ruined; that where food-fish are not actually caught in the purse seines they are driven off; that fish which frequent the bays and there undergo the spawning process are prevented from reaching the desired grounds by the presence of menhaden vessels at or near the mouths of the bays. Of the foregoing objections to the fishery, greater importance is laid on the first two points.

All of these statements are denied by the menhaden fishermen. They assert that the quantities of food-fish taken in the menhaden fishery are insignificant and do not even regularly supply the vessels' crews with food; that desirable fishes are not utilized for oil and guano; that the food-fish destroyed in a season by any one of the thousands of sharks killed each year in the menhaden fishery would vastly outnumber those caught by the entire fleet of vessels. The menhaden fishermen contend that there is no proof that their operations have even remotely affected the abundance of other fish and that this fishery is as legitimate and no more destructive than many other fisheries which are sanctioned by popular opinion.

Neither party to the controversy has brought forward any facts or made any arguments which the other felt bound to indorse, owing to the *ex parte* nature of the testimony; and during the entire controversy there has been an absence of detailed authentic data bearing on that phase of the subject now under consideration.

In the Report of the Commissioner of Fish and Fisheries for 1892 the following statement is made:

> Since it appears probable that the menhaden fishery will for some years at least be the object of legislative consideration and personal controversy, it seems important to secure and have available for use all information that can possibly be obtained that is calculated to aid in the solution of the very difficult problems involved. It is therefore conceived that valuable material relating to the special point under discussion may be obtained by placing the field force of the division [of fisheries] on vessels fishing off various parts of the coast, and having the agents make actual records of the results of every seine-haul during a period of two or three months. While this plan would involve a study of a small part of the menhaden fleet, it would nevertheless afford a valuable basis for generalization.

In 1894 the Commission made arrangements for carrying on the inquiries in question. Owing to the necessity for undertaking important field work of another character, it was impossible to utilize the full force of the division to which the investigation was assigned, and it became necessary to restrict the inquiry to two vessels, whose operations during the entire season it was the intention to cover.

Before the beginning of the fishing season, correspondence was opened with several prominent owners of vessels and operators of factories, explaining the object of the investigation and asking permission to place an agent on one of their vessels. It was finally decided to take advantage of the offers of Messrs. Luce Brothers, of Niantic, Connecticut, and Mr. A. J. Morse, manager of the American Fish Guano Company, of Harborton, Virginia, the Commission meeting all expenses connected with the work.

The steamer *Quickstep*, hailing from New London, Connecticut, was the vessel offered for this purpose by Messrs. Luce Brothers. To this vessel, on May 16, 1894, the Commission assigned as its agent Mr. Clarence E. Latimer, a former employee of the office, recently connected with the fisheries division of the Eleventh Census. At the end of two weeks, illness necessitated Mr. Latimer's withdrawal from the work, and his place was supplied by Mr. W. P. Hay, teacher in zoölogy in the Washington City High School. On June 22, owing to insufficient accommodations on the *Quickstep*, Mr. Hay was transferred to the steamer *Arizona*, of New London, which vessel was the basis for observations during the remainder of the season. On August 1, Mr. Hay was relieved by Mr. Andrew E. Marschalk, who continued on the vessel until the suspension of fishing, on November 7.

The *Arizona* is a screw steamer of 103 net tons, valued, with its outfit, at $25,000. The vessel's crew consists of 2 captains, 2 mates, 1 pilot, 1 engineer, 2 firemen, 2 cooks, and 30 fishermen. Two purse seines are used, the vessel being what is known as a "double-gang" steamer; only one other such steamer was employed in 1894. The seines are about 11,000 meshes (1,400 feet) long and 715 meshes (100 feet) deep, the sizes of mesh being $2\frac{1}{8}$ and $2\frac{1}{4}$ inches, stretch measure; the cost of each seine rigged is about $900. Four seine boats and two "drive" or "striker" boats are carried.

On May 7, Mr. E. F. Locke, field agent of the Commission, began his observations on the steamer *J. W. Hawkins*, of Onancock, Virginia, and continued with the vessel until December 3, being relieved during the month of October by Mr. Edward E. Race, field agent.

The *J. W. Hawkins* is a screw steamer of 125 net tons, with a value of over $20,000, including outfit. It carries 1 captain, 1 mate, 2 engineers, 2 firemen, 2 cooks, and 18 fishermen. Two seines are carried, but only one is in use at a time; it was 9,520 meshes (900 feet) long and 750 meshes (85 feet) deep; its value was about $700. During a part of the season the vessel had a larger seine, 1,500 feet long and 150 feet deep.

The instructions issued to the agents called for the exercise of great care in obtaining and recording correct data. For each haul of the seine it was required that a record be made showing the following information: Date, hour, location of fishing-ground, quantity of menhaden taken, the number of each kind of other fish taken, the disposition made of fish other than menhaden, and physical observations on the condition of water, direction of wind, etc. On charts the position of each seine haul was indicated in such a way that reference might be made to the record for a history of the haul. General notes on the condition of the fishery, the abundance, size, movements, and spawning condition of the fish were desired. The agents were cautioned to avoid the expression of any opinion as to results of the investigation and to refrain from a discussion of the general menhaden question.

OUTLINE OF THE VESSELS' MOVEMENTS.

By the selection of vessels making their headquarters on Long Island Sound and Chesapeake Bay, respectively, and fishing chiefly in or near these bodies of water, it was possible to cover the most important fishing regions on the coast and to secure data that were typical of a large part of the menhaden fleet. It happened, however, that the vessels in question did not confine their operations to the vicinity of the factories which they supplied, but extended their cruises over a wide area, and, in fact, took fish from Maine to North Carolina, inclusive.

Prior to June 22, during the period when the observations were conducted on the steamer *Quickstep*, that vessel mostly frequented the outer coast of Long Island, a few lots of fish being obtained from the northern part of the New Jersey coast and a few off Rhode Island. During the last few days of June and until July 3 the *Arizona* fished in Long Island Sound and off the adjacent coasts of Rhode Island and Massachusetts. From July 5 to 15 most of the time was spent in New York Bay, one visit being made to the New Jersey coast. During the last two weeks in July most of the fishing was done off the southern part of New Jersey and in New York Bay. During August and September practically all the time was passed in or near the mouth of Delaware Bay, where an unprecedentedly large body of fish was found. By October 1 the vessel moved east, and during the remainder of the season restricted its operations to Gardiner Bay, Neapeague Bay, and the Long Island coast.

The observations on the *J. W. Hawkins* began May 7 and ended December 3, fishing having commenced a few days before the agent reached the vessel. Up to June 18 all the fishing was done in Chesapeake Bay. The vessel then went east, and on June 29 began a six weeks' fishing cruise on the coast of Maine, chiefly near the mouth of the Kennebec River and in Casco Bay. On August 6 the vessel left Maine waters and started for the Chesapeake. Ten days were passed in Boston Harbor, where fish were found to be abundant. Fishing was renewed in the Chesapeake on August 30 and continued until October 13. The steamer then again cruised east and had a few days' fishing off the coast of New Jersey and New York. The remainder of the season was passed near the mouth of the Chesapeake and along the coast of Virginia and North Carolina, the final set being made November 27, 8 miles north of Cape Lookout, North Carolina.

GENERAL RESULTS OF THE FISHERY.

The season of 1894 was, on the whole, considered a very fair one for the menhaden fishery. While none of the menhaden firms made a great deal of money, nearly all had a balance to their credit at the close of operations. There was a large body of menhaden along the entire coast from Maine to North Carolina. One of the vessels on which observations were conducted had a much larger catch than usual, but the other's output was less than the average in recent years.

During the time when observations were conducted on the *Quickstep*, that is, from May 16 to June 21, the catch of that vessel was 2,532,000 menhaden. The number of menhaden taken by the *Arizona* in the remainder of the season was 16,174,800. The combined catch of these two vessels, while their operations were being studied by agents of the Commission, was therefore 18,706,800 menhaden. The *Arizona* took about 5,870,000 fish before June 22, and during the entire season obtained 22,000,000 menhaden. The catch in 1894 was the largest in the history of the vessel, with the exception of one season, when nearly 23,000,000 were secured.

The catch of the steamer *J. W. Hawkins* during the year 1894 was 9,301,955 menhaden. This was much less than in the previous season and far below the average of the past two or three years, and was smaller than that of other steamers fishing for the same firm. Prior to the arrival of the Commission's agent the vessel took 43,000 menhaden.

The inquiries of the Commission thus related to and completely covered the fishing operations during which 27,965,755 menhaden were caught, this quantity representing about one-twentieth of the total yield of menhaden in 1894, and affording, with the other data obtained, a reasonable basis for generalizations on certain important points.

The five weeks' fishing of the *Quickstep* on the Long Island coast was quite successful. Fish were abundant and on some days large catches were taken. The average number of fish to a set was 43,000. Each of 9 hauls out of a total of 60 resulted in the capture of between 100,000 and 200,000 fish. On June 18 230,000 menhaden were secured in 3 hauls off Shinnecock, Long Island, and on June 14 220,000 fish were taken in 4 hauls off Bridgehampton and Amagansett, these being the largest daily catches. At a single haul off Shinnecock (on June 19) 200,000 fish were obtained.

The principal feature of the operations of the *Arizona* was the extent of the fishing in Delaware Bay and off the adjacent coasts of Delaware and New Jersey. Of 558 times the seines of the *Arizona* were set between June 22 and November 2, 212 sets were made in or off the mouth of Delaware Bay and 164 additional sets in the ocean immediately adjacent to Capes May and Henlopen. Menhaden were more abundant in the Delaware Bay region during August and September than in any previous season, so far as available records show, and the *Arizona* took more menhaden in a single month than during a similar period in any other year in her history. The August catch of the vessel was 6,434,500 fish, of which 2,744,000 were secured in Delaware Bay, and 3,156,500 off the adjacent ocean shores. In September 3,210,000 fish were taken in this bay and 1,440,000 off the adjoining coasts.

The average number of menhaden taken at each seine haul of the *Arizona* was 30,850. While this was less than the average for the *Quickstep*, there were many days when the *Arizona's* total catch was double the largest daily yield of the other vessel. The single haul in which the largest number of menhaden were secured was on September 1, off Hereford Inlet, New Jersey, when 150,000 were taken. The following days were noteworthy in the *Arizona's* fishing operations for the quantities of menhaden caught: July 9, 362,000 fish in 14 sets in New York Bay; July 16, 554,500 fish in 9 sets off Squan Beach, New Jersey; July 19, 535,000 fish in 6 sets off the southern shore of New Jersey; July 23, 388,000 fish in 8 sets in New York Bay; August 6, 525,000 fish in 15 sets off the southern coast of New Jersey; August 7, the same number in 11 sets on the same ground; August 29, 398,000 fish in 12 sets in and near Delaware Bay; August 30, 395,000 fish in 7 sets off Cape May; September 1, 475,000 fish in 5 sets off the southern part of New Jersey; September 12, 425,000 fish in 12 sets in Delaware Bay and vicinity; September 17, 379,000 fish in 16 sets in Delaware Bay; September 20, 451,000 fish in 8 sets in the same place; October 27, 321,500 fish in 9 sets off Montauk Point, New York.

Of the 1,078 seine hauls of these vessels, 132 resulted in the capture of no menhaden, owing to various causes. Shyness of the fish, failure to drop the seine around the moving school in a way to intercept it, fouling of the seine by the tide,

breaking of essential parts of the net, and several other causes contribute to the making of a relatively large number of "stabs," as such failures are called. The *J. W. Hawkins* had 96 and the *Arizona* and *Quickstep* 36 "stabs."

KINDS AND NUMBERS OF OTHER FISH TAKEN.

The extensive areas covered by these vessels, the size of the seines used, and the frequency with which the hauls were made, would naturally be expected to yield a large variety of fishes that were among or adjacent to the schools of menhaden. An analysis of the records shows that there were taken with the menhaden some sixty species of fishes, which, considering the richness of the fish fauna of the east coast, is perhaps a smaller number than might have been anticipated.

The fish which appear most prominently in the returns are those which, like the menhaden, swim at or near the surface, such as bluefish, alewives, shad, butter-fish, and mackerel. With the exception of flounders and skates, which are taken in comparatively shallow water, the typical bottom fish, such as cod, pollock, hake, haddock, etc., are very sparingly represented in the catch.

The number of other fish taken with the menhaden was 94,795. Of these, 93,893 were what are ordinarily termed food-fish, and 902 were of no recognized value as food. The former consisted chiefly of a fish useful in the manufacture of oil and fertilizer in addition to having considerable value as food and bait. Omitting these, the number of food-fish taken was 6,990.

Outside of the menhaden more alewives were taken than all other fishes combined. Over 86,000 appear in the returns, nearly all being caught on the New England coast by one vessel; about half were obtained at one haul in Boston Harbor. These fish were usually among schools of menhaden, although in some instances the alewives greatly outnumbered the menhaden or appeared to be unmixed with other fish. Alewives swim at the surface like menhaden, and, when accompanied by menhaden, the entire school may be mistaken for the latter fish. The alewives contain some oil, and are suitable for use at the menhaden factories. On the Maine coast, where they are known as "kyacks" or "blueback herrings," they have for many years been utilized in larger or smaller quantities for fertilizer. In addition to the alewives retained, a number of large schools were released after their identity was discovered; these do not appear in the returns.

The fish of which the next largest number was taken was the bluefish. Only a few single seine hauls yielded a noteworthy number of bluefish, the bulk of the catch being made up of fish taken in small quantities in numerous hauls. The aggregate number was 2,274. The largest number secured in one haul was 140; this was in Chesapeake Bay.

The shad caught with the menhaden numbered 1,816. These were taken under the same conditions as the alewives, and nearly all were obtained at the mouth of the Kennebec River, Maine; in three seine-hauls, on July 5, 11, and 16, 1,700 were caught with 111,200 menhaden, 6,400 alewives, and small numbers of skates, flounders, mackerel, haddock, goosefish, and other species.

About 800 butter-fish, mostly of a size too small to serve as food, were caught. Two hundred of these were taken in two hauls.

The mackerel family is represented in the catch by the common mackerel, the Spanish mackerel, the cero, and the bonito; the numbers of each of these fish appearing in the returns are 631, 150, 3, and 35, respectively.

Nearly 500 squeteague or "sea trout" were taken. Of other members of the drum family, the croaker and spot were obtained in considerable numbers, while the red drum and the black drum were rarely caught.

Flounders belonging to four species were often seined, although the aggregate catch was comparatively small. The summer flounder was taken in largest numbers.

Nearly 400 sharks were secured. Among the species represented were the common dogfish, the dusky shark, the hammerhead shark, the thresher, the sand shark or shovelnose shark, and the angel-fish; the dogfish and dusky shark predominating in numbers.

Almost as numerous as the sharks were the skates and stingrays. Of the 370 taken, a very large percentage were brier rays and common skates.

The cod family was represented in the catch by 1 cod, 1 pollock, 23 haddock, 40 hake, and 30 whiting or silver hake.

Following is a detailed statement of the number and kinds of fish taken, exclusive of menhaden:

Kind of fish.	Number.	Kind of fish.	Number.
Alewives or herring (Clupea pseudoharengus, C. æstivalis)	86,898	Pompano (Trachinotus carolinus)	8
Amber-fish (Seriola dumerili lalandi)	1	Rudder-fish (Seriola zonata)	1
Anchovy (Stolephorus mitchilli)	2	Sculpins (Cottus, species)	19
Bluefish (Pomatomus saltatrix)	2,274	Scup (Stenotomus chrysops)	73
Bonito (Sarda sarda)	35	Sea bass (Centropristis striatus)	39
Butter-fish (Stromateus triacanthus)	811	*Sea herring* (Clupea harengus)	5
Catfish (Ameiurus albidus)	2	Sea-horse (Hippocampus hudsonius)	4
Cero (Scomberomorus regalis)	3	Sea-raven (Hemitripterus americanus)	1
Cod (Gadus morrhua)	1	Sea-robins (Prionotus carolinus, chiefly)	43
Croaker (Micropogon undulatus)	134	Shad (Clupea sapidissima)	1,816
Cunner (Ctenolabrus adspersus)	4	Sharks (Carcharinus obscurus, Squalus acanthias, Sphyrna zygæna, Carcharias americanus, Mustelus canis. Alopias vulpes, Squatina squatina)	388
Cutlas-fish or hairtail (Trichiurus lepturus)	2		
Drums (Pogonias cromis, Sciæna ocellata)	11	Skates and rays (Raia erinacea, R. eglanteria, R. lævis, Dasyatis centrurus, Rhinoptera quadriloba)	372
Filefish or foolfish (Alutera schœpfii)	9		
Flounders (Paralichthys dentatus, Pleuronectes maculatus, Achirus fasciatus, Limanda ferruginea)	369	Spanish mackerel (Scomberomorus maculatus)	150
Gar (Tylosurus, species)	6	*Spot* (Leistomus xanthurus)	20
Goosefish (Lophius piscatorius)	11	Squeteague or weakfish (Cynoscion regalis, C. maculatus)	8
Haddock (Melanogrammus æglefinus)	23		
Hake (Phycis chuss)	40	Striped bass (Roccus lineatus)	1
Hickory shad (Clupea mediocris)	9	Swellfish, swell-toads (Chilomycterus geometricus, Tetrodon turgidus)	6
Kingfish (Menticirrhus saxatilis)	1		
Lamprey (Petromyzon marinus)	11	Tautog (Tautoga onitis)	17
Lumpfish (Cyclopterus lumpus)	8	Whiting or silver hake (Merlucius bilinearis)	30
Mackerel (Scomber scombrus)	631		
Pipefish (Siphostoma fuscum)	7	Total	94,795
Pollock (Pollachius virens)	1		

The animals besides fish taken with the menhaden were not especially numerous or important, but represented a comparatively large number of species of mollusks, crustaceans, reptiles, echinoderms, and porifers, most of which were bottom forms. The mollusks consisted of 2 oysters (*Ostrea virginica*), 75 mussels (*Mytilus edulis*), and 34 squid (*Loligo pealei*). Besides 12 lobsters (*Astacus americanus*), and 322 blue crabs (*Callinectes hastatus*), numerous other crustaceans were obtained, such as rock-crabs, spider-crabs, hermit-crabs, shrimp, and horseshoe or king crabs, of which no accurate count was made. The order of reptiles was represented by 2 loggerhead turtles (*Thalassochelys caretta*) and 1 green turtle (*Chelonia mydas*). Several species of starfishes and sponges were taken on numerous occasions.

THE FISHING-GROUNDS AND THE FISH TAKEN ON EACH.

If the operations of the vessels be classified by fishing-grounds, a very interesting and suggestive presentation may be made. The *Arizona* did not fish south of Delaware and took the largest numbers of manhaden on the outer coasts of New York and New Jersey, and in New York and Delaware bays. The *J. W. Hawkins*, on the other hand, fished from North Carolina to Maine, but secured by far the most fish in Chesapeake Bay and on the western Maine coast.

Of the 619 sets of the seine made by the *Arizona* (and *Quickstep*), 212 were in Delaware Bay and 158 were off the eastern coast of New Jersey, these two regions yielding two-thirds of the vessels' catch of menhaden and an equally prominent part of other fish taken. In Delaware Bay comparatively few bluefish were obtained, the average catch being less than one fish to two seine-hauls. More butter-fish were here caught than elsewhere, although the average was only one fish to a set. The yield of other food-fish was insignificant. A conspicuous feature of the fishing in this bay was the relatively large number of sharks caught; more of these predaceous fishes were there destroyed than on any other grounds. Following is a summary of the operations of the *Arizona* on the different grounds (*a*):

Summary by fishing-grounds of the number of menhaden and other fish taken by the steamer Arizona in 1894.

Fish taken.	Long Island Sound.	New York Bay.	Neapeague Bay.	Gardiner Bay.	Delaware Bay.	Off Massachusetts coast.	Off Rhode Island coast.	Off New York coast.	Off New Jersey coast.	Off Delaware coast.	Total.
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Menhaden	466,800	1,009,000	423,000	520,000	5,935,500	15,000	86,500	3,093,500	6,159,500	998,000	18,706,800
Alewives *b*	5	8			16			1	5		35
Amber-fish									1		1
Anchovy		2									2
Bluefish		22	7		94			9	496	19	647
Butter-fish	3	99	30	1	226	3	8	62	157	8	597
Bonito	2				8				17	6	33
Croaker									30	10	40
Cunner	2										2
Drum					1				2		3
Flounders	108	36	9	4		1	22	32	51	6	269
Hake	1	3								1	5
Kingfish									1		1
Mackerel		6					175	93			274
Pipefish	1	4					2				7
Pompano					1						1
Rudder-fish										1	1
Scup		44	1					28			73
Sea bass								39	2		41
Sea-horse		3									3
Sea-raven				1							1
Sea-robins		11			1			13	17	1	43
Sculpins								3			3
Shad								6	2		8
Sharks	1	15			166		2		90	49	323
Skates and rays	33	19	26	25	18		3	33	139	7	303
Spanish mack'l					8			86	12	2	108
Squeteague or weakfish		2			25		8	11	190	13	249
Striped bass				1							1
Swellfish								1			1
Tautog	1	5					11				17
Whiting or silver hake							8				8
Total	466,957	1,009,279	423,073	520,032	5,936,064	15,004	86,739	3,093,917	6,160,712	998,123	18,709,900
Seine-hauls	36	44	15	25	212	1	8	67	158	53	619

a In all tabular statements of the catch of the steamer *Arizona*, the operations of the steamer *Quickstep* up to June 21 are included (see page 288).

b Includes alewives, hickory shad, and sea herring.

The *J. W. Hawkins* made 315 seine sets in Chesapeake Bay and its tributaries out of a total of 459; 77 hauls were made on the Maine coast. Over two-thirds of the menhaden were taken in the former region. Among the most numerous food-fish caught were bluefish, butter-fish, alewives, mackerel, shad, and squeteague; of these only the bluefish, alewives, and shad were noticeably numerous. Nearly all the bluefish were obtained in Chesapeake Bay, where the average catch to a set was 5 fish; the butter-fish were taken on the Maine and Maryland coasts, and in the bay; the alewives were chiefly secured in Casco Bay, Maine, and Boston Harbor, Massachusetts; the mackerel were found on the coast of Maine and in Long Island Sound; practically all the shad were from Casco Bay and the mouth of the Kennebec River; the squeteague were principally from Chesapeake Bay and the North Carolina coast. The number of each kind of fish taken on each ground is shown in the following table:

Summary by fishing-grounds of the number of menhaden and other fish taken by the steamer J. W. Hawkins in 1894.

Fish taken.	Maine coast.	Massachusetts coast.	Long Island Sound.	New Jersey coast.	Maryland (ocean side).	Virginia (ocean side).	Chesapeake Bay and tributaries.	North Carolina coast.	Total.
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Menhaden	965,850	540,600	95,503	30,097	577,500	408,800	6,263,005	377,60 0	9,258,955
Alewives	43,876	41,500					1,501		86,877
Bluefish		1			59	27	1,530	10	1,627
Bonito							2		2
Butter-fish	59				102	3	50		214
Catfish							2		2
Cero							3		3
Cod	1								1
Croaker						1	85	8	94
Cunner	1			1					2
Cutlas-fish							2		2
Drum							8		8
Eel	11								11
Filefish							9		9
Flounders	68	2			2	1	21	6	100
Garfish							6		6
Goosefish	11								11
Haddock	23								23
Hake	33			2					35
Lumpfish	8								8
Mackerel	235	6	116						357
Pollock	1								1
Pompano							7		7
Sculpins	3	12					1		16
Sea-horse							1		1
Shad	1,799			1			8		1,808
Sharks					1	2	60	15	78
Skates	28	10		2	2	3	18	6	69
Spot								20	20
Spanish mackerel							42		42
Squeteague				17	2	6	81	143	249
Swellfish							3	2	5
Whiting	22								22
Total	1,012,029	582,131	95,619	30,120	577,668	408,843	6,266,445	377,810	9,350,665
Seine-hauls	77	22	7	2	11	15	315	10	459

DISTANCES FROM SHORE AT WHICH FISHING WAS DONE.

The prominent feature of several proposed or enacted measures for the regulation of the menhaden fishery by Congress and the State legislatures has been the prohibition of the fishing operations within certain distances of the shore. By the advocates of this method of restricting the fishery, the 3-mile limit has been regarded as a proper or desirable one within which no menhaden fishing should be permitted. The question of constitutionality has debarred the States from assuming jurisdiction over this zone, and Congress has shown no inclination to attempt the regulation of the fishery,

so that at present the capture of menhaden is attended with but few restrictions as to fishing-grounds, and these apply chiefly to bays and other waters under the control of the States.

As is well known, the menhaden is a fish which, as a rule, is found in comparatively close proximity to the land, both during the time of its sojourn on the coasts of the different States and during its spring and fall migrations. A large part of the catch has consequently always been taken within a few miles of the shore.

The operations of the two vessels under consideration, which may be regarded as entirely typical of the fleet, are shown in the following table, which brings out in detail the special point under discussion. The distances from the shore within which the menhaden and other fish were taken are specified as (1) under one mile, (2) between one and two miles, (3) between two and three miles, (4) between three and five miles, (5) five miles and beyond. More fish were taken between 1 and 2 miles from shore than within any other distances; more than half were caught within 2 miles of shore, and more than two-thirds under 3 miles from shore. Less than two-ninths of the total yield was obtained 5 miles or more from land, and a large part of the fish thus shown was secured in Chesapeake and Delaware bays.

The farthest distance from shore at which the *Arizona* fished was 9½ miles. This was in Delaware Bay. The *J. W. Hawkins* took fish 9⅛ miles off Windmill Point, Virginia, in Chesapeake Bay. None of the fishing of these vessels in the open ocean was so far from land, and most of it was under 2 miles from shore.

STEAMER ARIZONA.

Species.	Under 1 mile.	Between 1 and (under) 2 miles.	Between 2 and (under) 3 miles.	Between 3 and (under) 5 miles.	Five miles and over.	Total.
Menhaden	3,525,500	7,057,500	1,891,200	1,486,600	4,746,000	18,706,800
Alewives or river herrings[a]	8	10	1	.....	16	35
Amber-fish	.....	.....	1	.....	.....	1
Anchovy	.....	.....	2	.....	.....	2
Bluefish	189	312	28	22	96	647
Bonito	17	6	2	3	5	33
Butter-fish	124	155	288	18	12	597
Croaker	12	26	2	.....	.....	40
Cunner	1	1	.....	.....	.....	2
Drum	.....	2	.....	1	.....	3
Flounders	44	87	74	61	3	269
Hake	2	1	1	1	.....	5
Kingfish	1	.....	.....	.....	.....	1
Mackerel	2	231	41	.....	.....	274
Pipefish	2	1	1	3	.....	7
Pompano	1	.....	.....	.....	.....	1
Rudder-fish	.....	1	.....	.....	.....	1
Sculpins	.....	3	.....	.....	.....	3
Scup	.....	27	46	.....	.....	73
Sea bass	41	.....	.....	.....	.....	41
Sea-horse	1	1	.....	1	.....	3
Sea-raven	.....	.....	1	.....	.....	1
Sea-robins	9	22	6	5	1	43
Shad	.....	8	.....	.....	.....	8
Sharks	52	76	32	76	87	323
Skates and rays	52	165	35	30	21	303
Spanish mackerel	10	93	.....	1	4	108
Squeteague or weakfish	74	133	15	1	26	249
Striped bass	.....	1	.....	.....	.....	1
Swellfish	.....	1	.....	.....	.....	1
Tautog	12	3	1	1	.....	17
Whiting	.....	.....	8	.....	.....	8
Total	3,526,154	7,058,866	1,891,785	1,486,824	4,746,271	18,709,900
Number of times seine set	98	234	77	67	143	619

[a] Includes a few hickory shad and sea herring.

STEAMER J. W. HAWKINS.

Species.	Under 1 mile.	Between 1 and (under) 2 miles.	Between 2 and (under) 3 miles.	Between 3 and (under) 5 miles.	Five miles and over.	Total.
Menhaden	2,324,631	2,107,389	1,481,150	2,002,681	1,343,104	9,258,955
Alewives or river herrings	50,966	35,900			11	86,877
Bluefish	147	203	451	481	345	1,627
Bonito			1	1		2
Butter-fish	114	70	12	6	12	214
Catfish		2				2
Cero		1		1	1	3
Cod	1					1
Croaker	34	17	6	22	15	94
Cunner	1	1				2
Cutlas-fish	2					2
Drum			1	3	4	8
Eel	6	3	2			11
Filefish	2	3	2	2		9
Flounders	64	22	4	8	2	100
Gar	1	1	1		3	6
Goosefish	6	3	2			11
Haddock	14	8	1			23
Hake	24	11				35
Lumpfish	6	2				8
Mackerel	198	59	96		4	357
Pollock		1				1
Pompano	2	3			2	7
Sculpins	14	2				16
Sea-horse				1		1
Shad	1,156	644	1	2	5	1,808
Sharks	21	18	28	9	2	78
Skates and rays	40	17	6	6		69
Spanish mackerel	10	10	2	10	10	42
Spot	20					20
Squeteague or weakfish	210	29	6	2	2	249
Swellfish	2	1		1	1	5
Whiting	13	9				22
Total	2,377,705	2,144,429	1,481,772	2,003,236	1,343,523	9,350,665
Number of times seine set	109	102	70	103	75	459

From the foregoing table it appears that the largest average hauls were made under 1 mile from shore and the next largest between 1 and 2 miles. Between 3 and 5 miles from shore the average number taken was less than elsewhere.

THE CATCH IN DIFFERENT MONTHS.

The season for menhaden fishing is from the latter part of April to the first part of December, though but few fish are caught as early as April or as late as December, except in North Carolina. The best months are generally considered to be from August to November, inclusive. During the latter part of the season the fish are fatter and consequently yield more oil; they move in larger schools than at other times, and they are less shy and more easily caught.

The following table shows the monthly catch of menhaden and other fish by the steamers *Arizona* and *J. W. Hawkins*. Considerably more than half the menhaden taken by the former vessel were obtained in August and September; the largest catch of the other vessel was in September, followed by May and November. The months in which the largest numbers of other fish were taken were as follows: Flounders, mackerel, shad, and skates in July; alewives, sharks, squeteague, and butter-fish in August, and bluefish in September:

STEAMER ARIZONA.

Species.	May.	June.	July.	August.	September.	October.	November.	Total.
Menhaden	751,000	2,291,100	2,851,700	6,434,500	4,731,000	1,529,500	118,000	18,706,800
Alewives or river herrings *a*			14	16	5			35
Amber-fish				1				1
Anchovy			2					2
Bluefish	3	12	152	382	91	7		647
Bonito				31		2		33
Butter-fish		6	167	307	35	81	1	597
Croaker			12	28				40
Cunner			2					2
Drum				3				3
Flounders	16	67	142	27		17		269
Hake		1	4					5
Kingfish				1				1
Mackerel	88	180	6					274
Pipefish			7					7
Pompano				1				1
Rudder-fish				1				1
Sculpins	3							3
Scup	28		44			1		73
Sea bass	39	1	1					41
Sea-horse			3					3
Sea-raven						1		1
Sea-robins	4	1	36	2				43
Shad	2					4	2	8
Sharks		1	42	185	94		1	323
Skates and rays	15	27	107	81	11	61	1	303
Spanish mackerel				17	5	81	5	108
Squeteague or weakfish	3		24	190	4	8	20	249
Striped bass					1			1
Swellfish	1							1
Tautog			17					17
Whiting		8						8
Total	751,202	2,291,404	2,852,482	6,435,773	4,731,246	1,529,763	118,030	18,709,900
Number times seine set	24	44	102	258	120	65	6	619

a Includes a few hickory shad and sea herring.

STEAMER J. W. HAWKINS.

Species.	May.	June.	July.	August.	September.	October.	November.	Total.
Menhaden	2,542,000	595,050	776,800	854,600	2,576,000	491,105	1,423,400	9,258,955
Alewives or river herrings	1,500	13	14,864	70,500				86,877
Bluefish	224	50		64	1,158	30	101	1,627
Bonito				2				2
Butter-fish		50		55	4		105	214
Catfish	2							2
Cero					3			3
Cod			1					1
Croaker	53				1	31	9	94
Cunner			1			1		2
Cutlas-fish					2			2
Drum	4			2	2			8
Eel			11					11
Filefish	2	4			3			9
Flounders	8	37	36	6	3		10	100
Gar		5				1		6
Goosefish			11					11
Haddock			23					23
Hake		5	28			2		35
Lumpfish		6		2				8
Mackerel			228	13		116		357
Pollock			1					1
Pompano	1				6			7
Sculpins	1	1	2	12				16
Sea-horse		1						1
Shad	8	1	1,760	38		1		1,808
Sharks		2		4	52	2	18	78
Skates and rays	2	8	27	12	6	2	12	69
Spanish mackerel		1		3	36	2		42
Spot							20	20
Squeteague or weakfish	5				51	34	159	249
Swellfish	2	1					2	5
Whiting			22					22
Total	2,543,812	595,235	793,815	925,313	2,577,327	491,327	1,423,836	9,350,665
Number times seine set	115	60	58	43	99	36	48	459

Of 1,078 seine-hauls, 301 were made in August and 219 in September. Some idea of the variations in the relative sizes of the schools, shyness of the fish, etc., may be obtained from the following table, showing the average number of menhaden taken at each seine-haul during each month:

Months.	Number of successful sets.	Number of unsuccessful sets.	Average catch at each successful set.
May	117	22	28,145
June	83	21	34,773
July	130	30	27,912
August	277	24	26,315
September	211	8	34,630
October	79	22	25,577
November	49	5	31,457
Total	946	132	29,562

DISPOSITION MADE OF THE CATCH.

The following table is a detailed exhibition of the use which was made of the menhaden and other fishes taken, the figures for the two vessels being shown separately in order to illustrate more fully the variations that occurred. It will be observed that 199,900 menhaden were sold for bait and 25,000 were salted for food by the vessels' crews. The remainder of the menhaden catch was rendered into oil and scrap, with the exception of 2,500 fish that were thrown away, owing to the vessel's distance from the factory.

Of the most important food-fish taken, bluefish, 1,292 were consumed fresh by the crew and factory hands, and 572 were salted on occasions when more were taken than were necessary for the food of the crew. The agent on the steamer *J. W. Hawkins* reports that the bluefish landed at the factory with the menhaden numbered 410; none of the fish caught by the other vessel was so disposed of. It is probable that a large part of these were later taken by the shore employees and eaten; there are about the factories persons always on the lookout for good fish brought in by the vessels.

The foregoing statement applies also in part to the croakers, flounders, shad, squeteague, and other typical food-fish shown in the table as being utilized for oil and guano. The discharge of the vessels' cargoes is usually accomplished at night and some fish are thus overlooked in the darkness. In warm weather, and when fishing is done at places remote from the factories, menhaden are sometimes landed in a partly decomposed state, and whatever food-fish happen to be mixed with them are thus lost.

All of the sharks caught were thrown in the vessels' holds and taken to the factories to be treated with the menhaden, with the exception of 13 which were thrown back into the water after being killed. The skates and rays were rendered into oil and guano like the sharks, only 4 being returned to the water.

The observations of the Commission's agents proved that, as a general thing, not enough desirable food-fish are taken by the menhaden steamers to keep the vessels' crews regularly supplied with fresh fish. As a rule, all the food-fish caught are eaten either by the crews or by the factory hands, but it occasionally happens that schools of bluefish, butter-fish, shad, river herrings, etc., are taken, and more fish are thus provided than can be consumed.

STEAMER ARIZONA.

Species.	Utilized for oil and guano.	Eaten fresh by crew and factory men.	Salted by crew.	Sold for bait.	Thrown overboard, etc.	Total.
Menhaden	18,546,800	.....	10,000	150,000	.....	18,706,800
Alewives or river herrings *a*	34	1	.....	.....	.....	35
Amber-fish	.....	1	.....	.....	.....	1
Anchovy	.....	2	.....	.....	.....	2
Bluefish	.....	526	121	.....	.....	647
Bonito	.....	16	17	.....	.....	33
Butter-fish	315	232	50	.....	.....	597
Croaker	.....	40	.....	.....	.....	40
Cunner	.....	2	.....	.....	.....	2
Drum	.....	3	.....	.....	.....	3
Flounders	174	75	20	.....	.....	269
Hake	.....	5	.....	.....	.....	5
Kingfish	.....	1	.....	.....	.....	1
Mackerel	.....	274	.....	.....	.....	274
Pipefish	7	.....	.....	.....	.....	7
Pompano	.....	1	.....	.....	.....	1
Rudder-fish	1	.....	.....	.....	.....	1
Sculpins	3	.....	.....	.....	.....	3
Scup	36	37	.....	.....	.....	73
Sea bass	.....	41	.....	.....	.....	41
Sea-horse	.....	.....	.....	.....	3	3
Sea-raven	.....	.....	.....	.....	1	1
Sea-robins	43	.....	.....	.....	.....	43
Shad	.....	2	6	.....	.....	8
Sharks	323	.....	.....	.....	.....	323
Skates and rays	303	.....	.....	.....	.....	303
Spanish mackerel	.....	108	.....	.....	.....	108
Squeteague or weakfish	.....	159	90	.....	.....	249
Striped bass	.....	1	.....	.....	.....	1
Swellfish	1	.....	.....	.....	.....	1
Tautog	.....	17	.....	.....	.....	17
Whiting	.....	8	.....	.....	.....	8
Total	18,548,040	1,552	10,304	150,000	4	18,709,900

a Includes a few hickory shad and sea herring.

STEAMER J. W. HAWKINS.

Species.	Utilized for oil and guano.	Eaten fresh by crew and factory men.	Salted by crew.	Sold for bait.	Thrown overboard, etc.	Total.
Menhaden	9,191,555	.....	15,000	49,900	2,500	9,258,955
Alewives or river herrings	71,854	23	.....	10,000	5,000	86,877
Bluefish	410	766	451	.....	.....	1,627
Bonito	2	.....	.....	.....	.....	2
Butter-fish	41	161	.....	.....	12	214
Catfish	2	.....	.....	.....	.....	2
Cero	.....	3	.....	.....	.....	3
Cod	1	.....	.....	.....	.....	1
Croaker	44	46	.....	.....	4	94
Cunner	2	.....	.....	.....	.....	2
Cutlas-fish	2	.....	.....	.....	.....	2
Drum	8	.....	.....	.....	.....	8
Eel	5	.....	.....	.....	6	11
Filefish	9	.....	.....	.....	.....	9
Flounders	72	18	.....	.....	10	100
Gar	5	1	.....	.....	.....	6
Goosefish	8	.....	.....	.....	3	11
Haddock	15	8	.....	.....	.....	23
Hake	28	7	.....	.....	.....	35
Lumpfish	8	.....	.....	.....	.....	8
Mackerel	.....	357	.....	.....	.....	357
Pollock	.....	1	.....	.....	.....	1
Pompano	6	1	.....	.....	.....	7
Sculpins	16	.....	.....	.....	.....	16
Sea-horse	.....	.....	.....	.....	1	1
Shad	266	161	706	.....	*a* 675	1,808
Sharks	65	.....	.....	.....	13	78
Skates and rays	65	.....	.....	.....	4	69
Spanish mackerel	.....	42	.....	.....	.....	42
Spot	20	.....	.....	.....	.....	20
Squeteague or weakfish	31	72	146	.....	.....	249
Swellfish	5	.....	.....	.....	.....	5
Whiting	22	.....	.....	.....	.....	22
Total	9,264,567	1,667	16,303	59,900	8,228	9,350,665

a Released alive.

OBSERVATIONS ON THE HABITS, MOVEMENTS, SPAWNING, ETC., OF MENHADEN.

The full notes obtained by the agents while on the menhaden vessels contain a great deal of interesting general information on menhaden and the fishes associated with them. While much of it does not add to existing knowledge of these fish, some of it may be properly incorporated in this paper because of its bearing on the special points under consideration.

Enemies of the menhaden.—The observations of the agents on the *Arizona* indicated that of all the enemies of the menhaden the bluefish appear to be the most destructive. This predaceous fish destroys immense numbers of menhaden in pure wantonness, killing many times more than are actually eaten. Each of 50 stomachs of bluefish examined by Mr. Marschalk contained fragments of menhaden, but none had a whole fish.

Sharks also destroy enormous quantities of menhaden, but do less damage to the fishery than do bluefish, as they consume the menhaden quietly and do not as a rule scatter the schools. Two bluefish will cause more disturbance in a body of menhaden than a dozen sharks.

Examination of the stomachs of a number of sharks caught by the *Arizona* showed that these fish were subsisting chiefly on menhaden, although croakers and occasionally squeteague were found in a few.

Of fish taken with the menhaden on the *Arizona*, the weakfish, next to the bluefish and sharks, appeared to be the most destructive. The agent on the vessel examined the stomachs of 22 of these fish, finding in them 13 whole menhaden and parts of 32 others.

Flounders do not seem to prey on menhaden. Most of the flounders taken in the seines were too small, however, to afford ground for satisfactory conclusions. Of 15 opened, none contained any menhaden, except the largest, a fish 18 inches long, which had one menhaden in its stomach.

Six mackerel caught by the *Arizona* in September were examined with reference to their food. No signs of menhaden were discovered in their stomachs.

Notes on the movements of the schools.—The well-defined migrations of the menhaden to and from the coasts of the Atlantic States, and their movements in the bays and rivers, depending largely on temperature, are often, in the case of even large bodies of fish, much modified by the presence of such predaceous species as bluefish, squeteague, and sharks. Several well-marked illustrations of this were observed in 1894.

The autumnal migratory movement of the menhaden begins with the fish on the shores of Maine and Massachusetts and gradually embraces the entire coast. The menhaden frequenting the bays and inlets of New England are driven out by the falling temperature and begin to move toward the south, following the shores as far as the eastern end of Long Island. In that region, according to the observations of the fishermen, by far the greater part of the fish leave the coast, move directly out to sea, and are seen no more. In the fall of 1894, owing to the remarkable abundance of bluefish and squeteague in the vicinity of Montauk Point, vast schools of menhaden were detained in Gardiner and Neapeague bays for several weeks beyond their accustomed time and were unable to reach the ocean until their enemies had left. About October 21, the bluefish disappeared from that region and the departure of the menhaden rapidly ensued.

By the middle of November the menhaden had very generally withdrawn from Chesapeake Bay, and all the schools observed during the latter part of that month on the ocean shores of Maryland and Virginia, north of Cape Henry, were moving south at the rate of 1 or 2 miles an hour. On November 16, the *J. W. Hawkins* made three hauls off Currituck Light, North Carolina. All the fish caught or seen were swimming north several miles an hour. After the last set, 3 miles southeast of Currituck Light, the vessel steamed 20 miles farther south and fell in with a large body of bluefish, which had apparently driven the menhaden back. A week later, in the same region, all the menhaden met with were moving north along the coast at the rate of 1 to 3 miles per hour, while between Currituck and Bodie Island lights large schools of bluefish were found which had evidently intercepted the migrating menhaden and caused them to reverse their course. Bluefish were practically absent from the schools of menhaden; in the 6 seine-hauls made in this section on November 16 and 23, only 2 bluefish were taken with 140,500 menhaden; 84 squeteague, however, mostly of small size, were caught.

Size and fatness of menhaden.—On the size and fatness of the fish depends, to a considerable degree, the financial success of the industry. Some years, during the greater part of the season, especially in the more southern waters, the fish are very lean and yield practically no oil. In the Chesapeake a million fish have frequently been known to produce less than a barrel of oil; in July, 1893, the steamer *I. N. Veasey* caught 2,000 barrels of menhaden (equivalent to about 700,000 fish) which yielded only 6 gallons of oil. The fish taken on the New England coast always average larger and fatter than those obtained elsewhere. The menhaden caught by the steamer *J. W. Hawkins* on the Maine and Massachusetts coasts in June, July, and August were from 10 to 12 inches long, averaging 11 inches. The quantity of oil produced was from 8 to 12 gallons per 1,000 fish, though menhaden taken in Boston Harbor in August yielded 14½ gallons per 1,000, and those caught about September 1 produced 16 to 18 gallons.

The menhaden caught on the coasts of New York, New Jersey, and Delaware were from 6 to 12 inches long, the average prior to October being rather under 9 inches, while in October and November the average was 10½ or 11 inches. At times in July the schools were made up of menhaden showing an unusually large variation in size, some hauls consisting of fish as small as 6 inches and as large as 12 inches, with every gradation between those limits. The remarkable body of menhaden in Delaware Bay in August and September consisted of small fish. No fish over 10 inches long were taken, and the average size was probably not over 8 inches. These fish were almost invariably smaller than those caught at the same time outside the bay and seemed to the fishermen to be an entirely different lot from those taken in the adjacent ocean.

The menhaden on the coasts of Maryland, Virginia, and North Carolina in October and November were mostly from 9 to 12 inches long and were quite fat, making about 10 gallons of oil per 1,000, but those obtained in the Chesapeake at the same time continued to run small (6½ to 8 inches, on an average); some schools had fully half the fish 12 inches long, and toward the end of the season the fish averaged 11 inches.

The fish obtained in the Chesapeake during the spring and summer are usually of small size, and it is reported that since 1890 the average size of the fish in the bay has been smaller than prior to that time. In 1894 the menhaden obtained during the spring and summer by the *J. W. Hawkins* ranged from 4½ to 11 inches in length, the average being 6 to 8 inches; these produced under 2 gallons of oil per 1,000.

The largest menhaden observed during 1894 was taken by the *J. W. Hawkins*, July 27, at the mouth of the Kennebec River, Maine. The fish was 14 inches long and weighed 1 pound 14 ounces.

Spawning of menhaden.—Notwithstanding the attention which the subject has received, much yet remains to be learned regarding the spawning season and spawning-grounds of the menhaden. Knowledge of the spawning habits of the fish has a very important practical bearing on the question of legislation, for it is clear that any truly protective measures adopted by the States must take cognizance of the time and place chosen by the menhaden for depositing their eggs.

Throughout the season, the agents of the Commission examined the menhaden with reference to the condition of their reproductive organs. The observations of Mr. Locke on the steamer *J. W. Hawkins* were especially complete. In Chesapeake Bay early in the season, when only small fish were caught, examinations were made daily, but later, on the New England coast and on the southern grounds, when the fish taken were of larger size, some menhaden in every seine haul were eviscerated.

The diversity of the testimony of fishermen on the question of the spawning season of menhaden and the observations of the Commission suggest the existence of different spawning times on different parts of the coast, a peculiarity strikingly exemplified in the case of the sea herring, which spawns in May in the Gulf of St. Lawrence and in November on the New England coast.

The testimony of fishermen and others as to the spawning of menhaden on the Maine coast indicates that the spawning period occupies part of the summer and may extend over most of the time when the fish are in those waters. The observations of the Commission's agent, extending from June 29 to August 6, tended to corroborate this view. An examination of 7 large menhaden, caught in Muscongus Sound July 3 in a school of 19,500 fish, showed that 3 males and 1 female were spent fish, while 3 females (12 inches long) had very large but immature ovaries. From a haul of 42,500 fish at the mouth of the Kennebec River July 5, 1 male examined was about half spent and 5 females had finished the spawning process. Examination of 6 fish from a haul of 66,700 in the same place on July 11 gave the following result: One male spent; 1 male with very large, hard spermaries; 1 female spent; 3 females with very large ovaries full of unripe eggs. On July 20 at the mouth of the New Meadow River, 6 fish from a lot of 14,900 consisted of 1 male with very large but immature spermaries, 3 spent females, 1 female from which eggs (apparently not ripe) would run on very gentle pressure, and 1 female with ovaries much enlarged and containing eggs very nearly ripe. Fish in a similar condition were taken in Casco Bay, July 24. On July 26 and 27, 12 menhaden from schools taken in Casco Bay and off Seguin Island were found to be spent fish, 8 being males. This examination was typical of a number of others made during the latter part of July. In August the fish were found with their reproductive organs in various stages of development. In some male fish the organs were three fourths mature; some ovaries were one-third to one-half full size with well-defined but unripe eggs, but in most of the fish, especially those taken after August 10, the organs were quite small and the eggs not differentiated.

All the menhaden caught in the Chesapeake in May and June had such very small organs as to suggest the recent completion of the spawning process or the immaturity of the fish. The spermaries of some 7-inch fish taken June 4 were only three-eighths of an inch long, and the ovaries only three-fourths of an inch; on June 6 some 8-inch fish had spermaries 1 inch long and ovaries 1¼ inches long, and no further development

was observed during the month. On the resumption of fishing in the bay on August 30 the condition of the fish as to spawning appeared to have undergone little change since June, and during the remainder of the season no fish taken in the Chesapeake contained organs of noteworthy size, with the exception of one 13½ inches long, taken October 13 off New Point, Virginia, which contained large ovaries; the others examined from the same school were small and the reproductive organs rudimentary.

In the latter part of October menhaden taken on the New York, New Jersey, and Virginia coasts contained well-developed organs, three-fourths to seven-eighths of the females opened having large ovaries with distinct eggs.

By the first week in November, the development of the reproductive organs had progressed so far that the approach of the spawning period appeared to be imminent in the fish caught close to land on the ocean shores of Maryland, Virginia, and North Carolina. On November 6, large hauls of menhaden, off the Maryland coast, contained fish 9 to 12 inches long that were very nearly ripe, and on November 7, 9, and 13, small quantities of eggs or milt could be forced by gentle pressure from most of the fish examined taken on the same grounds. On November 13, a female menhaden 11 inches long, caught in a school off the Virginia coast, appeared to be spent; November 16 a similar specimen, with shriveled and empty ovaries, was found among some almost ripe fish on the North Carolina coast. In the latter part of November, eggs or milt could be forced by gentle pressure from nearly all menhaden caught south of Cape Henry.

Complying with instructions from headquarters, Mr. E. E. Race, field agent, forwarded to Washington three lots of fresh menhaden taken off the mouth of Chesapeake Bay on October 30, November 1, and November 2. The first lot, consisting of 8 fish (1 male, 7 females) 11½ to 13 inches long, and weighing three-fourths of a pound, were from a school of 3,000 fish caught by the steamer *Virginia* in water 6 fathoms deep off the coast of Virginia, between Smith Island Light and Old Plantation Light; the water temperature was 62° or 63°. In the male a little milt appeared at the vent on pressure, the condition of the spermaries suggesting the partial completion of the spawning process. In 5 of the females a few eggs could be extruded by making gentle pressure on the abdomen; in the others, although the ovaries were large (4 inches long), no eggs could be expressed.

The second lot contained 19 specimens, taken by the steamer *I. N. Veasey* in a haul of 3,000 fish 4 miles east of Cape Charles Light, in 3 fathoms of water, the temperature of the water being 61°. Fourteen of these fish were over 12 inches long (12½ to 13½); 3 were males with spermaries from three-fourths of an inch to 1 inch wide, but unripe; all the females contained large ovaries (4 to 5 inches long) from which small quantities of eggs could be freely extruded on gently pressing the abdomen; the 5 remaining fish were smaller, averaging about 11 inches long, and had organs much less developed. The third lot of 10 fish came from a haul of 15,000 by the steamer *I. N. Veasey*, three-fourths of a mile northeast of Cape Henry Light, in water 4½ fathoms deep; water temperature, 61°. These fish were about 11 inches long. Their organs were more immature than those in the other lots. The ovaries were only 2½ inches long or less, and no free eggs or milt could be expressed.

These fish were examined by Mr. Richard Rathbun, in charge of the scientific inquiries of the Commission, who has given much attention to the spawning of the menhaden. He regarded none of the specimens as quite ripe, as the eggs were not entirely transparent or wholly spherical; but he thought there was no question that all the larger fish would soon have spawned.

4.—THE FISHES OF THE NEUSE RIVER BASIN.

By BARTON W. EVERMANN and ULYSSES O. COX.

In the summer of 1890 a small collection of fishes was made for the writers in the streams near Raleigh, N. C., by Messrs. H. H. and C. S. Brimley, taxidermists and natural-history dealers of that city. Collecting was done in the Neuse River itself, in Walnut Creek and its smaller tributaries, and in various backwater holes, ponds, and ditches that at times are connected with the creek or the river. Though the number of species represented in the collection is small, it shows us what are the common species of the locality and the relative abundance of each.

The greater parts of five days in June and July were given to the work of collecting, and seining was done in all manner of places, which are described in the collectors' notes, from which we quote:

Collecting was done in Neuse River, in Walnut Creek about a mile above its union with the river, and in neighboring mud-holes. The river is a fairly swift stream, bottom mostly sand or gravel, very much broken with small, medium, and huge granite bowlders. Nearly all fish from the river were caught along shore, where the bottom is mostly mud and exceedingly snaggy. Water seldom over shoulder-deep and temperature warm.

July 8.—The top minnows [*Gambusia affinis*] were caught by dip net, from a pond of water fed by springs in a granite quarry on the edge of town. These seem to be the only fish found in this place. The balance of the specimens from Walnut Creek and lake holes near here, say 8 miles from mouth of creek. We were particular about fishing the riffles and sand-bars for darters, but failed to get any. Most of the round-bodied shiners [*Hybognathus nuchalis* and *Notropis niveus*] were caught in fishing for darters. Nearly all the rest of the fish came from a lake hole connected with the creek.

Walnut Creek is a medium swift stream, bottom chiefly sand. Very few fish seem to stay in the clear, open reaches, where it is possible to seine. One haul of the net, some two hundred yards down a straight reach, with an even depth of from 1 to 2½ feet, clear sand bottom, seine taking in full width of stream, resulted in absolutely nothing, not a single specimen of any kind coming to hand. The fish that are in the creek seem only to frequent the eddies and around logs and tree roots and tops, just where a net can not be used. The backwater holes have, almost invariably, a mud bottom. Some have a deep layer of soft mud and dead leaves, others a fairly firm bottom, but always more or less muddy. Some are permanently connected with the creek, some only when the waterworks turbines at the next dam above where we fished are running (daily or oftener). Others again take high water or even heavy freshets to make the connection. We had no means of determining the temperature of the water, but in some of the smaller and more exposed holes the water seemed very warm.

The small perch with rather faint vertical bars [*Lepomis megalotis*] was not very plentiful.

June 18.—This day's collecting was in the valley of Walnut Creek. No specimens came from the creek itself and only a few from the smaller tributary streams. These included a few "top minnows" [*Gambusia affinis*], a very small percentage of shiners and cats, and the pirate perch. All the other species came from the meadow ditches. On this day we did not use the seine, but used small dip nets of fine mesh (mosquito netting). All specimens taken of the following were preserved: Shiners of all kinds, the larger perch [*Acantharchus pomotis*], which we have never taken elsewhere; pike [*Lucius americanus* and *Lucius vermiculatus*], cats, mullets, and speckled perch [*Enneacanthus gloriosus*]. The use of the dip nets accounts for the large number of "top minnows" taken where we had never secured any with the seine.

June 23.—Walnut Creek again, but further up stream. Three top minnows were found in a shallow mud-hole in the meadows. All the rest came from a long "lake hole" connected with the creek, a small stream flowing through it. This hole is about 150 yards long, with an average width of 20 feet. The bottom is of a soft mud, in some places 2 feet deep. The water will average waist-deep, and is warm. Pike and mullets [*Erimyzon sucetta*] were plentiful, while perch occurred in greater numbers than found anywhere previously; large shiners were common, but many were injured by contact with other fish and trash in the net and by gilling themselves in the meshes. None of the small, round-bodied shiners was taken; all seemed to be of the "shad roach" type [*Notemigonus crysoleucas*].

Fourteen specimens of "mudfish" [*Umbra pygmæa*], the only specimens of the species we have ever taken, were obtained from a ditch back from Walnut Creek in an open meadow. This ditch is 3 or 4 feet wide and 3 feet deep, including a layer of soft mud about 1 foot thick. The surrounding meadow is springy and marshy, the water is not stagnant, though it is not connected with the creek except in times of freshets. In this ditch were also found pike [*Lucius vermiculatus*] and several species of sunfish and shiners. In a pond near by, which has a muddy bottom but a constant stream flowing through it, were found "white perch" [*Pomoxis sparoides*], pike, and "mullets" [*Erimyzon sucetta*].

June 27.—Collecting done in Neuse River, Walnut Creek—about the last mile before joining the river—and neighboring mud-holes. The gar [*Lepisosteus osseus*] came from the river; all the darters were taken in the creek, in swift shallow water, with gravel or sand bottom. Black bass came from a mud-hole connected with the creek only at quite high water. Water in it was shallow and warm and mud quite deep. Most of the fork-tailed cats [*Ameiurus catus*] came from a mud-hole, shoulder-deep in places, connected with the river during freshets. This hole is fed by a small spring and the water is very cold (comparatively). We have on former occasions taken a small barred or spotted cat from this place, but could find none this time. Most of the other specimens came from the river with the exception of some few shiners, cats, redhorses, and sunfish found in the creek and holes. All darters, shiners, and small cats taken were preserved; likewise the only flounder. One other gar and black bass were caught.

Several species of turtle and terrapin were abundant in the places fished, and many were caught. No "snappers" caught, although they are found in these places. Bonnet lilies grow in some of the mud-holes, and marsh grasses grow around the edges in the shallower parts of others. Well-grown bullfrogs often come up in the seine, also other frogs.

The total number of species contained in the collection is 30, distributed among 12 families and 23 genera, as follows: Lepisosteidæ, 1; Siluridæ, 3; Catostomidæ, 3; Cyprinidæ, 6; Pœciliidæ, 1; Esocidæ, 2; Anguillidæ, 1; Umbridæ, 1; Aphredoderidæ, 1; Centrarchidæ, 8; Percidæ, 2; and Pleuronectidæ, 1.

Or, as to genera: Lepisosteus, 1; Ameiurus, 2; Noturus, 1; Erimyzon, 1; Moxostoma, 2; Notemigonus, 1; Notropis, 2; Hybopsis, 1; Semotilus, 1; Hybognathus, 1; Gambusia, 1; Lucius, 2; Anguilla, 1; Umbra, 1; Aphredoderus, 1; Pomoxis, 1; Chænobryttus, 1; Acantharchus, 1; Enneacanthus, 1; Lepomis, 3; Micropterus, 1; Etheostoma, 2; Achirus, 1.

It will be noticed that almost half of the species belong in the two families, the Centrarchidæ and the Cyprinidæ.

The following is a list of the species of fishes which the collection contains:

1. **Lepisosteus osseus** (Linnæus). *Gar.* One small specimen, 13 inches long.
2. **Ameiurus natalis** (Le Sueur). *Yellow Cat.* Very abundant; nearly 100 specimens, 1½ to 5⅞ inches long.
3. **Ameiurus catus** (Linnæus).
   Amiurus niveiventris Cope, Proc. Am. Philos. Soc. 1870, 486. Type locality, Neuse River, N. C.
   Fourteen specimens, agreeing well with the original description of Professor Cope. Body not slender; head not narrow, its width 1⅔ in its length; base of anal equal to length of head, or 4 in total length; length of humeral spine about half that of pectoral spine, but variable. Dorsal inserted midway between snout and adipose fin. A. 20.
4. **Noturus insignis** (Richardson). Five specimens, 4 to 5 inches long.
5. **Erimyzon sucetta** (Lacépède). *"Mullet"; Chub Sucker.* Five specimens. Called "mullet" by the collectors. Scales, 44 to 46.

6. **Moxostoma papillosum** (Cope). *Redhorse; White Mullet.*
   Ptychostomus papillosus Cope, Proc. Amer. Philos. Soc. Phila. 1870, 470.
   Type localities, Catawba and Yadkin rivers, N. C. One specimen obtained June 27 from Walnut Creek.
7. **Moxostoma cervinum** (Cope). *Redhorse; Jumping Mullet.* One specimen obtained with the preceding. Both of these species of *Moxostoma* are common in the Neuse River basin.
8. **Notemigonus crysoleucas** (Mitchill). *"Shad Roach"; Roach; Golden Shiner.* Excessively abundant, especially in the meadow ditches and isolated pools and ponds.
9. **Notropis niveus** (Cope). *Shiner.*
   Hybopsis niveus Cope, Proc. Amer. Philos. Soc. Phila. 1870, 460.
   Type locality, Catawba River, N. C. The collection contains five samples of this species.
10. **Notropis albeolus** (Jordan). *"Shiner."* Not uncommon; six specimens in the collection.
11. **Hybopsis kentuckiensis** (Rafinesque). *River Chub; Jerker.* Abundant in the creek; 16 specimens in the collection. Head more slender and pointed than in northern examples. Head, 4 to 4½; depth, 4 to 4½; eye, 2; snout, 2⅞ to 2¾. D. 8; A. 7; scales, 7–41–4.
12. **Semotilus atromaculatus** (Mitchill). Several small specimens from Walnut Creek.
13. **Hybognathus nuchalis** Agassiz. Common. Called "round-bodied minnow" or "shiner" in the collectors' notes.
14. **Gambusia affinis** Girard. *"Top Minnow."* Abundant in the small ponds, springs, and pools. This was the only species found in a pond in a granite quarry near Raleigh.
15. **Lucius americanus** Gmelin. *"Pike."* Several small specimens, 2 to 7 inches long. Common in grassy places in ditches and ponds.
16. **Lucius vermiculatus** (Le Sueur). *"Pike."* Several small specimens, 5 to 6 inches long, which agree with this species rather than with *L. reticulatus*. The snout is shorter and the scales are larger than in *L. reticulatus*, the number in the lateral line being about 104.
17. **Anguilla chrysypa** Rafinesque. *Common Eel.* One specimen.
18. **Umbra limi pygmæa** (De Kay). *Mud Minnow; "Mudfish."* Fourteen specimens from a ditch near Walnut Creek. These vary from 2⅞ to 4 inches in length.
19. **Aphredoderus sayanus** Gilliams. *Pirate Perch.* A dozen good-sized examples of this species.
20. **Pomoxis sparoides** (Lacépède). *Calico Bass; Strawberry Bass; "White Perch."* Three small specimens from the ponds.
21. **Chænobryttus gulosus** (Cuvier & Valenciennes). *Warmouth; Red-eyed Bream.* Numerous specimens; abundant in the ponds.
22. **Acantharchus pomotis** (Baird). *"Perch"; Mud Sunfish.* Ponds along Walnut Creek, common. Two specimens. D. XII, 10 or 11; A. VI, 10.
23. **Enneacanthus gloriosus** (Holbrook). *"Speckled Perch."* Two small examples from pond near Walnut Creek, which we refer to this species.
24. **Lepomis auritus** (Linnæus). *Long-eared Sunfish; Yellow-belly.* Two small specimens.
25. **Lepomis megalotis** (Rafinesque). *Long-eared Sunfish.* Only one specimen in the collection.
26. **Lepomis gibbosus** (Linnæus). *Common Sunfish.* Apparently the most common sunfish of the region. Many specimens in the collection.
27. **Micropterus salmoides** (Lacépède). *Large-mouth Black Bass.* Two small specimens from Walnut Creek. Common in the Neuse River basin and the entire South.
28. **Etheostoma peltatum** Stauffer. One specimen. Head, 3½; depth, 6. D. XIV, 13; A. II, 9; scales, 8–65–9; some scales on preopercle and lower part of opercle.
29. **Etheostoma vitreum** (Cope).
   Pœcilichthys vitreus Cope, Proc. Amer. Philos. Soc. Phila. 1870, 263.
   The collection contains seven specimens of this interesting darter, which, with *E. peltatum*, was found on the riffles in the creek.
30. **Achirus fasciatus** Lacépède. *"Flounder"; Sole.* A single example of this species.

We have thought it might prove valuable to bring together all accessible references to fishes of the Neuse River basin, and have therefore taken this opportunity to go over the literature and compile all the definite references to localities in the basin of that stream. We give (1) the title of the paper containing the reference, (2) a list of the species mentioned in each paper, and (3) a complete list of all the species now known from the Neuse River basin, together with all the definite localities within that basin from which each has been reported, and a citation to the authority for the same.

1870*a*. E. D. COPE. On some Etheostomine Perch from Tennessee and North Carolina. <Proc. Amer. Philos. Soc., XI, 1870, 261–270.

In this paper Professor Cope describes as new two species of darters collected by him from Neuse River. In the following table we give (1) the page on which the species is mentioned in the paper cited, (2) the name under which the species was there recorded, (3) our identification of the nominal species, (4) the locality as given in the paper cited. Names of new species and new genera are printed in italics.

Page.	Species as recorded	Identification.	Locality.
261	*Etheostoma nevisense*	Etheostoma peltatum	Neuse River near Raleigh.
264	Pœcilichthys *vitreus*	Etheostoma vitreum	Walnut Creek, Neuse River, Wake County.

1870*b*. EDW. D. COPE, A. M. A Partial Synopsis of the Fishes of the Fresh Waters of North Carolina. <Proc. Amer. Philos. Soc., XI, 1870, 448–495.

In this, the most important contribution to our knowledge of the fishes of North Carolina that has yet appeared, Professor Cope credits 36 species to the Neuse River basin. Of these, 34 are given in the body of the paper and 2 additional species (*Esox ravenelii* and *Hybopsis ? amarus*) are mentioned in the table at the end of the article. In the table, however, only 32 species are credited to the Neuse, all having been collected by Professor Cope. Seven of the 36 species are described as new; the names of these are printed in italics in the following summary:

Page.	Nominal species.	Identification.	Locality.
449	Stizostedium, sp	Stizostedion	Neuse River.
448	Perca flavescens	Perca flavescens	Neuse River.
448	Roccus lineatus	Roccus lineatus	Neuse River.
449	Pœcilichthys vitreus	Etheostoma vitreum	Walnut Creek.
449	*Etheostoma* nevisense	*Etheostoma* vitreum	Neuse River.
451	Micropterus nigricans	Micropterus salmoides	Neuse River.
451	Pomoxys hexacanthus	Pomoxis sparoides	Neuse River.
451	Centrarchus irideus	Centrarchus macropterus	Neuse River.
452	Chænobryttus gillii	Chænobryttus gulosus	All streams of North Carolina east of the Alleghany Mountains.
452	Enneacanthus guttatus	Enneacanthus obesus	Neuse River.
452	Lepomis rubricauda	Lepomis auritus	Neuse River.
455	Pomotis maculatus	Lepomis gibbosus	All the rivers of North Carolina east of the Alleghany range.
455	Aphredodirus sayanus	Aphredoderus sayanus	Sluggish waters tributary to the Neuse River in Wake County.
457	Haplochilus *melanops*	Gambusia affinis	Still water of the Neuse River basin, Wake County.
457	Esox affinis	Lucius reticulatus	Neuse River.
457	Semotilus corporalis	Semotilus atromaculatus	Neuse River.
459	Ceratichthys biguttatus	Hybopsis kentuckiensis	Neuse River.
459	Hypsolepis cornutus cornutus	Notropis megalops	Neuse River.
459	Hypsolepis analostanus	*Notropis analostanus*	Neuse River.
463	Photogenis leucops	Notropis photogenis	Neuse River near Raleigh.
465	Alburnellus *matutinus*	Notropis umbratilis matutinus	Neuse River, Wake County.
465	Stilbe americana	Notemigonus crysoleucas	Neuse Basin.
468	Catostomus teres	Catostomus teres	All the rivers of the State on both sides of Alleghany watershed.
468	Moxostoma oblongum	Erimyzon sucetta	Neuse River.
471	Ptychostomus *collapsus*	Moxostoma collapsum	Neuse River.
473	Ptychostomus *robustus*	Moxostoma robustum	Neuse River.
474	Ptychostomus *lachrymalis*	*Moxostoma macrolepidotum*	Neuse River near Raleigh.
477	Ptychostomus *crassilabre*	Moxostoma crassilabre	Neuse River at Newbern.
487	Amiurus lynx ?	Ameiurus catus	Neuse River.
488	Amiurus *niveiventris*	Ameiurus catus	Neuse River.
491	Anguilla, sp	Anguilla chrysypa	All Atlantic waters of the State.
494	Perca flavescens	Perca flavescens	Neuse River.
494	Boleosoma maculaticeps	Etheostoma olmstedi	Neuse River.
494	Pomoxis hexacanthus	Pomoxis sparoides	Neuse River.
494	Lepomis rubricauda	Lepomis auritus	Neuse River.
494	Esox ravenelii	Lucius americanus	Neuse River.
494	Hybopsis ? amarus	Notropis amarus	Neuse River.
495	Acipenser, sp	Acipenser sturio oxyrhynchus	Neuse River.
495	Lepidosteus, sp	Lepisosteus osseus	Neuse River.
495	? Amia	Amia calva	Neuse River.

1877. DAVID S. JORDAN. Contributions to North American Ichthyology, II. <Bulletin U. S. Nat. Mus., No. 10, 1877.

In this paper (p. 27) *Enneacanthus pinniger* Gill & Jordan is described as new, from specimens obtained by J. W. Milner at Kingston. *Amiurus niveiventris* Cope (= *A. catus*) is also mentioned from the Neuse (p. 83).

1878. DAVID S. JORDAN AND ALEMBERT W. BRAYTON. On the Distribution of the Fishes of the Alleghany Region of South Carolina, Georgia, and Tennessee, with Descriptions of new or little-known species. <Contributions to North American Ichthyology, No. III, *A*; <Bull. U. S. Nat. Mus., No. 12, 1878, 1–96.

In the Recapitulation at the end of this paper (pp. 82–96) the following species are referred to the Neuse River, chiefly on the authority of Professor Cope:

Nominal species.	Identification.	Nominal species.	Identification.
Ioa vitrea	Etheostoma vitreum.	Luxilus cornutus	Notropis megalops.
Alvordius crassus	Etheostoma peltatum.	Photogenis analostanus	Notropis analostanus.
Alvordius nevisensis	Etheostoma peltatum.	Alburnops chlorocephalus*	Notropis chlorocephalus.
Boleosoma maculaticeps	Etheostoma nigrum olmstedi.	Alburnops amarus	Notropis amarus.
Perca americana	Perca flavescens.	Notropis photogenis*	Notropis photogenis.
Micropterus pallidus	Micropterus salmoides.	Notropis matutinus	Notropis umbratilis matutinus.
Acantharchus pomotis	Acantharchus pomotis.	Notemigonus americanus	Notemigonus crysoleucas.
Chænobryttus viridis	Chænobryttus gulosus.	Ceratichthys biguttatus	Hybopsis kentuckiensis.
Lepiopomus auritus	Lepomis auritus.	Semotilus corporalis	Semotilus atromaculatus.
Eupomotis aureus	Lepomis gibbosus.	Moxostoma velatum	Moxostoma.
Enneacanthus pinniger	Enneacanthus gloriosus.	Moxostoma crassilabre	Moxostoma crassilabre.
Enneacanthus margarotis	Enneacanthus gloriosus.	Moxostoma macrolepidotum et vars.	Moxostoma macrolepidotum.
Centrarchus irideus	Centrarchus macropterus.	Erimyzon sucetta	Erimyzon sucetta.
Pomoxys nigromaculatus	Pomoxis sparoides.	Catostomus commersoni	Catostomus teres.
Pomoxys annularis	Pomoxis annularis.	Amiurus albidus	Ameiurus catus.
Aphredoderus sayanus	Aphredoderus sayanus.	Amiurus niveiventris	Ameiurus catus.
Zygonectes melanops	Gambusia affinis.	Amiurus natalis	Ameiurus natalis.
Zygonectes *atrilatus*	Gambusia affinis.	Amiurus catus	Ameiurus catus.
Melanura pygmæa	Umbra pygmæa.	Noturus eleutherus	Noturus eleutherus.
Esox reticulatus	Lucius reticulatus.	Anguilla vulgaris	Anguilla chrysypa.
Esox raveneli	Lucius americanus.		
Hybognathus argyritis	Hybognathus nuchalis.		

* Probably erroneously credited to the Neuse River basin.

1884. GEORGE BROWN GOODE. The Black Bass Family—Centrarchidæ. <The Fishery Industries of the United States, Part I, 401–404, 1884.

In this article the large-mouth black bass (*Micropterus salmoides*) is mentioned as being known as "Welshman" on the Neuse River.

1889. DAVID STARR JORDAN. Descriptions of Fourteen Species of Fresh-water Fishes collected by the U. S. Fish Commission in the Summer of 1888. <Proc. U. S. Nat. Mus., XI, 1888 (1889), 351–362, plates XLIII–XLV.

Two of these (*Noturus furiosus* and *Etheostoma roanoka*) were found in the Neuse River at Milburnie, near Raleigh, and the latter also in Little River at Goldsboro. The jumping mullet, *Moxostoma cervinum* (Cope), is also mentioned from the Neuse River.

1890. DAVID STARR JORDAN. Report of Explorations made during the Summer and Autumn of 1888, in the Alleghany Region of Virginia, North Carolina and Tennessee, and in Western Indiana, with an Account of the Fishes found in each of the River Basins of those Regions. <Bull. U. S. Fish Comm., VIII, 1888 (1890), 97–173, plates XIII–XV.

This paper records 41 species from the Neuse River basin, a larger number than has been reported in any other paper. The new species contained in this collection were described in the paper cited above. The collections from the Neuse River basin recorded in this paper were made by Dr. O. P. Jenkins and Prof. S. E. Meek.

Page.	Nominal species.	Identification.	Locality.
127	Amia calva	Amia calva	Moccasin Swamp near Goldsboro.
127	Noturus furiosus	Noturus furiosus	Little River at Goldsboro and Neuse River at Milburnie.
127	Noturus insignis	Noturus insignis	Little River at Goldsboro and Neuse River at Milburnie.
127	Ameiurus natalis	Ameiurus natalis	Little River at Goldsboro and Moccasin Swamp near Goldsboro.
127	Ameiurus erebennus	Ameiurus erebennus	Moccasin Swamp near Goldsboro.
128	Ameiurus niveiventris	Ameiurus catus	Little River at Goldsboro and Neuse River at Milburnie.
128	Catostomus nigricans	Catostomus nigricans	Neuse River at Milburnie.
128	Erimyzon sucetta	Erimyzon sucetta	Moccasin Swamp near Goldsboro, Little River at Goldsboro, and Neuse River at Milburnie.
128	Moxostoma papillosum	Moxostoma papillosum	Little River at Goldsboro and Neuse River at Milburnie.
128	Moxostoma *conus*	Moxostoma conus	Little River at Goldsboro.
128	Moxostoma crassilabre	Moxostoma crassilabre	Little River at Goldsboro.
129	Moxostoma cervinum	Moxostoma cervinum	Neuse River at Milburnie.
129	Hybognathus nuchalis	Hybognathus nuchalis	Neuse River at Milburnie and Little River at Goldsboro.
129	Notropis procne	Notropis procne	Neuse River at Milburnie and Little River at Goldsboro.
129	Notropis hudsonius	Notropis hudsonius	Little River at Goldsboro.
129	Notropis megalops albeolus	Notropis albeolus	Neuse River at Milburnie.
129	Notropis niveus	Notropis niveus	Little River at Goldsboro and Neuse River at Milburnie.
129	Notropis amœnus	Notropis amœnus	Neuse River at Milburnie.
129	Notropis matutinus	Notropis umbratilis matutinus.	Neuse River at Milburnie.
129	Hybopsis kentuckiensis	Hybopsis kentuckiensis	Little River at Goldsboro and Neuse River at Milburnie.
129	Notemigonus chrysoleucus	Notemigonus crysoleucas	Little River at Goldsboro and Neuse River at Milburnie.
129	Clupea sapidissima	Clupea sapidissima	Little River at Goldsboro and Neuse River at Milburnie.
129	Gambusia patruelis	Gambusia affinis	Little River at Goldsboro and Neuse River at Milburnie.
129	Lucius americanus	Lucius americanus	Little River at Goldsboro.
129	Lucius reticulatus	Lucius reticulatus	Moccasin Swamp near Goldsboro and Little River at Goldsboro.
129	*Anguilla anguilla rostrata*	Anguilla chrysypa	Neuse River at Milburnie.
129	Aphredoderus sayanus	Aphredoderus sayanus	Little River at Goldsboro.
130	Pomoxis sparoides	Pomoxis sparoides	Little River at Goldsboro, Moccasin Swamp at Goldsboro, and Neuse River at Milburnie.
130	Centrarchus macropterus	Centrarchus macropterus	Moccasin Swamp near Goldsboro and Little River at Goldsboro.
130	Enneacanthus gloriosus	Enneacanthus gloriosus	Little River at Goldsboro.
130	Acantharchus pomotis	Acantharchus pomotis	Moccasin Swamp near Goldsboro.
130	Chænobryttus gulosus	Chænobryttus gulosus	Moccasin Swamp near Goldsboro and Neuse River at Milburnie.
130	Lepomis auritus	Lepomis auritus	Little River at Goldsboro and Neuse River at Milburnie.
130	Lepomis holbrooki	Lepomis holbrooki	Little River at Goldsboro.
130	Lepomis gibbosus	Lepomis gibbosus	Moccasin Swamp near Goldsboro.
130	Micropterus dolomieu	Micropterus dolomieu	Moccasin Swamp near Goldsboro and Neuse River at Milburnie.
130	Micropterus salmoides	Micropterus salmoides	Moccasin Swamp near Goldsboro, Little River at Goldsboro, and Neuse River at Milburnie.
130	Etheostoma vitreum	Etheostoma vitreum	Neuse River at Milburnie and Little River at Goldsboro.
130	Etheostoma nigrum olmstedi	Etheostoma nigrum olmstedi	Neuse River at Milburnie and Little River at Goldsboro.
130	Etheostoma peltatum	Etheostoma peltatum	Neuse River at Milburnie and Little River at Goldsboro.
130	Etheostoma *roanoka*	Etheostoma roanoka	Neuse River at Milburnie.

The following is a list of all the species of fishes now known to occur in the Neuse River basin:

1. **Acipenser sturio oxyrhynchus** (Mitchill). *Common Sturgeon.* Neuse River (Cope, 1870*b*).
2. **Lepisosteus osseus** (Linnæus). *Long-nosed Gar.* Neuse River (Cope, 1870*b*); Raleigh.
3. **Amia calva** (Linnæus). *Dogfish; Bowfin; Blackfish; Brindlefish.* Neuse River (Cope, 1870*b*); Moccasin Swamp near Goldsboro (Jordan, 1890); Raleigh.
4. **Ameiurus catus** (Linnæus). *White Catfish.* Neuse River at Newbern (Cope, 1870*b*); Raleigh.
5. **Ameiurus erebennus** Jordan. Moccasin Swamp near Goldsboro (Jordan, 1890).
6. **Ameiurus natalis** (Le Sueur). *Yellow Cat.* Little River and Moccasin Swamp, Goldsboro (Jordan, 1890).
7. **Noturus insignis** (Richardson). *Mad-Tom.* Neuse River at Milburnie and Little River near Goldsboro (Jordan, 1890); Raleigh.
8. **Noturus furiosus** (Jordan & Meek). Neuse River at Milburnie and Little River near Goldsboro (Jordan, 1889 and 1890, type).
9. **Catostomus teres** (Mitchill). *Common Sucker; Fine-scaled Sucker.* "All the rivers of the State" (Cope, 1870*b*).
10. **Catostomus nigricans** Le Sueur. *Hog Sucker; Hog Molly.* Neuse River, Milburnie (Jordan, 1890).
11. **Erimyzon sucetta** (Lacépède). *Chub Sucker; "Mullet."* Neuse River (Cope, 1890*b*); Moccasin Swamp near Goldsboro (Jordan, 1890); Raleigh.
12. **Moxostoma papillosum** (Cope). *White Mullet; "Redhorse."* Neuse River, Milburnie, and Moccasin Swamp near Goldsboro (Jordan, 1890); Walnut Creek, Raleigh.
13. **Moxostoma collapsum** (Cope). Neuse River (Cope, 1870*b*, type).
14. **Moxostoma robustum** (Cope). Neuse River (Cope, 1870*b*, type).
15. **Moxostoma macrolepidotum** (Le Sueur). *Common White Sucker; Large-scaled Sucker.* Neuse River (Cope, 1870*b*, as *Ptychostomus lachrymalis*, type).
16. **Moxostoma crassilabre** (Cope). Neuse River near Raleigh (Cope, 1870*b*, type); Little River at Goldsboro (Jordan, 1890).
17. **Moxostoma conus** (Cope). Little River, Goldsboro (Jordan, 1890).
18. **Moxostoma cervinum** (Cope). *Jumping Mullet.* Neuse River, Milburnie (Jordan, 1889 and 1890); Walnut Creek, Raleigh.
19. **Hybognathus nuchalis** Agassiz. *Silvery Minnow.* Neuse River at Milburnie and Little River at Goldsboro (Jordan, 1890); Raleigh.
20. **Semotilus atromaculatus** (Mitchill). *Creek Chub.* Neuse River (Cope, 1870*b*); Walnut Creek, Raleigh.
21. **Notemigonus crysoleucas** (Mitchill). *Golden Shiner; Roach; "Shad Roach."* Neuse River (Cope, 1870*b*); Neuse River at Milburnie (Jordan, 1890); Raleigh.
22. **Notropis hudsonius** (De Witt Clinton). *Shiner.* Little River at Goldsboro (Jordan, 1890).
23. **Notropis amarus** (Girard). Neuse River (Cope, 1870*b*).
24. **Notropis niveus** (Cope). *"Shiner."* Little River at Goldsboro (Jordan, 1890); Raleigh.
25. **Notropis analostanus** (Girard). Neuse River (Cope, 1870*b*).
26. **Notropis megalops** (Rafinesque). *Redfin; Shiner.* Neuse River (Cope, 1870*b*).
27. **Notropis albeolus** (Jordan). *"Shiner."* Neuse River at Milburnie (Jordan, 1890); Raleigh.
28. **Notropis amœnus** (Abbott). Neuse River at Milburnie (Jordan, 1890).
29. **Notropis photogenis** (Cope). Neuse River near Raleigh (as *Photogenis leucops*, Cope, 1870*b*).
30. **Notropis umbratilis matutinus** (Cope). Neuse River, Wake County (Cope, 1870*b*, type).
31. **Hybopsis kentuckiensis** (Rafinesque). *Horny-head; River Chub; Jerker.* Neuse River at Milburnie and Little River at Goldsboro (Jordan, 1890); Raleigh.
32. **Clupea sapidissima** Wilson. *Shad.* Neuse River at Milburnie (Jordan, 1890).
33. **Gambusia affinis** (Baird & Girard). *"Top Minnow."* Neuse River (Cope, 1870*b*, type of *Haplochilus melanops*); Neuse River at Milburnie (Jordan, 1890); Raleigh.
34. **Umbra pygmæa** (De Kay). *Mud Minnow; "Mudfish."* Ditch near Walnut Creek, Raleigh.
35. **Lucius americanus** Gmelin. *Pike; Banded Pickerel.* Neuse River (Cope, 1870*b*); Little River at Goldsboro (Jordan, 1890).
36. **Lucius reticulatus** (Le Sueur). *Common Eastern Pickerel; Green Pike.* Neuse River (Cope, 1870*b*); Moccasin Swamp and Little River near Goldsboro (Jordan, 1890).

37. **Lucius vermiculatus** (Le Sueur). *Little Pickerel; "Pike."* Raleigh.
38. **Anguilla chrysypa** Rafinesque. *Common Eel.* "All Atlantic waters of North Carolina" (Cope, 1870*b*); Neuse River at Milburnie (Jordan, 1890); Raleigh.
39. **Aphredoderus sayanus** Gilliams. *Pirate Perch.* Little River at Goldsboro (Jordan, 1890); Raleigh.
40. **Centrarchus macropterus** (Lacépède). *Sunfish; "Flyer."* Neuse River (Cope, 1870*b*); Moccasin Swamp and Little River near Goldsboro (Jordan, 1890).
41. **Pomoxis sparoides** (Lacépède). *Calico Bass.* Neuse River (Cope, 1870*b*); Neuse River at Milburnie, and Moccasin Swamp and Little River near Goldsboro (Jordan, 1890); Raleigh.
42. **Chænobryttus gulosus** (Cuvier & Valenciennes). *Warmouth; Red-eyed Bream.* "All streams of North Carolina east of the Alleghany Mountains" (Cope, 1870*b*); Neuse River at Milburnie and Moccasin Swamp near Goldsboro (Jordan, 1890); Raleigh.
43. **Acantharchus pomotis** (Baird). *Mud Sunfish.* Moccasin Swamp near Goldsboro (Jordan, 1890); ponds about Raleigh.
44. **Enneacanthus obesus** (Baird). Neuse River (Cope, 1870*b*).
45. **Enneacanthus gloriosus** (Holbrook). Little River at Goldsboro (Jordan, 1890); ponds about Raleigh.
46. **Lepomis auritus** (Linnæus). *Yellow-belly.* Neuse River (Cope, 1870*b*); Neuse River at Milburnie and Little River at Goldsboro (Jordan, 1890); Raleigh.
47. **Lepomis holbrooki** (Cuvier & Valenciennes). Little River at Goldsboro and Neuse River at Milburnie (Jordan, 1890).
48. **Lepomis gibbosus** (Linnæus). *Pumpkin-seed; Sunny.* "All the rivers of North Carolina east of the Alleghany Mountains" (Cope, 1870*b*); Moccasin Swamp near Goldsboro (Jordan, 1890); Raleigh.
49. **Micropterus salmoides** (Lacépède). *Large-mouth Black Bass; "Welshman"; "Trout."* Neuse River (Cope, 1870*b*); Neuse River at Milburnie and Little River and Moccasin Swamp near Goldsboro (Jordan, 1890); Raleigh.
50. **Micropterus dolomieu** Lacépède. *Small-mouth Black Bass.* Neuse River at Milburnie and Moccasin Swamp near Goldsboro (Jordan, 1890).
51. **Etheostoma vitreum** (Cope). Neuse River, Wake County (Cope, 1870*a*, type); Neuse River and Walnut Creek (Cope, 1870*b*); Neuse River at Milburnie and Little River at Goldsboro (Jordan, 1890); Walnut Creek.
52. **Etheostoma peltatum** Stauffer. Neuse River at Milburnie and Little River at Goldsboro (Jordan, 1890); Walnut Creek.
53. **Etheostoma nigrum olmstedi** (Storer). Neuse River at Milburnie and Little River at Goldsboro (Jordan, 1890).
54. **Etheostoma roanoka** Jordan & Jenkins. Neuse River at Milburnie (Jordan, 1889 and 1890, type).
55. **Achirus fasciatus** Lacépède. *"Flounder"; Sole.* Neuse River at Raleigh.

5.—NOTES ON FISH-CULTURE IN GERMANY.

NOTES BY S. JAFFÉ ON INTENSIVE POND-CULTURE AT SANDFORT.[1]

In my pamphlet entitled "Trout-culture" (published by Rockhorst, Osnabrück), I have earnestly warned persons who carry on pond-culture on a small scale not to introduce into their ponds artificial food that can not be reproduced in the pond itself. They should till their ponds the same as their fields, and stock them only with fish which the water of the pond will feed without much aid. They should cultivate and increase the live pond-food by introducing snails, mussels, small crustaceans, and useful aquatic plants, but should avoid all dead food.

Wherever water, food, and energy are found, there is no reason why intensive pond-culture should not be carried on. I would, however, lay special stress on the fact that this pond-culture can become remunerative only where there is ample water, food, and time. The principles laid down in this treatise have been successfully followed at Sandfort and other establishments founded on the same plan.

The water of an establishment where trout are to be raised for market should come from ample and steady springs; the ponds should be near, but not too close to the springs, which near their origin contain very little oxygen. It is useful to introduce brook or river water into the pond, so as to occasionally render the water turbid; but river water alone is rather hurtful on account of the rising temperature. To make the water in the ponds occasionally turbid is useful, not only because the particles of soil which are precipitated act as a disinfectant on the remnants of food, but also because they furnish the trout, particularly in cemented and other entirely artificial basins, those particles of earth which they need for the mechanical process of digestion. After the water has been turbid for a short while, trout have invariably been observed to take to their food with particular readiness, and probably not merely because they had to fast while the water was turbid.

It is difficult to state the minimum quantity of water for a raising-pond; the temperature, the saturation of the water with oxygen by a strong fall, and other circumstances will render changes in the quantity of water necessary; but no fish-cultural establishment should be started without a steady total influx of 0.5 cubic meter (17.7 cubic feet) of water per minute.

If the ponds can get shade during the hot afternoon hours from rising ground in the neighborhood they will be all the cooler, but the condition which will exercise the greatest influence on the quantity of fry to be put in the ponds, and on their safety,

[1] Intensive Teichwirthschaft. Von S. Jaffé in Sandfort. From Allgemeine Fischerei-Zeitung, No. 24, 1894. H. Jacobson, translator.

is the depth, which should be as considerable as the nature of the ground and the absolute necessity of occasionally draining the ponds will allow. Even if there is a heavy flow of water into the raising-ponds, they should not have a depth of less than 1 meter (3.28 feet); and if it were not desirable to be able at all times to survey the bottom of the pond, through the water, throughout its entire extent, I would rather have the depth 3 than 2 meters (10 rather that 6½ feet).

The bottom of the pond should slope gently toward the aperture for letting the water off. The enormous pressure of the water, which is necessary in a pond of this depth, makes it desirable not to dam up the entire quantity of water, but to obtain at least half the depth by digging. It will be found advantageous to construct, if possible, several ponds (say four) at one and the same time, having a depth of 1.55 meters (4.92 feet) and a surface area of about 9 by 20 meters (29.5 by 65.6 feet).

It is necessary that every pond be arranged so that it can be absolutely drained; and it is an advantage if every pond has its inlet of fresh water independent of others. But with two pairs of ponds the lower ones should also receive the water of the upper ponds. The slopes on the banks and the bottom of the ponds should be well planed, and all hiding-places, sticks, stones, etc., should be removed, to provide for dragging nets through the ponds, which at a later period becomes necessary.

It is advisable to sow watercresses (the seed can be obtained from any seedsman) on the bottom and slopes of the pond immediately after it has been finished, and let in the water only about a week later, unless it is preferred to leave the second pair of ponds dry, to serve as reserve for emergencies. Wherever, in intensive feeding, it becomes necessary to deprive especially the shy brook trout of every hiding-place, the watercresses, which will soon grow luxuriantly, will later furnish shade for the fish and homes for the small aquatic animals which are as much needed for food in these ponds as in natural ponds. Long bean-poles (say, four to every pond) are laid in the surface of the water at regular intervals and bunches of watercresses are thrown among them; the cresses freely take root in the water and can easily be removed before the pond is dragged.

So far, I have only had reference to ponds dug out of the ground and have ignored the existence of raising-ponds constructed of boards or laid in with cement, such as are found in many places. These ponds, whose construction is very expensive, can be managed very easily, and the perpendicular sides afford good shade and a clear view of the entire pond. The growth of the fish, however, is very unsatisfactory in them, compared with ponds dug out of the ground (not to mention the smaller expense of the latter), and the excrements are not put to as good a use as in the earth-ponds, where the aquatic animalcula, which serve the purpose of removing refuse excrements, etc., thrive much better. I also think that trout make use of earth in digesting food.

Other fish than trout should of course not be kept in the ponds, and if possible only one kind of trout should be kept in each pond (char in the coolest ponds, brook trout in the warmer, and rainbow trout in the warmest). It is urgently recommended to introduce into the raising-ponds, at the very outset, swamp snails, small crustaceans, etc., to furnish the fish as much good natural food as possible and provide a means of clearing the ponds of the refuse of food and the excrements of the fish. Wherever fish are crowded together in a small space, and dead food is introduced, the natural equilibrium is disturbed, and this should be restored as far as possible by the introduction of live animalcula. At Sandfort there are, above and between the raising-ponds, special smaller basins dug out of the ground, which are thickly covered with

vegetation and which successfully answer the purpose of supplying the water with oxygen and live animalcula. For raising these animalcula I would not recommend ditches with standing water and liquid manure. It is true that these ditches develop a vast quantity of suitable live food, but they also produce water-beetles and other injurious animals.

The difficult question as to the proper quantity of fry to be placed in a pond can be satisfactorily answered to suit each individual case only. At Sandfort 4,000 young fish are placed in autumn in a raising-pond with an area of 180 square meters (1,937.5 square feet) and a depth of 1.5 meters (4.9 feet), and as the principal object is to produce as fast as possible a fish weighing not more than one-fourth pound (the favorite weight), all small and weakly as well as all fry of excessive size are eliminated, and the normal fish measuring 8 to 11 centimeters (3.1 to 4.3 inches) are used for raising. Where artificial food is used, artificially raised and fed fry are the best, as fry from natural ponds are as a general rule not so even in size and are not evenly fed. I am also of the opinion that they are more inclined to cannibalism than domesticated fish.

The great advantage which a fish-cultural establishment possesses over the culture of natural ponds, is in its ability to place its products on the market or retain them, just as it suits the proprietor. The natural pond puts its products on the market at the wrong time, either in autumn when the season for selling trout has not yet commenced in the great fish market, or in spring after Lent is over. No wonder that under these circumstances fish-dealers guard their interests by making only cheap offers. But fish-dealers also know where they can get fish at a season when ice covers the natural ponds, without running any risk from short weight, losses from death, and other causes. With some little care, a fish-cultural establishment can manage to have its fish ready for sale at the proper time and when they will fetch the highest price.

Even if the young fish in course of raising are most carefully sorted, some will be retarded in their growth, while others will grow more rapidly than the rest. Those whose growth has been retarded (probably 10 to 15 per cent) should be placed in a reserve pond and fed there; customers for them will be found in the spring. Most fish, however, will have their full weight from October to December, and the regular rotation of a raising-pond can be completed within one year. Those fish which have grown more rapidly than the rest will, in a well-regulated fish-cultural establishment, serve for selecting breeders for future campaigns; and if there are larger ponds it will pay (as far as rainbow trout are concerned) to keep these fish for two years longer.

In stock raising-ponds it is, above everything else, necessary to have normally developed and evenly sorted fish; and these are best obtained in autumn from the yearling ponds, immediately after the close of the fisheries. The fish are then in prime condition, and, owing to the cooler weather, transportation is cheaper than in spring. In the raising-ponds the fish will eat and grow all winter through, and a 10-centimeter (3.9 inches) fish obtained in autumn will naturally turn out better than such a fish obtained in spring.

As a general rule, it is very difficult to accustom the German brook trout to artificial food. It is a shy fish, and must be deprived of every hiding-place, and placed in pretty close confinement to induce it to eat artificial food. But its Scotch cousin, the "Loch Leven," through domestication continued for several generations,

has not only lost much of its shyness, but by adapting itself to our circumstances has become a fish very closely resembling the German brook trout, and is particularly well adapted to artificial culture.

Our fish-culture, however, would hardly have reached its present height, if we had not adopted the two Americans, the char or American brook trout (*Salmo fontinalis*) and the rainbow trout (*Salmo irideus*). They must be considered as of primary importance in fish-cultural establishments. They will never crowd out our brook trout but will maintain a place in the public favor. The char, wherever it is known, already fetches a higher price than the brook trout; and the rainbow trout, which, owing to its enormously rapid growth, easily becomes too fat, finds a ready sale as a three-year-old fish, weighing from 1 to 3 pounds.

At Sandfort and several neighboring establishments a ready market has rapidly been created for all the above mentioned kinds of trout. When sold at the ponds they fetch the following prices: Brook trout, rainbow trout, and char weighing one-fourth to one-third pound, 3 to 4½ marks per pound (71 cents to $1.07); large rainbow trout, 2½ marks (59 cents). The last-mentioned price pays better, as regards large fish weighing 3 to 5 pounds, which require but one young fish for raising, than 3 marks (71 cents) for fish weighing one-fourth pound, where four are required to make 1 pound. It is, of course, not possible to procure in every locality sufficient space for raising trout as large as that; in comparatively small ponds the fish will not reach such a weight in three or four years, even if there is an abundant supply of fresh water and very ample food.

Fish need, as they grow older, more space and greater depth of water. At Sandfort, therefore, the two-year-old rainbow trout which have outgrown the desired weight and weigh about half a pound are (to the number of 600 or 700) placed in a pond having an area of about 1⅞ acres and a depth of water of 6 feet, and there reach during one more year the weight of 3 to 4 pounds per fish. It is probable that the same result could be obtained in a smaller pond with a greater depth of water; at any rate, 1,400 fish averaging 4 pounds are, from one year to the other, kept in Scotland in a pond having an area of 30 by 70 meters (98.4 by 229.6 feet) and a depth of 4 meters (13.1 feet).

It will be useful to get a proper idea as to the quantity of food required per year in a trout-raising establishment of average size and to learn the cost of intensive artificial culture as compared with extensive natural culture. It should be remembered that trout are very settled in their way of feeding and that it is difficult to accustom them to a change in the color and consistency of the food. It will therefore be useful, from the very start, to select such food as can be obtained regularly and when mixed can be steadily given to the fish. It is true that it does not hurt the trout to fast for a few days, but regular feeding is nevertheless one of the conditions of success.

Trout-raising establishments should, with the view to facilitate the sale of the fish, not be removed too far from the great highways, and if this condition is fulfilled it will also be easier to obtain food.

Salt-water fish make excellent food for trout and can be obtained regularly and cheaply; and these, with the refuse from the slaughter-house, must be principally relied on.

The fish-auctioneers at Hamburg, Altona and Geestemünde will gladly indicate the sources from which salt-water fish can be obtained. It is best to take such as are sold with the blood and entrails, as the sea scorpion and cod; herring are generally too

fat. Of slaughter-house refuse, the liver and lungs are the most important, and both are excellent. It is urgently recommended that only such food should be bought as has passed the inspection of slaughter-house inspectors. Large pieces of animals which are not suitable for human food are also dangerous for fish, and only when they have been boiled (as is done in some slaughter-houses) so as to bind the albumen contained therein, is it advisable to use them.

Both salt-water fish and the refuse from the slaughter-houses are ground fine in a machine made for the purpose (for establishments of the average size I would recommend No. 91, by Scheffel & Schiel, Mühlheim-on-the-Rhine, which, worked by hand, grinds 100 pounds in an hour) and then mixed; an addition of shrimp flour or meat flour is useful and gives consistency to the food.

According to my experience, 5 to 6 pounds of such food will be required for 1 pound of fish, provided the water is kept at the proper temperature—char, 12° Réaumur (59° F.); brook trout, 14 to 16° Réaumur (63.5° to 68° F.); rainbow trout, 16° to 18° Réaumur (68° to 72.5° F.)—which temperatures can easily be maintained if the direction in which the sun strikes the ponds and the flow of water through the ponds are carefully calculated. The cost of raising 1 pound of fish, including cost of administration and culture will in an average-size establishment be, at the very highest, 90 pfennig (21 cents) per pound. For fish weighing from 1 to 5 pounds the cost of rearing will be still less.

It is also recommended to use snails, caterpillars, etc., for fish-food. They will form an excellent addition to the above-mentioned articles of food. Even if the expense of collecting is rather high, I would give my fish nearly all the food of this kind which could be obtained.

The trout is a very voracious fish. An average establishment which has, e. g., two ponds of 4,000 young fish and intends to produce with these 8,000 fish, with a total weight of 2,000 pounds, will during one campaign have to procure 10,000 to 12,000 pounds of food, or on an average 240 to 250 pounds of food per week (say 200 pounds of fish and 50 pounds of slaughter-house refuse). Even in summer fish-food can be kept sufficiently fresh for three days if placed in large earthen crocks, covered with a little salt, and washed by running water. Even average establishments will therefore be able to procure twice a week a 100-pound basket of salt-water fish by railroad.

It is quite evident that, food being so cheap, a profitable intensive culture is possible. The greatest danger to be feared is the possibility of epidemics; this danger can not be entirely eliminated, but I am justified in saying that (1) healthy food, (2) a sufficient supply of aquatic animalcula for destroying the refuse in the ponds, (3) ponds dug out from the ground which, after every campaign, are cleaned (both bottom and slopes), well supplied with watercresses, and laid dry periodically, will form efficient preventives of epidemics.

In summer the fish should be fed about sunset, otherwise shortly after noon, and they should never get more food than about 5 per cent of their average weight. They ought not to be fed in sultry weather nor when the temperature is considerably above 22° Réaumur (81.5° F.).

I strongly object to feeding-tables in these ponds. The food ought to be thrown to the fish with a ladle, and so little at a time that they catch it before it sinks to the bottom of the pond. In using feeding-tables there is danger that the attendant, from sheer laziness, will pour the entire quantity on the table at once, thereby causing the

loss of a good deal of the food by its becoming watered, etc., not to mention that a feeding-table becomes a receptacle for decaying matter and enemies of the fish which fear the light of day.

The duty of tending the fish should be in the hands of one person; and, if possible, the fish should not be disturbed by visitors.

Fish raised for the market should, as long as the pond is well stocked, be caught with a smooth drag net, and the water should be allowed to flow off thoroughly; if this is observed their flavor is just as fine as that of the wild fish, although their flesh has not the same degree of firmness. The older fish are not in any way inferior to the wild fish; and the rainbow trout in particular, when older, gains an excellent, salmon-like, pure flavor. On some estates, and especially in many factories (particularly paper mills) an establishment, as recommended above, will be possible and profitable and might, on account of the better supervision, be founded close to the house, in a simpler manner and within a small space. I have laid special stress on the advantage of such an intensive culture conducted on a small scale, but it is certain that it will also afford a good deal of pleasure to the cultivator.

If, as in many cases, there are, near factories, dams with spring water which can be let off and which are to be devoted to intensive culture, though the area exceeds that referred to above, it will be advisable to put in a smaller number of fish, as in such cases the brook trout will not very readily take the food provided for it. I would confine the culture to the American fish, particularly the rainbow trout, and from the start arrange for a two year's rotation and for raising large fish. The largest possible fry should be selected (even if the price should be somewhat high), and not more than 2,000 young fish should be set out per acre. The American fish will in such ponds take to the food at once; and as far as the rainbow trout are concerned, it does not matter if there is a temporary stagnation in the pond.

In conclusion, I would state, as the leading principles of intensive pond-culture, the following:

(1) Plenty of cool water and deep ponds.

(2) Use evenly sorted young fish which are accustomed to the food which is to be provided for them.

(3) Stock the pond pretty thickly, especially with the fry of the char and the rainbow trout.

(4) Never use inferior food.

(5) At proper times clear the ponds of all fish, dry the ponds thoroughly, and clean them well.

NOTES BY S. JAFFÉ ON THE REARING OF YEARLING TROUT AT SANDFORT.[1]

Repeated inquiries as to the manner in which yearling trout are raised at Sandfort have induced me to give a brief sketch of our local experiences and manipulations. The results regularly obtained here (and which can be obtained in other places by similar methods, perhaps slightly modified to suit local conditions) presupposes a large and regular business, with the fundamental conditions of a regular supply of suitable water and ample opportunities for obtaining fresh food. The establishment must, moreover, have one suitable person devote himself entirely to the propagation of the young fish. It is also important, according to the Sandfort method, to know from what trout eggs the young fry are hatched. Fry whose progenitors were accustomed to artificial food are more easily and safely raised and (I here refer to the different varieties of the *fario*) the result will be all the better the further back the pedigree of the tame generation goes. These experiences agree with those of English and American establishments, like the other experience, that the fish if possible shall leave the egg in the water in which it is to live during its helpless period, which extends into the summer.

The manipulations employed in raising *fario* and the American varieties of the trout are nearly the same in the Sandfort establishment. Eggs of both kinds are hatched in thin layers in wooden troughs about 4 meters (13.1 feet) long, which, on the inside, are charred to the depth of 1 centimeter (0.39 inch). The breadth in the clear is 22 centimeters (8.65 inches); height, the same; the depth of water is 6 to 8 centimeters (2.4 to 3.15 inches). The young fry, immediately after they have left the eggs, are placed in freshly cleaned hatching-troughs (about 15,000 in a box), which at the end have oblique sieves of perforated sheet-zinc (perforation No. 9). The fry are not counted (the eggs are counted immediately before hatching), as the least touch will affect the mucous skin of the young fish and lay the foundation for fungous development. Healthy young fish will, wherever unfiltered brook water is used, entirely clean the bottom of the box, and until the loss of the umbilical bag little remains to be done except an occasional cleaning of the sieves. During this period the young fish lie densely packed close to the inlet on a space extending hardly 0.25 meter (10 inches) in length; and toward the end of the umbilical period the current of water passing through the box—which hitherto has been about 20 liters (5.3 gallons) per minute and per box—is strengthened and the solid lids of the box are replaced by lids made of fine wirework. From the very beginning of the feeding period a strong light is good for the young fish.

As soon as the young fish begin to look around for food it should be given them. The food consists of fresh hog-liver (that over a day old is dangerous), which is put through a small meat-chopper and then, with a knife, forced through a finely perforated piece of sheet zinc (perforation No. 4, pin size) and afterwards mixed with a raw egg, in the proportion of two eggs to one hog's liver. During the first time, one hog's liver and the attention of one person are sufficient for daily serving four boxes, each containing about 15,000 young fish.

[1] Die Aufzucht von Jahrfingen in Sandfort. Von S. Jaffé. From Allgemeine Fischerei-Zeitung, No. 9, 1895. H. Jacobson, translator.

This food is given by the teaspoonful from a feeding spoon, which is covered with zinc (perforation No. 4 for char, No. 6 for other salmonoids) and from which the pulp gradually sinks under the water. The young fish take to this food very readily, but only when it is driven toward them by a strong current. Trout will not, till far into the summer, skirmish for food. The *fontinalis* and *fario* act very differently in taking their food. The *fario* kinds (and I include among these the Scotch Loch Leven) remain close to the bottom, and only a movement of the head indicates that they are taking food; the *fontinalis* are distributed throughout the entire depth of the water and almost rush at the food. In order to satisfactorily raise the young fish it requires extraordinary patience and great care not to let any food fall to the bottom unused. The young fish soon learn to gather at the head of the trough, and the sooner they do this the better are the prospects of success.

Fry which have been badly raised or hatched—and I include among these both fry from too young parent fish, apparently looking very nice in the eggs, and those which in a closely packed hatching-apparatus have not received a sufficient supply of oxygen in the egg during hatching—will perish at this stage; and I can not sufficiently urge the necessity of obtaining eggs (unless they have been laid and hatched in the establishment itself, which is of course preferable) only from thoroughly reliable establishments, whose eggs may be somewhat higher priced but whose careful management is a sufficient guaranty for a good article.

Failure to raise young fish is in many cases caused by mistakes made in remote stages of the development of the eggs or the parent fish. Whenever fry perish it is by no means right to seek the cause in recent occurrences, as the feeding of the parent fish and the hatching of the eggs may have had a great deal to do with it. The great care which is essential for producing high-grade eggs will naturally limit their production and will justify the higher price asked.

Healthy fry will, as soon as they commence to eat, give very little trouble. In addition to the utmost care in giving the food to the young fish it will be necessary to thoroughly clean the boxes at least once a week. A nail-brush with strong bristles will answer this purpose admirably, and, after the water has been let out of the hatching-trough until it is only an inch deep, the sides are thoroughly brushed, commencing at the head. The young fish skillfully evade the brush and are rarely injured. From the commencement of the feeding period the water in each trough is twice a day made thoroughly turbid by pouring in a bucketful of water and rich sod soil mixed. After this has been done the young fish will always take their food more readily. After they have been thoroughly accustomed to take the food the troughs are emptied by taking out the bung at the end and the young fish are swept into large buckets with the water. Prior to this the Sandfort "nurseries" (large raising-boxes) are laid at anchor in the open bed of the brook near the hatching-house by being fastened to boxes and poles.

These "nurseries" are strong boxes made of wood 1½ inches thick with a well-finished and tightly fitting bottom of wood three-fourths inch thick. The sides are covered with plates of perforated zinc (perforation No. 9) and the boxes are furnished with closely fitting lids, which are covered with wirework and admit as much light as possible. The boxes should be placed in a strong current, and the stronger the pressure of water which the young fish have to resist the stronger and healthier they appear to be. The Sandfort brook is a mill stream with a very irregular current,

frequently rendered turbid by rainstorms, and with a depth of water varying from 0.5 to 1 meter (1.6 to 3.28 feet). After the water has become turbid the young fish appear to be in particularly fine condition. Each box now contains 10,000 to 20,000 young fish—the smaller number if brook trout, the larger if rainbow trout. It is customary in Sandfort to pour the tiny fish, immediately after they have been hatched, into these "nurseries" and to begin the feeding process, which with the rainbow trout is very easy, in these boxes. As the young fish grow the food is gradually changed to calf-liver without egg and then to beef-liver, which in June is fed to the fish just as it comes from the chopper. The feeding process has now become exceedingly easy and consists in simply throwing the food into the boxes with a common spoon. One person can easily serve six and later even ten boxes.

In June the young fish are transferred to earth-ponds and sorted closely according to their size. Henceforth the losses will be very few. The use of "nurseries," especially for young rainbow trout, has the advantage of great safety and cleanliness. The boxes are, after every campaign, covered with a coating of asphalt lac, and thus last for years. While the young fry are in the boxes, the earth-ponds can be thoroughly cleaned and dried; and as they are filled again late in the season (in June) a limit is thus set to the development of larva and vermin. The cost of such a box, according to its more or less careful finish, varies from 50 to 70 marks ($11.90 to $16.66), which can hardly be considered too much, in view of the comparatively high value of the yearlings produced.

Of fourteen boxes which in 1893 were used in the Sandfort establishment, those containing rainbow trout yielded the best results. One box, which had been stocked with young fry from 20,000 eggs, produced in June over 17,000 young fish. It is possible to keep the young fish in the boxes till November, in smaller numbers (up to 5,000); but, from June on, the growth in the earth-ponds is much more satisfactory than in the boxes, especially as in ponds filled late in the season young fish find an ample supply of natural food, such as *Cyclops* and other small crustaceans, and later the small pond-snails.

The only objection which could be raised against this system, which is apparently based entirely on artificial food, is that such fish would not be able to get their food in a brook or open pond. But apart from the fact that the instinct for seeking food and for self-preservation is exceedingly strong in all animals, the well-fed young fish from the fish-cultural establishment will surely carry with him a greater reserve of food than the hungry wild fish, and would be more apt to push the latter away from the food than perish. Fish can (and this is hardly sufficiently known) live a long time without any food whatever, and even lose 50 per cent of their weight without perishing or losing the faculty of seeking food. To see how fish which have just been fed will go gnat-hunting, it will be sufficient to watch yearling ponds, like those at Sandfort, some afternoon or evening. The eye can not quickly enough count the fish which leap out of water for gnats. If this is not sufficient proof all that will be necessary will be occasionally to dissect an artificially raised fish, and see what its little stomach contains, in addition to the artificial food, in the shape of snails, gnats, and small crustaceans.

FISH-CULTURAL METHODS AT THE AGRICULTURAL SCHOOL AT FREISING.[1]

Not far from Munich is the little town of Freising, one of the most ancient places in Bavaria. At this place the ancient Benedictine convent of Weihenstephan has been converted into a school of agriculture and a modern brewery. When I learned that instruction in fish-culture was given at this school I was glad to accept an invitation of Professor Steuert, who has charge of the instruction in fish-culture and the care of fish, to visit Weihenstephan, and on December 12 I went there to study the methods pursued. All the arrangements are exceedingly simple. As the buildings of the ancient convent lie very high above the stream which flows through the town, the supply of water for the entire institution has to be forced up by a steam pump. From the general reservoir a small pipe leads the water to the place where the fish-cultural section of the establishment is located.

This section, which is intended both for hatching and rearing trout, consists of a large box whose bottom is elevated a little above the ground. On this stand two Le Petit apparatus, which serve as filters, the hatching apparatus, and, when the fish have developed, an apparatus for raising larvæ. Fig. A shows the appearance of the box. The water flows into the apparatus through the pipe *r*, is filtered, flows through the box and out into a collector at the side of the apparatus. Thence it is led into the collecting pipe R, which pours the water over a wheel *m*, which is in the trough *t*, above the surface of the water, and is thereby kept in rotation. In the trough *t* the young fish are generally kept till they are seven to eight months old. At the time of my visit Professor Steuert had in this trough both rainbow trout, which had been hatched last spring, and brook trout which had been used in autumn for supplying roe. All of these fish had been fed during the last few months on cheese, which seemed to have made them grow healthy and strong.

Fig. B gives a profile view of the apparatus. To keep out the cold of winter, the inner walls of the box had been lined with straw *h*. We found the water warm enough to prevent all danger of freezing during ordinary winters. As both the Le Petit apparatus and the wheel *m* (fig. A)—the so-called "feeding wheel"—have been thoroughly tested and found to answer, a drawing and a short explanation of the apparatus may not be out of place.

Fig. 1 shows the apparatus, viewed from the side, and a section of part of it. At *a* the water enters the apparatus, which is filled for about two-thirds of its height with gravel *c*, serving as a filter. Above this layer of gravel there is a perforated vessel (sieve), on the bottom of which the fish eggs are spread. Through the pipe *d* the water flows out into the collector above referred to. The apparatus is closed by a lid which has a small glass window at the top. After the young fish have been hatched and placed in the trough, and have grown so large that they begin to snap after larger morsels of food, the apparatus is made to answer another purpose (fig. 2.) The gravel is emptied out, the perforated vessel is taken away, and a frame with a coarser grating *e* is laid in the apparatus. On this frame meat (refuse from butcher shops) is placed, the lid is put on, and a cover is placed over the little window. Through the opening *b* flies go to seek the meat and lay their eggs thereon.

[1] Letter from Bavaria, translated by H. Jacobson, from Fiskeritidskrift for Finland, No. 2, Helsingfors, February 17, 1895.

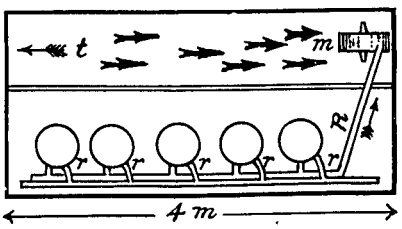


Fig. A.

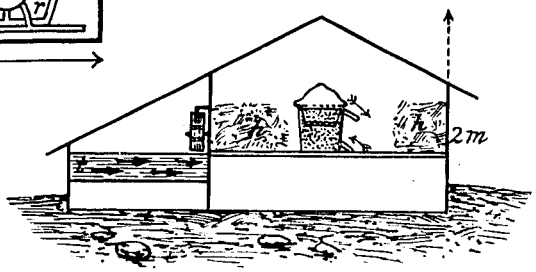


Fig. B.

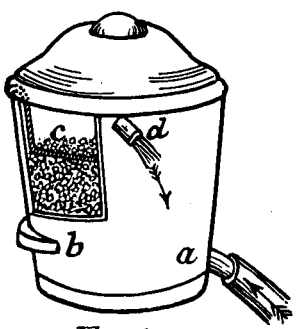


Fig. 1.

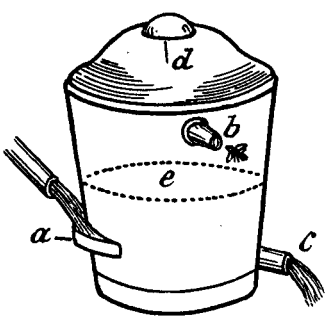


Fig. 2.

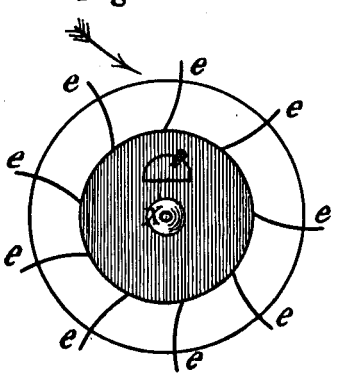


Fig. 3.

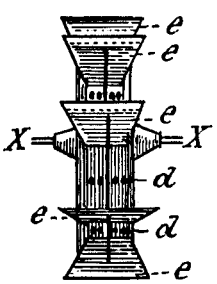


Fig. 4.

HATCHING APPARATUS AT FREISING.

When the larvæ have developed in the meat, the window is opened, so as to cause the larvæ, through the influence of the light, to go to the bottom. A stream of water is now let in through *a*, which drives the larvæ into the pipe *c* (fig. 2). Below this the trout gather in schools and watch for the food carried out with the water, with such eagerness that it is impossible for the larvæ to escape their voracity. On this fare the young trout thrive marvelously, and grow large and strong. The greatest advantage, however, of this arrangement is in the circumstance that there is no refuse to render the water impure or actually dangerous for the young fish; which is greatly to be feared when young fish are fed on liver or similar articles of food.

The so-called "feeding-wheel" consists of a cylindrical tin tray about 14 centimeters (5½ inches) in diameter, and 5 centimeters (nearly 2 inches) deep (fig. 3). The outer rim of the cylinder is perforated at *d d d* (fig. 4), and is provided with paddles *e e e e e*. The cylinder is moreover provided with an axletree. As this rests on two supports, and as a stream of water is forced against the paddles in the direction of the arrow (fig. 3), the cylinder is made to rotate, which motion causes the finely ground food inclosed therein to be gradually ejected through the apertures *d d d*. The young fish, which soon find this out, gather under the wheel—the waterfall—and catch the food. This arrangement has all the greater practical importance in feeding young trout, because, when the fish are fed by hand, they never get that portion of the food which falls to the bottom.

THE COURSE OF INSTRUCTION OF THE BAVARIAN FISHERY ASSOCIATION.[1]

I had the pleasure of receiving an invitation from Professor Steuert, who is a member of the Bavarian Fishery Association, to attend its course of instruction, where both theoretical and practical instruction in fish-culture are given. The meeting was held in the old building of the Royal Academy of Fine Arts, in Munich. The excellent work of the association was spoken of, and attention was called to the fact that the results were not solely due to practical work, but also to the aid which the association had at all times received from the scientists of the Munich University. Waters which were formerly fishless had been stocked with suitable kinds with such success as to give them a perfect wealth of fish.

A lecture by the well-known zoologist, Dr. Hofer, lasted from 10 a. m. to 7 p. m., with a recess of two hours. The lecture was in three parts: (1) Biological description of the kinds of fish which form the subject of the association's fish-cultural efforts; (2) the proper care and protection of the fishing waters; (3) fish-food.

Among the fish which the association had cultivated the speaker mentioned: Carp, tench, perch, bass (American), eel, trout (rainbow trout), German brook trout, American brook trout, and Alsace trout (a cross between the American brook trout and the European trout), grayling, gwiniad, etc., and finally the pike.

The speaker said that the carp was not indigenous to Germany, but was now found everywhere. He exhibited a number of select carp, which by cultivation had reached large and well-rounded dimensions, and which differed very much from the so-called peasant's carp, a small and insignificant-looking fish. There are two kinds

[1]Letter from Bavaria (concluded), translated by H. Jacobson, from Fiskeritidskrift for Finland, February 17 and March 16, 1895, Helsingfors, Finland.

of select carp in Germany, viz, Bohemian, which has a more elongated, and the Galician, which has a rounder shape.

It was formerly thought that carp lived on vegetable food, but it is now definitely settled that snails, crustaceans, and other small aquatic animals form its principal food. The carp gets albumen and soluble hydrates of carbon also from plants, and in many places it is therefore fed on boiled potatoes. For spawning the carp need water having a temperature of at least 14° to 15° Réaumur (63.5° to 65.75° F.); 18° Réaumur (72.5° F.) may be considered the best average temperature for the carp, and it can even stand 25° to 28° Réaumur (88.25° to 95° F.) without difficulty. With abundant food it can reach the weight of 4 pounds at the age of one year. Under ordinary circumstances it weighs 1 pound at two years, 2½ to 3 pounds at three years, and 3 to 5 pounds at four years. In many localities there is a demand for carp of a certain size, and owners of carp ponds must bear this in mind. An idea of the vast extent to which carp are raised in Germany may be gathered from the circumstance that Prince Schwarzenberg annually spends 250,000 florins ($100,000) for ground meat for feeding his carp. Mr. Burchardt, a prominent fish-culturist, received from Prince Hatzfeld 40,000 marks for bringing the prince's ponds up to a higher state of productiveness.

Perch are now quite common in Bavaria, but are not well suited for ponds. In their place American bass, both small and large mouth, have recently been introduced. The large-mouth, which can stand water of a high temperature, reaches the weight of 20 pounds. The small-mouth bass, on the other hand, requires colder water. The fish increase rapidly and with certainty, especially as the young are protected from enemies by their parents. For spawning they require a rocky bottom or one covered with coarse gravel. As perch grow slowly and generally do not reach a greater weight than 3 pounds, they should be supplanted by this more valuable fish. In Munich bass bring 2½ marks (59.5 cents) per pound.

The raising of eels is exceedingly profitable in Germany. One hundred young eels set out in a pond yielded 2,000 kilograms (4,410 pounds) of eels after three years.

The trout is very generally raised in Germany. It requires running water, but some kinds thrive in ponds. The common brook trout (*Salmo fario*) is not found in water of more than 18° Réaumur (72.5° F.). It is a predaceous fish.

The rainbow trout (*Salmo irideus*) which comes from the west coast of America, can stand both cold and warm water, the latter up to 25° Réaumur (88.25° F.). This alone makes it suitable for fish-culture. It spawns in spring, April and May. In cold water it reaches the length of 12 centimeters (4.7 inches) during the first year; 22 centimeters (8.7 inches) during the second year; 28 centimeters (11 inches) during the third year, and is then ready to spawn. The male fish are ready one year sooner. Under very favorable circumstances, and in water of high temperature, three-year-old rainbow trout have reached a weight of 5 pounds. It is much easier to raise this kind of trout than the common brook trout. It takes food much easier, is not predaceous, and is admirably adapted for pond-culture.

Of late years a brook trout (*Salvelinus fontinalis*) imported from America has been raised considerably in Germany. It has a dark-red belly and fins. It is found in very cold water, having a temperature of 7° to 8° Réaumur (47.75° to 50° F.), and grows faster in such water than other kinds of trout.

The speaker exhibited a cross between the German and the American brook trout, which has been called the *Alsace trout.* It is fatter and larger than the American and is best suited for small streams.

As regards the care of fish water, great stress was laid on the proper pains in establishing and maintaining the spawning-places. In Prussia certain spawning-places were protected all the year around in all larger sheets of water. The speaker did not consider it useful to place entire bays and coasts under protection, as these places then become favorite places of sojourn for predaceous fish. Arrangements should be made not to place in ponds too many kinds of fish living on the same kind of food, but rather such as live on different kinds of food. In this respect special regard should be had to shoal-water fish and to deep-water fish. Fish waters cared for in this manner have yielded good results in Bavaria.

As regards the *pike* the speaker stated that it was one of the most unsatisfactory fish for raising, on account of its voracity. Experiments had shown that it took 47 pounds of meat to raise 1 pound of pike. A beginning, however, had recently been made to raise pike in special ponds having a good supply of small fish. This had, for instance, been done in ponds having too large a stock of carp.

In regard to *artificial impregnation*, the speaker stated that, since the so-called "dry method" had been adopted, the percentage of impregnated eggs had increased from 50 to 80 or 90 per cent. Numerous investigations had shown that the spermatozoa of the male fish do not live in the water longer than 22 seconds, during which short time the eggs are not nearly all impregnated. Immediately after impregnation the eggs are very tender to the touch; and the fact had been positively ascertained that if a few days after impregnation the roe is disturbed on the frames in the apparatus, many eggs will perish. The germ in the egg is specifically lighter than the fluid contained in the shell, for which reason the germ always rises to the top. If the egg is turned, the germ again rises to the top, and this causes such a disturbance as to make the impregnated egg die. This does not apply, however, to gwiniad, perch, and some other kinds of fish, whose roe develops best if it is well stirred in apparatus specially constructed for the purpose.

The speaker finally showed, greatly magnified, the principal small aquatic animals which serve as food for fish. Experience had shown that Daphnia—very small crustaceans, most of them measuring no more than 1 to 2 millimeters in length (0.04 to 0.08 inch)—if properly treated, can be brought to a great degree of productiveness. The method is very simple. A ditch or small pond is filled with dry leaves, suitable aquatic plants, and manure (opinions differ as to the kind of manure to be used); a number of Daphnia are planted there and under the influence of the summer heat develop very rapidly. If the water in the ditch is allowed to flow through a pipe into the pond where the young trout are kept, the fish will thus be supplied with a sufficient quantity of natural food. When the fish are larger they are fed on larvæ of flies raised in Le Petit's apparatus. As the larvæ often grow too large for the fish, this difficulty is obviated by placing a fine grating before the opening of the apparatus so that only smaller kinds of flies can enter and lay their eggs; whereby, of course, smaller larvæ are obtained. As the air becomes cooler toward autumn the young fish are fed on the roe of salt-water fish (especially cod roe), which can be bought very cheap. Whenever the temperature is higher, the roe should be slightly salted and afterwards well soaked before it is fed to the fish by means of the feeding-wheel.

After the fish have grown they are distributed in small ponds measuring 15 to 20 square meters (161.5 to 215.3 square feet), which are always kept supplied with aquatic plants producing fish-food. The trout are now fed on a mixture of 30 per

cent blood and 70 per cent flour, dried and pressed through an apparatus which makes it come out in the shape of worms. Grown trout may also be fed on fresh refuse from butcher shops, but there should be an ample supply of fresh water in the ponds and suitable aquatic plants, in case the trout are fed on such refuse. Two-year-old trout are most in demand in the fish-markets.

The Starnberg Fish-Cultural Establishment, which belongs to the Bavarian Fishery Association, is near the little town of Starnberg and the large lake of the same name. This establishment, which is not very favorably located, was considerably enlarged and improved two years ago. The supply of water is furnished almost direct by the seven springs from which the little stream called Der Sieben Quellen Bach—the Seven Springs Brook—takes its origin. As the fall is but short and not very abrupt the water is led into the hatching-house through an iron pipe and forced to the height needed for the apparatus. On the higher bank of the stream a great many ponds have been dug, in which trout of different ages and of different kinds are raised. Mr. Le Petit has made several experiments in crossing different kinds of trout. He finds that it is of the greatest importance in what order the sex is employed.

The establishment yields a net revenue of 3,000 marks per annum ($714), and is expected to yield a great deal more after everything is put in proper working order. I was informed that some private establishments yield an annual revenue of 15,000 marks ($3,570).

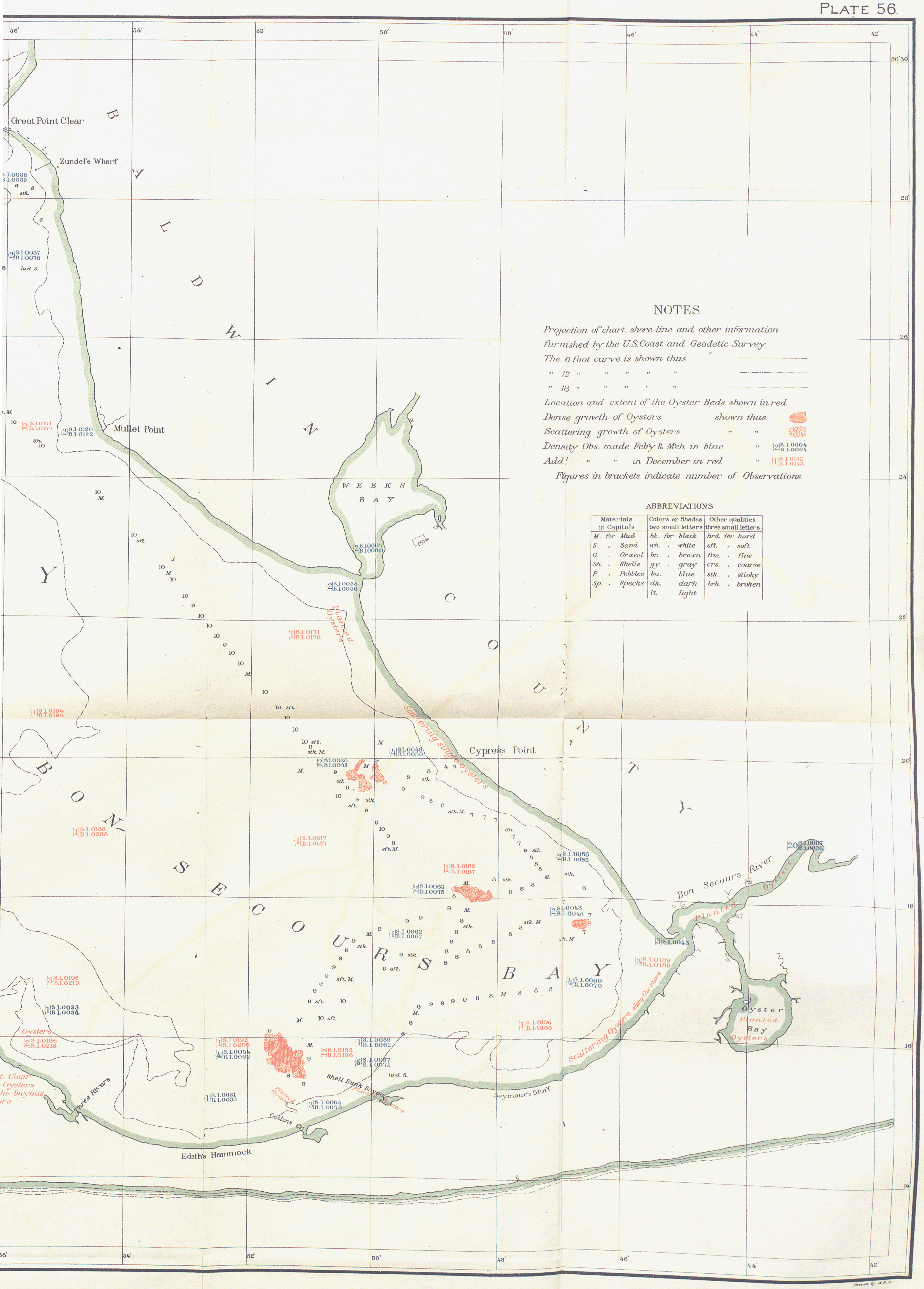
The visitors witnessed the so-called "striking" of trout, i. e., the impregnation of trout eggs. In doing this, Mr. Le Petit, who was considered to possess great skill and experience in these matters, employed a method halfway between the so-called dry and wet methods. First the roe was squeezed into a tin vessel and then the milt from the male fish. Then water was poured in the vessel; the milt of one more male fish was squeezed into it; the whole was thereupon stirred with the hand, the water was poured off, and the roe was slightly rinsed with the remnant of the water. After the eggs, impregnated in this manner, had been allowed to stand about five minutes in clean water they were placed in the apparatus for further development. The result of the impregnation was stated to have been very favorable, as high as 90 per cent.[1]

As the water used in the establishment has a natural temperature of 6° Celsius (42.8° F.), the eggs develop very rapidly, so that the eye-spots become visible after 36 days. The quantity of water used is 2.38 gallons a minute for each apparatus.

In January I again visited the establishment to take further observations of some of its arrangements, and during the same trip I also visited the fish cultural establishment near Mühlthal belonging to Prince Ludwig of Bavaria. This was founded two years ago, and appears to be arranged in a very simple and practical manner. The supply of water is furnished by a large spring. Here I had an opportunity to see a very large number of rainbow trout, born April, 1894. These trout, which were of considerable size for their age, were crowded together in a dense mass below a "feeding-wheel" containing cod roe. In an area of about 400 square meters (4,305.6 square feet), 10 small ponds had been dug, in which fat trout of different ages were basking in the sunshine. The water is introduced into these ponds through iron pipes.

[1] Special stress is laid on the fact that it cost a good deal to gain the experience that only trout seven to eight months or, better still, one year old, guarantee the reproduction of trout in waters which are to be stocked with these fish.

U.S. COMMISSION OF FISH AND FISHERIES,
MARSHALL McDONALD, Commissioner.
CHART
OF
MOBILE BAY
ALABAMA
SHOWING THE LOCATION
OF THE NATURAL OYSTER BEDS.
From a Survey made during Feby. & Mch. 1894,
By Party under direction of Homer P. Ritter, U.S.C.&G.S.
Assisted by W.F. Hill, U.S.F.C. and J.A. Smith, U.S.N.
Statute Miles
Nautical Miles
Feet
MOBILE COUNTY
BALDWIN COUNTY
MOBILE BAY
BON SECOURS BAY
MISSISSIPPI SOUND
DAUPHIN ISLAND
Dredged Channel to City 21 feet deep
Fowl River Pt.
White Ho.
Great Point Clear
Zundel's Wharf
Mullet Point
WEEKS BAY
Cypress Point
MOBILE BAY LIGHT
Portersville
Oysters
Planted Oysters
Fowl R.
FOWL RIVER BAY
Isle aux Herbs
No detailed Survey from Cedar Pt. westward
Mon Louis I.
HERON BAY
Cedar Pt.
Marsh Id.
Cat I.
Grants Pass
Pass Aux Herons
North Point
Little Dauphin Id.
Dauphin I. Bay
Ft. Gaines
Pelican I.
Middle Ground
BEACON R.
Little Point Clear
From Little Pt. Clear to Ft. Morgan Oysters are found in the bayous and along shore
Hog Bayou
The Spit
Navy Cove
Pilot Town
St. Andrews Bay
Three Rivers
South Bank
Ft. Morgan
Mobile Point
Edith's Hammock
Shell Bank
OLD BOILER
THE NORRIS PETERS CO., PHOTO-LITHO., WASHINGTON, D. C.


Great Point Clear
Zundel's Wharf
Mullet Point
BALDWIN COUNTY
WEEKS BAY
Planted Oysters
Scattering single oysters
Cypress Point
BON SECOURS BAY
Bon Secours River
Planted Oysters
Oyster Bay
Planted Oysters
Scattering Oysters along the shore
Shell Bank Bayou
Planted Oysters
Three Rivers
Collins Cr.
Seymour's Bluff
Edith's Hammock
NOTES
Projection of chart, shore-line and other information furnished by the U.S.Coast and Geodetic Survey
The 6 foot curve is shown thus
" 12 " " " " "
" 18 " " " " "
Location and extent of the Oyster Beds shown in red
Dense growth of Oysters shown thus
Scattering growth of Oysters " "
Density Obs. made Feb'y & M'ch in blue " {2}S.1.0004 B.1.0004
Add.l " " in December in red " {1}S.1.0152 B.1.0173
Figures in brackets indicate number of Observations
ABBREVIATIONS
Materials in Capitals: M. for Mud; S. " Sand; G. " Gravel; Sh. " Shells; P. " Pebbles; Sp. " Specks
Colors or Shades two small letters: bk. for black; wh. " white; br. " brown; gy. " gray; bu. blue; dk. dark; lt. light
Other qualities three small letters: hrd. for hard; sft. " soft; fne. " fine; crs. " coarse; stk. " sticky; brk. " broken

6.—REPORT OF A RECONNOISSANCE OF THE OYSTER BEDS OF MOBILE BAY AND MISSISSIPPI SOUND, ALABAMA.

By HOMER P. RITTER,
Assistant, United States Coast and Geodetic Survey.

INTRODUCTION.

On February 1, 1894, I was detailed by the Superintendent of the United States Coast and Geodetic Survey to conduct, under the direction of the United States Commissioner of Fish and Fisheries, an investigation relative to the oyster beds of Mobile Bay and vicinity. Having received the necessary instructions, and having obtained from the office of the Coast Survey the requisite instruments, projections, charts, and other data for carrying on the inquiry, I proceeded on February 7 to Mobile, Alabama, where a tugboat had been placed in readiness for the work.

The party consisted, besides myself, of Mr. W. F. Hill, assistant, United States Fish Commission, and Mate James A. Smith, United States Navy, with the addition of a leadsman, who also acted as boatman, oyster pilot, etc. The crew of the boat comprised Capt. Barclay Spottswoods, an engineer, a fireman, and a cook.

The instrumental observations were made conjointly by Messrs. Smith, Hill, and myself; and in running sounding lines the captain of the boat acted as pilot.

Field operations began on February 10, and were continued until March 24, when the party disbanded. Soon after my return to Washington I was ordered to Alaska. During the summer the field notes were reduced and platted by Mr. W. F. Hill, who has also done considerable of the collating, measurement of the areas, and detailed description of the oyster beds.

During the time that the survey was made, extensive freshets prevailed in the streams tributary to Mobile Bay, nearly filling the entire bay with fresh water and extending far into Mississippi Sound, so that it was considered desirable to take an additional series of densities at a time when more normal conditions prevailed. Upon my return from Alaska I was therefore instructed to make another visit to Mobile Bay, where I succeeded in chartering a small oyster schooner, and from December 1 to 7 made a series of density observations distributed over the oyster-bearing portion of the bay.

INSTRUCTIONS.

The instructions issued by the Commissioner of Fisheries for the guidance of the party in conducting the observations, and which were adhered to so far as the time and weather permitted, were essentially as follows:

It will be the special object of the investigation to determine—

1. The positions, outlines, and characteristics, and the general richness of the oyster beds located in the waters of Mobile Bay and Mississippi Sound, within the boundaries of the State of Alabama.

2. The positions, outlines, and characteristics of all areas of the bottom, in the same region, which appear to be suitable for the planting of oysters, either (*a*) in their present or natural condition, or (*b*) after preparation.

It is considered most important to complete the survey in Mobile Bay first, and then to carry it through Mississippi Sound to such an extent as the time will permit.

By the term oyster bed is understood an accumulation of oysters of sufficient extent and productiveness to permit of its being worked with more or less profit by the customary methods of oystering. That any collection of oysters is entitled to be so designated may be determined by the testimony of the oystermen of the region, one of whom will be engaged as pilot, and by the actual examination of specimens obtained by tonging or by other means. All deposits of oysters, however, whether of workable extent or not, should be taken into consideration and be appropriately described and platted upon the chart. Areas of bottom suited to oyster planting and growth are generally considered to be such as are sufficiently firm to prevent the oysters from sinking into the bottom and at the same time possess sufficient cohesion to resist the shifting action of the waves, all other conditions being also favorable. Very soft, muddy bottoms are unsuitable, but those of a somewhat firmer consistency can often be rendered appropriate by first covering them with a layer of stones and shells, and such areas should be noted. In fact it will be best to so indicate upon a chart the conditions of the bottom throughout the bay, where the conditions are otherwise suitable, that all of its characteristics in this respect may be plainly brought out.

In connection with this subject, however, it is of prime importance to determine the density or salinity of the water, the observations upon which may alone be sufficient to show the unsuitableness for oyster growth of any portion of the bay or sound. Density and temperature observations should therefore be made over the entire bay and sound, to the extent of ascertaining with certainty the conditions of their waters in this respect in all parts during the continuance of this survey; and from local authorities information should be sought concerning the greater influx of fresh waters during freshets in rivers tributary to the bay. Officers of the United States Engineer Corps now stationed at Mobile may be able to furnish this information. The minimum density in which oysters are considered to grow to advantage in Chesapeake Bay is about 1.0100 or 1.0110.

This survey will be regarded as in the nature of a reconnoissance, and the work should be pushed as rapidly as seems to you expedient. It will be best, however, to make collections of oysters from time to time, by means of tongs or such other methods as are available, and the specimens preserved for transmission to Washington. Specimens of any natural enemies of the oyster which you may discover or which the oystermen may point out should also be preserved for future study.

It is not considered advisable to spend more time in those parts of the bay where oysters do not occur or could not be made to grow than may be regarded by you as necessary to establish those facts. From information now at hand it seems probable that the existing beds in the bay are confined to the lower part of the bay, and chiefly to the eastern and western sides. It is therefore possible that your work will be mostly limited to those localities, so far as the bay is concerned, and that you may be relieved from a detailed consideration of other parts of the bay, after they have been subjected to a rapid examination.

Mate James A. Smith, United States Navy, and Mr. W. F. Hill, assistant, United States Fish Commission, who will be members of your party, have both had considerable experience in this character of oyster investigations, and they will be able to advise you as to many details which have not been explained in these instructions.

It is requested that the results of the investigation be presented in the form of a chart and descriptive report suitable for publication. The chart should show, by means of colors, the distribution of oysters in the bay and sound (their relative abundance being indicated by differences in intensity of coloring), the areas of bottom suitable for oyster-planting, and all other areas which may be considered as offering no opportunity or advantages for oyster growth.

METHODS USED AND SUMMARY OF WORK.

The areas and location of the oyster beds were determined by the ordinary methods in use in hydrographic surveying. A chart projection of the locality to be examined was obtained from the Coast and Geodetic Survey before starting for the field. On this projection there had been platted triangulation points, shore lines, and other data from Coast Survey records. Upon arrival in the field some of the triangulation points were found and signals erected thereon; and such additional intermediate signals as were needed were put up and located by triangulation (sextant). In the

execution of the survey there were erected seventeen of these tripod signals, which with flag pole were about 20 feet high. These signals, together with known triangulation points, such as Mobile Bay Light, Fort Morgan Light, Sand Island Light, and others, enabled us to locate ourselves in any part of the bay at all times.

Most of the signals were erected by Mr. James A. Smith, whose general executive ability and long experience in hydrographic surveying were of much value in the successful execution of our work.

The method of procedure was generally as follows: After having obtained from the local oystermen the approximate position of the oyster beds, or "reefs" as they are locally designated, the locality in the immediate vicinity was subjected to a careful examination by running a series of sounding lines covering the entire area. The soundings were taken with a pole whenever the depth permitted it. In addition, a chain let off from the bow of the tug and dragging along the bottom was found to be of great assistance, the lack or the intensity of the rumbling of the chain invariably indicating whether it was passing over mud, sand, broken shells, or live oyster beds. As often as necessary the position of the boat was fixed by measuring with sextant the angles between three or more of the triangulation signals. In this manner a sufficient number of points marking the outline and extent of the oyster beds were determined. Frequent stops were made and samples of the bottom dredged up and examined.

During most of the time that the survey was in progress, tidal observations were made in the bay at Shellbank Bayou. From these observations a mean low-water plane was established, to which the soundings shown on the chart have been reduced.

In determining the density of the water, United States Fish Commission hydrometers Nos. 7114, 7164, 7145, and 7152 were used. They are of the type described in Appendix 16, Coast and Geodetic Survey Report for 1874, except that in those now used the centigrade thermometer has been substituted in place of the Fahrenheit and the hydrometer graduated to give densities referred to pure water at 4° C.

In obtaining the water from places other than the surface the Haskell hydrophore, or water-specimen cup, was used and found to give satisfaction. This instrument, devised by Mr. E. E. Haskell, formerly of the Coast Survey, enables one to obtain the specimens of water with the certainty that the water brought up comes from the level to which the instrument had been lowered.

The examinations were made from February 10 to March 24, 1894, and December 1 to 7, 1894. The following is a summary of the field work:

Number of days on which field work was done	23
Number of days during which field work was prevented by stormy weather and other causes	26
Number of soundings and determinations of bottom	3,220
Number of angles taken	1,400
Number of density observations	394
Number of temperature observations	591
Number of signals erected	17
Number of days of tidal observations	23
Area examined roughly, square miles	200
Area examined more minutely, square miles	50
Area of natural oyster reefs located, acres	3,105
Number of miles of sounding lines and determinations of bottom	177
Number of specimens collected	35

GENERAL REMARKS.

The results of this survey, which must be regarded more in the nature of a reconnoissance, are shown upon the accompanying chart. The investigations were confined principally to the waters of Mobile Bay and the eastern end of Mississippi Sound. The location and extent of the natural oyster beds are shown, as is also the density of the water in the different parts of the bay, showing what it was during a heavy freshet and also after the succeeding protracted drought. The depth of water and nature of the bottom are also indicated wherever examined. The sounding lines as run are given, thus showing what areas have actually been gone over and where to make future examinations if desired. As most of the information obtained by us will be found in the detailed description of the various localities examined, I will preface them with only a few remarks. From the most reliable information we could gather, and which is borne out by our investigations, the northern limit for oyster growth in Mobile Bay is a line extending from Fowl River on the west to Great Point Clear on the east.

The location of the oyster beds as shown on the chart indicates that in the bay the greater part of the natural oyster beds lies between the 6-foot and 12-foot curves. From all the information we could obtain the local impression seems to be that few if any oyster beds exist beyond the 12-foot curve. On account of this information and the limited time at our disposal, which was still further curtailed by almost continuous stormy weather, all of which restricted the investigation to the localities close along shore, this large area could not be gone over. On the Coast and Geodetic Survey chart of Mobile Bay the bottom of a large part of this area is designated as soft, though portions of it are shown to be sticky mud, and even shells and shelly bottom; this seems to indicate that close examination might discover oyster beds not now known.

EASTERN SHORE OF MOBILE BAY.

On the eastern shore our investigations were confined to the survey of the oyster reefs pointed out to us by the local oystermen, and some sounding lines run in passing from one locality to the other. The known reefs are few in number, of small size, and considerably depleted, due doubtless to excessive fishing. The total acreage of the reefs surveyed by us on this side of the bay amounted to less than 500 acres; but the oysters are generally large and of fine quality. They do not grow so much in bunches as those found on the western reefs.

Oyster planting is carried on to a considerable extent in the southeastern part of this side of the bay, especially in and around the mouth of Bon Secours River and in Oyster Bay.

Bon Secours River and Oyster Bay are said to have very little space suitable for oyster-culture which is not already occupied. At the mouth of Fish River and at several places on the south shore, such as Shellbank Bayou and Collins Creek, the culture of the oyster has been undertaken by some progressive people and, so far as reported, with good results.

By an inspection of the accompanying chart it will be seen that that portion of the bay lying to the eastward of a line drawn from Fish River to Shellbank Bayou Reef contains the principal natural oyster beds which are at present worked. The lines of sounding show just how closely this area was gone over during our investigation. It will be seen that the beds are distributed quite evenly over this whole area and

there seems to be no apparent reason why those particular spots should offer any special advantages to the growth of the oyster. The bottom, although generally soft, contains areas which are of somewhat firmer consistency. From an inspection of the densities it will be seen that during the freshet which prevailed during the early part of the year the density of the water was uniform over this part of the bay and that the densities which were taken the following December (after a protracted drought) likewise show the salinity of the water to be uniform. The depth of the area lying outside of the 6-foot curve varies from 7 to 10 feet, of which a considerable part is about 8 feet. Between the 6-foot curve and the shore are areas of hard sandy bottom. This area contains 19,000 acres, and a large part of it may be classed as suitable for oyster-culture.

In the large area which lies to the north and northwestward of the section just described—taking that portion which lies between the shore and the 12-foot curve—no oyster reefs are said to exist, except the one in the vicinity of Great Point Clear. It would be interesting to make a more minute examination and determine from actual survey if oysters exist, and to what extent, over this area containing over 37,000 acres.

The bottom of a large portion of this area which lies outside of the 6-foot curve is soft; but sticky bottom, hard mud, and even sand frequently occur. The observed densities taken in this section do not vary much from those at the places where the oysters are found. If there are no more oyster reefs it may be simply due to the lack of something suitable on which the spat could catch during the spawning season.

WESTERN SHORE OF MOBILE BAY.

On the western side of the bay the natural oyster beds are found to be much more extensive than those on the eastern shore. The beds are larger, and at present in a more flourishing condition. They may be somewhat favored in the struggle for existence by locality, lying as they do more in the pathway which the fresh waters from the large tributaries at the head of the bay are said to take. This may be the source of an abundance of food, although at times this fresh-water supply may become a danger by continuing too long.

At present oyster beds are found all along this side of the bay, and they extend from Fowl River to Grant Pass, a distance of 12 miles, and then for 4 miles more in a southeasterly direction and parallel to the northern shore of Little Dauphin Island.

From the accompanying chart it will be seen that they are almost entirely confined to the area lying between the 6-foot and the 12-foot curve. That the 6-foot curve defines the inshore limit of these beds is probably due to the fact that this is about the outer limit of the sandbar which skirts the entire shore in this part of the bay. The outer edge of this bar is from one-half to 1 mile from shore. It is only along the outer edge that this sandy cordon is continuous, for in many places between here and the shore are found areas of mud of various degrees of hardness.

The area between the shore and the 12-foot curve, from Fowl River to the eastern end of Little Dauphin Island, comprises about 25,000 acres, 5,000 acres of which lie between the shore and the 6-foot curve. The actual location and extent of the natural beds or "reefs" are shown on the chart. As far as surveyed they amount to 2,245 acres.

MISSISSIPPI SOUND.

After finishing the survey of the reefs in the vicinity of Grant Pass, but a few days more being at our disposal, a trip on the sound as far as Portersville was made. A number of density observations which were taken on the way showed that the water was fresh at this time as far as Portersville, and we were told that it extended much farther to the westward. The general shallowness of the oyster-bearing portion of this part of the sound, the wide distribution of the oysters, the necessity of doing most of the work from small boats, and the close distinction to be made between the natural and the plant beds—as it is claimed that a large part of the present plant beds is located upon sites of depleted natural beds—precluded any detailed survey being made at the time.

A survey of this region to be of practical value must be one of considerable detail and will have to be made when the contemplated oyster investigations in these waters are continued, but a few remarks as to the general extent of the oyster-grounds are here given. The distance, measured on a straight line, from the western end of Grant Pass to a point where the Alabama State line strikes the sound, is 15 miles. The water area embraced between that line and the shore north of it may be roughly estimated at 35,000 acres; two-thirds of this area has less than 6 feet of depth and the remaining third averages less than 9 feet.

That much of this area may be considered suitable for oyster-culture is borne out by the circumstance that oysters are growing in all parts of it. To the above area may be added no less than 10,000 acres of marsh, which if the occasion should demand might, with comparatively small outlay for dredging, be changed into canals or basins, which would make ideal oyster gardens. It will then be possible to exclude the voracious drumfish; and the catch of the spat of the oyster can be controlled, and not subjected, as at present, to chance conditions of wind, waves, and currents.

Between the above-mentioned line and the islands south of it the area of that part of the sound which lies in Alabama amounts to something over 55,000 acres. Little is known of the bottom of this region. The depth does not go over 17 feet and a quarter of the area is less than 12 feet. Much valuable information in regard to oysters in this vicinity was obtained from Mr. John J. Delchamps, a gentleman of wide information and experience, whose study of the oyster extends over many years. At my request he has written a short article on the subject, and I have taken the liberty to insert it in this report. (See page 339.)

EASTERN SHORE—DESCRIPTION OF AREAS EXAMINED.

Great Point Clear.—In this locality there is an oyster reef which lies 2¾ miles SSW. of Great Point Clear. It contains 53 acres, of which 30 acres are "rank" (a term which is used to express dense growth) and 23 acres are scattering. The depth of water ranges from 8½ to 10½ feet. The bottom consists of soft mud, with occasional patches of hard mud and sand; no grass found. The changes in depth over the reef were found to vary but little, no more than a foot.

Two density observations taken here, one February 16 and one March 16, give a mean of 1.0009 for the surface and 1.0032 for the bottom. During the early part of the following December the density for this locality was about 1.0160. The above densities and those following in this report have all been reduced to a standard temperature of 15° C.

The temperature of the water at both surface and bottom on February 16 was 11° C.; on March 16 the surface was 22° and the bottom 19°. During the early part of December there was a uniform temperature of 17° top and bottom.

The condition of this oyster reef can hardly be said to be flourishing. Although comparatively little oystering is done here at present, there is little indication that the reef is extending its limits; rather, judging from the condition of the specimens of oysters we caught and its situation near the northern limitation of oyster life in the bay, the tendency may be to diminish the extent of these grounds.

The quality of the oysters was fair; some were quite fine and fat, but of course at that time very fresh to the taste. Oysterman Robert Cook, who showed us the locality of the reef, said that most of the oysters on this reef were soft-shelled and did not well stand shoveling. The growth of mussels was very abundant and their presence must be deleterious to the growth of the oyster. Several borers, locally known as conchs, whelks, or drills, were brought up with the specimens we obtained by tonging; also several "oyster fish," though the latter are probably not injurious.

Great Point Clear Reef to Cypress Point.—From Great Point Clear Reef to Cypress Point is a distance of about 10 miles. We were informed that there were no known oyster reefs in this locality at present. Years ago there had been a reef off Mullet Point, but it is now extinct. Our time being short and bad weather threatening to further curtail it, the investigation of the bottom of this area was limited to a single line of soundings, which was run from Great Point Clear Reef to Cypress Point without discovering any reef. Abreast of Mullet Point an area of mud and shells was passed over, and this may have been the old reef.

Mr. Dorval Weeks, who lives at the entrance of Weeks Bay, told us that twenty-five years ago oysters grew in that bay, though none were growing there now; he also said that several attempts had been made in late years to plant them there, but with poor success. Lately Mr. Weeks has started a plant bed just south of the mouth of Fish River. This plant bed is about 1,000 yards long and 200 yards from shore and is doing well at present.

That a more minute investigation in this locality would discover a number of beds of small extent is quite likely; in fact we were told such lumps have been found, but the finder generally keeps the knowledge to himself.

Fish River Reef.—This oyster reef lies 1¼ miles W. by S. of Cypress Point. The reef contains about 83 acres, 19 of which are rank and 64 are scattering. The depth of water ranges from 7 to 10 feet. The bottom is soft mud, with some sticky and some hard areas. No grass was found. The area covered by the oysters generally is found to be from 1 to 3 feet higher than the surrounding terrane, doubtless due to the fact that the reef has built itself up.

The mean of two density observations taken on February 27 and March 16 give 1.0036 for surface and 1.0043 for the bottom density. The mean of four taken half a mile west of Cypress Point during the period between February 24 and March 16 give 1.0049 for surface and 1.0050 for bottom. Density observations taken in this locality on December 4 gave at a point south of the reef 1.0187 both for top and bottom, and at a point north of the reef 1.0171 for surface and 1.0176 for bottom.

On February 17 the temperature of the water in this locality was 12°; February 24 it was 11.5°; February 27 it was 8.5°, and March 16 it was 23°; the surface and bottom varied no more than half a degree. On December 4 the temperature was 18°.

This reef is said to be much overworked, and judging from our investigation such seems to be the fact. There were evidences of a good set of young oysters from the preceding summer, but the greater portion had been killed, and that, too, after obtaining quite a fair size, the shells being about an inch in diameter. A great many dead and broken shells, perforated by borers and covered with barnacles, were found on this reef.

Some of the oysters caught were of remarkably fine size, of good shape, and fat, but fresh, the latter quality of course being only temporary.

The enemies observed were mussels, barnacles, small crabs, and drills; the mussels thickly covered the oysters and the barnacles were plentiful. Almost every oyster was found to have a small crab living on the outside of the shell. Quite a large number of little conchs were found. The broken shells may indicate that the drumfish was a visitor to this reef, although it is said that this fish prefers to attack the oyster when single and seldom in the reef, as the oysters are then not so easily accessible. The planted oysters are more scattered, and then the drumfish becomes quite a serious enemy. I was told by one of the oystermen from the western side of the bay that recently he had taken 25 barrels of oysters from a reef, culled them, and then bedded them previous to taking them to market, and in one night the entire lot was destroyed by a school of drumfish.

Some good-sized oysters were found along the shore near Cypress Point. They were in good condition and were picked up at low water while going ashore to erect a signal.

Bayou Cour Reef.—This reef lies 2¼ miles S. ½ E. of Cypress Point. It contains 68 acres, 12 of which are rank and 56 are scattering. The depth of water ranges from 4 feet in the central portions to 9 feet at the edges of the reef. Sticky mud with frequent patches of hard and shelly bottom and occasional areas of soft mud characterize the bottom and for a considerable distance around it. The formation of this reef, like the previous one, is simply the result of a gradual accumulation of oysters and dead shells built up by the bivalves themselves and is now elevated above the surrounding bottom. This elevation is now about a foot near the edges and becomes as much as 5 feet at places near the middle of the reef. No grass was observed on this reef.

Two observations taken here on the 20th and 27th of February give 1.0063 for the top and 1.0075 for bottom. On December 4 it was 1.0189 for the top and 1.0187 for the bottom.

February 20 the surface temperature was 16°, bottom 14.5°; February 27, surface 12°, bottom 10.5°; on December 4 the surface temperature was 18° and the bottom 17.5°.

The condition of this reef, the quality of the oysters, enemies observed, etc., are about the same as found on Fish River Reef.

Bon Secours Reef.—This reef lies N. by W. 1½ miles from the mouth of Bon Secours River. It contains 38 acres, of which 12 are rank and 26 are scattering. The depth of water ranges from 4 to 7½ feet. The bottom is sticky mud, patches of soft mud, and shelly places. The surface of the reef is uneven and its general elevation is about 2 feet.

A mean of two density observations taken on March 1 and 16 gives surface 1.0043 and bottom 1.0046. Three observations taken here on December 4 give 1.0189 for surface and bottom.

In March the temperature of the water ranged from 13° to 22°. In December the water had a uniform temperature of 18.5°.

The condition of this reef seemed to be fairly good at the time of our investigation. It does not seem to have been overworked as much as the one northward of it, as the rank oysters are found to be more in proportion to area. There were found a great many dead shells and a few shells of young oysters. The young oysters were not plentiful, but this may have been due to the violation of the culling law, which requires that the oysters should be culled on the reef and the cullings (oysters not coming up to the requisite standard in size) thrown back into the water. The purport of this law is to prevent the extinction of the reef, but many local oystermen claim that by knocking off the young oysters and throwing them back into the water on the reef you make it easier for the drumfish to consume them, while if the reefer took the young oysters and planted them in his oyster garden the general prosperity of the industry would be increased even if the natural beds suffered.

The quality of the oysters from this reef was found to be very fine both as to size and condition, being fat and well-shaped.

The enemies observed were the same as on the neighboring reefs.

Bon Secours River and Oyster Bay.—In this locality the planting of oysters is carried on to a considerable extent. We were told that in Bon Secours River and Oyster Bay there remained very little space suitable for oyster-culture not already occupied. In the river the oyster gardens occupy the space between shore and the channel. They are situated on both sides of the river and extend from its mouth for a distance of nearly 3 miles. Oyster Bay has an area of a trifle over 1 square mile and is said to be equally as thickly planted. As in our investigation actual survey was confined to the natural reefs, the number of acres under cultivation can not be given. The bottom area of the river as far as planted, together with that of the bay, amounts to about 1,000 acres.

The planted oysters from this locality are considered very fine in the local market. The drumfish is said to be very destructive to the plant beds, so much so that in many instances brush fences are used to prevent their unwelcome visits; these fences are simply underbrush stuck in the mud around the oyster beds. This method, of course, is limited to shallow water and small areas.

Shellbank Reef.—This oyster reef, which derives its name from its proximity to a collection of oyster-shell heaps on the shore, lies N. by W. ¼ W., distant 1 mile from the mouth of Collins Creek. It contains 188 acres, 90 of which are rank and 98 scattering. The depth of water ranges from 4 to 10 feet. The bottom consists of soft and sticky mud and hard shelly lumps. This reef is similar in formation to those already described and is in the nature of a nearly flat mound, which rises in places to an elevation of 5 or 6 feet. There are also several outlying lumps.

One observation taken on February 22 and three on March 1 give a mean density of 1.0054 for top and 1.0062 for bottom. The density observation taken December 3 showed 1.0192 for top and 1.0205 for bottom.

During the latter part of February and the first days of March the temperature of water varied from 12° to 15°, with no change for difference in depth. On December 3 it was 18° for top and 19.5° for bottom.

This reef, we were informed by residents of this locality, was being rapidly depleted by excessive fishing and other causes, drills mostly, and is of much less extent than in former years; however, its condition seems to be as good as or better

than any of the territory in the eastern part of the bay. The evidence, from the specimens obtained, points to the fact that the drills cause considerable depredation. The specimens show that fine oysters grow on this reef; they were fat, well formed, and large. The oysters from this reef always command a good price in the Mobile market; and this fall, when 75 cents per barrel was being paid for western "reefers," the "Shellbank" oysters brought $1.75 per barrel.

Shellbank Reef to Fort Morgan.—No detailed survey was made in this section of the bay, for we were told that westward from Shellbank Reef as far as Fort Morgan there were no oyster reefs of importance. Up to within a few years there was a reef a little to the northeastward of Little Point Clear, but drills and sanding up have nearly destroyed it. Years ago it had an area of about one-fourth of a square mile.

From Little Point Clear to Fort Morgan oysters of fair quality are found in the bayous and along the shore. Some are of the variety locally called snapper or slough oysters, having a white shell. Although not generally in the market, they are said to be good oysters.

Planting is done to some extent in the bay north of Collins Creek, and is reported to give fair results. Shellbank Bayou and Collins Creek are also planted, the plants in these places being very fine. Some exceptionally fine specimens were shown us by Hon. H. P. Hanson from his planted beds in Collins Creek.

WESTERN SHORE—DESCRIPTION OF AREAS EXAMINED.

Fowl River.—In the area lying between the mouth of Fowl River and Mobile Bay Light a number of reefs of scattering oysters and oyster shells were found, separated from each other in some instances by a considerable distance. Altogether they cover about 100 acres, scattered over an area of several square miles. The depth of water here ranges from 5 to 14 feet. Soft mud, mud and shells, and patches of hard shelly places characterize the bottom.

During February and March the water was entirely fresh in this neighborhood and extended from the shore nearly to the light-house. In the early part of the following December a density observation taken near the shore gave 1.0116 for surface and 1.0117 for bottom, while another taken nearer the channel and just north of the beds gave 1.0118 and 1.0182, respectively.

During the first time that observations were made in this locality the temperature of the water varied all the way from 12° to 22°, depending on time and location, surface and bottom generally the same. On December 6 it was 17°.

The specimens obtained from these beds were mostly mud-covered shells, and, as well as could be judged, the beds were several inches under the mud. The proximity of these beds to the channel, which is being continually dredged, and the dumping of the mud taken from this channel near by are responsible for the depletion of these beds.

White House Reef.—This oyster reef, which received its name from a house standing on shore just west of the reef, lies between Mobile Bay light-house and Point Juliet. The reef is 3 miles long, extending NNE. and SSW. It varies in width from a few yards to 1,300 yards. Its nearest approach to the shore is at its southern extremity, which is 1½ miles offshore; its northern end is about 3 miles from shore. This reef contains 881 acres, of which 286 are rank and 595 are scattering.

The depth of water ranges from 7½ to 12 feet, with a general average of about 10½ feet. The bottom is about the same as that of the other oyster beds in the bay, except

that here there are numbers of patches of soft mud which are higher than the places upon which are found the oysters. These are doubtless scow loads of mud dredged from the channel and dumped here. I should say that the reef has become fully a third smaller from the above cause.

Two density observations, about a fourth of a mile apart, taken on March 13, gave 1.0007 for surface and 1.0035 for bottom for one and 1.0007 and 1.0016 for the other. Several other density observations were taken in this neighborhood, all indicating the water to be very fresh during the then prevailing freshet. The observations taken in December showed an average of about 1.0120 for this locality.

In March a temperature of 19° was found; in December about 17°.

The indications are that this reef is in good condition. Many young oysters were found attached to the larger specimens. The northern part of this reef is affected more or less by mud dumped in the neighborhood; but I presume that by the time the mud has become somewhat hardened the growing will go on again, for this whole western shore of the bay seems to be a favorable locality for oyster growth, judging from the wide extent of the reefs. The reef is separated into two parts by a short distance of mud bottom on which no oysters were found growing. As this mud is higher than the surrounding oyster-ground it presumably has been dumped there.

The quality of the oysters was good. They were fat and of nice flavor. The specimens caught had a good many young oysters attached, which in the lower part of the reef were growing nicely. While passing over this reef in December a hasty examination seemed to indicate that the young oysters had not suffered from the preceding drought in the early part of the year. Some perforated dead shells were noticed. The washing over of mud from the dredging dumps is probably of more injury to this reef than anything else. Many of the specimens taken had a coating of mud.

White House Reef to Birmingham Reef.—No oysters exist, so far as we could learn during our limited stay, south of Point Juliet until Birmingham Reef is reached. A distance of about 3 miles intervenes between Birmingham Reef and White House Reef. A series of sounding lines was run in passing from one reef to the other, but it will be seen by an inspection of the map that this area covered by our lines lies outside of the 12-foot curve, so that we can not say from actual examination whether or not there are any oysters there.

A number of density observations were taken in this locality during March, at different places along the 6-foot curve, showing that the fresh water extended at that time this far down the bay. In December the density of the water was found to be 1.0120. Depth of water and character of bottom are also identical with the locality just north of it.

Birmingham Reef.—This oyster reef lies about 2 miles E. by N. of Cedar Point. It is divided into two large beds and three smaller ones; in all containing 267 acres, 211 of which are rank and 56 are scattering. The depth of water over the reef varies all the way from 6½ to 12½ feet, the changes often being quite abrupt. The bottom is soft mud, with frequent hard shelly lumps.

This reef has gradually raised itself to a height of 5 or 6 feet above the surrounding bottom, the slopes at its edges being often quite abrupt. In considering this reef there has been taken into account all that portion which lies between the 6-foot curve and the wreck buoy.

On March 14 the density here was found to be 1.0018 for surface and 1.0065 for bottom. On December 5 it was found to be 1.0152 and 1.0173, respectively, for top and bottom.

In March the temperature of water was found to be 20° on top and 18° on the bottom; in December 17.5° for top and bottom.

The condition of this reef was good; the oysters were of good size, well flavored, and appeared to be in fair marketable condition. No enemies noted here.

Locality of Cedar Point.—A fair-sized oyster reef lies just northeast of Cedar Point, about half a mile from shore and extending toward Birmingham Reef, with which it may be connected, as the intervening patches of oysters shown on the chart seem to indicate. Its area is 139 acres, 87 of which are rank and 52 are scattering. The depth of water ranges from 2½ to 9 feet, with an average of about 5½ feet. The character of the bottom, condition of reef, quality of oysters, etc., are the same as for Birmingham Reef.

The mean of four density observations taken in March gives 1.0005 for top and bottom. The observed temperature was 15.5° to 16°. No density observation at this particular spot was taken in December.

Cedar Point Reef.—A reef of scattering oysters lies east some 300 yards off Cedar Point. It covers an area of about 45 acres. The depth ranges from 4½ to 7½ feet. The character of the bottom, condition of reef, and quality of oysters are the same as in the preceding reef, of which it may be considered a part. The reef was found to be overworked, its situation near the shore and largely in shoal water making it convenient for oystering.

Cedar Point to Pass Drury.—In the southwestern part of Mobile Bay, extending from Cedar Point to Pass Drury, a distance of over 4 miles, is found an extensive oyster reef, or rather a series of reefs which are practically connected. They begin about a third of a mile south of Cedar Point and extend from the shoals (which are occasionally bare at low water and which lie just north of Grant Pass) across the northeast end of Grant Pass and Pass aux Herons; thence in a southeasterly direction and parallel to the northern shore of Little Dauphin Island as far as Pass Drury. The width of the reef varies from about a third to half a mile and contains 813 acres 301 of which are rank and 512 are scattering. The depth ranges from 2½ to 14 feet.

The bottom is hard and shelly, with occasional patches of hard mud. Toward the eastward the reef becomes somewhat sandy, which has given the name of sand oysters to those taken from that locality.

A density observation taken in March in Pass aux Herons gave 1.0005 for surface and 1.0029 for bottom. A few days later one taken abreast of Pass Drury gave for surface 1.0056 and for bottom 1.0074. On the following 1st of December observations taken in the same localities made the surface density in Pass aux Herons 1.0173, the bottom being 1.0174. Near the southeastern end of Little Dauphin Island the surface was 1.0189 and the bottom 1.0227.

From March 8 to 15 the temperature of the water varied from 15.5° to 20.5°. On December 1 it was 17° in the pass and 18° in the bay.

The condition of the reef is good, though the portion lying in the vicinity of Grant Pass is somewhat depleted, probably due to excessive oystering. We were told that a great many of the oysters on this end of the reef had been killed by a storm in the fall of 1893. We found numbers of shells which had apparently been killed only recently. On the eastern portion of the reef the oysters were growing very rank

and we were informed that not much oystering was going on there; that, although very fine, the oysters were not well liked in the local market on account of the sand which was liable to get on them in opening. They were also said to "open" (become fat and fit for market) much later in the season than those nearer the pass. At the time we were here the oysters appeared to be of good size, fat, and palatable.

Grant Pass and vicinity.—Extending across Grant Pass and lying on both the north and south side of it is an oyster reef covering about 237 acres, 64 of which are rank and 173 scattering. On the south this bed extends to and across Pass aux Herons channel and onto the flats for some distance. To the northward the same is true; here it extends for some distance toward Cedar Point, increasing the area of this reef to about 400 acres. The depth of water over this area ranges all the way from 2 to 9½ feet, with an average depth of less than 6 feet.

The character of the bottom is largely hard and shelly, with areas of soft mud. The greater portion of the area is shoal, except where it is crossed by Pass aux Herons and Grant Pass.

We were told that the present condition of this reef was not flourishing. No doubt excessive fishing is the prime cause. While taking observations on this reef in December I was shown a number of fresh oyster shells with drill holes made by the "conch," and was informed by the local oystermen that these "conchs" were found to be more numerous this fall than had been noted heretofore, and that they sometimes found the oysters on large areas of the reef killed in that way. They also said that the "conchs" or "drills" are seldom found in the gullies, and that the "drill" seems to prefer hard shells to soft ones.

When culling oysters on the reef the oystermen generally separate the conchs from the cullings before throwing the latter back on the reef. The conchs are then destroyed. A persistent adherence to this rule must be of some benefit to the reef.

The quality of the oysters in this neighborhood was found to be good, their size and shape varying somewhat in the different localities of the reef.

Dauphin Island Bay and vicinity.—West of the entrance to Dauphin Island Bay are two small reefs containing about 15 acres each; one is composed of scattering oysters, the other about half rank and half scattering. From the mouth of Dauphin Island Bay to Pass aux Herons the bottom was examined with the above result and a few additional patches of scattering oysters were noticed. In this bay oysters have been planted and are said to be doing well; it is said that toward the eastern end they do not thrive so well, owing to a prevalence of water of high degree of saltness. Quite a fine specimen of oyster from the reef at the mouth of the bay was given us by Mr. Marshall, who lives on Little Dauphin Island; also a specimen showing the type of oysters growing in the bayous connecting this bay with Mobile Bay. The latter are of the "coon oyster" variety (long and slender) and some grow to such length that they are locally called "cow horns."

The bottom of the bay is mostly sticky mud; near the mouth areas of shelly bottom and sand are met with.

The mean of eleven observations taken at various times from March 8 to 21 gives a density of 1.0051 for surface and 1.0093 for the bottom; the lowest found was 1.0032 and the highest 1.0136. Six observations taken December 1 and December 4 give for surface 1.0182, bottom 1.0181.

It will be noticed that in the densities taken in December the water at the bottom was a trifle fresher than that at the surface. By an inspection of the densities shown on the chart it will be seen that this occurs in a number of instances. In our observations it was of frequent occurrence (especially at low-water stage), showing the prevalence of fresh-water springs in various parts of the bay. Whether this has anything to do with the distribution or the well-being of the oysters in this locality can hardly be determined from the limited number of our observations, and is here only pointed out as a possible field for investigation. Below is given a statement from the field notes showing that the phenomenon (fresher water at the bottom) was not due to an accidental reading of the hydrometer.

Dauphin Island Bay (middle) abreast Marshall's Store.

Date.	Time.	Temperature of air.	Temperature of water.		Observed density.		Depth.	Remarks.	Densities reduced to standard temperature, 15° C.	
			Surface.	Bottom.	Surface.	Bottom.			Surface.	Bottom.
1894.		° C	°	°			*Feet.*			
Dec. 1	8.30 a. m....	21.0	16.5	16.5	1.0176	1.0176	4.5	Water clear...	1.0179	1.0179
4	4.50 p. m....	17.0	17.0	17.0	1.0178	1.0176	5.0	Water clear, tide west.	1.0182	1.0180
5	7.30 a. m....	15.0	16.0	16.0	1.0182	1.0180	4.5	.....do	1.0184	1.0182
5	8.30 a. m....	14.0	16.0	15.5	1.0182	1.0180	5.0	.....do	1.0184	1.0181
5	9.00 a. m....	16.0	16.0	16.0	1.0180	1.0180	5.0	.....do	1.0182	1.0182
5	10.10 a. m...	15.5	16.0	16.0	1.0178	1.0181	5.0	.....do	1.0180	1.0183

Natural oyster reefs in Mobile Bay, Alabama.

Locality.	Area in acres.	Density of water during freshet, March, 1894.		Density of water, end of drought, December, 1894.		Depth of water.	Character of bottom.
		Surface.	Bottom.	Surface.	Bottom.		
						Feet.	
Great Point Clear Reef...	53	1.0009	1.0032	1.0160	1.0160	8½ to 10½	Soft and hard mud; sand.
Fish River Reef.....	83	1.0036	1.0043	1.0187	1.0187	7 10	Soft and sticky mud.
Bayou Cour Reef.....	68	1.0063	1.0075	1.0189	1.0187	4 9	Soft and sticky mud; shelly.
Bon Secours Reef	38	1.0043	1.0046	1.0189	1.0189	4 7½	Do.
Shellbank Reef.....	188	1.0054	1.0062	1.0192	1.0205	4 10	Do.
Mobile Bay Light to Fowl River	100	1.0000	1.0000	1.0118	1.0182	5 14	Do.
White House Reef	881	1.0007	1.0035	1.0120	1.0120	7½ 12	Do.
Birmingham Reef.....	267	1.0018	1.0065	1.0152	1.0173	6½ 12½	Do.
Cedar Point NE. ¼ mile...	139	1.0005	1.0005	.....	.....	2½ 9	Do.
Cedar Point E. 300 yards..	45	1.0067	1.0071	.....	.....	4½ 7½	Do.
Cedar Point to Pass Drury	813	*1.0005 †1.0056	*1.0029 †1.0074	*1.0173 †1.0189	*1.0174) †1.0227)	2½ 14	Hard, shelly, and sand.
Grant Pass.....	400	.....	.....	.....	.....	2 9½	Hard, shelly, sand, and mud.
Dauphin Island Bay and vicinity	30	1.0051	1.0093	1.0182	1.0181	3 7	Do.
Total.....	3,105						

* West. † East.

NOTE.—The above densities have been reduced to the standard temperature of 15° C. Fresh water = 1.0000; standard sea water = 1.0260.

NOTES RESPECTING OYSTERS OF MOBILE BAY AND SOUND IN MOBILE COUNTY, ALABAMA.

By JOHN J. DELCHAMPS.

From Cedar Point to Dauphin Island is a little over 2 miles, Grant Pass being midway. Within that distance are found a dozen sorts of oysters which, though all of the same variety, are yet so different in size, shape, etc., as to be recognizable at sight by oystermen, who tell at once from what flat, reef, or gully they were fished. Their differences are due to locality, depth of water, character of ground, and currents; so that oysters from one spot and removed to one only a few yards distant will in time assume the look and character of those native to the latter. Such varieties are "Oyster Pass," "sharpers," Dutch Island "gullies" and "flats," "Grant Pass oysters," "Pass Heron flats" and "Pass Heroners," "redfish gullies," "west-edgers," "new reefers," "sand reefers," "Dauphin Island Bay oysters," the last mostly classed now as plants but inferior.

Westward we find "Halfmoon" and "East and West Heron Bay" plants, the first of the class to fatten well in the fall; "Fowl River Bay plants," very fine also, but owing to circumstance of locality fattening later; thence westward, "Coden," "Portersville," "Bayou Batre," and "Little River" plant beds; none west of Fowl River Bay very extensive. Further on is Grand Bay, which is large and said to have a good many oysters, but of an inferior quality and therefore little visited by oyster boats.

Leaving the Sound we find in Mobile Bay proper, extending from near Dauphin Island and east of Grant Pass, an extensive reef; then from the Birmingham Shoal, a mile or so northeastward from Cedar Point, some 8 or more miles northwardly, there extend reefs or a succession of reefs distinguished locally as "Birmingham," "White House," "Austin," and "Middle Light," the oysters on all of which are about identical.

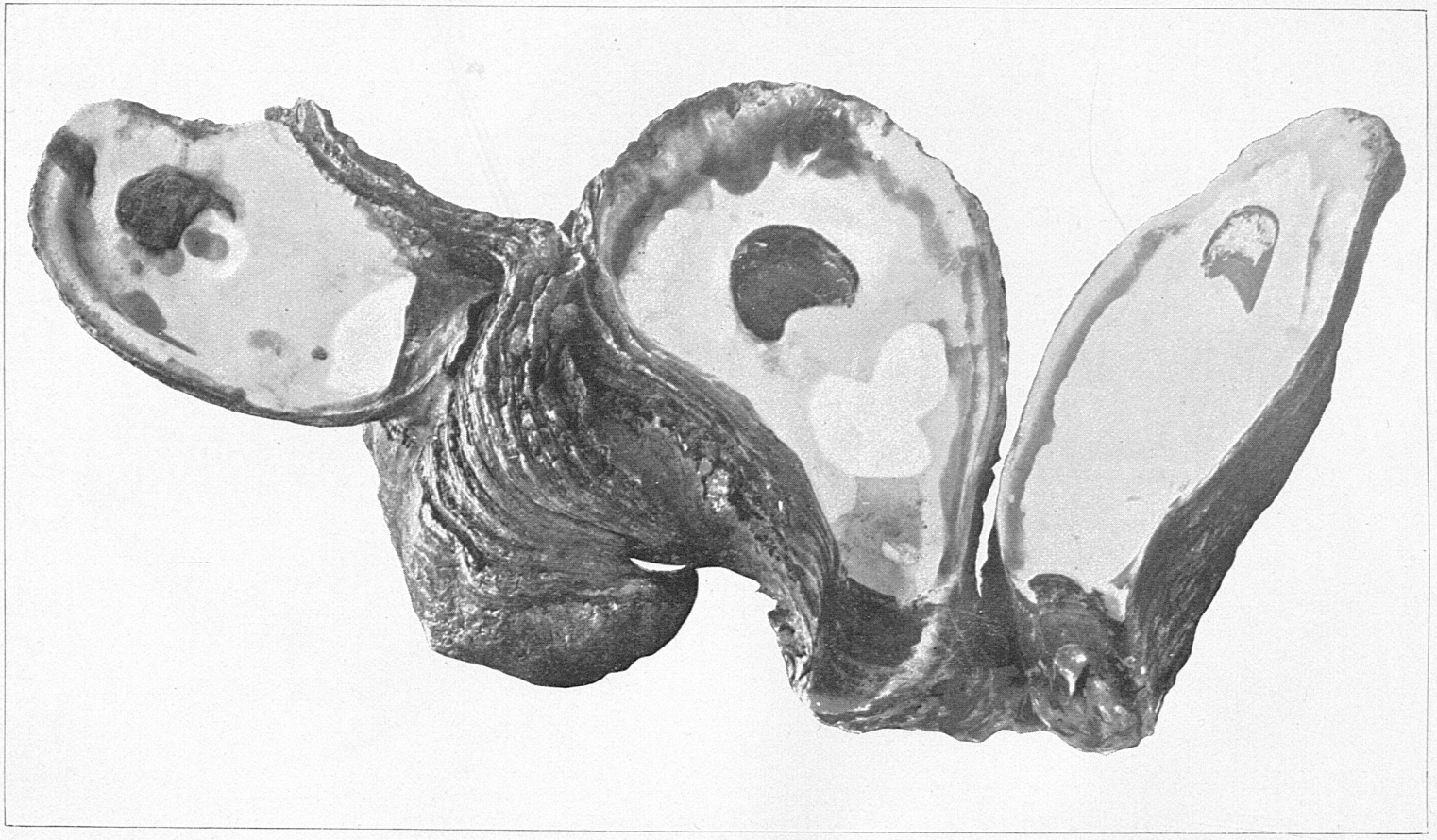
It is only of late that these reefs, long known, have grown to be of importance and to yield many for market. Most of them are outside the bar and in water 10 to 12 or more feet deep, requiring 14 to 16 foot rakes for catching. The growth is doubtless due to a succession of favorable seasons; a like succession of long-continued floods of fresh water would probably prove very injurious. These oysters are in character intermediate to the "gullies" and "sharpers," and like the last are very good for planting. Some of these are covered with mud dumped by scows from the dredges at work on the ship canal. It is not unlikely that when that mud has settled and hardened somewhat these reefs will be benefited and the oysters improved.

Oyster-planting here has never been carried on to any large extent. Unfortunately, just as a few enterprising persons were embarking in the business some four years ago, our State legislature passed a law which proved an effectual bar thereto, and two years after passed a new law retaining if not emphasizing the obnoxious features of the first.

The best time for oyster-planting is from May to October, when they are chiefly in spawn; it is also the time when oystermen are mostly idle. Oysters for seed or planting should be taken up in the rough and planted unculled, as much in bunches as possible. Those sought for seed would be mostly "sharpers," small oysters in bunches, unmarketable ones.

If the State would foster and encourage this industry the result would be that, by taxing plants as well as reefers, it would within a few years realize a handsome revenue at 5 cents a barrel.

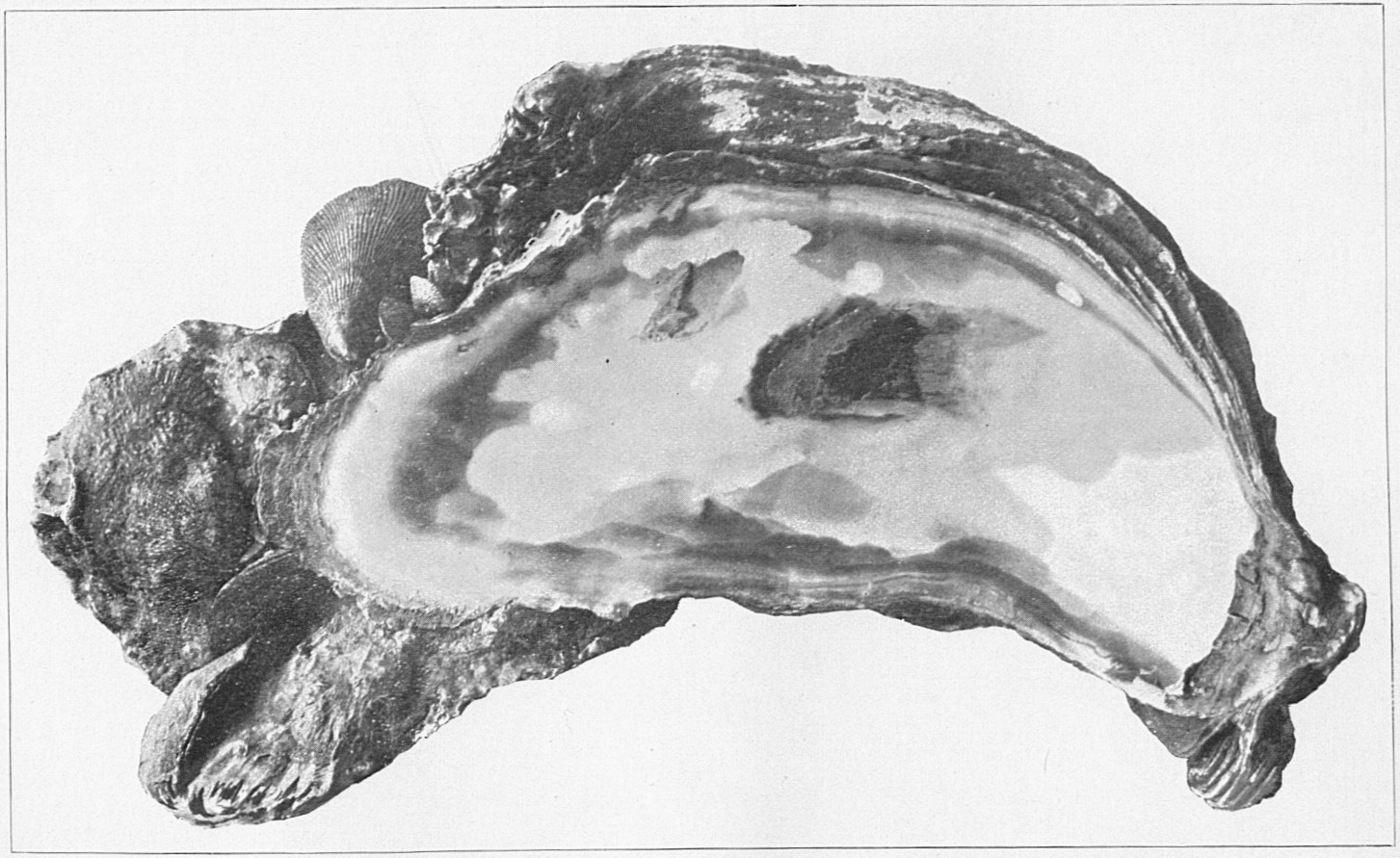
The enemies to the oyster are the drumfish, which grinds up and devours many single ones and universally the small culled-off ones the State orders scattered on the reefs whence taken, and the whelks, which bore through the shell and destroy the oyster. This is the first year that I have heard serious complaint of their destructiveness. As there must be a cause for every effect, I assume the reason of their prevalence to be the long continuance of salt water, unbroken for months by any heavy rains and consequent rise of our rivers.



SHELLS OF SPECIMENS OF CULTIVATED OYSTERS FROM PLANT BEDS OF MAJ. F. S. PARKER, SITUATED AT MOUTH OF FOWL RIVER, MISSISSIPPI SOUND, ALABAMA.

Length of oyster, right-hand specimen, 5¾ inches; width, 4 inches; thickness, 2 inches. Caught in December, 1894.

Bull U. S. F. C. 1895. Oyster Investigations in Mobile Bay. (To face page 340.)

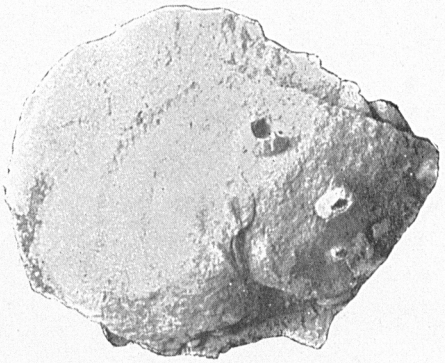


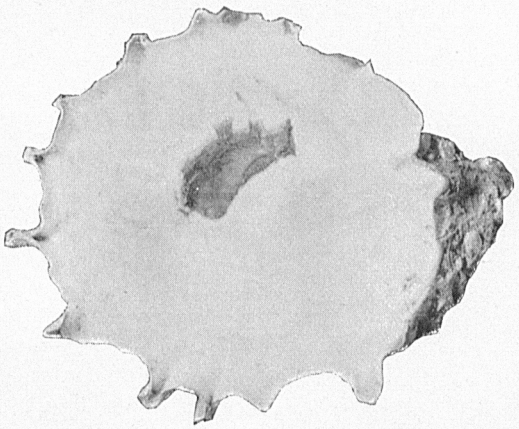
SHELL OF OYSTER FROM PLANT BEDS OF MAJ. F. S. PARKER, AT MOUTH OF FOWL RIVER, MISSISSIPPI SOUND.

Length, 7½ inches; width, 3¾ inches; thickness, 1 inch.

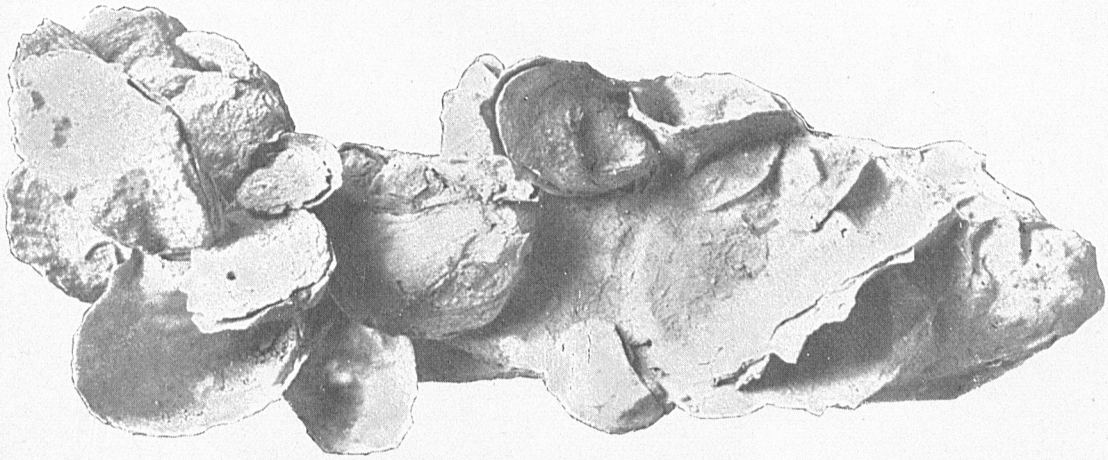
BUNCH OF OYSTERS FROM GREAT POINT CLEAR REEF, SHOWING GROWTH OF MUSSELS AND BARNACLES

SHELLS OF OYSTERS FROM FISH RIVER REEF.



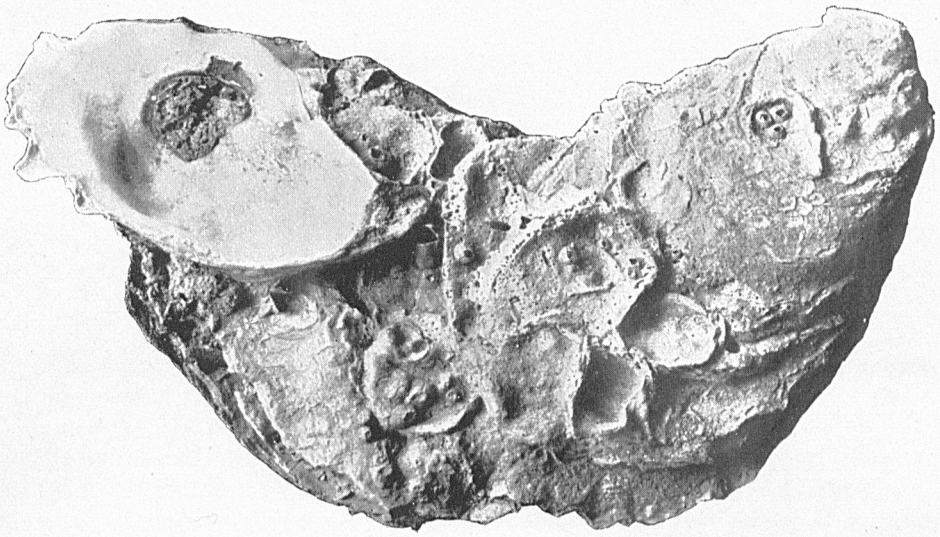


SPECIMEN SHELLS OF YOUNG OYSTERS FROM BON SECOURS REEF.



UPPER FIGURE SHOWS "COON" OYSTER FROM PILE BAYOU, LITTLE DAUPHIN ISLAND.

LOWER FIGURE SHOWS SPECIMENS OF YOUNG OYSTERS ATTACHED TO OLD SHELL, FROM REEF NORTH OF LITTLE DAUPHIN ISLAND. ONE OF THE SHELLS SHOWS HOLE MADE BY BORER.



SHELLS OF OYSTERS FROM LITTLE DAUPHIN ISLAND BAY.

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7.—A LIST OF FISHES AND MOLLUSKS COLLECTED IN ARKANSAS AND INDIAN TERRITORY IN 1894.

By SETH EUGENE MEEK, PH. D.,
Associate Professor of Biology and Geology in the Arkansas Industrial University.

INTRODUCTION.

The following paper is based on two collections of fishes made by the writer under the auspices of the United States Fish Commission and the Museum of the Arkansas University.

The first collection was made during the last week in May, 1894, along the line of the St. Louis and San Francisco Railroad, between Fort Smith, Arkansas, and Arthur, Texas. The second collection was made during the last two weeks of August, 1894, in the St. Francis River in northeastern Arkansas. As these two regions are somewhat remote from each other, and unlike, for the most part, as to physical characteristics, they are treated separately in this paper.

For assistance in the identification of doubtful species and in the preparation of this report I am indebted to Prof. Barton W. Evermann, ichthyologist of the United States Fish Commission.

WESTERN ARKANSAS AND EASTERN INDIAN TERRITORY.

The Poteau and Kiamichi rivers are the most important streams draining the eastern portion of Indian Territory south of Fort Smith. These rivers rise in the Ozark Mountains, between the Arkansas and Red rivers, the Poteau flowing north, the Kiamichi south; each drains, for the most part, in the upper two-thirds of its course, a mountainous sandstone region, where their currents are swift and their bottoms usually rocky. Between Poteau, Indian Territory, and Fort Smith the Poteau River flows with a slow current in a deep and rather broad channel, with an occasional rocky shoal; in dry weather the depth some 5 or 6 miles above Fort Smith is more than 15 or 20 feet in places; so broad and deep is this channel and so slow is the current that the river partakes somewhat of the nature of a lake.

Collections were made from the Poteau River near Fort Smith and a few small rocky tributaries near Poteau, Indian Territory.

The Kiamichi River collections were made from Walnut Creek and Kiamichi River, at Kiamichi, Indian Territory, and Flat Creek, near Goodland, Indian Territory. Those from the Red River were made at Arthur, Texas. The Kiamichi River was too deep and rocky to admit of successful collecting at the places mentioned, especially at the latter place.

At Arthur the Red River is similar to the Arkansas at Fort Smith. There are along the stream many bayous, from which most of our collections were made.

LIST OF FISHES.

The fishes are listed as follows:

Arthur = Bayous and Red River near Arthur, Texas.
Goodland = Flat Creek near Goodland, Indian Territory.
Poteau = Creeks, bayous, and lake at Poteau, Indian Territory.
Fort Smith = Poteau and Arkansas rivers.
Kiamichi = Kiamichi River and Walnut Creek at Kiamichi.

1. **Lepisosteus osseus** (Linnæus). *Long-nosed Gar Pike; Common Gar Pike.* Quite abundant in the Poteau and Arkansas rivers at Fort Smith; specimens frequently seen floating quietly near surface of water. The other two species of gar found in these waters seem much less abundant; neither of them was taken by me.
2. **Ictalurus punctatus** (Rafinesque). *Channel Cat; White Cat.* Quite abundant at Arthur and in the Poteau and Arkansas rivers at Fort Smith. In the former place it is the most important food-fish. The largest specimen observed was taken on a trot line; its weight was 20 pounds.
3. **Ameiurus nebulosus** (Le Sueur). *Common Bullhead.* Poteau, one specimen; Kiamichi, scarce.
4. **Ameiurus melas** (Rafinesque). *Small Bullhead.* Common in bayous at Arthur, Kiamichi, and Poteau; especially common in Poteau Lake.
5. **Noturus nocturnus** Jordan & Gilbert. One specimen from Walnut Creek at Kiamichi.
6. **Leptops olivaris** (Rafinesque). *Blue Cat.* Common at Arthur and Goodland and at Fort Smith in Arkansas River. It is an important food-fish at these places.
7. **Ictiobus cyprinella** (Cuvier & Valenciennes). *Buffalo.* One small specimen from Arthur.
8. **Carpiodes velifer** (Rafinesque). *Quillback.* Common at Arthur (dorsal rays 29 to 30), Goodland, and in the Poteau and Arkansas rivers at Fort Smith.
9. **Erimyzon sucetta** (Lacépède). *Chub Sucker.* Common at Goodland, Kiamichi, and Poteau. It is usually found in small streams with sluggish currents.
10. **Minytrema melanops** (Rafinesque). *Striped Sucker.* A few specimens were taken at Goodland and Poteau. This species is usually found with the preceding.
11. **Moxostoma macrolepidotum duquesnei** (Le Sueur). *Common Redhorse.* Apparently scarce; a few specimens from Goodland, Kiamichi, and Poteau, and the Poteau River at Fort Smith.
12. **Campostoma anomalum** (Rafinesque). *Stone-lugger; Stone-roller.* Scarce; Goodland, Kiamichi, and Poteau, and the Poteau River at Fort Smith.
13. **Hybognathus nuchalis** (Agassiz). *Silvery Minnow.* Quite abundant and variable in Arkansas and Indian Territory. Some specimens quite slender and more finely scaled than others. No doubt the specimens at hand include *argyritus* and *placita*. In the Red and Arkansas rivers it is the most abundant minnow. Common at Poteau, Fort Smith, and Arthur.
14. **Pimephales notatus** (Rafinesque). *Blunt-nosed Minnow.* Apparently scarce; Arthur, Goodland, Kiamichi, and Poteau.
15. **Cliola vigilax** (Baird & Girard). Scarce at Goodland and Poteau; also in Arkansas and Poteau rivers at Fort Smith.
16. **Notropis heterodon** (Cope). Arthur, scarce.
17. **Notropis blennius** (Girard). *Blunt-nosed Minnow.* Arthur, Goodland, and the Arkansas and Poteau rivers at Fort Smith, scarce.
18. **Notropis shumardi** (Girard). Arthur, scarce; Goodland, Kiamichi, and Poteau, abundant.
19. **Notropis buchanani**, new species.

    Type locality: A small creek near Poteau, where 14 specimens were secured in May, 1894.

    Type, No. 47532, U. S. Nat. Mus.

    Head, 4; depth, 4; D. 8; A. 8. Scales, 6–31–2. Teeth, 4–4. Body rather robust, back considerably elevated, snout blunt, mouth small and nearly horizontal. Snout short, about two-thirds diameter of eye. Preorbital bone slightly longer than broad. Eye moderate, 3 in head. Lateral line complete, or nearly so. About 12 scales in a series before dorsal fin. Dorsal fin slightly nearer tip of snout than base of caudal. Pectorals reaching ventrals; ventrals reaching anal. Color light olivaceous, a faint silvery lateral band; no dark lateral band or black caudal spot. This species belongs to the *N. blennius* type. It is a smaller species, lighter in color, and has fewer scales in the lateral line. I take pleasure in naming this fish for Dr. John L. Buchanan, president of the Arkansas Industrial University.
20. **Notropis bubalinus** (Baird & Girard). Poteau River at Fort Smith, scarce.

21. **Notropis venustus** (Girard). Arthur and Goodland, very common.
22. **Notropis umbratilis** (Girard). Abundant at Goodland, Kiamichi, and Poteau; scarce in the Poteau at Fort Smith.
23. **Notropis dilectus** (Girard). *Emerald Minnow.* Arthur and Goodland, scarce; Poteau and Arkansas rivers, common.
24. **Notropis whipplii** (Girard). *Silver-fin.* Goodland, Kiamichi, and Poteau; Arkansas and Poteau rivers at Fort Smith, not common.
25. **Notropis lutrensis** (Baird & Girard). Poteau and Arthur, common.
26. **Notropis jejunus** (Forbes). Poteau and Arkansas rivers at Fort Smith, scarce.
27. **Phenacobius mirabilis** (Girard). Poteau and the Poteau River at Fort Smith, scarce.
28. **Hybopsis amblops** (Rafinesque). Goodland, scarce.
29. **Hybopsis storerianus** (Kirtland). Poteau River at Fort Smith, common.
30. **Hybopsis tetranemus** Gilbert. Arkansas River at Fort Smith, scarce.
31. **Opsopœodus emiliæ** Hay. Poteau and Goodland, scarce.
32. **Notemigonus chrysoleucus** (Mitchill). *Golden Shiner.* Arthur and Poteau, common.
33. **Gambusia affinis** (Baird & Girard). Goodland, Poteau, and Fort Smith, scarce. Very abundant in the bayous along the Red River at Arthur. Females taken at Arthur the last week of May contained partially hatched young.
34. **Zygonectes escambiæ** Bollman. Poteau, scarce.
35. **Zygonectes notatus** (Rafinesque). *Top Minnow.* Goodland, Kiamichi, and Poteau, and the Poteau River at Fort Smith, not common.
36. **Dorosoma cepedianum** (Le Sueur). *Hickory Shad; Gizzard Shad.* Arthur and the Poteau River at Fort Smith, abundant in bayous.
37. **Hiodon alosoides** (Rafinesque). *Moon-eye.* Arkansas River at Fort Smith, scarce.
38. **Lucius vermiculatus** (Le Sueur). *Little Green Pickerel.* Arthur, Goodland, Kiamichi, and Poteau, apparently scarce. A difficult fish to capture with a small seine.
39. **Lucius reticulatus** (Le Sueur). *Eastern Pickerel.* Arthur, one specimen taken. This is the extreme southwestern locality from which this species has been taken.
40. **Labidesthes sicculus** Cope. Goodland, Kiamichi, and Poteau, not common.
41. **Chænobryttus gulosus** (Cuvier & Valenciennes). Poteau, one specimen.
42. **Pomoxis annularis** Rafinesque. *Crappie.* Common in the Red River bayous at Arthur; scarce at Goodland and Poteau.
43. **Lepomis cyanellus** Rafinesque. *Green Sunfish; Perch.* Arthur, Goodland, Kiamichi, Poteau, and Fort Smith, not very common.
44. **Lepomis macrochirus** Rafinesque. Poteau and the Poteau River at Fort Smith, scarce.
45. **Lepomis pallidus** (Mitchill). *Blue Sunfish; Perch.* Arthur, common; Kiamichi and Poteau, scarce.
46. **Lepomis humilis** (Girard). *Red-spotted Sunfish; Perch.* More abundant than any other of the sunfishes found in the region covered by this paper. Arthur and Poteau River at Fort Smith, common; Goodland and Poteau, scarce.
47. **Lepomis megalotis** (Rafinesque). *Long-eared Sunfish; Perch.* Arthur, Goodland, Kiamichi, Poteau, and the Poteau River at Fort Smith, common. This species is very variable. Scales vary in the lateral line from 34 to 44, the usual number being from 36 to 42; some specimens are deeper than others; these usually have the larger scales. The more slender specimens usually have a rather steep and trenchant profile.
48. **Micropterus salmoides** (Lacépède). *Large-mouthed Black Bass.* Arthur, Goodland, Kiamichi, Poteau, and the Poteau River at Fort Smith, common; absurdly called "trout" here, as elsewhere throughout the South.
49. **Etheostoma chlorosoma** (Hay). Arthur, Goodland, Poteau, and Kiamichi, and the Poteau River at Fort Smith, scarce.
50. **Etheostoma ouachitæ** Jordan & Gilbert. Arthur, Goodland, and Kiamichi, common. Specimens from Kiamichi have D. XI or XII, 11 or 12; A. 11, 8; scales, 55 to 58.
51. **Etheostoma caprodes** (Rafinesque). *Hogfish; Log Perch.* Arthur, Poteau, and Goodland, scarce; Poteau River at Fort Smith, scarce.
52. **Etheostoma whipplii** (Girard). The most abundant and variable darter found in the region covered by this paper. Abundant at Arthur, Poteau, Goodland, Kiamichi, and in the Poteau River at Fort Smith.
53. **Etheostoma lepidum** (Girard). Arthur, common; scales, 45 to 49; D. IX or X–13; scales, 45 to 49, no scales on the head. Goodland and Poteau, common.

54. **Etheostoma phoxocephalum** Nelson. Poteau River at Fort Smith, scarce.
55. **Etheostoma fusiforme** (Girard). Arthur, common; scales, 46 to 52; D. IX or X–11; cheeks and opercles scaly; breast naked; a small black spot at base of caudal fin. Kiamichi, scarce.
56. **Etheostoma microperca** Jordan & Gilbert. Kiamichi and Poteau, scarce. This species has sometimes but one anal spine.
57. **Stizostedion canadense** (C. H. Smith). *Sauger.* Said to be common in the Poteau River at Fort Smith.
58. **Aplodinotus grunniens** Rafinesque. *Fresh-water Drum.* Goodland, scarce; Arthur and the Arkansas River at Fort Smith, common.

THE ST. FRANCIS RIVER.

The region drained in Arkansas by the St. Francis River is low and flat, except the eastern slope of Crowley Ridge, which is more or less rolling. The river soon after passing south of the northern line of Arkansas widens, forming a lake from a few rods to 5 miles wide and about 50 miles long. On either side of this lake are many shallow bayous which quite or entirely dry up during the summer. The region between the St. Francis and Mississippi rivers is very low and contains a number of lakes, some of which are 5 or 6 miles wide and three or four times as long. Most of these lakes discharge their waters into the St. Francis, the others into the Mississippi River. In the spring nearly all of this region, including a large area west of the St. Francis River, is flooded with water from a depth of a few inches to as much as 10 feet. Thus, at least once a year, the Mississippi, these lakes, the St. Francis, and even the head waters of the Black and Cache rivers, are all united in one vast sheet of water. There is probably no time in the year when it is not possible with a small skiff to go from St. Francis through Little River to the Mississippi River.

The present conditions of this region are due to the New Madrid earthquake of 1811–12. After the quaking of the earth, which lasted for several months, had subsided large areas of land sunk several feet below their former level, while a few smaller areas became somewhat elevated. The large lakes now in this region and the broad lake-like channel of the St. Francis River are due to this earthquake. Many of the large cracks made in the earth at that time are still visible as shallow ditches 1 or 2 yards wide and 6 inches or more in depth. To the ordinary observer these would be scarcely noticed. Although the people who witnessed that earthquake have about all passed away, so vivid were their recollections of it that their descendants point out with much accuracy the marks left by it and discuss with clearness its destructive features. I visited Old River, about 10 miles east of Greenway. This was formerly the main channel of the St. Francis, but after the earthquake its new channel was formed about 6 miles farther east. The Old River is little more than a large bayou. It has but little current, has a sandy bottom, and contains only a small amount of vegetation. It varies much in width, being from half a mile to only a few rods wide. It is as much as 20 feet deep in places, and seems to be full of fish life.

It was a comparatively easy matter with a collecting seine to catch pickerel and black bass weighing from 1 to 3 pounds. The water was quite clear, and large gars, buffalo, pickerel, black bass, and sunfishes could be seen in abundance. The usual method of catching black bass (the favorite food-fish) was trolling. The parts of two days I spent on Old River I saw many black bass taken this way. Two men would be out one or two hours and return with a dozen or more black bass weighing from 2 to 5 pounds. In all of my collecting I have never seen another stream that seemed to contain the enormous amount of fish life found in Old and St. Francis rivers.

I visited the main river near Big Bay and at Marked Tree. At Big Bay the river is about 5 miles wide, although the main current is much narrower. The river contains much vegetation on each side and in shallow places in the main channel. The vegetation was too abundant in shallow water to enable us to use a seine; where less abundant the water was too deep. This made collecting very irksome and unsatisfactory, but our labors were rewarded by getting a few species not taken elsewhere.

The bottom of the river, especially in the main channel, is sandy, and the water very clear. The current was moderate. The amount of fish life in the river was very great. Large fishes were everywhere coming to the surface and with a quick motion, sufficient to agitate the water considerably, would sink below the surface. In quietly floating down the stream in a dugout, many large fishes could easily be seen moving slowly about in the river below or resting quietly among the weeds. Professor Sampson and myself, in a half dozen strokes with a gig, caught one large gar and a 3-pound black bass. This was our first attempt to capture fish by this method.

In the spring, as the overflow water recedes, many large fishes become stranded in shallow bayous and even on level ground. Many of these are taken by farmers and lumbermen and used by them for food, while a large number are left to die as the water recedes. The buffalo are among the largest number destroyed for lack of water; some are reported of immense size.

One of the most noticeable features of Old River is the immense numbers of mollusks found in the sandy bottom and the banks of the stream. The Arkansas hogs feed on the mollusks in the shallow water; they root the mollusk out of the sand, crack the shell, and extract the meat; they also destroy many gasteropods, which are very abundant, by the same method. The hogs also consume many of the stranded fishes. Minnows were found in the St. Francis in much less quantities than one would at first suppose. They are probably reduced in number by the abundance of large predatory fishes. Crawfishes seemed quite scarce; only two species, the young *Cambarus palmeri*, and a small new species, *Cambarus faxoni*, being all that were found in the river.

At Marked Tree the St. Francis is confined to an ordinary river channel. It has clear water, a rather slow current, and a sandy bottom. About 2 miles above Marked Tree the Little River, its most important tributary from the east, empties into the St. Francis. When visited the water was low, there being scarcely enough water in Little River to enable us to get a small boat more than a mile above its mouth. The Little River is the outlet of Big Lake, and other smaller lakes between the St. Francis and the Mississippi rivers. Its water was clear and its current more swift than that of the St. Francis River. In places its sides and bottom were covered with vegetation. In dry weather it does not have enough water for the larger fishes, except in an occasional hole along its course. It afforded excellent opportunity to collect the smaller fishes, and nearly all of those listed from Marked Tree are from Little River.

At the mouth of the Little River the St. Francis is wide and very deep. Large schools of minnows, *Hybognathus nuchalis*, seem to loiter on the shallow sandbar bordering the deep water. We baited our hooks with some of these minnows and soon had a nice string of striped bass, *Morone interrupta*.

Near Greenway we seined in a small bayou. Only a few species of fishes were found in it and most of them in abundance. Among the most abundant was *Aphredoderus sayanus* and *Noturus gyrinus*. Several specimens of *Amia calva* and one specimen of *Umbra limi*, besides a few others of less importance, were taken.

At Paragould we did some seining in Eight-mile Creek, a western tributary of the St. Francis. This creek goes nearly dry in the summer. Like the bayou, it has a muddy and sandy bottom. The day before our visit a heavy thunder-shower had so swollen the stream as to render seining somewhat difficult and unsuccessful.

The time at my disposal did not permit me to visit the Cache River which drains the western slope of Crowley Ridge. This river is much smaller than the St. Francis, but is reported as being of considerable importance from an ichthyological standpoint. It is also said to suffer in this respect on account of the large quantity of sawdust deposited in it by sawmills. The injury the sawdust does the fish is not fully appreciated by either citizens or sawmill men, or it is quite certain it would be stopped.

Northeast Arkansas and adjacent portions of Missouri, Kentucky, and Tennessee are especially inviting to the biologist. A large portion of this region is yet wild and thinly settled. Thus the balance of life has not been seriously disturbed by man. On account of malaria some naturalists are prevented from visiting this region in the summer. Reports as to the unhealthful condition of this region have been considerably exaggerated. It no doubt contains its full share of malaria, but with moderate care no evil results need be feared. The people who live in this region, and who are engaged in cutting timber, suffer very little from malaria.

In making the collections at Greenway I was assisted by Mr. S. E. Mitchell, a former student of the Arkansas University. At Paragould I was assisted by the Oxley brothers. At Jonesboro I was the guest of a fishing party consisting of Professors Sampson and Johnson, Mr. H. C. Townley, Mr. Freer, and Mr. George Peters. Mr. Peters also accompanied me to Marked Tree, and to him I am under special obligations. At Paragould I was entertained by Mr. Richard Jackson.

LIST OF FISHES FROM THE ST. FRANCIS RIVER.

In order to abbreviate, I have used the names of localities as follows:

Bayou = Bayou near Greenway, Arkansas.
Old River = Old River at Buckhorn Landing near Greenway, Arkansas.
Paragould = Eight-mile Creek near Paragould, Arkansas.
Big Bay = St. Francis River near Big Bay, Arkansas.
Marked Tree = Little and St. Francis rivers near Marked Tree, Arkansas.

At Marked Tree nearly all of the collections were made in the Little River from its mouth to about 1 or 2 miles above it. This stream and the St. Francis resemble each other very much. The Little River has a little more current and is much the smaller. A few hauls were made in the St. Francis, but they resulted in nothing new.

1. **Lepisosteus osseus** (Linnæus). *Long-nosed Gar Pike.* Very abundant in the Old and St. Francis rivers; only a few specimens taken, but many were seen floating near the surface of the water.
2. **Lepisosteus platystomus** Rafinesque. *Short-nosed Gar.* Less abundant than the preceding. Gars over 10 feet long are reported from the St. Francis. No doubt these large specimens are the alligator gar.
3. **Amia calva** Linnæus. *Grindle.* Quite abundant and very well known in northeastern Arkansas; used as food to some extent. Bayou, abundant; Old River and Paragould, common.
4. **Ictalurus punctatus** (Rafinesque). *Channel Cat; White Cat.* A few specimens were taken at Marked Tree. A very common and highly esteemed food-fish in the St. Francis River.
5. **Ameiurus melas** (Rafinesque). *Small Bullhead.* Not common. Bayou, Old River, and Paragould.
6. **Noturus nocturnus** Jordan & Gilbert. Marked Tree; only a few specimens taken.
7. **Noturus gyrinus** (Mitchill). *Stone Cat.* Bayou and shallow stagnant pools along Old River, very abundant. A few specimens also taken at Big Bay and Marked Tree.

8. **Carpiodes velifer** (Rafinesque). *Quillback.* A few specimens taken in Old River. Buffaloes in abundance and of large size are reported in the St. Francis River. Many large ones are captured as the overflow each year recedes.
9. **Erimyzon sucetta** (Lacépède). *Chub Sucker.* Bayou, Big Bay, and Paragould, common.
10. **Minytrema melanops** (Rafinesque). *Striped Sucker.* Bayou and Old River, common.
11. **Catostomus nigricans** Le Sueur. *Hog Sucker; Stone-roller.* Marked Tree, a few specimens seen in Little River.
12. **Moxostoma macrolepidotum duquesnei** (Le Sueur). *Common Redhorse.* Old River, scarce.
13. **Hybognathus nuchalis** Agassiz. *Silvery Minnow.* Bayou and Old River, scarce. Very abundant in the mouth of Little River at Marked Tree.
14. **Pimephales notatus** (Rafinesque). *Blunt-nosed Minnow.* Apparently scarce; a few specimens from Old River, Paragould, Big Bay, and Marked Tree.
15. **Cliola vigilax** (Baird & Girard). Old River and Big Bay, scarce.
16. **Notropis heterodon** (Cope). Old River, scarce; Big Bay and Marked Tree, abundant. Usually found among vegetation. Those from St. Francis River have the lateral band darker and broader than usual.
17. **Notropis cayuga** Meek. Old River, scarce.
18. **Notropis blennius** (Girard). Marked Tree, apparently scarce.
19. **Notropis xænocephalus** Jordan. Old River and Big Bay, scarce.
20. **Notropis shumardi** (Girard). Old River and Big Bay, scarce.
21. **Notropis umbratilis** (Girard). Old River and Big Bay, scarce; Paragould, common.
22. **Notropis venustus** (Girard). Marked Tree, common.
23. **Notropis megalops** (Rafinesque). *Shiner.* Paragould, common.
24. **Notropis dilectus** (Girard). Old River, scarce; Marked Tree, common. Head, $4\frac{2}{3}$; depth, $5\frac{1}{4}$; anal, 11. Scales, 41; lateral line slightly decurved. Diameter of eye greater than length of snout, 3 to $3\frac{1}{3}$ in head. Side with silvery band.
25. **Hybopsis amblops** (Rafinesque). Old River and Big Bay, scarce.
26. **Opsopœodus emiliæ** Hay. Old River and Paragould, scarce.
27. **Notemigonus chrysoleucus** (Mitchill). *Golden Shiner.* Bayou, Old River, Paragould, and Big Bay, common.
28. **Fundulus scartes,** new species.

    Type locality: St. Francis River, Big Bay, Arkansas, where two specimens were collected in August, 1894.

    Type, No. 47301, U. S. Nat. Mus.; Co-type, No. 2277, L. S. Jr. Univ. Mus.

    Head, $3\frac{1}{3}$; depth, 4; D. 8; A. 10 or 11; P. 4. Scales, 36–11. Body compressed, back slightly arched, head depressed in usual way. Mouth small, subterminal, lower jaw projecting slightly. Interorbital space, $1\frac{1}{2}$ eye. Eye equal to snout, $3\frac{1}{2}$ in head. Dorsal fin short, beginning slightly behind anal, neither fin reaching caudal. Teeth in narrow bands, outer row enlarged. Scales large, closely imbricated and minutely spotted with black. Color, dark-green above, becoming lighter below; belly, yellowish; large spots of white on some of the scales give appearance of several ill-defined silver bars on sides. Two small specimens, the longest $1\frac{1}{2}$ inches long, from St. Francis River, Big Bay, Arkansas. Although but two small specimens of this species were taken, it is quite common. Many were observed where vegetation was entirely too abundant to enable us to use a net. When frightened, these little fishes will jump out of the water, lodge for an instant on some portion of a plant above the surface, and then dart back into the water. These two specimens I caught in my hand. I made many attempts to catch others, but failed to do so. I at first supposed them to be the young of *Z. notatus.* Σκάρτης, one who leaps.
29. **Zygonectes notatus** (Rafinesque). *Top Minnow.* Bayou, Old River, Paragould, Big Bay, and Marked Tree, apparently not common.
30. **Zygonectes guttatus** Agassiz. Big Bay, scarce.
31. **Gambusia affinis** (Baird & Girard). Bayou, Old River, Paragould, Big Bay, and Marked Tree, common.
32. **Umbra limi** (Kirtland). *Mud Minnow.* Bayou, one specimen.
33. **Lucius vermiculatus** (Le Sueur). *Little Green Pickerel.* Old River, Bayou, Paragould, Big Bay, and Marked Tree, apparently an abundant species.
34. **Lucius reticulatus** (Le Sueur). *Eastern Pickerel; Jackfish.* Quite a favorite and an important food-fish in the St. Francis River region. Only a few taken by us, but many others were seen in the water. Old River and Big Bay.

35. **Labidesthes sicculus** Cope. *Silverside.* Old River, Big Bay, and Marked Tree, apparently scarce.
36. **Aphredoderus sayanus** (Gilliams). *Pirate Perch.* Bayou and Old River, very abundant. A few taken at Paragould, Big Bay, and Marked Tree.
37. **Elassoma zonatum** Jordan. Big Bay, common; Marked Tree, scarce.
38. **Centrarchus macropterus** (Lacépède). Old River and Bayou, abundant; Paragould, common.
39. **Chænobryttus gulosus** (Cuvier & Valenciennes). *Warmouth; Red-eyed Bream.* Big Bay, one specimen; color, nearly uniform black. Old River, scarce.
40. **Pomoxis sparoides** (Lacépède). *Calico Bass.* Big Bay and Old River, common.
41. **Pomoxis annularis** Rafinesque. *Crappie.* Old River and Big Bay, apparently less abundant than the preceding.
42. **Ambloplites rupestris** (Rafinesque). *Goggle-eye; Rock Bass.* Big Bay and Marked Tree, common.
43. **Lepomis cyanellus** Rafinesque. *Green Sunfish; Perch.* Bayou and Paragould, common.
44. **Lepomis macrochirus** Rafinesque. *Perch.* Bayou, Old River, and Big Bay, scarce.
45. **Lepomis pallidus** (Mitchill). *Blue Sunfish; Perch.* Old River and Bayou, common; Marked Tree, scarce.
46. **Lepomis garmani** Forbes. Old River, Big Bay, and Marked Tree, scarce.
47. **Micropterus salmoides** (Lacépède). *Large-mouthed Black Bass.* Very abundant throughout the St. Francis region, and is the favorite game-fish. Specimens frequently weigh from 4 to 6 pounds. The small-mouthed black bass is very scarce, if found at all, in St. Francis River Basin in Arkansas. Bayou, Old River, Paragould, Big Bay, and Marked Tree, abundant.
48. **Etheostoma pellucidum** Baird. *Sand Darter.* Marked Tree, Big Bay, and Old River, abundant.
49. **Etheostoma chlorosoma** (Hay). Paragould, Big Bay, Old River, and Marked Tree, scarce.
50. **Etheostoma shumardi** (Girard). Marked Tree, scarce.
51. **Etheostoma caprodes** (Rafinesque). *Log Perch.* Marked Tree, scarce.
52. **Etheostoma aspro** Cope & Jordan. *Black-sided Darter.* Old River, Paragould, Big Bay, and Marked Tree, common.
53. **Etheostoma ouachitæ** Jordan & Gilbert. Old River, scarce; Marked Tree, common.
54. **Etheostoma scierum** (Swain). Big Bay, scarce; Marked Tree, abundant. Head, 4; depth, 5½; D. XII or XIII, 12 to 14; A. II, 9. Scales in lateral line, 7-68 to 73-12. Gill-membranes broadly united. Cheeks with small scales; opercles with larger ones. Nape scaly; breast naked. Middle line of belly with enlarged, persistent scales. The preopercle is serrate in the older specimens, almost entire in the larger ones.
55. **Etheostoma histrio** Jordan & Gilbert. Marked Tree, scarce.
56. **Etheostoma jessiæ** (Jordan & Brayton). Big Bay, Marked Tree, and Old River, common. Marked Tree specimens have the scales 45 to 55. D. IX or X-11 to 14. Color very dark.
57. **Etheostoma saxatile** (Hay). Marked Tree, common.
58. **Etheostoma copelandi** (Jordan). Paragould, scarce.
59. **Etheostoma fusiforme** (Girard). Old River, Paragould, Big Bay, and Marked Tree, scarce.
60. **Etheostoma microperca** Jordan. Old River, Big Bay, and Marked Tree, scarce. Anal spines, one or two.
61. **Morone interrupta** Gill. Marked Tree, common.

RECAPITULATION.

The total number of species of fishes obtained by me in western Arkansas and eastern Indian Territory is 58. The total number obtained in the St. Francis River is 61. Of the 58 species found in the first list, the following were not found in the St. Francis:

1. *Ameiurus nebulosus.*
2. Leptops olivaris.
3. Ictiobus cyprinella.
4. Campostoma anomalum.
5. Notropis buchanani.
6. Notropis bubalinus.
7. Notropis whipplii.
8. Notropis lutrensis.
9. Notropis jejunus.
10. Phenacobius mirabilis.
11. Hybopsis storerianus.
12. Hybopsis tetranemus.
13. Zygonectes escambiæ.
14. Dorosoma cepedianum.
15. Hiodon alosoides.
16. Lepomis humilis.
17. Lepomis megalotis.
18. Etheostoma whipplii.
19. Etheostoma lepidum.
20. Etheostoma phoxocephalum.
21. Stizostedion canadense.
22. Aplodinotus grunniens.

No fewer than 25 of the 61 species found in the St. Francis were not found in western Arkansas and eastern Indian Territory. They are the following:

1. Lepisosteus platystomus.
2. Amia calva.
3. Noturus gyrinus.
4. Catostomus nigricans.
5. Notropis cayuga.
6. Notropis xænocephalus.
7. Notropis megalops.
8. Fundulus scartes.
9. Zygonectes guttatus.
10. Umbra limi.
11. Aphredoderus sayanus.
12. *Elassoma zonatum.*
13. Centrarchus macropterus.
14. Pomoxis sparoides.
15. Ambloplites rupestris.
16. Lepomis garmani.
17. Etheostoma pellucidum.
18. Etheostoma shumardi.
19. Etheostoma aspro.
20. Etheostoma scierum.
21. *Etheostoma histrio.*
22. Etheostoma jessiæ.
23. Etheostoma saxatile.
24. Etheostoma copelandi.
25. Morone interrupta.

Adding these 25 species to the 58 found in western Arkansas and eastern Indian Territory gives a total of 83 species of fishes as the result of less than three weeks' collecting in these waters. There are but few regions in the United States that will yield so many species of fresh-water fishes.

MOLLUSKS COLLECTED IN OLD RIVER, NEAR GREENWAY, ARKANSAS.

No special effort was made to collect the mollusks occurring in the water examined. Some little time was given to collecting the different species in Old River, the names of which are given in the following list. I am indebted to Mr. Charles T. Simpson, of the National Museum, for the specific determinations and for the technical notes on each.

Unio pyramidatus Lea. Scarce.

Unio gibbosus Barnes. A thin, compressed, elongated variety, found rarely throughout the range of the species. Quite common.

Unio parvus Barnes. Scarce.

Unio texasensis Lea. Scarce.

Unio tuberculatus Barnes. Scarce.

Unio turgidus Lea. So far as I know this species has not hitherto been reported north of southern Louisiana.

Unio anodontoides Lea. A pale, rather delicate variety, found in the Gulf States; abundant.

Unio lienosus Conrad. The peculiar variety of this species found here has not been reported hitherto north of Columbus, Mississippi; not common.

Unio castaneus Lea. A common southern species found as far north as Clinton, on the Little Red River, Arkansas, 125 miles southwest of Greenway; common.

Unio hydianus Lea. Very abundant. The most northern limit heretofore known was Little Rock and Wittsburg, Arkansas.

Unio cerinus Conrad. A species of southern Louisiana and Mississippi, and not previously known north of Little Red River. There can be no doubt that these shells are genuine *cerinus*. Abundant.

Unio undulatus Barnes. Scarce.

Anodonta imbecillis Say. Scarce.

Anodonta edentula Say. Not common.

Anodonta opaca Lea. A form not known hitherto north of Little Rock, Arkansas. Scarce.

Sphærium solidulum Prime.

Pleurocera elevata Say.

Campeloma coarctata Lea. A southern species.

Planorbis trivolvis Say.

Vivipara subpurpurea Say. Banded.

This collection is remarkable from the fact that it contains no less than six species of Unionidæ found at a locality farther north than they have ever been reported from before. In fact the species of general distribution throughout the Mississippi Valley that were taken at this locality have a most decidedly southern aspect, and the entire collection is such as one would expect to find among the streams near the shores of the Gulf of Mexico.

ARKANSAS INDUSTRIAL UNIVERSITY,
Fayetteville, Arkansas, November 7, 1894.

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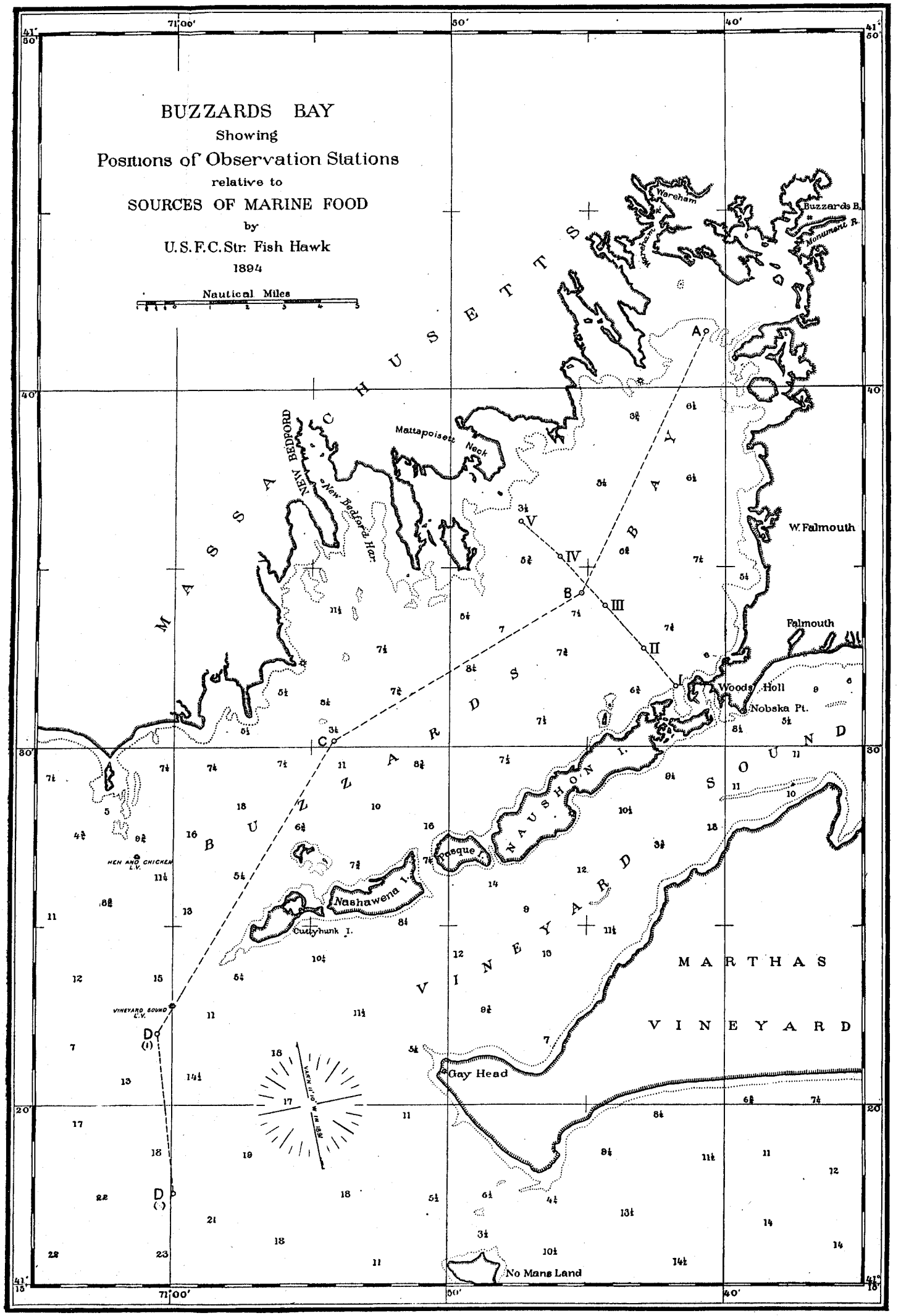


Map of Buzzards Bay (southern coast of Massachusetts) indicating the lines of sections studied, Stations A, B, C, D being the "longitudinal" section, Stations I–V being the "cross" section studied.

8.—THE SOURCES OF MARINE FOOD.

By JAMES I. PECK,
Assistant Professor of Biology in Williams College.

During the summer of 1894 studies were continued, under the auspices of the United States Fish Commission, upon the food of marine fishes, and in working out somewhat in detail some of the ways in which several of them are related to their environment in these respects, and especially in trying to get a more accurate idea of the primary basis upon which they all rest; that is to say, the body of micro-organic material suspended in the water.

Much importance naturally attaches to the study of the feeding habits of marine fishes, for attention is thus immediately called to the delicate adjustments upon which their life-history is based, especially in their young and defenseless stages of growth; and in no better way can the resources of any given species be approached than in understanding the possibilities of its obtaining sufficient food supply, together with its liabilities of falling a prey to other species.

Such studies, moreover, lead to very broad considerations of the resources of the ocean, such as logically involve all its wealth of living substance, and so it is that the two sections of this paper, although dealing with such different subjects, are yet phases of the same theme.

I. THE FOOD OF CERTAIN FISHES.

Having ascertained in 1893 the food of the menhaden,* which is not carnivorous at all, but subsists upon microorganic material filtered from the water, I have now considered the squeteague, which is a voracious and insatiable devourer of other species, and which visits the New England coast as a summer migrant and is taken regularly in the traps here located. Five hundred and seventy of these were examined during the month of July and the first days of August, and their food tabulated as correctly as could be done by me, as it was taken from the stomachs of the fish when brought in each morning from the traps. This method is of course subject to somewhat unnatural conditions, because when confined in traps they may fall upon victims imprisoned with them, or they may be deprived of their normal quantity of food by their inclosure, but it seems to me that, after all, the results are not materially changed.

* See U. S. F. C. Bulletin for that year, p. 113.

The following tabulated statement is so classified as to express graphically the main constituents of the food of the squeteague:

Date.	Number of specimens examined.	Containing menhaden.	Containing adult herring.	Containing butter-fish.	Containing young herring.	Containing squid.	Containing small crustacea.	Containing nothing.	Miscellaneous.
July 4	8	.....	.....	.....	2 (3)	1 (4)	3 (many).	3	
5	11	1 (1)	.....	1 (2)	.....	3 (3)	.....	6	
6	8	.....	.....	.....	2 (2)	3 (4)	.....	5	
7	4	.....	.....	.....	1 (1)	2 (3)	.....	1	
9	20	.....	5 (5)	1 (1)	4 (many).....	.....	.....	11	
10	30	2 (2)	7 (7)	3 (3)	8 (very many)...	.....	.....	9	1 hermit crab.
11	33	2 (2)	.....	6 (6)	5 (few).....	2 (2)	4 (few)...	17	1 small crab.
13	17	3 (3)	1 (1)	4 (5)	4 (14)	3 (6)	.....	5	1 knot seaweed.
14	30	.....	1 (1)	6 (8)	5 (many).....	3 (3)	1 (3)	16	
16	37	.....	2 (2)	13 (18)	2 (several)	3 (4)	.....	18	1 lobster (soft).
17	56	5 (5)	1 (1)	6 (7)	2 (2)	5 (5)	3 (many).	35	Shrimps, with other crustacea.
18	43	1 (1)	.....	4 (4)	1 (1)	1 (1)	3 (few)...	34	
19	7	.....	.....	.....	.....	.....	1 (2)	6	1 small crab.
23	31	.....	.....	6 (8)	6 (many).....	3 (3)	.....	19	3 annelids and 2 lady crabs.
24	40	.....	3 (3)	6 (6)	29 (many).....	4 (4)	2 (few)...	3	1 small crab.
25	15	.....	4 (4)	1 (1)	3 (few).....	.....	.....	8	
26	20	1 (1)	2 (2)	.....	1 (1)	.....	.....	16	
27	12	.....	.....	.....	.....	.....	.....	12	
28	26	2 (2)	5 (7)	1 (1)	4 (7)	3 (5)	.....	11	
30	27	2 (2)	13 (15)	1 (1)	3 (few).....	1 (1)	3 (few)...	5	
31	14	.....	3 (3)	5 (17)	5 (several)	.....	.....	4	
Aug. 1	17	.....	.....	2 (7)	5 (many).....	1 (1)	8 (many).	2	1 mackerel.
2	14	.....	5 (5)	5 (8)	6 (several)	2 (2)	1 (1)	.....	Squid contained 1 young fish.
7	11	.....	1 (1)	.....	.....	.....	1 (1)	6	Young scup.
8	13	.....	.....	.....	.....	.....	.....	13	2 annelids.
9	13	.....	1 (1)	3 (5)	.....	.....	.....	10	
10	7	.....	3 (4)	6 (22)	1 (2)	1 (1)	.....	.....	
11	6	.....	.....	.....	1 (2)	.....	.....	5	Young scup.
	570	19 (19)	57 (62)	80 (130)	100 (very many) ..	41 (52)	30 (many).	280	
Per cent	.....	3.3	10	14	17.5	7.2	5	49	

NOTE.—The figures and words in parentheses indicate the number of victims found in the given number of squeteague. The figures without parentheses indicate the number of squeteague containing such victims; thus, 19 squeteague contained in their stomachs (19) menhaden as victims, 57 squeteague contained (62) adult herring as victims, and so for the other columns following. The column headed "Miscellaneous" includes victims not otherwise enumerated.

It will be seen that the column of the table headed "young herring" is the one most constantly filled, and that the aggregate number of fish included in it (100) is larger than in any of the other columns where food is found, covering 17½ per cent of the whole number of fish studied. It is very evident, in fact, to the investigator that schools of young herring, menhaden, and alewives, with young fish of other species found less often during this particular period, are especially sought by the squeteague. In a single specimen 25 inches long were found 166 young 2-inch herring. It seems hardly credible that one fish could manage to consume this number at a single meal, but very frequently they thus get opportunities of gorging themselves—from a single school, too, since the process of digestion had acted uniformly upon the whole.

In the next left-hand column* one sees that butter-fish (*Stromateus triacanthus*) also form a large part of the food of this species. I have found as many as 7 small-sized victims (all together weighing 8½ ounces) in a single squeteague, while 14 per cent of the whole number examined contained these victims. In the column recording the fish feeding upon squid one sees a large representation; 7 per cent of the whole number of squeteague examined used them.

*In this column also are included young bluefish, which often occur, and in the nearly digested state can with difficulty be distinguished from small butter-fish.

I think that the food materials thus far mentioned, i. e., young fish, butter-fish, and squid, are closely interrelated, and that the young fish are again the central point, for one finds upon examining the stomachs of the butter-fish that they are carnivorous, feeding upon small fish; in fact, one was taken from a squeteague which was itself in the act of capturing a minnow, which stuck, half-swallowed, from its mouth. The squid, as is well known, swims along under schools of young fish, rising now and then to the surface with great accuracy and securing its prey. One can often see them during the summer in the large pool of the station of the Fish Commission at Woods Hole, Massachusetts, feeding upon small silversides at the surface.

I have many times in the same way watched young bluefish from the wharf as they swim along 3 or 4 feet beneath a school of young fish at the surface, changing their position, direction, and their rate constantly, according to the movements of their victims above them. At times a continuous stream of schooling silversides would pass along the end of the wharf as far as the eye could discern them, while just as regularly, though of course in much fewer numbers, one could see a scattered column of young bluefish, a few feet beneath, moving in exactly the same manner, rising constantly into the mass above, as one might plainly know by the scattering, even out into the air, of the invaded minnows. The schools of young herring, menhaden, and alewives, are subject to the same foes, and one can imagine that it is in this way that the giant squeteague also regulates its feeding times and places to this kind of material, preying at once both upon the young herring and their enemies, which fall so easily to its strength and swiftness. It is often found also that when the young fish are fed upon in abundance by the squeteague, small crustacea—amphipods, and less often small shrimps—and also the green remains of many annelids (*Phyllodoce*) are frequently taken with them. These organisms also swarm in shallower areas frequented by young fish, for these latter prey upon the smaller crustacea, larvæ, and copepods, while some of the larger kinds of the crustacea are consumed by the squeteague directly.

Not only are young fish used by the squeteague, but the adults of the same species, and one can see by reference to the table before given that the columns devoted to adult menhaden and herring have a good representation, especially the latter. So well adapted for its predaceous life is the squeteague that it swallows a large thick menhaden more than half its own length, while the full-grown herring figures very commonly in the same way as food.

The food of the squeteague (*Cynoscion regale*) may be characterized perhaps most clearly by a concrete instance: On the morning of July 23 there was taken a large specimen whose stomach contained an adult herring, in the stomach of the herring were found two young scup (besides many small crustacea), and in the stomach of one of these young scup were found copepods, while in the alimentary tract of these last one could identify one or two of the diatoms and an infusorian test among the mass of triturated material which formed its food. This is an instance of the universal rule of this kind of food; the squeteague captures the butter-fish or squid, which in turn have fed on young fish, which in their turn have fed upon the more minute crustacea, which finally utilize a microscopic food supply. And the food of the squeteague must be regarded as a complex of all these factors, a resultant of several life-histories to the given environment. Moreover, circumstances arising to modify any of the separate factors cause correlative changes throughout the whole series.

The species most like the squeteague as regards its food material in this locality is the bluefish (*Pomatomus saltatrix*). Only thirty-eight of these, however, were obtained by me during the summer; not a sufficient number for any complete analysis, yet they indicate somewhat the feeding habits of this notably predaceous animal. Thirty-two per cent contained adult menhaden, 18 per cent contained butter-fish, 10 per cent herring, 8 per cent squid, and 3 per cent young fish. Thirty-nine per cent contained nothing at the time of capture, although not much can be based upon the last fact, since this fish is well known to disgorge its food when captured by hook and line. Moreover, all that can be said of the food of the squeteague applies equally well to the bluefish, and as regards habits of feeding they may be in most respects associated together.

Another class of food of fishes may be illustrated by the sea bass (*Serranus atrarius*), which is a bottom feeder. Though only forty specimens were obtained in the period studied, they probably give a fair representation of the general feeding habits of the fish, and the results may perhaps be more easily considered if tabulated:

Date.	Sea bass examined.	Containing lobsters.	Green crabs.	Lady crabs.	Hermit crabs.	Amphipods.	Young fish.	Mollusks.	Nothing.
July 6	10	.....	.....	1 (2)	1 (1)	7 (very many)	.....	1 (1 Crepidula)	1
7	4	.....	3 (6)	1 (1)	1 (1)	.....	.....	1 (1 Urosalpinx)	.....
18	2	.....	1 (1)	1 (2)	1 (2)	1 (1)	.....	1 (1 Solen)	.....
26	5	2 (3)	.....	3 (9)	.....	1 (many)	.....	.....	.....
28	7	.....	3 (22)	1 (4)	.....	1 (2)	2 (9 sculpins)	1 (1 Urosalpinx)	2
Aug. 3	1	.....	.....	1 (2)	.....	.....	1 (2 sculpins)	.....	.....
4	4	.....	3 (5)	.....	.....	.....	2 (2 sculpins)	.....	1
6	4	2 (2)	3 (5)	2 (5)	.....	.....	1 (1 sand eel)	1 (1 Natica)	.....
13	3	.....	2 (8)	.....	.....	.....	1 (2 sculpins)	.....	1
Total.	40	4 (5)	15 (49)	10 (25)	3 (4)	10 (many)	7 (16)	5 (5)	5

NOTE.—The figures and words in parentheses denote the number of victims. The figures without parentheses indicate the number of sea bass containing such victims.

From this table will be seen how largely the sea bass depends for its food upon various crustacea; not a single fish containing food was without them, while most of the specimens examined contained many crustacea of several genera. The young lobster from the bottom is especially conspicuous with the other crustacea taken by the sea bass; four fish obtained by me contained five young lobsters averaging 5½ inches in length. Several specimens of young lobsters, all of about the same size, were also obtained from a fish-market at Vineyard Haven, where this fish is dressed. Young fish—but only those of strictly bottom habits—were also much preyed upon by the sea bass; also lamellibranch mollusks of several genera. The habits of this species are therefore eminently carnivorous, and yet its immediate food is widely removed from those species of fish heretofore considered.

A few specimens of two other of our migratory fishes were also examined to illustrate somewhat further the material used by bottom-feeding fish; these were the scup (*Diplodus argyrops*) and the tautog (*Tautoga onitis*). While only a few were examined, the various constituents seemed so constant, both in quantity and general make-up, that one may get a fairly good detailed idea of their food from studying a relatively few specimens. Thus in these rocky-bottomed localities, covered over with thick banks of algæ, the large simple alimentary tract of the tautog is almost invariably filled with lamellibranch Mollusca—*Solen, Mytilus*, and the like, together with many of the smaller similar forms—all of which have evidently been torn from their attachments and broken up by the sharp incisor-like teeth at the front of the mouth; the shells and all are consumed in incredible numbers by this sluggish hunter. The

food of the scup, however, is somewhat more varied, comprising a wider range of victims, but of the same general character as belong to the bottom fauna. Thus one finds, in fish taken by hook and line, a great quantity of amphipods, some of the compound ascidians (*Leptoclinum*), many small lamellibranch mollusks, and at times very many of the sand-dollars (*Echinarachnius parma*) ground up with sand and deep black mud of the bottom from which they were feeding, just above which also the amphipods are usually so abundant.

Now, on the floor of these littoral waters the food of the lamellibranch mollusca is of course drawn from the microscopic organisms living suspended in the water above, which the animal obtains from the currents of water passing through its gills and mantle. The tautog, therefore, which consumes these molluscan victims to so large an extent, is only one step removed from their primary food supply of microscopic organisms, and is directly dependent upon such a supply, although not quite actually using it itself. So also the predaceous gastropods which feed upon other mollusks are directly conditioned upon the ability of some members of their food supply, by however many steps in the series they may be removed, to obtain the microscopic organisms from the surrounding water.

With regard to the great group of the Crustacea I have not yet had the opportunity of demonstrating the steps by which their victims are passed on from one form to another, from the primary feeders upon microscopic food up to the higher forms. They are fierce devourers of their own kindred at least, as may be abundantly proven if any one group—as the crabs—be investigated, for smaller species are constantly preyed upon by the larger. They are scavengers to some extent, as dead material comes to them, and they also secure the young fish alive when their size will permit them, but the necessity of masticating their food before eating makes the identification of the material harder to follow.

It is entirely probable that some vegetal feeders may be found among the adult crustacea, as is certainly true to some extent in *Panopeus*, but the larval history is without doubt largely conditioned upon the Protozoa and Protophyta, amid which the earliest free-swimming stages are passed. Vegetal feeders, indeed—i. e., those using marine algæ and the like—may exist in every large order of animals, but under the present conditions they are manifestly quite too few to supply the food material of the larger carnivorous forms, and we are inevitably brought back to a food supply similar to that of the menhaden, which forms the stable basis upon which marine animal organisms of all classes are laid. This is not a new fact, of course, but it is one which will bear demonstrating in many ways and under many circumstances. Professor Brooks has recently shown* how all marine life has been evolved out of these ancient pelagic conditions; and any rational and thorough consideration of fisheries problems must eventually descend in steady steps to them.

There have now been shown in several cases how marine food is elaborated, as it were, along different lines, from the primary sources of supply; the squeteague and bluefish stand farthest removed in one way, the sea bass in another, the scup and tautog less distantly in another. Many fish, such as the herring, alewife, and shad, fall into another group, since they use mainly the minute crustacea; and so the plan might be enlarged to include many other species, always leading back, however, to the microscopic basis which is so easily demonstrated through the feeding processes of the mussels and the menhaden.

* The genus Salpa, p. 167.

II.—OBSERVATIONS ON THE PLANKTON OF BUZZARDS BAY.

In order to contribute toward a knowledge of the quality, quantity, life-history, and conditions of environment of this primary food supply, consisting of Protozoa, Protophyta, free-swimming larvæ and the like, many observations were made during the earlier part of the summer of 1894 with respect to the surface water in the larger harbor at Woods Hole, where collections of the organisms were systematically obtained from measured quantities of the water at different times of the day and tide, and under different conditions of temperature. Likewise, by means of the steamer *Fish Hawk*, which was provided with suitable apparatus for the purpose,* I was enabled to collect many samples from the waters of Buzzards Bay, not only at the surface, but also at mid-depth and at the bottom. A definite section was laid out across the bay (see plate 64, Stations I–V) and another running longitudinally (Stations A–D) through the same body of water some distance out to sea. These lines of section were divided into equal intervals with definite stations established, in order that a rigid system of representative localities might be followed, by a study of which a knowledge of the bay as a whole might be increased; and it is earnestly hoped that these studies may be but a preliminary to wider observations which may reveal to some degree at least the possibilities of such lines of research in the understanding of the biology of these littoral waters.

If one will dip up a small dish of sea water and place in it some bits of algæ scraped from a pile or an old float it will, especially if allowed to stand a day or two in the laboratory, present a wonderful complex of organisms of the most varied types. In order to express some of the ways in which the organisms in common sea water interact upon one another I have given in plate 65 some pen-and-ink drawings illustrating, as well as I could by these means, the comparative forms and sizes of some of the commonest types, under a magnification of about a thousand diameters. (A partial identification of these is given in the explanation of this plate.)

If, now, one can imagine all these organisms as seen alive under the microscope, there would appear the greatest diversity of habits. For instance, the large infusorian *c* glides swiftly and gracefully through the field, turning this way and that, bending with its flexible body around or under or over obstacles, stopping now at a colony of bacteria, now at a diatom, searching, as it were, for material suitable to its taste. As the cell is figured in the drawing it is occupied apparently in digging with its band of strong cilia at the colony of bacteria against which it rests; after remaining in this locality, even for several minutes, it suddenly turned about to the left, quickly ate the diatom there represented, and glided out of the field of vision.

Other infusoria are constantly appearing; thus the *Mesodinium m* represented in the center of the plate is a rapid mover by means of the strong blades of the membranellæ placed upon one face of it. This cell also is a strong swimmer and a predaceous consumer of many organisms inferior to itself in size. Just above the last-named cell are represented two flagellates, at *k*, whose flexible flagella give the characteristic rolling movement of the organisms. Three other small flagellate infusoria are

* In addition to large funnels with detachable tubes, in which a film of sand is laid upon a roll of wire gauze (which closes the bottom end of the tube of the funnel), for filtering out the organic material, the large steam pump of the vessel was used in drawing up water from any desired depth through a 2-inch hose.

haunting the colony of bacteria at *i;* one of the two flagella on each, by its corkscrew movement, gives direction and motion to the cell, while the other drags along behind quite passive. These are very abundant; several may be in sight at the same time. Another infusorian, *n* is also prominent both by its strong cilia and its peculiar movements. One of these will suddenly appear in the field of the microscope and after remaining perfectly motionless for some time, except for the rapid rotation of a band of long cilia at the mouth end, will disappear with such a quick jump that with the high-power lens it can hardly be detected.

Besides these infusoria heretofore mentioned, which come and go in restless irregular sequences, there are other animal cells which are almost motionless, simply floating through the water, reaching out their long delicate protoplasmic threads, which entangle their prey upon all sides. Such an organism, for instance, is represented by the heliozoan at *g.* The perfect regularity of these radii in the living animal is very beautiful; each one of them is very sensitive to stimuli and capable of a slow regular withdrawal into, or further extension from, the parent cell at the center. One also may see the numerous irregular thickenings upon very many of these threads, especially if the organism is actively feeding. The cell figured has in its grasp two of the small flagellates which came into contact with its outlying snare, and were thus, very slowly at first and more rapidly as they neared the cell, drawn into the material of the central organism. This particular heliozoan in twenty minutes had in this way consumed three of these small flagellates and captured a fourth. The process of engulfing one of these small food particles is very interesting to the observer; the whole organism stretches out to meet it (as it draws near the central cell) along the lines of the radius upon which it was captured, but all the processes are very gradually carried out, and the globular form of the central mass is not much disturbed notwithstanding the active streaming of the protoplasm in the direction of the victim.

One other organism of similar plan is represented at *a.* This is the infusorian *Acineta,* from whose test the protoplasmic filaments, each tipped with a delicate knob, project only at definite corners. This, too, ensnares its prey at a considerable distance, penetrating its victim with the strong pseudopodia, by which the food particle is ingested by the central mass. The particular *Acineta* figured is represented as reproducing itself by a kind of budding, the daughter cell *x* being derived from the mother organism through one corner, where the protoplasmic "tentacles" are thrust out. The young one will then lead a free-swimming life for a season in passing to the adult condition. Yet another type of the marine infusoria may be illustrated by the stalked *Vorticella* (*v* in the plate). This can range about over a relatively quite large area, being tethered, as it were, and securing safety by the quick contraction of the stalk. Food is brought to the organism in two large vortexes of water, caused by the rapid rotation of the collar of strong cilia. One can see particles of material thus drawn down into the mouth, and when those are secured which are fit for food they are quickly retained. The cell is always exceedingly sensitive and quick in all its motions. One often sees them attached to the shells of copepods, by which they are carried about and secure a greater range of locomotion and area. Under the microscope the vortexes of water may be readily seen by the small bits of material carried in them, which are thus swept in toward the organism.

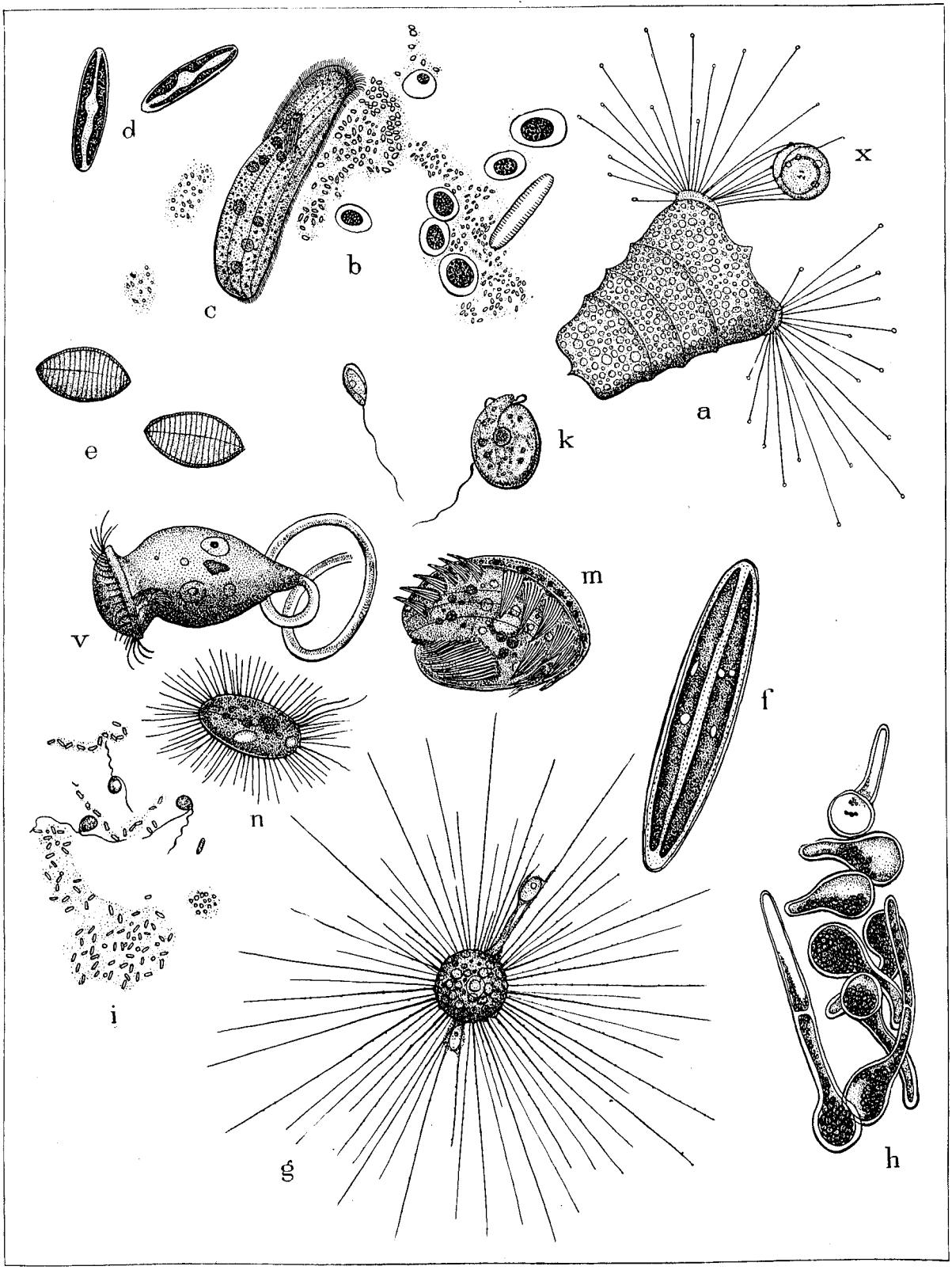
Vegetal organisms of course constitute a very large part of the material bred in such a portion of water as is here considered. Especially numerous are such diatoms

as are represented at *f* and *d*, which have the characteristic gliding motion back and forth over the field among the other organisms. Great bunches of stalked forms, of free-living species, of bundles, and chains of many varieties of these could easily be added from other positions on the field under consideration, and they form also the prey of organisms larger than themselves. Colonies of bacteria, especially in their zooglea investment, are everywhere visible, and at the time when this material is represented the alga at *h* had overspread the entire inner surface of the glass. Some of the resting cells are shown at *b*, some of the germinating ones at *h*. Among these bunches of growing algæ are the favorite resorts of many of the organisms heretofore described.

If one can imagine the figures of plate 65 to be moving about upon the field of a microscope, each one according to its characteristic habits of living, feeding, and reproducing by division of each cell into two or more, among much other growing algæ, with débris of different kinds, then some idea might be gained of the wealth of life which inhabits, or may inhabit, ordinary sea water in the place where this small quantity was taken. Just as the piles of the wharf are occupied by small animals of different orders—the creeping nudibranch mollusks and amphipods crawling around among the algæ and Hydrozoa for food—and as these comprise many forms which branch out to ensnare their prey, as hydroids and sea-anemones, and are associated with many other sessile forms which create currents of water by strong appendages thus to bring themselves food—such as the barnacles and Bryozoa—all intertwined with a small forest of delicate algæ of several tints and many forms; so also if we increase our powers of vision in the same places the same story is seen to be repeated by a much more numerous and diversified series of forms, of similar adaptations but so small as to be quite unsuspected in our ordinary means of observation by the unaided eye. They also consume each other in the same manner, and themselves in turn become the victims of other and larger foes.

I have therefore figured these organisms heretofore described, and mentioned something of their habits in their environment, not with the view of adding new scientific descriptions or drawings to those already given by others, but rather to graphically call attention to the aggregate meaning of this kind of living organisms in their particular associations, such as make them and their cogeners the broad staple food basis upon which marine life hangs. The presentation of a few of these forms gathered from a few drops of water especially selected, may naturally lead to the consideration of the wide range of similar forms of life which one may ordinarily gather from the surface of the littoral waters of these localities, and may thus help to bring about an understanding of some of the ways in which they are interrelated, what precede and what depend upon them, and some of the conditions regulating the problems of their distribution. To do this at all broadly is at present impossible, but observations upon the quantity of material may be one of the steps in the process of understanding some of the other features attending the study, and it is the purpose of the following account to describe such a series of quantitative observations.

Some of the vegetal micro-organisms, on account of the definite investment of the cell, as the siliceous skeleton of the diatoms, or the thick sculptured wall of the Peridinia, are the most readily preserved and distinguished in material filtered out from the water; moreover, they are eminently characteristic of given localities and exceedingly abundant. The following illustrations of the distribution of marine organisms are drawn therefore from them, to include also of minute crustacea only the copepods



This plate illustrates organisms very abundantly found in common sea water that has stood a few days in an open, shallow dish. *a*, *Acineta* with embryo budding off; *b*, resting *spores of Alga*, with bacteria; *c*, *Chilodon*; *d*, small *Navicula*; *e*, *Cocconeis*; *f*, larger species of *Navicula*; *g*, heliozoan, with two entrapped infusoria; *h*, germinating Alga cells; *i*, small colony of bacteria in zooglea stage, with small flagellate infusoria near by; *k*, flagellate infusorian; *m*, infusorian, *Mesodinium*; *n*, ciliate infusorian; *v*, *Vorticella*, with small portion of its stalk. Magnified 1,000 diameters.

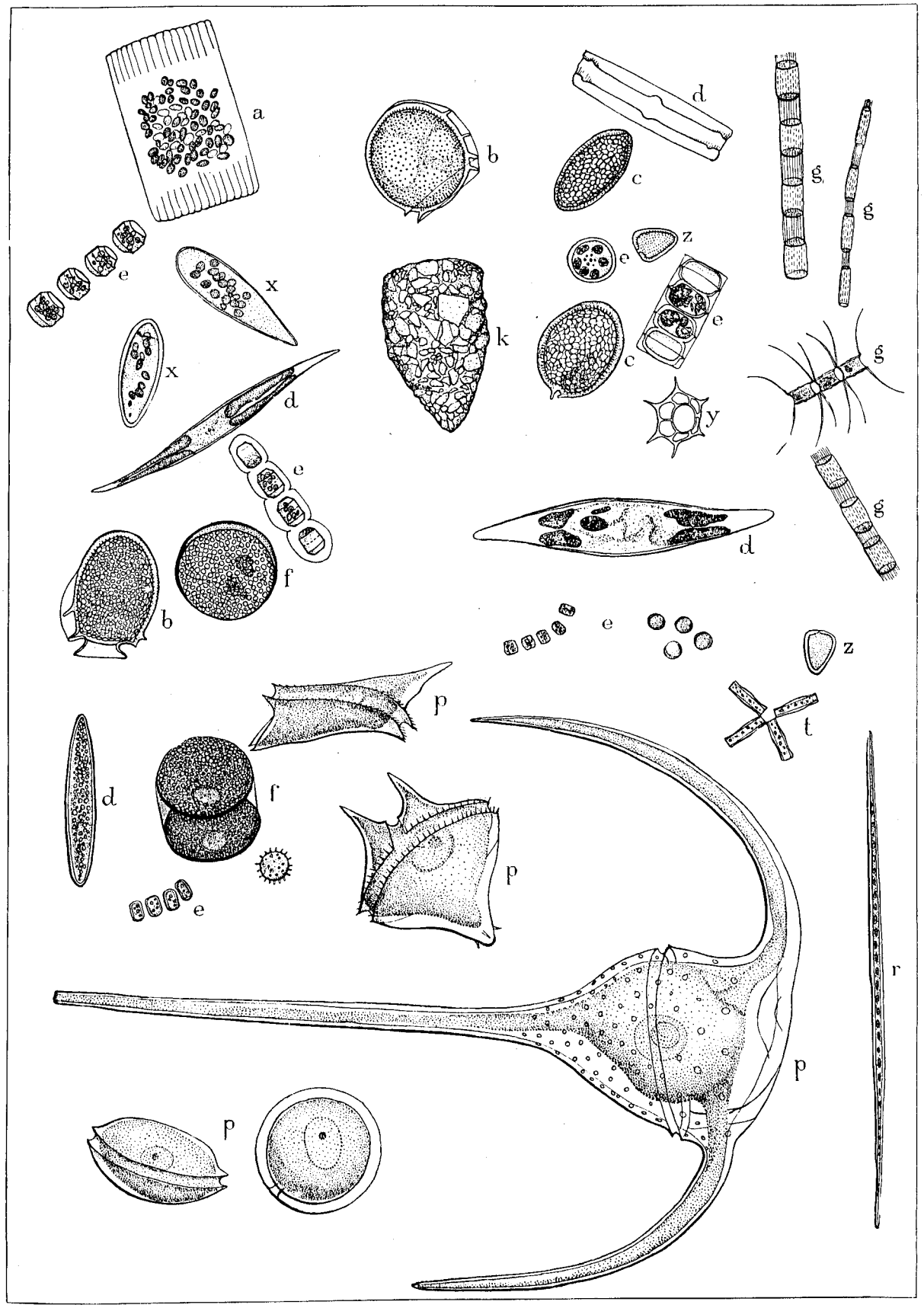
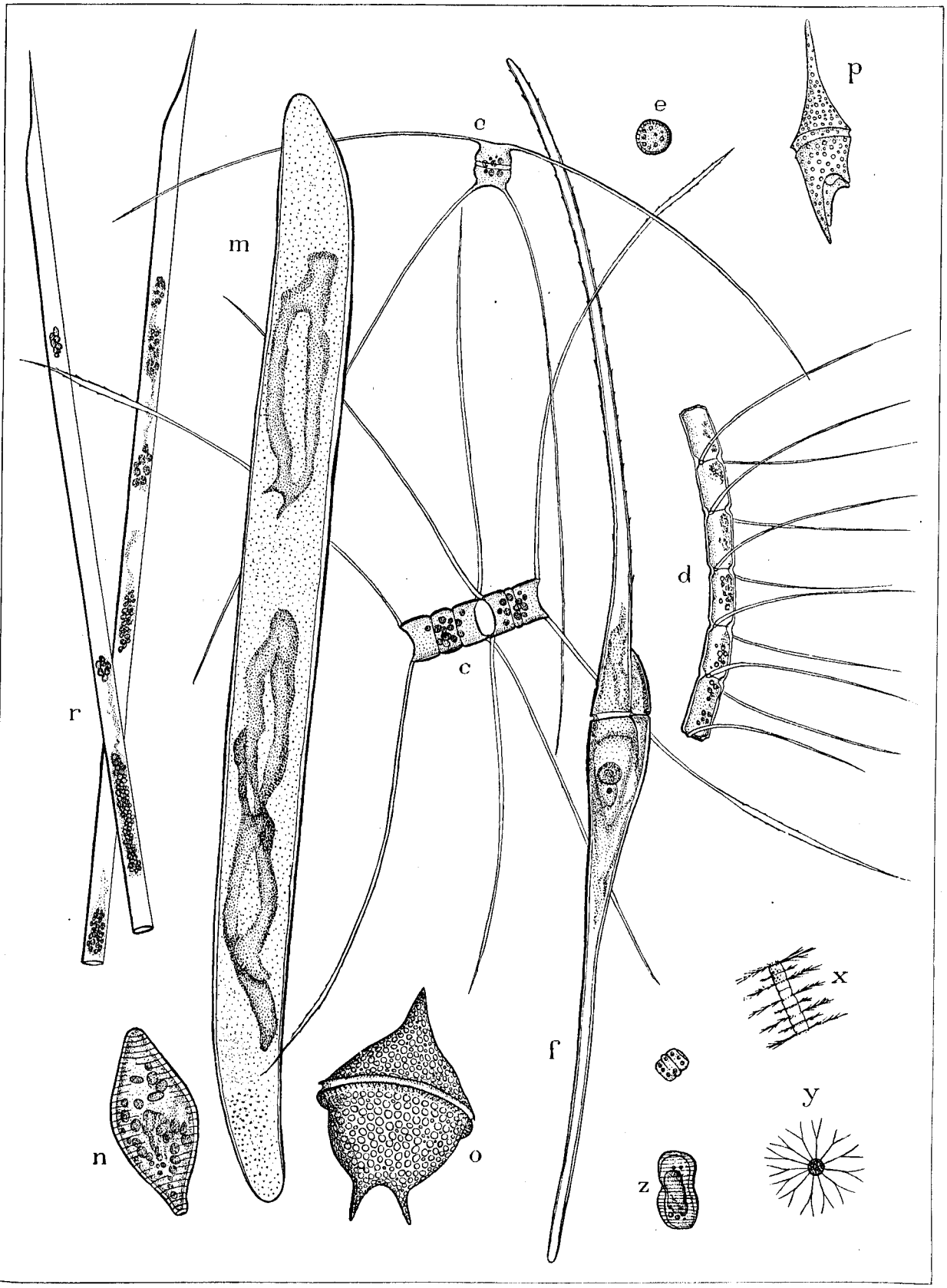


Plate 66 illustrates organisms common in the Plankton of Buzzards Bay, most of which enter into plattings represented on plates 68–71. *a*, *Striatella*; *b*, *Dinophysis*; *c*, *Exuviella*; *d*, *Stauroneis*, *Pleurosigma*, *Navicula*; *e*, *Melosira*, *Cyclotella*; *f*, *Coscinodiscus*; *g*, *Melosira costata*, with small *Chætoceros*, called *Chætoceros* in the text of this paper and in the plattings; *k*, *Codonella*; *p*, *Peridinium* and *Ceratium*; *r*, *Homœocladia*; *t*, *Tabellaria*; *x*, *Surirella*; *y*, *Dictyocha*; *z*, unknown diatom. Magnified 500 diameters.



Organisms common in Plankton of Buzzards Bay, continued: *c*, *d*, *Chætoceros*; *e*, *Melosira*: *f*, *Peridinium fusus*; *o*, *P. divergens*; *p*, *P. fusca*; *m*, *Pleurosigma*; *n*, *Navicula*; *r*, *Rhizosolenia* divided into two parts; *x*, *y*, side and end view of *Chætoceros* chains (little magnified); *z*, *Pinnularia*. Magnified 500 diameters.

as being of wide and abundant distribution and ready recognition. Such selections of organisms of course will leave out many important details of distribution, for if all the animal organisms, larvæ, other infusoria and the like, could be determined at the same time with these plant cells and flagellates, the two kingdoms would perhaps show many interrelations. But a study of these few vegetal organisms and Infusoria alone, in Buzzards Bay, will give some of the manifold characteristics of the Plankton of such a body of water. The bay itself is shallow, with broken shore line (see plate 64), fed by many streams, of very uniform bottom, and not subject to marked tidal changes.

There are also represented upon plates 66 and 67, under a magnification of 500 diameters, some of the chief representative organisms to which the following accounts of distribution and quantity apply. In the tabulated estimates several genera are grouped together under one heading in order to simplify the plattings of quantities. Thus the group *Melosira* includes all those lettered *c* in plate 66, the small *Cyclotella* being classed with the other and larger forms; in estimating this group the actual numbers of individuals is taken, although they are often laid in short chains. So also the estimated *Peridinia* are based upon the forms *p* (plate 66), *o*, *p*, and *f* (plate 67). *Chætoceros* takes in not only the larger forms represented at *c*, *d*, *x*, *y* of plate 67, but also the forms at *g* (i. e., *Melosira costata*) on plate 66, since it is impossible, with the low power used in making these estimates, to distinguish perfectly the finer structure of these small chains, and the chain of *Melosira costata*, usually about the length represented in the upper *g*, is so similar in appearance under a low magnification to that of short chains of the small *Chætoceros* that they were classed together in platting. This of course is an unfortunate complication in grouping and counting, and it is to be remembered that the *Chætoceros* hereafter discussed includes at times almost wholly the ones here designated at *g*, plate 66, i. e., principally the small *Melosira costata*. The *Navicula* group is inclusive of all the diatoms of that general outline—*Pleurosigma*, *Stauroneis*, and the like, at *d* of plate 66, *m* and *n* of plate 67. *Rhizosolenia* includes only *r* of plate 67 (one individual being divided into two equal parts in this drawing). Many *Exuviellæ* are normally present, as *e* of plate 66. The infusoria *Dinophysis* (*b*) and *Codonella* (*k*) are also readily preserved and were estimated, but the results are not tabulated. Many other organisms of course were common, some of which are here represented, while a partial classification of each one will be found in the explanation of plates at the close of this paper.

Suppose now that the ship start from Station A (plate 64), at the upper extremity of the bay, at 11.35 a. m., September 27, being low-water slack, upon a course running the length of the bay and out some distance to sea (along the course A B C D, plate 64). As the vessel proceeds over her course she encounters the incoming tide, therefore meeting in succession any changes which may be caused by a Plankton drifting in from outside waters. Three samples—surface, mid-depth, and bottom—in a vertical, are taken at each station, from which the organisms are filtered and their results tabulated. At the surface of Station A (see plate 68) are found countless numbers of the diatoms, which will be classed with *Chætoceros* (being in reality *Chætoceros* plus the small *Melosira costata*), the relative numbers of which were so numerous that they could not be limited by the scale here used in platting the distribution. At mid-depth and bottom (4 fathoms) of Station A are also found great quantities of these same diatoms, insomuch that other organisms are relatively few indeed. In the first 8 miles of the course, however, from Station A to B, there is a marked diminution in

this group of plant cells, so much so that in the vertical taken at Station B (6 fathoms) there are only about a tenth as many as in the former instance, which dimunition affects the numbers at surface, mid-depth, and bottom in about the same ratio. In the same 8 miles, however, that mark the lessening of *Chætoceros* there is a very notable increase of the round diatoms which are here classed together as *Melosira;* there are thus at Station B more than ten times as many as were previously obtained at A, this increase also affecting surface, mid-depth, and bottom numbers of *Melosira* in about the same ratio. In like manner all the other organisms here estimated (i. e., *Peridinium*, *Exuviællæ*, *Lauderia*, *Rhizosolenia*, *Navicula*, with the copepods) show at B an increase over the quantity at A, this being especially true of the *Peridinia* and *Exuviællæ*.

As the ship advances now to Station C (8½ fathoms), another distance of 8 miles, against the flowing tide, there is again a further diminution, not only of *Chætoceros* forms, but also of most of the other organisms, except the copepods and the large diatoms, *Lauderia* and *Rhizosolenia*, which increase at about the same rate for surface, mid-depth, and bottom distribution, while it is to be noted that *Lauderia* becomes very abundant at the bottom of this vertical at C.* From C, however, out to the last collecting-point of the day, D, 9½ miles, there is a general diminution of all the organisms except the copepods, which as regularly increase, until at the close of the course the organisms obtained from the given samples of water in the vertical at D are much fewer than they were at the outset from A. The *Chætoceros*, which was so abundant at A, is all but absent at D, while all the other organisms except copepods have suffered very marked changes. It is to be noted also that Station D is nearly four times as deep as A, that the mean temperature of the water is 4° colder, and that the amount of microscopic organic débris in suspension (flocculent, yellow-colored, "amorphous" matter) at D is relatively very much greater than it was at A.

In order to express the exact relations which these kinds of organisms bear to each other as regards quantity, at the different points studied in this representative section, reference is made to plate 68, which is a platting of the relative numbers representing each kind of organisms in their distribution at surface, mid-depth, and bottom. The plan of platting adopted on plates 68–71 in illustration of the planktonic distribution is plain. All the organisms used are placed in separate columns under each of the respective stations—A, D, etc. The three collecting points in a vertical—i. e., surface, mid-depth, and bottom—are so placed in order at each station, while the relative abundance of each of the factors may be read by the numerals graduated upon the left-hand margin of the plate. The relative quantities of all the organisms are constantly maintained, except that the copepods are a hundred times multiplied as compared with the others, as will be explained hereafter, while the quantities of *Melosira* are so great that one-half their relative number is used upon the plates; their whole number, however, is given in the tables in the text following. In order also that comparisons may be made from the totals of these organisms at the different points, the following table is inserted:

* The large species of *Lauderia* here referred to are not figured in plates 65 and 66, and Prof. Hamilton Smith, of Geneva, N. Y., informs me that it is an unusual if not new species. The same gentleman, who has done me the great kindness of studying the tangle of *Melosira costata* and *Chætoceros* found at Station A, as above described, says that he has never before seen those forms from American shores, and that they have been hitherto regarded as characteristic of Oriental—especially Chinese—waters, but that he has detected them in the waters of the Firth of Say, Scotland.

Letter M, September 27, 1894, 11.35 a. m. at Station A, low-water slack; reaching Station D at 3.20 p. m., third hour of flood tide; wind southeast, force 5; sky partly cloudy.

Organisms.	Surface.	Middle.	Bottom.	Stations.			
				A	B	C	D
Copepods	23	13	13	7	8	10	24
Peridinium	53	22	20	10	43	30	12
Exuviælla	57	49	51	24	64	50	19
Chætoceros	1,424	758	407	2,241	240	104	4
Melosira	339	230	202	40	439	269	23
Lauderia	25	29	33	.....	18	62	7
Rhizosolenia	19	23	20	7	23	30	2
Navicula	23	29	20	12	29	26	5
Total	1,940	1,140	753	2,334	856	571	72
Average temperature (°F.)	.....	.....	.....	66.1	66.5	65.3	62
Depth (fathoms)	.....	.....	.....	4	6	8.5	15

In this table the copepods are estimated upon a different basis and are therefore not added in making up the totals. Otherwise all the organisms of the surface of all the stations are added into the first column of numbers, all those from the mid-depth into the second column, and all those from the bottom into the third. So also the same numbers are properly distributed according to their occurrence at the respective stations A, B, C, D, the total sum of the surface, mid-depth and bottom being represented in each number. Such a table shows in the first place that the sum total of all these organisms at the surface is greater than those of mid-depth, which latter are in turn more abundant than those of the bottom. Also that this is the rule for each separate factor of the series except the *Exuviælla*, least at mid-depth, and the *Lauderia* forms, which are slightly most abundant at bottom, and the *Rhizosolenia* and *Navicula* forms, which are most abundant at mid-depth. Similarly the sum total of all the various groups of organisms at A is much greater than at any of the succeeding stations, the numbers diminishing very rapidly, especially between A and B, and between C and D. It is to be noted, however, that this remarkable abundance of material at A is due very largely to the item *Chætoceros*, with its abundant *Melosira costata*, and if this be left out of the calculation, Station A will be seen to be next to D as regards numbers, being much less than either C or B. Station B is the richest in these organisms, all reaching their maximum excepting *Lauderia* and *Rhizosolenia*, which increase to Station C, especially at bottom. The *copepods* also increase most rapidly from C out to D. All of these features are analyzed into their component parts by the platting on plate 68, from which the distribution of these several forms may be compared.

The same section run three days earlier is represented in the same way by the platting on plate 69, and the totals of the organisms by the following table:

Letter K, September 24, 7.45 a. m. at Station A, low-water slack; 11.53 a. m. at Station D, third hour of flood; wind north-northwest, force 5; sky clear.

Organisms.	Surface.	Middle.	Bottom.	Stations.			
				A	B	C	D
Copepods	13	5	6	4	2	6	12
Peridinium	59	13	7	14	23	38	4
Exuviælla	65	39	25	38	36	52	3
Chætoceros	1,891	1,273	1,126	3,609	610	67	4
Melosira	266	91	60	87	170	146	14
Lauderia	21	8	13	.....	2	25	15
Rhizosolenia	24	11	14	5	12	31	1
Navicula	19	18	30	14	18	31	4
Total	2,345	1,453	1,275	3,767	871	390	45
Average temperature (°F.)	.....	.....	.....	70.5	69	67.5	64
Depth (fathoms)	.....	.....	.....	4	7.5	7.5	15.5

Here again there is the greatest quantity of *Chætoceros*, which extends out to Station C in such quantities that the scale used in platting (see plate 69) can not represent them at the surface or mid-depth until they fall to a relatively small figure at Station C, while from this point on to D they steadily diminish to a minimum, so that *Chætoceros* of surface Station A stands related to surface Station D as 3,609 is to 4, while mid-depth and bottom samples indicate the same relations, though to a less marked extent. So also, as in the section before described, the diatoms *Melosira* culminate at Station B, while all the other forms culminate at C, diminishing gradually to D, which is relatively poorest in vegetal micro-organisms, but richest in *Copepoda*. At this date also the water at Station D contained very much of flocculent organic débris, more by far than was found at any of the other points studied.

Reference also to the preceding table (Letter K) shows that of the totals of all the organisms considered, the greatest number is to be found at the surface, a less number at the mid-depth, and the least number at the bottom, even in the shallow waters here under observation. This is not, however, true of each individual factor in the series, since some of the items of bottom distribution are greater than that of the same organisms at mid-depth or surface distribution, as is apt to be the case with *Lauderia*, *Navicula*, and *Rhizosolenia* groups. It is also true that the greatest quantity of total organisms is found at Station A, diminishing in regular sequence as one proceeds out to D, where very few are met with. This aggregate, however, is of course determined largely by the great numbers of *Chætoceros* in the first two stations, while if these be omitted in the reckoning the organisms will be seen to be most abundant at Station C. The relative vertical distribution, however, remains the same, being greatest at surface and least at bottom. Here also the *Lauderia* are most abundant some distance from the shore and at mid and bottom depths. The copepods also are most abundant at Station D. In all the essential features, therefore, these two sets of observations agree as to the way in which these organisms are disposed through the water.

The same section was also studied at a still earlier date (September 13), but an unfortunate loss of the material taken from mid-depth at Station A and surface at Station C rendered the observations too incomplete for platting for comparison. Nevertheless, by representing the missing sample in each case by the one next below it, the compilation has been finished and is given in the following table:

Letter E, September 13, 1894, 12.20 p. m. at Station A, low-water slack; 4.40 p. m. at Station D, three-fourths flood; wind southwest, force 3; sky clear.

Organisms.	Surface.	Middle.	Bottom.	Stations.			
				A	B	C	D
Copepods	14	6	5	6	13	1	5
Peridinium	33	29	24	8	44	26	8
Exuviælla	78	89	53	20	108	69	23
Chætoceros	191	174	160	304	56	137	28
Melosira	421	315	268	148	484	299	73
Lauderia	34	111	76	.....	7	11	203
Rhizosolenia	42	32	22	4	13	37	42
Navicula	37	30	22	18	27	37	7
Total	836	780	625	502	639	616	384
Average temperature (°F.)	.....	.....	.....	69.8	69.3	67.7	63.3
Depth (fathoms)	.....	.....	.....	3.5	3	8	15.5

Although I do not think it is safe to depend upon all the relative details of this table on account of the two deficient samples, yet certain conclusions are evidently admissible. In the first place even the two available samples of the vertical taken at Station A show beyond a doubt that the *Chætoceros* had not then attained at that locality the great abundance which they showed at the later dates heretofore described, while at all the succeeding stations they extend much farther from the shore in considerable quantities, as at B and C, and at D in much greater proportion than they did two weeks later.

It is also to be noted that *Lauderia* was at this earlier date much more abundant than on the two subsequent dates described here, being by far the most characteristic organism at Station D; of 78 bottom organisms at this locality, 70 were *Lauderia* of one, or at most two, species. There was at this time also relatively very little of the flocculent amorphous débris suspended in the water at Station D.

The above table also shows the increase of micro-organisms at Stations B and C, and agrees with the two preceding ones in showing more organisms at the surface than occur at either mid-depth, or at bottom where there are least.

The extent to which the Plankton of Buzzards Bay may be shifted by the tidal currents might be tested by running this same longitudinal section on an ebbing tide by which the ship would register a somewhat different set of conditions from those here recorded, while the line should be extended out as far at least as the Gulf Stream (60 miles distant) in order to show the relation between the offshore and littoral quantities and distribution of these and other forms as they might occur.

The section across the bay (plate 64, Stations I–V) was designed to get as near a synchronous series of observations as was possible upon any given tide or fraction thereof. The whole distance was divided into four equal intervals, the stations being then about a mile and a half apart, and a vertical of surface, mid-depth, and bottom samples was taken at each station.

Letter N, shown by the platting on plate 70, represents the distribution of this material under consideration in a cross section of Buzzards Bay on the day following the longitudinal section given on plate 68, and there is a great regularity in the results obtained. The irregularity is confined almost entirely to the one group *Chætoceros* (plus the *Melosira costata*) which from Station IV begin to increase very rapidly for the last mile of the course to Station V at surface, mid-depth, and bottom samples in the same manner, until at the last collecting point, Station V, they form by far the greater part of the aggregate organisms and, as in previous instances of the kind already cited, the other organisms are especially few.

Of such other organisms except *Chætoceros*, the general rule is that they gradually increase as one approaches the middle of the section, and then decrease again as the other limit is reached; this is especially noticeable in the group *Melosira*, which is the chief element as regards abundance and continuity in occurrence in these cross-section analyses. The copepods also conform to the same distribution, i. e., are more abundant at the middle portion of the bay than at either end.

The following table gives the arrangements of the total organisms for each group in their proper order at the several stations:

Letter N, September 28, 1894, 3.10 p. m.; low water; wind east-southeast, force 5; sky clear.

Organisms.	Surface.	Middle.	Bottom.	Stations.				
				I	II	III	IV	V
Copepods	26	14	11	7	19	16	7	2
Peridinium	52	20	15	14	14	24	23	12
Exuviælla	51	33	37	14	32	39	19	17
Chætoceros	1,626	577	495	217	226	175	285	1,795
Melosira	376	268	282	151	200	274	192	109
Lauderia	24	16	15	17	21	14	3	.....
Rhizosolenia	27	20	26	34	8	17	9	5
Navicula	83	51	76	35	52	52	31	40
Total	2,239	985	946	482	553	595	262	1,978
Average temperature (°F.)	.....	.....	.....	67	67	67	67	67.5
Depth (fathoms)	.....	.....	.....	3	7.5	6.75	5.75	4.5

It is again here seen that the greatest total of the organisms is located at the surface, an intermediate quantity at mid-depth, the least at the bottom, while *Melosira*, *Rhizosolenia*, and *Navicula* have a tendency to increase at bottom distribution, as has been previously demonstrated by the tabulated results of the sections taken longitudinally, letters M, K, and E, through this body of water; also that the greatest number of organisms in a given vertical are found at Station III, if one excepts the one item of *Chætoceros* at Station V. Taken in connection with letters K and M, heretofore described, one can infer that there is at these dates a belt of water next the shore line which is heavily charged with the minute *Chætoceros* (plus *Melosira costata*), which here far exceed in number all the other organisms of the verticals in which they occur taken together, but which rapidly disappear as one gains the more open waters of the bay. It may be presumed also that this belt extends far around on the eastern shore, but the swift tides which sweep over Station I make the conditions there very different from those obtaining at the other end of the section, i. e., at Station V.

The only collecting done by the *Fish Hawk* at nighttime over this course is given in the cross-section Letter H (low water), of which the platting on plate 71 represents the distribution of the organisms. This section presents the greatest irregularities in distribution of any one studied, and thus offers many contrasts to the previous instances cited, due, I think, to the removal of the influences of daylight.

In the first place one notices especially the irregularity of the distribution of the *Melosira* group, which seem to lie in a thick windrow, especially at bottom, at Station II, although they are otherwise quite abundant and quite regularly distributed. So also the *Chætoceros*, which are relatively so few that no attempt was made to express them on the platting except at Stations IV and V mid-depth and bottom), seem to lie in a stratum at middle depth of Station IV and shade away toward the bottom of Station V. Otherwise there is considerable regularity in the distribution of the organisms, with a tendency now to increase at Station II, instead of at Station III as was the case in the cross section heretofore described. The copepods are very uniformly distributed, being most abundant also at surface.

The following table presents in order the classified distribution of total organisms of this cross section:

Letter H (low water), September 18, 1894, 2.45 a. m., low-water slack; wind north-northwest, force 2; sky overcast, hazy.

Organisms.	Surface.	Middle.	Bottom.	Stations.				
				I	II	III	IV	V
Copepods	24	9	5	7	9	7	6	9
Peridinium	76	59	27	20	45	32	29	36
Exuviælla	143	112	154	91	103	52	79	84
Chætoceros	14	119	59	2	12	5	99	74
Melosira	652	592	1,160	340	1,081	325	384	274
Lauderia	14	16	20	32	7	8	.....	3
Rhizosolenia	46	25	38	64	22	9	4	10
Navicula	58	68	89	34	63	39	33	46
Total	1,003	991	1,547	583	1,333	470	628	527
Average temperature (°F.)	.....	.....	.....	68.1	69	69	69.1	69
Depth (fathoms)	.....	.....	.....	4	7.5	7	6	4

From this table the irregularity of distribution is plainly illustrated, this being the first instance in which the surface organisms have not exceeded in quantity the mid-depth or bottom. This is evidently due to a withdrawal of organisms from the surface, while the peculiarly obscured condition of the light may be held responsible for the failure to become as regularly localized as is usual, as well as for the change from the ordinary daytime vertical arrangements in such a way as to well illustrate the effects of heliotropism, or rather the lack of the same, for the influences of so little light would produce weak results except in such organisms as the freeswimming larvæ or copepods. This is well shown by the copepods, for in this cross section taken at nighttime 85 per cent of the whole number observed are found at the surface, while in all the other observations, taken as they were at daytime, only 52 per cent on an average were found at the surface. The night in question was unusually dark, with a thick haze, and in the shallow water of this bay the much disturbed vertical distribution would be expected except in the case of such organisms as the copepods, which can most easily change their location in the water, and are known to be so abundant normally at the surface during the nighttime. It is also fair to suppose that even the normal nighttime distribution would be materially affected by such extreme darkness as was experienced upon this course.

This same section was retaken on the following forenoon and on high tide water with results represented by the following table:

Letter H (high water), Sept. 18, 1894, 10.35 a. m., high-water slack; wind NE., force 3; sky cloudy.

Organisms.	Surface.	Middle.	Bottom.	Stations.				
				I	II	III	IV	V
Copepods	10	5	4	9	2	1	3	4
Peridinium	100	46	43	3	64	23	57	42
Exuviælla	141	132	113	40	162	73	44	67
Chætoceros	102	81	39	16	32	9	21	144
Melosira	550	408	485	234	428	302	281	198
Lauderia	4	7	24	11	12	8	3	1
Rhizosolenia	40	44	31	12	20	21	6	6
Navicula	54	59	87	49	47	27	40	37
Total	991	777	822	365	815	463	452	495
Average temperature (°F.)	.....	.....	.....	68.3	68.5	69	69	69.3
Depth (fathoms)	.....	.....	.....	4.5	8	7.5	7	5

The preceding figures were compiled from material in which two samples were missing, but inasmuch as they were one surface and one bottom, a mid-depth in the same vertical was used in the stead of each, and I believe the general results are very little disturbed. It here appears that on the return of daylight the organisms are again arranging themselves in the relations previously described, there being more total organisms at the surface than at either mid-depth or bottom, and while the total at bottom still exceeds those at mid-depth, this is due to the diatoms, which usually show this peculiarity of increasing at bottom, i. e., those here grouped as large species of *Lauderia* and *Navicula*. It is also noteworthy that in this series the copepods are not so abundant as they were in the preceding instance—i. e., the same section taken at low water at nighttime. The vertical at Station II also shows the most organisms on this series; and for all the stations the *Melosira* group is the most important factor, as it was likewise in the series taken eight hours earlier on this same date.

I had fully expected to find a section taken at high water, or on a strongly flowing tide, to be richer in these organisms than the same section taken at low water, but such has not proven to be the case. This is perhaps explained by the fact that as the longitudinal sections of Buzzards Bay show a marked decrease in this material as the open waters of the ocean are approached, so also a strong incoming tide in these shallow depths would tend to materially affect the numbers of organisms at the center of the bay by bringing in a great bulk of water from the outside, which is relatively poor in these. As this tide drifts out again the aggregate material is brought out from more inshore localities, thus increasing the amount of material in low-water analyses as compared with those taken at high water.

In all that has thus far been proposed concerning the quantitative analyses of these organisms, the actual number per liter of ocean water has not been given, for the reason that the numbers tabulated were the ones actually observed under the microscope, from which the numbers in any given quantity of water must be estimated. The relative estimates here given are obtained in the following way: Five liters of water at each sample were filtered through a film of fine white sand at the bottom of a large funnel, the filtrate of organisms remaining upon the sand was then gently washed off in a small quantity of sea water and treated with a strong solution of formalin; when the material had thus been killed and had entirely settled to the bottom of the vial, the first formalin was decanted off and a fresh solution added, until the bulk of the formalin, including the filtrate, stood at just 15 cubic centimeters. Thus the organic material in a bulk of 5,000 cubic centimeters of water is collected into a bulk of 15 cubic centimeters of preservative, i. e., 333⅓ cubic centimeters of sea water are represented by every 1 cubic centimeter of the preserved material. The separation of the material—the filtrate—from the sand required the greatest care, but certainly all our errors were on the side of underestimation, inasmuch as we could not exaggerate the amount of organic matter in each 5,000 cubic centimeters of water used, and great pains were taken to transfer all the organisms from the sand to the preservative without loss. All the material here studied was collected in exactly the same manner by the same apparatus and persons.

The next step in the estimation is to compute the number of organisms in one cubic centimeter of the preserved material, and this was done by means of the "Rafter cell" and micrometer (1 inch) eye-piece, the latter being so graduated into squares that one square in the eye-piece views a thousandth part of the surface of the 1 cubic centimeter, arranged on the stage of the microscope in the "cell"; for as the Rafter

cell is 1 millimeter deep, to 1,000 square millimeter surface, each field of the eye-piece micrometer estimates $\frac{1}{1000}$ cubic millimeter out of the total 1,000 cubic millimeters inclosed in the Rafter cell; that is to say, as one counts the number of organisms in any one field of the microscope (a two-thirds inch objective being used) it represents a one-thousandth part of the 1 cubic centimeter of filtrate under consideration.*

The practice was observed of carefully studying over the entire field and then of tabulating the organisms from ten representative fields of the instrument, and these are the numbers given in the foregoing tables except the copepods, which were so few relatively and so large that it was my practice to count them with a lower power objective in the whole one cubic centimeter of filtrate under study. They are in numbers, therefore, *one hundred times multiplied* as compared with the other material tabulated. Two cells were always used in order to get a more complete representation of the 15 cubic centimeters of filtrate, and 20 or even 25 squares were counted from each 1 cubic centimeter in the Rafter cell until it was found that those averages did not very materially differ from the estimates based upon 10 squares, which were therefore finally taken as the basis of tabulation.

The *actual quantity of organisms per liter* of littoral ocean water as computed by these data must therefore be obtained *by multiplying each of the factors heretofore used in the tables (except the copepods, which must be multiplied only by 3) first by 100 and then by 3.* This gives the actual numbers of organisms in the normal ocean water as something truly wonderful, and I shall hope to substantiate or correct these estimates in the future, but for the present am convinced of the reliability of the comparative results, both because the material was handled so systematically in the same ways throughout and because the end results compare so regularly.

In order also to make these estimates as representative as possible those organisms were selected, as has been before stated, which were most numerous and of constant occurrence in the material as it came under the microscope, and which were provided with such skeletal elements as would resist dissolution in the process of filtration and preservation. And it is for this reason that although continual records were made of various other genera of infusoria, no general conclusions were based upon them, since they die so easily and wholly disintegrate. So, also, other diatoms of less usual occurrence were systematically recorded, though not given a place in the tables presented. All these plankton analyses, moreover, were made at the biological laboratory of Williams College during a busy term of teaching, at intervals, and the facts merely recorded and put on file, and it was only as such a study of the material was completed that the platting and tabulation were done, and then for the first time were the relations of the organisms seen.

These facts, and especially the harmony of surface, mid-depth, and bottom observations at each point acting as checks upon each other, give evidence as to the truth of the distribution shown. The truth is all too partial, no doubt, even for the organisms cited, to say nothing of the whole series of animal organisms which were associated with them in their natural environment. But I am convinced of the value of numerical

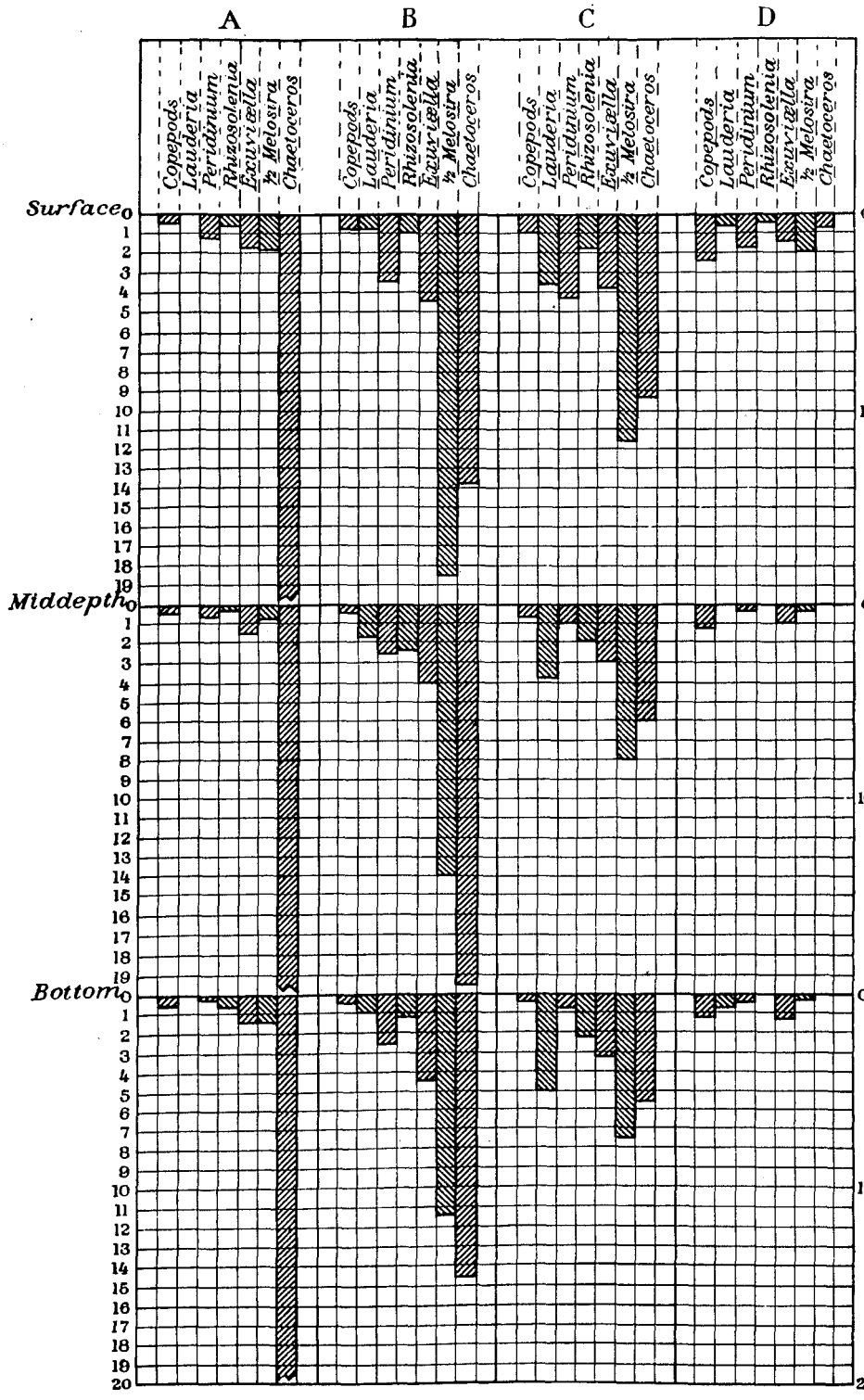
* This quantitative apparatus was first provided for me at the laboratory of the Boston Water-Works in the autumn of 1889, where it is still in use; this particular pattern of cell and the micrometer were designed, I believe, by Mr. G. W. Rafter, of Rochester, N. Y. It consists of a rectangular metal rim mounted upon an ordinary microscope slide, to be covered with a long coverslip. The inclosed contents then measure uniformly 1 mm. in depth, 20 mm. in width, 50 mm. in length, i. e., 1 cubic centimeter.

estimates in dealing with planktonic studies as giving definite data for larger comparisons to be gained by such lines of research. In many respects the classing together of several species of genera of organisms under one typical group is misleading; for instance, in the Peridinium family, heretofore platted and tabulated, there is a marked separation between genera such as *Ceratium*, which is closely limited to surface, and those extending more evenly down to the bottom samples, such as *Glenodinium* and *Gymnodinium* forms; other instances of this kind are noticeable, even in the shallow waters here investigated. The grouping together of allied organisms, therefore, or adding into totals, may lead to some more general results, but the finer analysis of the distribution of each species individually lays the foundation.

Of course numerical estimates of a Plankton may always be subject to Professor Hæckel's criticism, when he compares it to a farmer's estimating the yield of hay or grain by counting the number of blades of grass or kernels of grain, etc. But a numerical estimate of the constituents of the water expressed in terms "per liter" will certainly give as valid a basis for comparison of the same body of water under different conditions, and of different bodies of water also, as any other way, and will be a much more accurate test, I believe, than any volumetric results or data expressed in weight of material in suspension. For in these last cases the greatest disturbance would be caused by the presence of the organic débris, which is often most abundant where the real living material secured is at a minimum. The volume of filtrate secured from a given sample of water is no guaranty whatever of the actual bulk of living organisms contained therein. And I believe that with an efficient apparatus a numerical estimate of each class would show many constant interrelations; but planktonic distribution is so very variable that statements about one locality would not necessarily apply to other bodies of littoral waters, however alike the seeming conditions of environments might be.

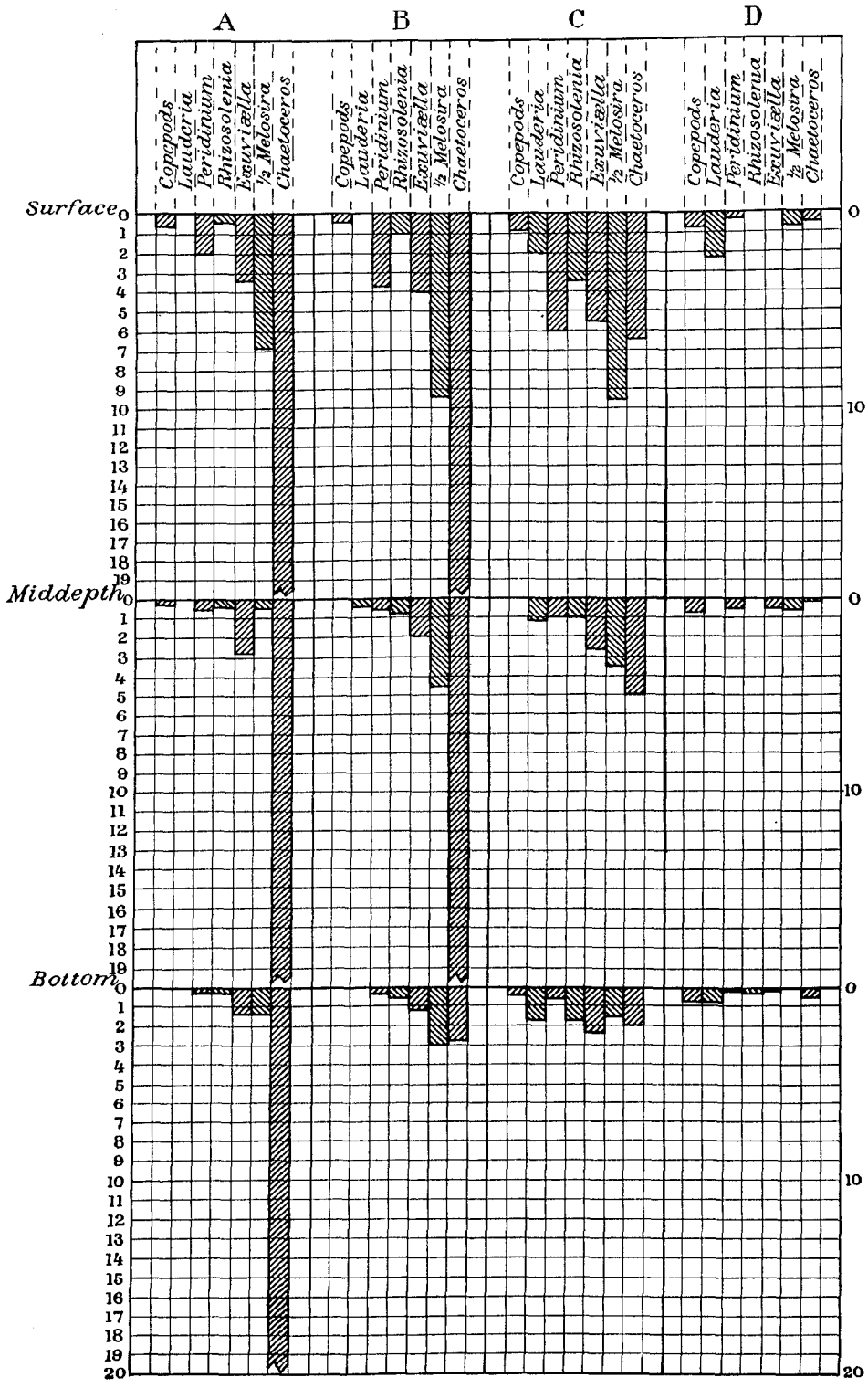
It is in the hope that studies carried on in this manner may contribute to a wider understanding of the resources of ocean water, not only from a purely economic standpoint—valuable as that might be—but for the sake of the biology of the organisms themselves, that this paper is here offered. The author sincerely regrets that at present he is without the opportunities of giving the observations here recorded their full treatment, but ventures to present the plan of the work through the means offered by the United States Fish Commission, as some token of the appreciation he feels for the liberal encouragement and help always extended to biological work by its present administration. My thanks are also due to my friend Mr. N. R. Harrington for the fidelity shown by him when in charge of the apparatus as these collections were taken; and also to all the officers of the *Fish Hawk* for their willing cooperation in every detail. The plan of the lines of sections of the survey was developed by the Commissioner of Fish and Fisheries, Marshall McDonald, and every hope is felt that this or other work of its kind may tend toward the solution of some of the ends desired by him.

WILLIAMS COLLEGE,
Williamstown, Massachusetts, December 23, 1894.



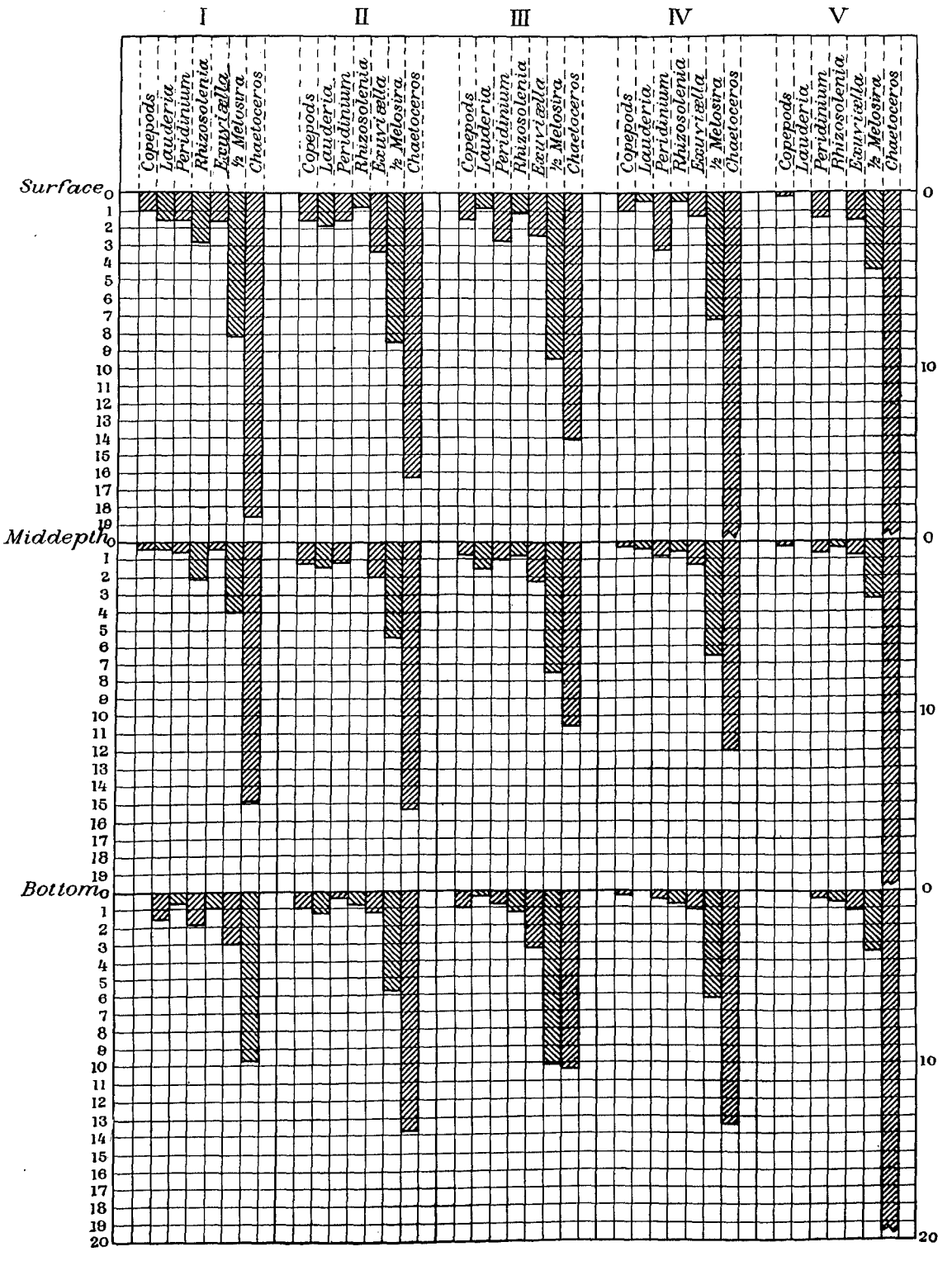
LONGITUDINAL SECTION, LETTER M.

Platting of the organisms of the longitudinal section designated "Letter M," the totals, together with the other data descriptive of the course, being tabulated on page 361 of the text of this paper. The same organisms are recorded under each station, A to D; their relative abundance at surface, mid-depth, and bottom is indicated upon left-hand margin of the diagram. In this and the following plates (69–71) the Copepoda are a hundred times multiplied as compared with the other organisms, but all the others are platted to the same scale except that only one-half the quantity of *Melosira* is used.



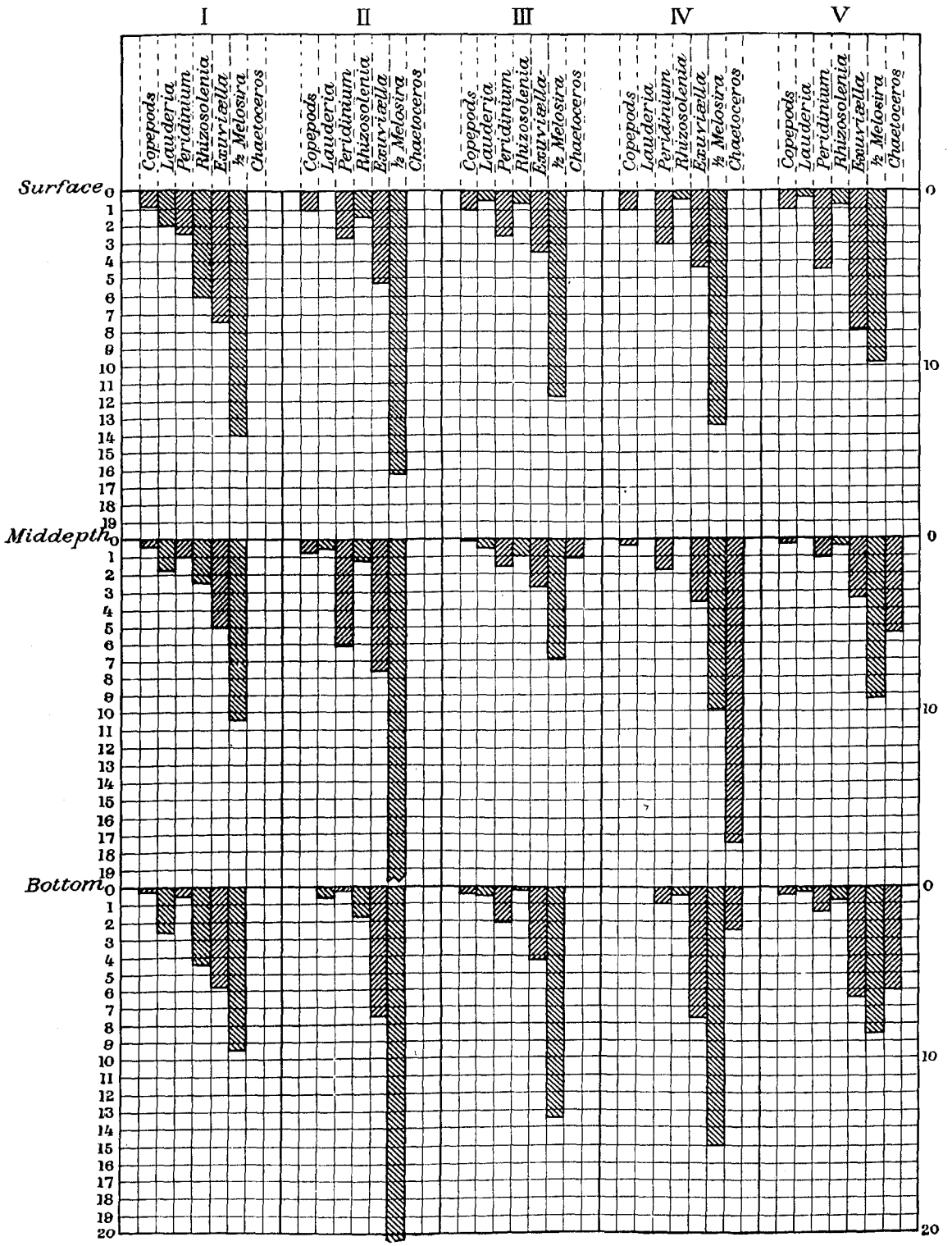
LONGITUDINAL SECTION, LETTER K.

Platting of organisms as obtained from longitudinal section called "Letter K," as tabulated by totals on page 361 of this report, together with temperatures, depths, and other data.



CROSS SECTION, LETTER N.

Platting of the same groups of organisms as obtained from the cross section "Letter N," the totals being tabulated on page 364, with the other data descriptive of the course.



CROSS SECTION, LETTER H (AT LOW WATER).

The same groups as collected from cross section "Letter H" (low water), totals of organisms tabulated on page 365 of this paper, together with other data descriptive of the course.

9.—CONTRIBUTIONS TOWARD THE IMPROVEMENT OF THE CULTURE OF SALMONOIDS AND CRAWFISH IN SMALLER WATER-COURSES.*

By KARL WOZELKA-IGLAU.

[From "Deutsche Landwirthschaftliche Presse," Nos. 28 and 31; Berlin, April 6 and 17, 1895.]

The present management of our smaller water-courses, of streams of different size, but containing a quantity of water sufficient at least for the steady working of a flourmill or sawmill, leaves a great deal to be desired in the matter of fish or crawfish culture. We can hardly speak of the cultivation of these water-courses (frequently the finest and most suitable streams for trout) in the proper sense of the word. In most cases they are left to themselves; and only between the different falls are fish and crawfish—if the stream contains enough to make the labor remunerative—caught with nets, reels, etc.; occasionally also by laying the milldam dry. In very few cases is the stream stocked with young fish or spawn or mother crawfish, and then only to maintain the actual supply of fish or crawfish.

These natural streams can never, or at best only partially, be laid dry; fishing can not be carried on systematically, and a proper management is consequently out of the question. We therefore find in those streams which have a large supply of fish, besides crawfish of every age, predaceous fish and other fish of many varieties and different sizes. Under such circumstances the stock of fish and crawfish can never be fully developed, because a constant war is going on between the different inhabitants of these streams, with a consequent reduction of numbers. The water could frequently contain a much larger quantity of fish or crawfish if they were only allowed to increase in number. Cultivated fish, in the full sense of the term, are not known in these waters. The spawn deposited by the more valuable fish (trout, grayling, etc.) is partly devoured by crawfish and partly destroyed by bullheads, gudgeons, etc. Natural occurrences (floods, drought, heavy ice, etc.) also contribute their share toward diminishing the spawn. Artificial impregnation, hatching, and the careful raising of the young fish and crawfish will be thoroughly appreciated if we bear in mind that of the spawn or young crawfish deposited in natural waters hardly 5 per cent are developed into full-grown fish or crawfish. If young fish or crawfish are placed with larger animals of their own kind, it may be assumed with absolute certainty that in a very short time 70 to 80 per cent will be destroyed. What is the use, therefore, of careful cultivation under such circumstances?

* Beitrag zur Hebung der Salmoniden- und Krebszucht in kleineren Wassergerinnen.—H. Jacobson, translator.

NOTE.—This article is presented in the hope that it may afford suggestions for the utilization of some of the waters of this country, even though all the conditions mentioned as present in the streams of Bohemia may not exist in those of the United States.

If the culture of fish or crawfish is to succeed in streams it is necessary—

(*a*) That there should be a possibility of laying these streams entirely dry at times and removing all fish.

(*b*) Fish of the same kind which are to be cultivated should be all of the same age. If several kinds of fish are cultivated in one and the same water, they must moreover be equally developed. Fish and crawfish, even if they are of the same age, must under no condition be raised in one and the same water. Trout, e. g., will, under suitable conditions, weigh 300 to 400 grams [about 10 to 13½ ounces] after the completed second year, and at that age fetch the best price in the market. The crawfish, however, needs from five to six years in order to find buyers at a weight of 50 grams [2⅓ ounces]. The objection to stocking water with young trout and crawfish of the same age is not so much the inconvenience caused by the circumstance that fishing will have to be carried on at two different times, as the vast difference in the growth of these two animals. If the yearling trout weighing about 100 to 150 grams [3½ to 5 ounces] do not entirely destroy the little crawfish of the same age, but weighing only 1 to 2 grams during the first year, the 2-year-old trout, now weighing about 400 grams [13½ ounces] and having become more voracious, will certainly succeed in destroying all the young crawfish which now have only reached the weight of 4 grams.

(*c*) Finally, care should be taken to furnish a constant supply of nutritious natural food.

As it will be far easier to introduce a well-regulated remunerative culture of fish and crawfish in small streams which are generally fed from springs, and consequently have pure and healthy water at all times, than in rivers whose water has been polluted by refuse from factories, more attention should be given to this matter.

In order to derive the greatest possible benefit from the water of a stream and to gain as many separate inclosures as possible for the proper rotation necessary in well-regulated fish-culture, ditches of varying breadth must be dug on both sides of the stream 70 to 90 centimeters [2½ to 3½ inches] deep and 50 to 100 meters [16¼ to 32½ feet] in length. With these ditches (fig. 7) puddles, and in fact larger or smaller depressions of the ground, may be advantageously united, and wherever the ground is favorable small independent ponds may be constructed and fed from the water of the stream.

In order that the water of the stream within the limits of the establishment may at any time be withdrawn from the different ditches (the smaller ponds, as well as from the channels through which the water flows in and out) so that all these water-courses or ponds may be laid dry and all the fish removed therefrom, they are arranged in such a manner that the bottoms form geometrically inclined planes (every valley of a stream will have sufficient fall), or at least do not deviate very much from such planes. The bottoms of the smaller ponds need not always have the same inclination as the bottoms of the ditches, etc., but may be dug out all the deeper, in proportion as their outflow channels are dug out deeper, supposing, of course, that there is sufficient fall. It is self-evident that the bottoms of the smaller ponds must always be a little higher than the upper part of the bottoms of their drains, in order that these small basins of water can be laid thoroughly dry at any time. If the water is led into these basins from a considerable height, and consequently with a smaller fall, they may be dug out deeper and their area may be likewise enlarged. All this work, however—which will be more fully described farther on—must be preceded by

the construction of a contrivance (a description of which will be given) which renders it possible to do all the digging, etc., after the bed of the stream has been laid dry, without any interference by the water.

The first thing to be done is to give to the portion of the stream concerned a bottom as evenly inclined as possible, by leveling sand banks, removing stones, and filling holes, so that there are no puddles in which fish or crawfish may remain when the stream is fished clean. If the mouths of the ditches are placed at the same height as the bottom of the stream after that has been regulated, the fall of the short stream will distribute itself throughout the longer ditches and channels, and, consequently, that portion of the water which enters the ditches and channels will flow much less rapidly than the water in the stream itself. Although it is not necessary that the bottoms of all the ponds should present the same geometrical inclination, it is essential that the bottom of each pond or inclosure from the place where the water enters to the place where it flows out into the stream should form an inclined plane.

In order to distribute the disposable water of a stream as evenly as possible throughout the ditches, their ponds or puddles—and in the bed of the stream itself, the entrance and outflow of two ditches, which are of course close together—should invariably be placed about the middle of the third opposite ditch. Into each ditch one-half of the disposable water of the stream is led, and into each pond channel one-third. In order that the water may, by partial damming, flow better into the ditches and channels, and to enable the cultivator to measure out to each inclosure a certain quantity of water, a board should be placed below the mouth of every ditch and channel. These boards (figs. 2 and 3), which are of varying length and breadth, to suit the different circumstances, have an oval opening in the lower central portion, so that the fish (and also the crawfish) have a chance to go up the stream.

If these boards are fastened so deep to two strong poles firmly rammed in the bottom that the lower edge of the oval opening is on a level with the bottom of the stream or of the ditches, the various inclosures can always be laid dry and all the fish removed therefrom, even if the boards are left standing, because the water, with its fish, has a sufficient outflow through the openings. The size of the opening depends on the quantity of water which can be counted on. Under no circumstances must the opening be larger than the cross section of the water flowing through the water-course, for otherwise there could be no damming, and no small waterfalls could be formed. The rushing of the water over the board in the form of a small waterfall is an advantage, not only because the water thereby becomes more impregnated with oxygen, and therefore more wholesome, but also because the trout loves such waterfalls and whirlpools. Such boards are also placed in other parts of the stream and the ditches, and, in fact, wherever the raising or damming of the water appears desirable for the purpose of making the sheet of water deeper or broader, or making the current slower. By means of these boards smaller water-courses, and even streams with higher banks and a stronger fall, will be rendered suitable for fish-culture.

The entrance and outflow of all the ditches are dug out as narrow as possible and as nearly of the same breadth as practicable. This is necessary in order that the ditches can be more easily and better shut off from the stream and the fish be removed therefrom, and in order that contrivances for shutting off having the same size may be used in all. Each individual ditch is shut off a little back of the entrance (above) and a little above its outflow (below), and thus forms an independent inclosure. In the same way the small channel through which the water flows in and out of each

independent pond is shut off from the stream, and each pond from its feeder by the same contrivance (instead of a fish-rake). It is best to use for this purpose strong galvanized-wire gratings (which can, at a reasonable price, and in all sizes and strengths and width of meshes, be obtained in all wire factories). These gratings must be a little larger than the ditches which are to be shut off (fig. 4), so that they can be let into the edges and the bottom of the ditch from 8 to 10 centimeters [about 3 to 3½ inches]. It is well known that salmon, owing to their strong migratory tendency, will leap over impediments found in their way, and will attempt to escape from inclosed waters.

In order to lay a ditch dry at any time and remove the fish therefrom, without interrupting the flow of the water in the stream and in the other ditches, a larger board or floodgate (fig. 5), having the form of the profile of the ditch, is placed above, near the entrance to the ditch, a little in front of the grating mentioned above. This contrivance consists of grooved boards with cross ledges and a handle, with sharp edges below; and on the sides it is let into the edges and bottom of the ditch. The consequence of this interruption of the current in the highest part of the ditch will be that the water, and with it the fish (crawfish can be picked off the bottom of the stream when it is laid dry), will slowly flow farther down, and all the fish can in this way be conveniently caught just in front of the lower grating of any ditch or inclosure which is treated in this manner. The water of the stream will only be dammed up very little in the lower part of the ditch, and only form a small puddle back of the lower grating, where the fish can be easily taken out. It can, of course, not be avoided that a few fish are found even back of the boards with the oval holes.

In order that the above-described work may be done in dry ground, that the establishment may be protected against floods, and that all the fish may at any time be taken from the stream itself (which is to be cultivated independently of the ditches and ponds), an arrangement must be made in the stream above the establishment which renders it possible to shut off the water there, either in part or entirely, and lead it into one or two specially constructed ditches. This arrangement consists of a stronger floodgate (fig. 6), with a higher and well-fitting wing. The two special ditches referred to above begin a short distance above the floodgate, are carried along the two sides of the establishment and empty their water into the stream below the establishment. In order to make a flood possible in longer ditches (without giving them a stronger fall, and therefore making them shorter), they are (as shown in fig. 7) furnished here and there with short steps paved with stones. If it is possible to cultivate grass in the flat ditches which are only temporarily used, it will not be necessary to construct these stone steps, and some little advantage may be derived from the grass, which may be used as fodder for cattle.

The wing of the floodgate of the stream is, during the season of cultivation, only raised high enough to allow the normal quantity of water to enter the establishment, and may therefore also remain open during periods of high water. In order to prevent, when the water is at its normal height, part of the water needed in the establishment from entering the two flood ditches, and thus carrying it away, a strong and tolerably high board is rammed firmly in each ditch near its entrance. The height of these two boards is regulated by the normal depth of the water. If the wing of the floodgate is opened wide enough for the water to wet its lower edge, the two boards in the flood ditches are placed at such a height that at the same depth of water their upper edges are laved by the water. In fig. 6 we see this

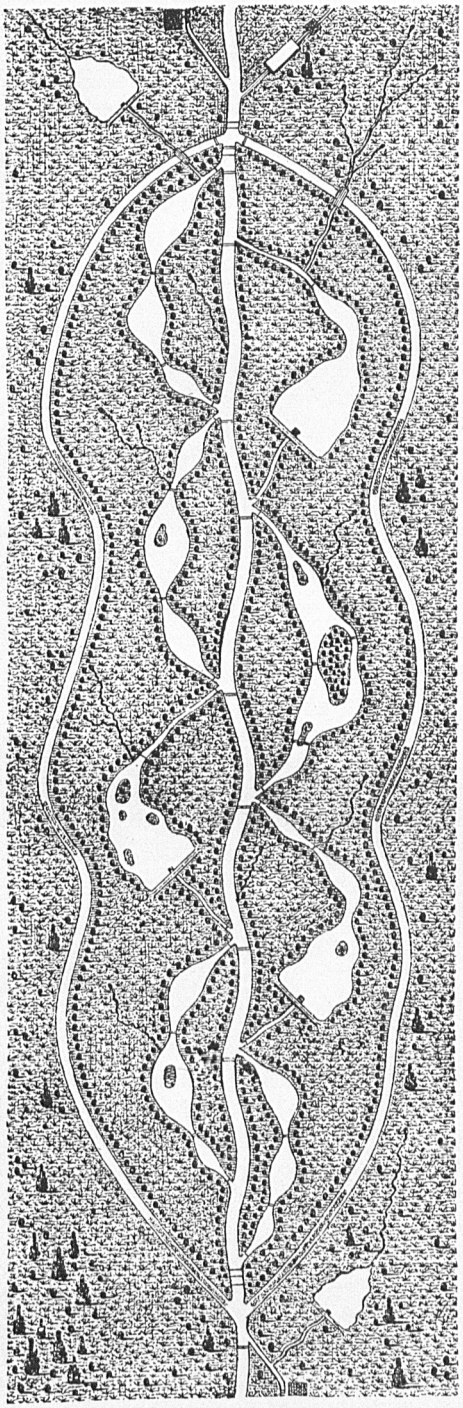


Fig. 1.—Plan for fish farm.

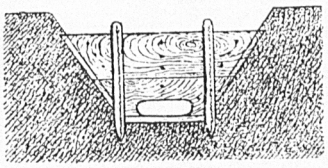


Fig. 2.—Sluice with fish runs (front).

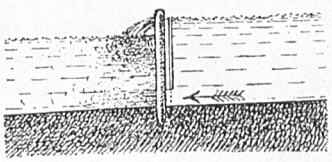


Fig. 3.—Sluice with fish runs (side).

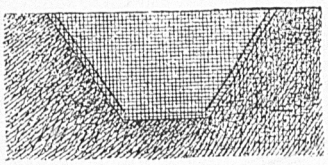


Fig. 4.—Permanent fish grating.

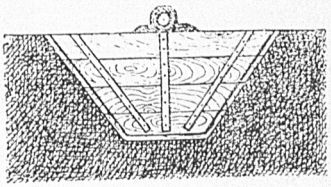


Fig. 5.—Temporary wooden dam.

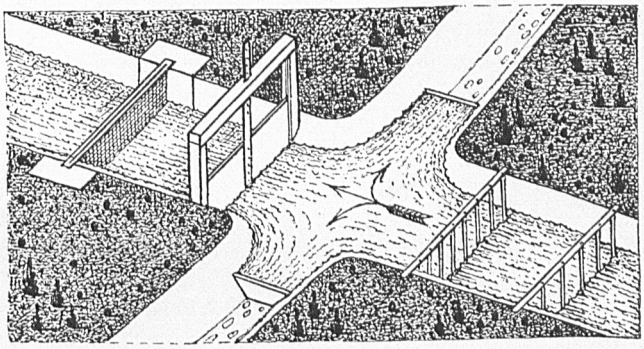


Fig. 6.—Head of farm water gate, grating, and side escapes.

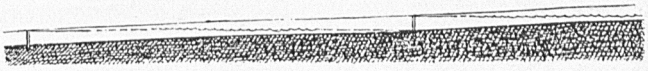


Fig. 7.—Sections emptied to clear of fish, repair, etc.

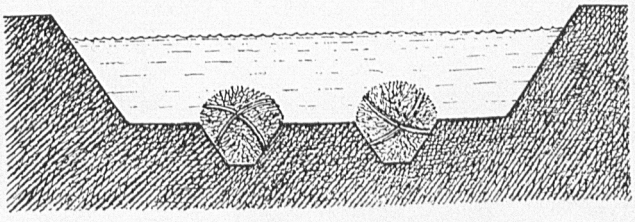


Fig. 8.—Cross section, with nests for living fish food.

process illustrated. If there is high water, the pressure of the water causes a little more to enter the establishment than during its normal course, but the remainder of the water, which would be detrimental to the establishment, is thrown back by the wing of the floodgate, and is led off over the two above-mentioned boards through the flood ditches. It is, of course, understood that if high water is expected, the wing of the floodgate is placed a little lower, if during the period of high water no more than the normal quantity of water is to be used in the establishment. By these precautionary measures the establishment is therefore at all times sufficiently protected against high water. To prevent fish or crawfish from escaping from the inclosures during the season of cultivation, and to prevent predaceous fish from entering, a thick galvanized-wire grating is placed in the stream both below (back of the outflow of the last ditch) and above (below the floodgate). These wire gratings are fastened in frames and set in grooved stone walls (fig. 6).

To prevent these wire gratings from being pushed out of position by floating pieces of wood, branches, leaves, and other objects which would interfere with the current, two primitive wooden rakes are placed in the water-course, both above the two flood ditches, at a distance of 2 to 3 meters [6½ to 9½ feet] from each other, and below, just in front of the lower grating. The teeth of each of the two front rakes (fig. 6) are at quite a distance from each other, so as to catch only larger objects, while the teeth of the two other rakes are closer together, so as to stop smaller objects which have passed the first rake. By this arrangement the two gratings will never become choked up and the water can flow through freely.

Whenever fish are to be taken out of that portion of the stream which is inclosed in the establishment, the water in all the ditches and ponds must be shut off. This object is best attained by the two damming boards (fig. 5) described above. Boards are at the same time placed in all the ditches in front of the lower gratings, and, if necessary, in the ditches themselves, invariably at even distances. It is, of course, understood that this measure is taken in one division after the other, and not in all at the same time. If, in constructing the ditches, care is taken that the damming is done in narrow passages and just in front of places where the ditches widen out, or where there are puddles or ponds, a large quantity of water can be shut off, even without using very broad boards. The longer a ditch is, and the stronger its fall, all the more boards will be needed for shutting off the water. While, e. g., a ditch with a strong fall will need three to five boards, the same object—viz, the shutting off of the water—will be attained in an equally long ditch, but with less fall, by two to three boards.

All that is needed is that the water in each division (see fig. 7) should only be dammed up to the foot of the higher board. There would be no harm even if in each section the upper part of the bottom were kept dry for a length of 1 to 2 meters [3.28 to 6.56 feet]. In the lower part of each section the water will, in the beginning, before it reaches its proper level, overflow the board a little both at the top and at the sides. It need not be feared that any fish will escape.

To better illustrate the use of the damming boards, we will give a practical example: A ditch 60 meters [19.6 feet] long, and 70 centimeters [2.4 inches] deep, will, with a total fall of 190 centimeters [7.4 inches] only need three damming boards placed at equal distances from each other. With three boards and a ditch 70 centimeters deep, however, a fall of 210 centimeters [8 inches] could be used. But as we need an entire height of boards of 190 centimeters [7.4 inches] in order to shut off the water in the ditch, the entire fall might be 20 centimeters [0.78 inch] more, and still three boards would suffice.

After the water, with its fish and crawfish, has been shut off in all the ditches and channels, the floodgate above the establishment is closed tight. The consequence is that the water is dammed up in front of the floodgate, flows back, and takes its course through the two flood ditches, while the stream is thereby gradually laid dry. In front of the lower grating the fish can then be easily caught.

After this general description of the arrangement of the establishment and of the use of its different portions, some important points remain to be spoken of. These are: (1) The starting of the cultivation operations; (2) the selection of the fish; (3) the cultivation itself; (4) the raising and feeding of the fish or crawfish.

In regard to these four points it is important to observe the following: After all the digging has been done in dry soil, after the two large wire gratings for shutting off the stream, the smaller gratings for shutting off the ditches and channels, the rakes inside and outside of the establishment, and the two boards in the flood ditches, have all been placed in position, and after the pits for producing food (to be described farther on) have been dug, and the posts have been rammed in the ground wherever there are to be damming boards, the floodgate is opened wide enough to admit into the establishment the normal quantity of water, and no more. Not till then, and when the water is already entering the establishment, the size of the oval openings of the damming boards is determined, which are now firmly fixed (screwed) to the posts.

As the water of small streams fed by springs is colder in summer and warmer in winter than stagnant water, these streams will rarely freeze entirely, and the culture of fish may therefore be carried on uninterruptedly. Under these circumstances the cultivation of the various salmonoids (which are always in demand) and of the crawfish is to be recommended. Of salmonoids several well-tried domestic and foreign species are at our disposal. Among the different varieties of trout preference must be given to the California rainbow trout (*Salmo irideus*) above our brook trout (*Salmo fario*), because it grows much quicker, makes an excellent article of food, and is not very choice in the matter of its food. Among the rest, the equally rapidly growing cross breeds between the brook trout and the salmon trout (*Salmo lacustris*), of the brook trout and the salmon (*Salmo salar*), of the brook trout and the char or "sälbling" (*Salmo salvelinus*), of our brook trout and the imported American brook trout (*Salvelinus fontinalis*), and of the German char and the American brook trout, deserve to be recommended. For the cultivation of the grayling (*Thymallus vulgaris*) these smaller water-courses are not so well adapted. If crawfish are to be cultivated in the establishment, either exclusively or in part, I would recommend our domestic central European brook crawfish (*Astacus fluviatilis*), which is considered a great delicacy. The larger crawfish of Carniola, Galicia, and Russia would, owing to the changed conditions, soon degenerate, and it is very questionable whether their cultivation would be possible.

The stocking of the various ditches with young fish or young crawfish, invariably of the same age and the same rapid growth, may be done in different ways. All the sections may be used either entirely for fish-culture or for crawfish-culture, or some of the sections for one and some for the other. Cultivation following the principle of rotation is to be highly recommended. In the culture of salmonoids, e. g., if the fish are to be used when 2 years old, one-half of the ditches might be stocked in spring, while in the other half the fish would be caught in the autumn of each year. If the fish are to reach the age of 3 years, only one-third part of the ditches will be fished and stocked anew every year. If crawfish are to be used, when 5 years old

there would be fishing every year in one-fifth part of the ditches, and one-fifth would be stocked anew, etc. In order, e. g., to introduce a two years' culture, either one-half only of the ditches would be stocked during the first year; or all the ditches are stocked during the first year, but the fish in half of them are allowed to grow one year older, while in the other half they are caught after the completed first year. In crawfish-culture those ditches which in the beginning are not to be stocked with crawfish may during that time be used for fish-culture. When the fishing in a rough or rapid stream is difficult, such stream should be used for crawfish-culture, so that there need not be any fishing except at longer intervals (five to six years). There need not, however, be any fishing whatever in the stream if it is used as a reservoir for crawfish which are ready for the market (which can at all times be caught with reels, etc.), or if it is utilized for the steady production of natural food for the fish.

In the small ponds belonging to the establishment, whose feeding channels may very advantageously be used for the exclusive production of live natural fish food, which is thus continuously furnished to the fish in the ponds, the culture of salmonoids or crawfish (or, if the water is softer and warmer, the culture of carp) may be carried on. The channels through which the water flows out of the ponds may be very suitably employed for crawfish-culture. In exclusive or partial salmonoid-culture, however, one to three of the smaller ponds, according to their size, should be used for the production of young food-fish, and in exclusive or partial crawfish-culture one to two of these sheets of water should be reserved for the pairing of crawfish. The ponds not used for this purpose, the channels through which their water flows off, and possibly also the stream itself, may be cultivated either independently, according to a system of rotation applying only to these waters, or in common with the ditches.

The fish-culturist will do well to raise his own propagating fish. The artificial impregnation of roe is a rather wearisome process, as suitable spawners have to be obtained from other places and as it requires a good deal of technical knowledge. It is, therefore, better for the fish-culturist to obtain embryonated roe from some well-known establishment and only attend to the further development of this roe. He thereby gains this advantage, that the young fish may be hatched in the same water in which they are to be raised. We know it for a fact that the brook trout can be raised even in soft waters, and the rainbow trout even in muddy ponds, if their roe has been hatched in the same water.

It is likewise somewhat difficult to obtain suitable young fish. In a small fish-tank, with water steadily flowing into it, which every establishment for raising salmonoids or crawfish should possess, it will be very easy to place apparatus for hatching fish. A walled basin, corresponding to the size of the establishment, from which the water can be let off, which is in the immediate proximity of the hatchery and must be supplied with a constant stream of running water, may receive, in fish-culture, the young fish which have slipped out of the eggs in the hatching apparatus, and in crawfish-culture the female crawfish with eggs which have been brought from the breeding-ponds. It should be mentioned that the female crawfish, soon after the young crawfish have been hatched, should be removed to the breeding-ponds where the males have been left, as they are very apt to attack and destroy their own offspring. Although the above-described basin is not absolutely necessary, because the young fish and the female crawfish may also be placed directly in the

vacant ponds which are free from predaceous fish, it is nevertheless an advantage to insure proper care and attention to the young fish or crawfish, which in the beginning are very helpless (the umbilical period, during which the young fish take no outside food, lasts with the salmonoids, e. g., four to six weeks), and to bring them sooner to a state of independence by placing them in the large basin covered with sand and gravel and amply supplied with aquatic plants, giving them plenty of good food (live crustaceans, maggots, worms, etc., to the fish; fish, frogs, meat, crustaceans, etc., chopped fine, to the crawfish).

The limited space at my disposal does not permit me to describe here an establishment for raising shrimps (which in the exclusive culture of salmonoids may take the place of the basin), by means of which the young fish will grow strong very rapidly, through the continuous nutritious natural food which is furnished to them. I would refer the reader to my pamphlet on the subject, entitled, Neues Fisch- und Krebszuchtverfahren mit Weidenkultur verbunden und auf die natürliche Fütterung basirend (new method of raising fish and crawfish in connection with the cultivation of willows, and based on the system of natural food).

It will be found an advantage to stock the waters with large and strong fish or crawfish, because fewer will be lost during raising, and because wider gratings may be used for shutting off the ditches. If the basin can be properly secured, it may, during autumn and winter, when there is no other use for it, be employed as a reservoir for fish or crawfish.

The number of fish or crawfish to be placed in the water of the inclosures depends entirely on the food conditions of the water. 'It may be said, however, that 20 to 30 young fish, or 30 to 40 young crawfish, to the cubic meter [35.3 cubic feet] will not be too many if the conditions are favorable for constantly supplying ample food as the fish or crawfish grow up and need more food. A cubic meter of water in a trout basin may, with ample and good food, hold 40 to 50 trout, each weighing 200 to 250 grams [6⅔ to 8⅓ ounces] and reaching even a heavier weight. I would warn against overstocking a sheet of water, because the food would then hardly be sufficient to properly support the fish.

As regards the feeding of fish, etc., nature furnishes an exceedingly welcome aid. The large river shrimp (*Gammarus fossarum*) is always found in enormous quantities in clear running water. In the kind of establishment described by me, the bottom current of the water caused by the holes in the damming boards proves exceedingly favorable to these shrimps, which form the most desirable food for trout and crawfish. They increase very rapidly, prefer the gravelly, sandy beds of our trout brooks, and love to hide in dark places among aquatic plants, roots, branches, etc. Wherever the bottom does not consist of sand or gravel this should only be introduced in small quantities, because the trout and crawfish like such a bottom as well as the shrimp. While the large trout in streams where it prevails will not suffer any other fish (whitings, minnows, gudgeon, bullheads, etc.) or crawfish to exist for any length of time, it will not succeed in exterminating the shrimp. But, on the other hand, the small trout will lose a great deal of its principal food if the above-mentioned fish or crawfish increase very rapidly. It will therefore be best to banish such fish or crawfish entirely from the trout waters.

In carp-raising ponds predaceous fish (pike, eel, perch, etc.,) are placed in order that they may destroy the too prolific offspring of the carp, as well as whitefish, frogs, etc., which would deprive the carp of a good deal of their food. As the shrimp is an

exceedingly important article of food in the culture of salmonoids and crawfish, we must seek to encourage its development by supplying artificial hiding-places and also by feeding it. Especially in the early stages of the establishment, when the bottom and sides of the ponds and ditches are not yet covered with plants, it will be well to supply such hiding-places (e g., by transferring or planting aquatic plants). Such artificial hiding-places for the shrimps may also be provided in the ditches and in the stream by digging round holes with an upper diameter of 40 to 50 centimeters (1.5 to 1.9 inches) and a depth of 20 to 25 centimeters (0.78 to 0.88 inches), at an angle of 45 degrees toward the bank. These holes should be dug at distances of about 5 meters (16 feet), and wherever the ditches widen out they may be scattered more frequently. Such holes may also be dug in the channels through which the water flows in and out of the basin.

In these holes are placed branches deprived of their leaves, which (by means of pine roots, willow branches, etc.) have been loosely bound together and formed into a sort of ball, and which may project over the middle of the hole and its edges, stones being put in the inside of these balls to keep them in position. In fig. 8 we see in a broad part of a ditch the cross section of two such shrimp holes with the balls of branches inserted. The fish and crawfish, when in search of food, can not, on account of their size, enter these holes, and the shrimps find sufficient protection in them, and can therefore undisturbedly increase in these hiding-places. This arrangement, moreover, permits a very rapid and simple method of feeding the shrimps, as it will be sufficient to throw on these branches from time to time a handful of coarse meat-meal, chopped-up fish, frogs, mussels, meat, maggots, etc. It has the further advantage that whenever the fish are taken out of the ditches, ponds, etc., the main portion of the shrimps will remain alive, because they can retire to their holes, in which some water will always remain while the ditches are slowly laid dry. To catch a large number of shrimps at any time, it will be sufficient to pull out the branches or balls of branches and shake them over a piece of cloth. In newly constructed inclosures the shrimps must, of course, be introduced in larger quantities and be evenly distributed.

The fish or crawfish should not be placed in the water until the shrimps have increased considerably and have occupied their holes. It might also be recommended to give these small crustaceans a short period of protection after each fishing season. The cultivator of salmonoids and crawfish possesses in these holes reliable, constant, and abundant sources of food for his fish. In the more stagnant water of the ponds shrimp-culture will not be so successful, but even there the above-described method of promoting the increase of other crustaceans in these ponds will benefit the entire cultivation.

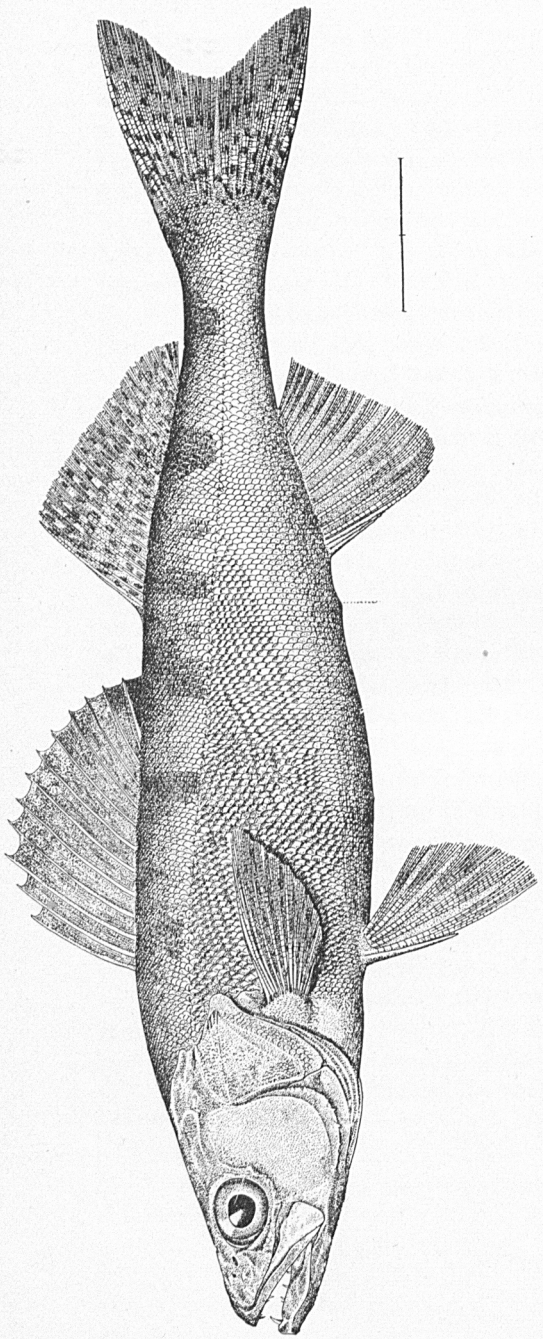
The supply of natural food for fish, etc., may be still further increased if willows are planted close together, each plantation extending from 2 to 2½ meters [6.8 to 8.5 feet] on both sides of the inclosures. Thereby many insects, especially many different kinds of gnats and flies, are attracted, which, owing to the sheltered condition of the water, deposit their eggs therein. In order to make this more convenient for them, it is recommended to fix widely spreading branches at certain distances in the banks in such a manner as to let them rest on the surface of the water. The larvæ of these insects make an excellent food for fish. The willows, moreover, will furnish a habitation for a large number of different kinds of caterpillars, beetles, spiders, bugs, etc., which often drop into the water and very considerably increase the food supply for the fish.

In order to furnish the fish with thousands of these insects, it will be sufficient to brush the narrow strip of willows with a small board attached to a light pole, especially early in the morning or late in the evening, when these insects are in a sort of torpor. To drive whole swarms of little grasshoppers—of which the fish are particularly fond—into the water, it will suffice to walk past the willows and brush against them at noon time, when these insects have retired from the neighboring meadows into the shade of the willows. The willows also furnish shade, which is very beneficial for the trout and shrimps, keep the water cooler, make the banks firmer, and may eventually yield a revenue by selling their branches to basket-makers. In places where the ditches widen out considerably, boards painted white and laid on posts fixed in the bottom of the ditch will keep the water cool and furnish very desirable resting-places for the fish. It may likewise be recommended in the beginning, especially in crawfish-culture, to dig horizontal holes in the sides of the ditches and thereby to furnish still more hiding-places.

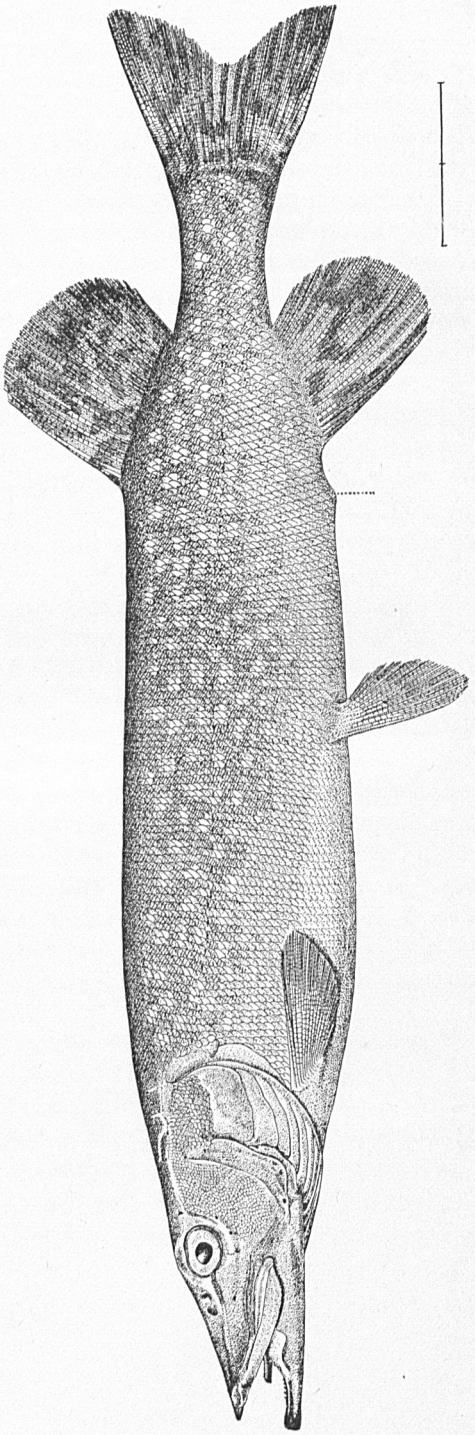
During the first year the above-mentioned crustaceans, insects, etc., will furnish sufficient food for the young salmon; but if they are to grow rapidly, and if the culture is to be made remunerative, they should, during the second and third year, be fed with a constantly increasing quantity of small fish, at regular intervals. To raise these fish separately, one or more sunny, shallow, and warm ponds, stocked with the rapidly increasing crucian carp (*Carassius vulgaris*), will answer the purpose. If the young crucian carp are to develop rapidly the spawners should be removed, either by catching them with nets just after the spawn has been deposited, or by draining the pond if the young fish have already been hatched. Crustaceans bred in liquid manure may be raised as food for them on the edges of the ponds. The young crucian carp are caught with nets whenever needed, and are given to the salmonoids alive, but to the crawfish and shrimps dead and chopped fine.

By an establishment like the one described the water of a stream will, without proving an injury to establishments of any kind farther down the stream, yield at least three times more than it would otherwise. The remunerative character of the rational culture of salmonoids or crawfish, especially in the neighborhood of large cities, will make it profitable to start such establishments on good pieces of ground (e. g., meadows). By the soil which is dug out the surrounding meadow will be improved (rejuvenated), by the ditches and channels it may possibly also be irrigated in part, and its productiveness will be increased.

Difficult as the management of such an establishment may appear at the first moment, it is not so in reality, if a systematic plan calculated for a number of years is followed. It would give me great pleasure if this article would contribute its share in inducing people to start many well-paying salmonoid and crawfish establishments.



PIKE PERCH OR WALL-EYED PIKE (*Stizostedion vitreum*).



PIKE OR PICKEREL (*Lucius lucius*).

10.—A REVIEW OF THE HISTORY AND RESULTS OF THE ATTEMPTS TO ACCLIMATIZE FISH AND OTHER WATER ANIMALS IN THE PACIFIC STATES.

By HUGH M. SMITH, M. D.

PREFATORY REMARKS.

Few subjects connected with the utilization of our natural resources present greater interest than the possibilities for the successful transfer of useful animals from one section of the country to another and their acclimatization in new regions. The benefits that may accrue to a community or section through the introduction of new resources are various, and there are few parts of the country in which valuable non-indigenous animals are not now found.

In the case of water animals, the benefits of successful acclimatization are doubtless proportionally greater than with any other class, owing to the little attention they require after introduction, their extraordinary fertility as compared with land animals, and the slight labor and expense incident to their utilization. At the same time, it is apparent that the difficulties in the way of introduction of fish, mollusks, etc., are greater than with other animals; the drawbacks in the mere transportation are often very serious, especially when long journeys are to be made; while the uncertainties attending the deposition of the animals, the determination of the general results, and the gauging of the economic effects are much greater.

Among other influences militating against the successful introduction of fishes and other aquatic animals into new areas, in addition to those incident to their transportation, are the following: (1) Unsuitable water temperature; (2) unsuitable food; (3) unfavorable topographical condition of the bottom; (4) absence of suitable rivers for anadromous fish; (5) enemies and fatalities acting on a relatively small number of individuals.

The results attending the experimental introduction of aquatic food animals into the waters of the Pacific States must be regarded among the foremost achievements in fish-culture. The striking illustrations here presented of the influence of man over the supply of free swimming anadromous fishes, to say nothing of his ability to affect the abundance of non-migratory species, are of great economic and scientific interest.

Aside from the direct economic results which have followed the introduction of east-coast fishes into the waters of the Pacific States, a very important basis has been furnished for judging of the general effects of artificial methods in regions where the object of fish-cultural operations has been to maintain and increase the abundance of native species. Attention was first drawn to this phase of the subject in an article

contributed by the writer to the issue of *Science* for August 18, 1893, in which the following paragraph appears:

> Of scarcely less consequence than the actual results of shad introduction on the west coast is the important bearing which the success of the experiment must have in determining the outcome of artificial propagation in regions in which it is not possible to distinguish with satisfactory accuracy the natural from the artificial conditions. If these far-reaching, and no doubt permanent, results attend the planting, on few occasions, of small numbers of fry in waters to which the fish are not indigenous, is it not permissible to assume that much more striking consequences must follow the planting of enormous quantities of fry, year after year, in native waters? There is no reasonable doubt that the perpetuation of the extensive shad fisheries in most of the rivers of the Atlantic Coast has been accomplished entirely by artificial propagation. On no other supposition can the maintenance and increase of the supply be accounted for.

The zealous efforts of the fish commissioners of California to increase the quantity and variety of food and game fishes of the State deserve special recognition. For more than twenty-five years the energies of the commission have been almost constantly directed to the acclimatization of desirable fishes inhabiting the waters of the Eastern States. Their remarkable success when acting on their own behalf and in conjunction with the New York Fish Commission and the United States Fish Commission entitles them to the great credit and praise which they have received both from the inhabitants of California and from the people of other States and foreign countries. The other States of this section have also exhibited great interest in the improvement of their fish supply through the acclimatization of eastern species.

Mention should be made of the efficient services rendered to fish-culture by Mr. Livingston Stone in successfully taking fishes across the continent at a time when fish transportation was an undeveloped art and when the difficulties encountered would have discouraged one less enthusiastically interested and less competently informed on the general subject. To Mr. Stone more than to any other person is the direct credit due for the introduction of most of those fishes which have since attained economic prominence.

In this report I have considered all those species not already indigenous which have been introduced, or the introduction of which has been attempted, in California, Oregon, Washington, Idaho, and Nevada. Idaho has been included in the discussions because all its water-courses are practically tributaries of the Columbia River, and fish planted in that stream might find their way into the State, while plants in the open waters of Idaho might produce results in Oregon and Washington. The proximity to California of the Nevada lakes and rivers in which new fishes have been planted, and the similarity of the fishery interests of the contiguous parts of the two States, have appeared to warrant the inclusion of Nevada in the list. In the case of a few species having special interest, reference to their acclimatization in Utah has been made.

An interesting chapter might be prepared treating of the experimental introduction of native western fishes into new waters of the region—as, for instance, the acclimatization of the chinook salmon and rainbow trout in landlocked Nevada waters and the successful transplanting of the Sacramento perch (*Archoplites interruptus*) in Nevada—but this subject is foreign to the scope of the present paper.

It is intended in this paper to recount the history of the introduction of each aquatic species; to record the general results of the experiments; to state what is known of the habits of the animals in their new environment; and to give an account

of the economic importance attained and of the fisheries prosecuted. To facilitate the identification of the fish, especially on their appearance in new localities, illustrations of the principal species are included. The reports of State fish commissioners have been freely quoted, either as general information or to bear out the writer's statements regarding the different species.

The importance of this subject and the absence of any special paper dealing with its various aspects make it proper to give to the matter the detailed notice which it receives in the following pages. While the printed references to the subject have been numerous, there are many prominent phases which have not been mentioned, and the full extent of the industry which has been established as a consequence of the acclimatization experiments is unknown even to the people of the States most concerned.

The following fish and other aquatic animals receive special mention and will be considered in the order given:

(1) The Bullhead or Horned Pout (*Ameiurus nebulosus*).
(2) The White Catfish (*Ameiurus catus*).
(3) The Spotted Catfish (*Ictalurus punctatus*).
(4) The Carp (*Cyprinus carpio*).
(5) The Tench (*Tinca tinca*).
(6) The Goldfish (*Carassius auratus*).
(7) The Hawaiian Awa (*Chanos cyprinella*).
(8) The Shad (*Clupea sapidissima*).
(9) The Common Whitefish (*Coregonus clupeiformis*).
(10) The Atlantic Salmon (*Salmo salar*).
(11) The Landlocked Salmon (*Salmo salar sebago*).
(12) The Von Behr or European Brown Trout (*Salmo fario*).
(13) The Loch Leven Trout (*Salmo trutta levenensis*).
(14) The Lake Trout or Mackinaw Trout (*Salvelinus namaycush*).
(15) The Brook Trout (*Salvelinus fontinalis*).
(16) The Muskellunge (*Lucius masquinongy*).
(17) The Pike or Pickerel (*Lucius lucius*).
(18) The Eel (*Anguilla chrysypa*).
(19) The Crappy or Bachelor (*Pomoxis annularis*).
(20) The Strawberry Bass or Calico Bass (*Pomoxis sparoides*).
(21) The Rock Bass (*Ambloplites rupestris*).
(22) The Warmouth Bass (*Chænobryttus gulosus*).
(23) The Blue-gill or Blue Bream (*Lepomis pallidus*).
(24) The Green Sunfish (*Lepomis cyanellus*).
(25) The Large-mouth Black Bass (*Micropterus salmoides*).
(26) The Small-mouth Black Bass (*Micropterus dolomieu*).
(27) The Yellow Perch or Ringed Perch (*Perca flavescens*).
(28) The Wall-eyed Pike or Pike Perch (*Stizostedion vitreum*).
(29) The Striped Bass or Rockfish (*Roccus lineatus*).
(30) The White Bass (*Roccus chrysops*).
(31) The Tautog (*Tautoga onitis*).
(32) The American Lobster (*Homarus americanus*).
(33) The Eastern Oyster (*Ostrea virginica*).
(34) The Soft Clam (*Mya arenaria*).

This paper is based chiefly on inquiries made by the writer in May and June, 1894, in the course of an inspection of the economic fisheries of the Pacific States. Acting under instructions from Hon. Marshall McDonald, the United States Commissioner of Fish and Fisheries, special attention was given to those fishes and other aquatic animals which had been artificially introduced into the waters of this region.

Much valuable information has also been obtained from Mr. A. B. Alexander, fishery expert on the steamer *Albatross*, who was detailed in 1893 for an investigation of this subject, and submitted a report embodying his observations on shad, striped bass, and catfish in the vicinity of San Francisco and in the Columbia River. In the following chapters Mr. Alexander's report has been freely quoted.

Use has also been made of the information on the foregoing fishes contained in the reports of Mr. W. A. Wilcox, field agent of the United States Fish Commission,

who has twice made a canvass of the fisheries of the entire Pacific Coast under very favorable circumstances.

In 1895, Mr. William Barnum, of the United States Fish Commission, visited parts of Idaho, Utah, Oregon, and Washington, and obtained information regarding non-indigenous fishes of those States that has been incorporated in this article.

The writer desires to express special obligations to Mr. John P. Babcock, chief deputy of the California Fish Commission, for numerous courtesies which have contributed to the completeness and accuracy of this paper. Mr. Arthur G. Fletcher, of the same commission, has also furnished a number of interesting notes.

Messrs. Babcock and Fletcher, cooperating with the writer, were able to secure accurate figures showing the monthly receipts of shad, striped bass, carp, and catfish in 1893 and 1894, which information is given elsewhere.

To the following fish-dealers of San Francisco acknowledgment is due for their kindness in according free access to their books, from which an accurate statement of the extent of the trade in the species under discussion could alone be obtained: American Union Fish Company, J. H. Kessing, A. Paladini, Pioneer Fish Company, G. Camilloni, S. Tarantino, B. Caito, and P. Gusmani.

The following-named gentlemen have courteously responded to inquiries and supplied useful data: Hon. George T. Myers, Portland, Oreg.; Mr. James Crawford, fish commissioner, Vancouver, Wash.; Mr. F. C. Reed, ex-fish commissioner, Astoria, Oreg.; Mr. Charles F. Lauer, The Dalles, Oreg.; Mr. George T. Mills, fish commissioner, Carson City, Nev.; Mr. W. H. Ridenbaugh, Boise, Idaho.

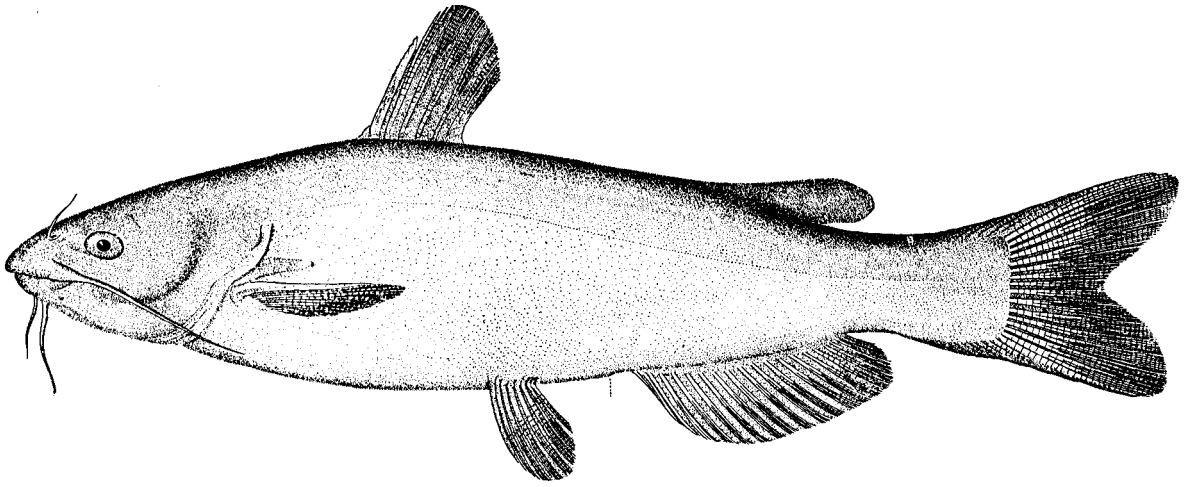
THE CATFISH.

INTRODUCTION TO PACIFIC STATES, AND RESULTS.

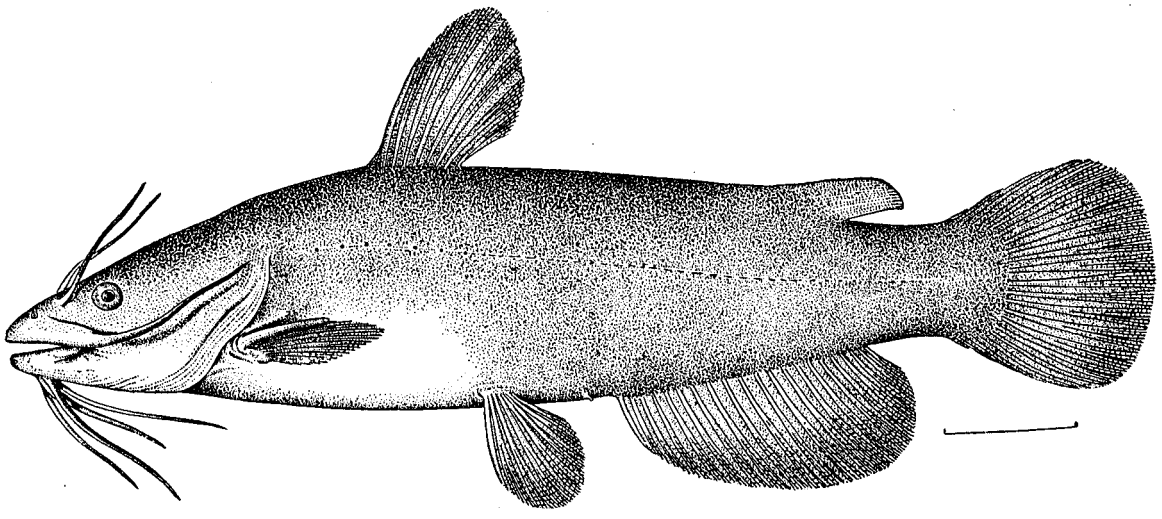
At least three species of catfish—the white catfish (*Ameiurus catus*), the yellow catfish or bullhead (*Ameiurus nebulosus*), and the spotted catfish (*Ictalurus punctatus*)—inhabiting parts of the United States east of the Rocky Mountains have been transferred to the Pacific States. Catfish were taken to California in 1874 by Mr. Livingston Stone,* of the United States Fish Commission, and subsequently one or two species were introduced into Oregon and Washington. Mr. Stone's assortment of eastern catfish consisted of 56 large Schuylkill catfish (*Ameiurus catus*) from the Raritan River, New Jersey, and 70 hornpouts or bullheads (*A. nebulosus*) from Lake Champlain, Vermont. The large white catfish were deposited in the San Joaquin River, near Stockton, Cal., and the bullheads were placed in ponds and sloughs near Sutterville, Sacramento County, Cal.; both plants were made on June 12, 1874.

It appears from Mr. Stone's account of his trip across the continent in 1874 that at Fremont, Nebr., on the Elkhorn River, he took on board some catfish from that stream, and that 18 of these were placed in the San Joaquin River, near Stockton, in conjunction with the other large catfish from New Jersey. Mr. Stone refers to these as "Mississippi catfish," but this designation is not definite enough to conclusively fix their identity; and as no specimens have recently been observed, and as no examples are preserved in collections, the ichthyological status of this fish must be considered unsettled. Recent collections in the Elkhorn River and neighboring waters by the

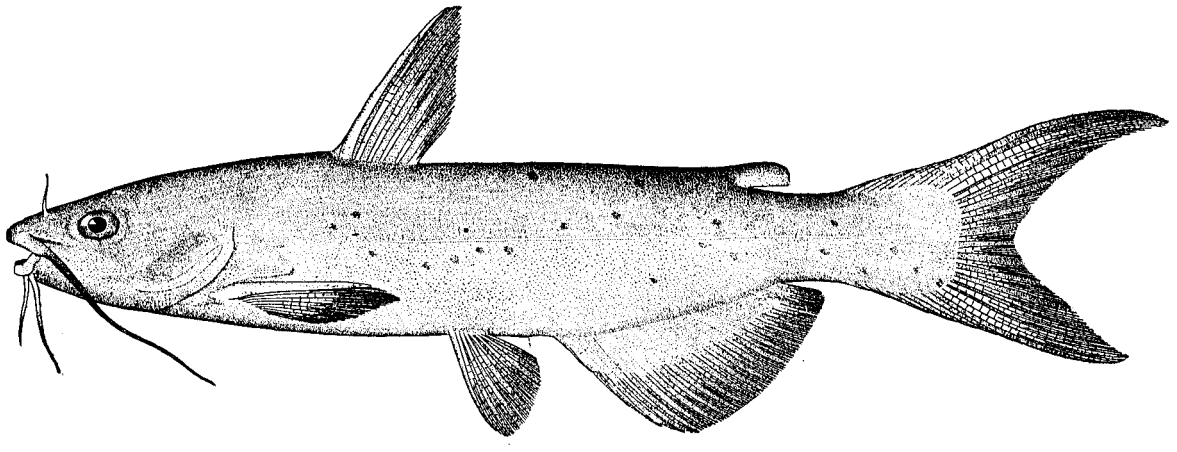
* See Report California Fish Commission, 1875-75, pp. 5, 6, 22, 30, 32.



WHITE CATFISH OR SCHUYLKILL CATFISH (*Ameiurus catus*).



YELLOW CATFISH OR BULLHEAD (*Ameiurus nebulosus*).



SPOTTED CATFISH (*Ictalurus punctatus*).

United States Fish Commission have disclosed the presence of a number of species of catfish, any or several of which might have been obtained by Mr. Stone. Among these are the spotted catfish, blue catfish, or channel catfish (*Ictalurus punctatus*); the fork-tailed catfish (*Ictalurus furcatus*); the mud catfish or yellow catfish (*Leptops olivaris*); the great fork-tailed catfish or Mississippi catfish (*Ameiurus lacustris*), and the black catfish or bullhead (*Ameiurus melas*). The first, third, and fifth named species are known to be common in the river in question, and only these are recorded from Fremont. It is therefore probable that specimens of one of these were secured by Mr. Stone.

The spotted catfish is probably the best of the tribe, and is the principal one distributed by the United States Fish Commission. In food value it is regarded by Jordan and Evermann as not inferior to the black bass. Several plants have in recent years been made in the Pacific States. In 1892 the following adult and yearling catfish were deposited in Washington waters, in response to requests: Seventy-five in Clear Lake, Skagit County; 125 in a private pond near Vancouver; 50 in Deer Lake, in Stevens County. In 1893, 100 were placed in the Boise River, Idaho, a tributary of the Snake River. Ten were put in the Balsa Chico River, California, in 1895. Plants of yearlings were made in Lake Cuyamaca and Feather River, California. in 1891, each water receiving 250 fish.

The results attending the introduction of catfish in California were immediate and marked. As early as 1875, the State commissioners reported on the matter as follows:

> The Schuylkill catfish and the Mississippi catfish, placed in the San Joaquin River, have grown rapidly and spawned, but several of the large fish and many of the young ones have been caught by the fishermen near the San Joaquin bridge, and have been returned to the river. The fishermen at that point are much interested in their successful cultivation, and seem desirous that they should be preserved. By another year they will be so numerous that they may be caught with safety and shipped to market, as it would be impossible to exhaust the river by ordinary fishing. The hornpouts, a species of small catfish from Lake Champlain, which were placed in the lakes near Sacramento, have increased so abundantly that nearly one thousand have been caught and transported to the various lakes and sloughs in the Sacramento Valley. We caused several hundred of them to be placed in lakes containing brush and dead trees, in which it would be impossible to seine them. The acclimatization and perpetuation of these fish in the Sacramento Valley is assured, as they are now so situated that no amount of fishing will exhaust them.

In their report for 1876–77, the fish commissioners stated:

> The 74 Schuylkill catfish imported in 1874, and placed in lakes near Sacramento, have increased to a vast extent. They already furnish an important addition to the fish food supply of the city of Sacramento and vicinity. From the increase we have distributed 8,400 to appropriate waters in the counties of Napa, Monterey, Los Angeles, Fresno, Tulare, Santa Cruz, Shasta, Solano, Alameda, San Diego, Yolo, Santa Barbara, and Siskiyou. These, should they thrive and increase as they have in Sacramento, will furnish an abundance of valuable food in the warm waters of the lakes and sloughs of the interior, and replace the bony and worthless chubs and suckers that now inhabit these places. It may be proper to call attention to the fact that these fish have become so numerous in the lakes near Sacramento that they can now be obtained in any quantity for stocking other appropriate waters in any part of the State.

In 1878–79 the California commissioners distributed 39,000 Schuylkill catfish to public waters in 22 counties, and reported as follows about the fish:

> These have increased to millions and furnish an immense supply of food. They have become so numerous that they are as regularly on sale in the city markets as the most abundant native fish, and are sold at about the same prices. They thrive in our rivers and lakes, and in the still-water sloughs of our plains, as well as in the brackish sloughs in our tule lands. They appear to be equally at

home in lakes on the mountains and in artificial reservoirs in the valleys. Many farmers who have natural ponds on their farms, or who have surplus water from windmills and have made artificial ponds, have stocked them with this excellent fish. The produce of the few fish of this species, imported in 1874, now annually furnishes a large and valuable supply of fish food to people in the interior of the State. The value of all the fish of this species now caught annually and consumed as food would more than equal the annual appropriation made by the State and placed at the disposal of the fish commissioners. This variety of catfish has valuable characteristics which admirably fit it for wide distribution and for self-preservation in the struggle for existence.

The report of the California Fish Commission for 1880, from which the following extract is made, shows that over 24,000 catfish were distributed in the State waters, and that the fish had become so numerous and widely scattered that further attention from the commission was hardly demanded:

The 74 catfish imported from the Raritan River in 1874 have increased and multiplied, and this increase distributed, until now we believe there is no county in the State, from Del Norte to San Diego, that has not been supplied with a greater or less number of these fish. They are regularly sold in all the markets at the same prices as our most abundant fish. They are admirably adapted to the sloughs and warm waters of the great valley, and in them have so multiplied as to furnish a large supply of food. The aggregate value of this fish alone, sold in the markets of San Francisco and Sacramento annually, would more than equal the appropriation annually made by the State for fish-culture. How constant has been the demand made upon us for the wide distribution of this fish may be seen in our report of expenditures, which shows quite a large amount paid for their capture and in sending them by express to different parts of the State. These fish are now so numerous and widely distributed that probably the time has arrived when their further distribution should be left to private enterprise, and the money of the State heretofore used for this purpose be employed in importing some other equally valuable fish.

In considering the question of the economic value of the catfish and of the effects of its introduction on the native fishes, the fish commissioners make the following comment in their reports for 1883–84 and 1885–86:

It has been stated by fishermen that they would destroy all the native fish. It is our opinion that it was a timely act on the part of the former State commissioners to plant them just when they did, as our native fish were giving out. * * * They are coming more into favor with our citizens every year. The prejudice that existed at the time of their introduction is fast dying out, and the majority of our people claim that they are a better food-fish than the carp. Whether such be the fact is a matter of taste. The idea that they would destroy our native fish is a fallacy, as in the last two years statistics tend to show that such is not the fact.

Catfish are coming more into favor with citizens as food, and by a large class of consumers are preferred to carp. The planting of these fish was regretted by many and approved by more.

Catfish have been successfully introduced into the Columbia River and its tributary, the Willamette, but the full history of the planting is not recorded. Mr. F. C. Reed, of Astoria, contributes the following note on the origin of the catfish in the Columbia:

The extent of my knowledge of the history of this fish is as follows: About eight years ago [1888], when I was fish commissioner for Oregon, these fish were reported to be in Silver Lake, Washington. How they came there, I never was able to find out. When I heard they were in the lake, I was told they could not get out of the lake into the Columbia River; this was in reply to a request I made on the Washington authorities that I be allowed to go over to the lake and kill the catfish for fear they would get in the river and be another enemy to our salmon. It was only a year or two after this that during an unusual rise in the lake the fish were sent into the Cowlitz River, and from there to the Columbia. I thought at the time they were the real catfish, and would grow large enough to eat a 20-pound salmon, but now I do not think they will injure our salmon very much, as I have never seen them near the spawning-grounds, and think they prefer still and warmer water.

The history of the introduction of catfish into the waters of Nevada is very interesting. It appears that in 1877 Mr. H. G. Parker, the State fish commissioner, obtained from the Sacramento River, California, a large number of "Schuylkill" catfish (*Ameiurus catus*), which were deposited in Washoe Lake, the Truckee, Carson, and Humboldt rivers, and several sloughs, 25,000 yearlings being placed in the Humboldt alone. In all these waters the catfish rapidly became acclimatized, and in his report for 1879 and 1880 the commissioner states:

Nothing can be more satisfactory than the evidence I have of the increase and growth of the several lots of catfish I put in Washoe Lake and Carson, Truckee, and Humboldt rivers. Washoe Lake is so fully stocked and the fish of that size and vigor that further experiments would be useless. Over one hundred a day have been taken by one fisherman, none less than 14 inches long, and weighing from 1 to 1½ pounds. Of those planted in Carson River, at Schultz's ranch, several have been caught at Woodfords, 30 miles up the river from where deposited, and others 60 miles down the river from place of deposit, the latter having passed through all the poisonous substances flowing into the river from mining operations. Advices from the Truckee and Humboldt rivers warrant me in reporting equally as favorably as from those planted in Washoe Lake, and with another year's growth, or on the opening of the rivers in the coming spring, I have no hesitancy in stating that good and profitable fishing may be had. * * * In December, 1880, I distributed catfish in Washoe, Humboldt, Churchill, Lander, Eureka, Elko, Nye, and White Pine counties. * * * In all, I planted fish at 81 different places. Outside of the Truckee and Humboldt rivers, Pine Creek, and Newark Valley, the plants were in lakes, sloughs, streams, and larger springs, but in every place public waters.

In the report of the Nevada commissioner for 1881 and 1882 it is stated that 2,000 catfish were distributed in various waters in those years, and that the results had been marked in all the waters stocked, thousands of pounds of catfish being taken from Washoe Lake with hook and line in 1882. From the reports for 1883–84 and 1889–90 the following extracts are taken, which refer to the value of the catfish in waters where better fish can not flourish and to the economic importance which the fish have attained in Nevada.

From nearly every plant of catfish I have reports several times a year, and in every instance I have been complimented on the introduction of this very prolific and superior food-fish. Its hardy nature so well fits it for our saline and muddy waters, that in localities where the trout can not flourish this fish is sure to thrive and multiply far beyond any of our transplants. In Washoe Lake, Carson and Humboldt rivers, they are now found in such great numbers that anglers of all ages and sexes never abandon the pleasure until well-filled baskets and sacks mark the day's sport. For two years the Carson and Virginia markets have been to a great degree supplied with these fish from Washoe Lake. They find a ready sale at the highest prices. It has been my custom, and I now have on hand over 1,000 yearlings ready for distribution, in lots from 50 to 100 fish. The species of catfish herein mentioned were taken from the Schuylkill River, Pennsylvania, where it is unusual to find them to exceed 1 pound in weight, while in this State many are caught weighing over 2 pounds, thus showing the favorable results from transplanting fish.—(Report for 1883–84.)

The introduction and planting of the Schuylkill River blue catfish by our first fish commissioner, Mr. H. G. Parker, was commenced in August, 1877, the first deposits being made in Washoe Lake, Carson and Humboldt rivers. In two years these fish had increased to such numbers that the commission was enabled to stock other waters from the supply furnished in Washoe Lake. Thousands of pounds have been taken annually for the last eight or ten years, every family living near these waters supplying their table for about seven months of the year, while the markets of Carson and Virginia cities, although receiving large consignments, find such large sale that their stock is exhausted long before the most desirable salt-water fish find a purchaser. Add to this the fact of the number engaged in fishing for the market, and it will be seen that an industry has been developed, not only giving employment to quite a number of men and boys, but furnishing a food-fish of a most desirable and salable quality, and this through the workings of the Nevada fish commission.—(Report for 1889–90.)

Mr. W. H. Ridenbaugh, of Boise, Idaho, in 1895 took with a minnow net a few small, spotted catfish in Natatorium Lake, in Boise, thus indicating that the fish planted in 1893 have spawned.

DISTRIBUTION AND ABUNDANCE OF THE CATFISH.

It is not possible to assign to each species of catfish its present distribution in the Pacific States. There is nothing in the habits of the two kinds known to have become acclimatized that would prevent both inhabiting the same waters, although the yellow catfish or bullhead (*A. nebulosus*) is probably more likely to be found in warm, muddy ponds, sloughs, and ditches than is the other species, which, on the east coast, is commonly known as the channel catfish, in allusion to its habit of frequenting the deeper, colder, and clearer parts of the rivers.

In California the catfish have a more general distribution than any other fish. The State commissioners in 1880 asserted that there is no county in which these fish were not found; the wide distribution which the fish had given themselves had been supplemented by the efforts of the commissioners, who, from 1877 to 1879, planted them in 30 counties.

In California catfish are most numerous in the valleys of the Sacramento and San Joaquin rivers, where the conditions are very favorable for their multiplication. They are found in most of the tributaries of those streams and in the sloughs connected therewith. They have ascended the Sacramento River as far as Kenneth, a station 17 miles above Redding, and the San Joaquin to Tulare Lake. In 1886, Mr. William Utter, writing from Campo Seco, Calaveras County, reported that there were millions of catfish in the Mokelumne River, which joins the Sacramento River a short distance below Sacramento. Catfish are also found in several of the coast rivers of California.

In a "List of the fishes inhabiting Clear Lake, California," by Jordan and Gilbert, printed in the Fish Commission Bulletin for 1894, the bullhead (*A. nebulosus*) is recorded as very abundant, and the white catfish (*A. catus*) is reported as occasionally taken with the other species. In Lake Cuyamaca, near San Diego, catfish are reported as abundant, and some weighing 1½ pounds have been taken with lines.

Catfish are generally distributed in the Lower Columbia River and in the Willamette and other tributaries. The limits of their range in the Columbia basin have not been determined. They are very abundant in the sloughs connected with the Willamette River below Portland. Mr. F. C. Reed, of Astoria, states that the catfish of the Columbia basin is the bullhead, and that the catfish proper (that is, the fork-tailed form) does not occur. He recently obtained and forwarded to the Fish Commission a specimen of Oregon catfish; it was secured in Portland and was evidently caught in the Willamette River. It is 8 inches long, and Mr. Reed states that it is about the average size of those taken in the Columbia basin, although rather smaller than the usual run of those now saved for the markets, which are 10 to 12 inches long. An examination of this example shows that it is referable to the species known as the black catfish or bullhead (*Ameiurus melas*); it has the square tail and other features found in the common bullhead (*Ameiurus nebulosus*) and closely resembles the latter species, but differs from it in having a flatter head, a rather stouter body, and a shorter anal fin. In this specimen the length of the head is contained 3⅓ times in the body length, and the greatest depth 4¼ times in length; the anal fin has 17 rays, including rudiments, and its base is contained 5½ times in body length. In *A. nebulosus* the anal rays number

22. This specimen adds to the doubt existing as to the origin of the catfish in the Columbia basin. The supposition that the original stock in Oregon and Washington may have been obtained from California must be discarded, as the existence of *A. melas* in the latter State has not been determined, although this may have been the fish obtained by Mr. Stone in the Elkhorn River, Nebraska, in 1874, as previously suggested.

The quotations previously made from the reports of the Nevada fish commissioner are sufficient to show the wide distribution and great abundance of the catfish in that State.

SIZE AND WEIGHT.

The average weight of catfish taken for market in California is under 1½ pounds. There is a great abundance of very small fish in the Sacramento and San Joaquin rivers, and many seine hauls might be made in some places without yielding any over 10 inches long. Those weighing 5 pounds and upward are quite uncommon. Specimens of both species caught with a line by the writer at Collinsville, in June, 1894, were all 8 inches long or under. These were taken from the muddy waters of the Sacramento, and partook to a great extent of the color of the water; some were almost milk-white, others pale green or yellowish green.

Up to May 31, 1895, Mr. Babcock had observed no catfish in the San Francisco markets weighing over 3 pounds; on that day, however, he saw an 8-pound fish from the Sacramento River, in the American Union Fish Company's market, and heard of a 15-pound fish that had been received the same day.

Salmon gill-net fishermen of the Sacramento and San Joaquin rivers, using nets with a 7½ or 8 inch mesh, sometimes take large catfish. A salmon fisherman on Sherman Island, in the San Joaquin, informed the writer that he had caught several catfish weighing 10 pounds.

Mr. Charles Cuneo, of the American Union Fish Company, states that a few catfish weighing 6 to 8 pounds are received by San Francisco dealers, but that 15 or 16 inches is the usual length.

Mr. Alexander reports as follows on the size and weight of the catfish in California and the Columbia River:

> The average weight of the catfish sold in the markets of San Francisco is 1 pound. Occasionally fish weighing 7 and 8 pounds are brought in, but few fish of this size meet with a ready sale, and there is little inducement for fishermen to save them. The average length of catfish is about 12 inches. In the Columbia and its tributaries the fish run somewhat smaller, three-quarters of a pound being a fair average in weight and 10 inches in length.

FOOD OF CATFISH.

The catfish have the reputation among the California fishermen of being large consumers of fry and eggs of salmon, sturgeon, shad, and other fishes. This accords with their known habits in other waters. Mr. Alexander's examination, however, of the contents of several hundred stomachs of catfish in California and Oregon yielded only negative results as to the presence of young fish and ova.

Writing of the bullhead in Clear Lake, California, Jordan and Gilbert say that it is extremely abundant and is destructive to the spawn of other species. The scarcity of the valuable Sacramento perch in that lake, which they attribute to the carp, here as in the Sacramento River may be partly due to the more numerous catfish, which feed almost exclusively on animal matter.

By some persons the catfish are held responsible for the scarcity of Sacramento perch in the Sacramento and San Joaquin rivers. Mr. Babcock writes that he is informed by reliable men living above Colusa that up to 1880 perch were very common there and catfish were seldom taken, but since that time the catfish have increased beyond all belief and the perch have almost disappeared. The supposed influence of the catfish on the abundance of the perch arises from the spawn-eating propensities of the catfish.

Mr. A. Paladini, an extensive and long-established dealer of San Francisco, believes that catfish are especially injurious to salmon in the Sacramento River, where he thinks they destroy large quantities of ova and fry. This matter is sufficiently important to warrant careful attention. It would seem that the centers of abundance of catfish are probably remote from the spawning-grounds of salmon.

ASSOCIATION WITH OTHER FISH, ENEMIES, ETC.

In California and Oregon catfish inhabit to a great extent waters in which few other fish could or do exist. In the lagoons and sloughs connected with the San Joaquin, Sacramento, and Willamette rivers, but few fish besides catfish are taken with the fyke nets and set lines. When fishing is done in the main streams, a number of varieties are caught with catfish, among which are split-tails (*Pogonichthys macrolepidotus*), hardheads (*Ptychocheilus oregonensis*), and carp (*Cyprinus carpio*), and, in the Columbia basin, young sturgeon (*Acipenser transmontanus*).

Few enemies and no diseases disturb the catfish in Pacific waters, according to Mr. Alexander. No fish are known to prey on them except the striped bass, and even that species must do so very rarely. In some instances the ingestion of catfish by striped bass results in the death of the latter, the formidable spines piercing the stomach and entering the abdominal walls of the bass.

ORIGIN AND GENERAL EXTENT OF THE FISHERY.

From the extracts from the reports of the California fish commission previously quoted it may be seen that very soon after the introduction of the catfish a fishery was inaugurated. The practice of taking the fish for market from public waters has probably increased from year to year, although no statistics are available for any early years. At present it is probable that more catfish are caught for local and home consumption than for sale in the large marketing centers, but no accurate idea of the extent of the desultory and semiprofessional fishing can be formed.

The catfish fishery is not of large proportions in either California or Oregon. Only a small amount of capital is invested in it, but few persons are regularly engaged, and the catch is insignificant compared with the yield of many other fish taken in the same waters. The industry is more extensive in California than in Oregon.

The commercial fishery, in California at least, has probably reached its height, if it is not already on the decline. The receipts of catfish by the San Francisco dealers in 1894 were nearly 30 per cent less than in 1893; the decrease was due wholly to the lack of demand, the fish being more abundant. The large receipts of shad in the markets in recent years have doubtless put a check on the value of catfish and the expansion of the fishery.

FISHERMEN, APPARATUS, AND METHODS.

Fyke nets and set lines or trot lines are the apparatus chiefly employed for taking catfish. Both these appliances are used in California; but in Oregon Mr. Alexander reports that only fyke nets are set. Considerable quantities are in some localities incidentally taken in drag seines. In the semiprofessional fishing, hand lines and dip nets are also employed. The catfish fishery of California is carried on by a few persons who make a business of taking those fish throughout the year. It may be followed with some regularity for a time, but is seldom allowed to interfere with the capture of salmon, striped bass, and other more valuable species.

The number of persons who may be regarded as catfish fishermen in 1893 was about 100. These made their headquarters at Red Bluff, Fremont, Sacramento, Knight's Landing, Isleton, Bouldin Island, Jersey Landing, and other points on the two rivers. More than half the regular fishermen were Chinese.

The apparatus used in the catfish fishery of California in 1893, as determined by Mr. Alexander, consisted of 750 fyke nets, valued at $8,500; 100 trawl lines, valued at $150, and 15 drag seines, valued at $375. The number of boats used for lifting nets and trawls was about 60, with a value of $900. It should not be understood that all of the apparatus shown is used at one time. A few nets or trawls may be set for a few days or weeks, taken up, and not employed again for several months or possibly not until the next year.

The catfish fishery in Oregon is carried on by seven fishermen in the vicinity of Sauvies Island, situated in the Willamette River, a short distance below Portland. Mr. Alexander reports that a Mr. Mitchell is more extensively engaged in the business than anyone else, and that the Portland dealers look to him for their supply of catfish. He lives, with his family and hired men, in a small portable house on the bank of a slough where the fishing is done. The house is so constructed that it may easily be put on a float and moved from place to place, as occasion requires. Another structure, 15 by 30 feet, is built on a scow, in which the skinning, dressing, and boxing of the fish for market are done. The fish as caught are kept in three live-cars until needed for shipment. Four fyke nets are employed by this crew; they are set at the ends of two leaders and are valued at $160; small skiffs are used to tend the nets. The aggregate investment in the fishery at this place is $445. Six other persons were in 1892 more or less regularly engaged in taking catfish, but less extensively than Mr. Mitchell. They had 5 scows, 9 skiffs, 12 cars, and 8 nets, with leaders, which property was worth about $1,615, making $2,060 the total value of the apparatus, boats, etc., devoted to the fishery.

The following account of the fyke-net fishery of California and Oregon has been furnished by Mr. Alexander:

> The fyke net has been found to be the most economical device yet employed for carrying on the catfish fishery. It has many advantages over the drag seine. The fyke net can be set and left remaining in the water for an indefinite length of time without the fish dying or making their escape. With the drag seine, the fish caught at each haul must be cared for immediately if they are to be kept alive, which involves considerable extra labor.
>
> The fyke nets employed on the Pacific Coast do not differ materially from those used on the Atlantic seaboard and on the Great Lakes. They are from 12 to 20 feet in length, the size largely depending on the locality. In places where the current runs swiftly, smaller nets are used than in localities where there is little or no current. The usual type consists of a tapering bag distended by four hoops from 3 to 4 feet apart. The hoop at the mouth is about 3½ feet in diameter, the one at the end 12 to 16

inches in diameter. As a rule, there is only one funnel, situated nearly in the middle of the net. There is no rule for the size of net, mesh, or hoops; each fisherman carries out his individual ideas as to what is best suited to the conditions. The size of mesh is usually 2½ to 3 inches, but the nets used by the Chinese have much finer meshes, those near the apex measuring not more than half an inch. Most of the fyke nets used in California for the capture of catfish are set without leaders; if the latter are used, they vary from 15 to 25 feet in length.

The average cost of such fyke nets as the Chinese use is $15; those employed by the white fishermen cost $10 or less, having a larger mesh.

In setting a fyke net the ends are fastened to stakes driven into the bottom, the leader—if one is used—being kept in position in the same way. In places where there is little current, the bag end of the net is made fast to a stake, but where the current runs swiftly it is allowed to swing freely by its mouth fastenings. Where the tide ebbs and flows, the mouth of the net is changed at each turn of the tide.

In Oregon the fyke net is used wholly for the purpose of taking catfish, although other species are frequently caught in it. The nets are of the same pattern as those of California. In most cases they are set double—that is, one leader directs the fish into two nets. The leaders are 150 to 200 feet long, and 16 feet deep. The bag end of the nets is made fast to stakes to keep them in shape and position, the water being still where this method is used.

The leaders are so made that they can be easily converted into drag seines, which is often done, and hauled over the same ground where the nets were set. This practice is only resorted to when the catfish become scarce or other fish are desired.

At Antioch, Courtland, Bouldin Island, and many other places on the San Joaquin and Sacramento rivers, trawl lines (locally known as trot lines) take catfish for the city markets, local consumption, and family use. The length of the lines varies with the river or slough in which they are fished. In the narrow sloughs and upper courses of streams they are about 100 feet long, with hooks at intervals of 2 or 3 feet, but in the wide sloughs and the lower parts of rivers they are often 700 to 800 feet long, with 250 to 300 hooks. When the current is swift, a wire ground line is used, but in other situations the bottom line is of twine. The hooks are small, being about the size of mackerel hooks employed in the New England fisheries. One end of the trawl is made fast to the shore, the other end to a stone which serves as an anchor. The line is placed either about parallel with the shore or, if the current be not swift, directly across the course of the stream or slough. The hooks are baited with fish or meat, beef hearts being a favorite bait.

In the aggregate, considerable quantities of catfish are taken with hand lines. Fish thus caught are rarely marketed, except those obtained by the Chinese. Many of the catfish sold in the Chinese fish markets of Portland are taken with hook and line. At places on the Sacramento River drop nets or dip nets, baited with meat or fish, are fished from wharves. Often large hauls of catfish are made in this way. Such nets are usually operated by boys, and the fish taken are apt to be small.

Catfish are usually dressed by the fishermen before they are sent to market, the cleaning being done on the fishing-grounds. The nets are hauled two or three times a week, usually in the afternoon, according to the demand for and abundance of fish, while the forenoon is spent in dressing and boxing the fish, which are kept in the live-cars until required. The fish are prepared for market by removing the skin, head, and viscera, and packed in boxes holding about 150 pounds, no ice being used.

The fishermen supplying the Sacramento market usually deliver their fish alive to the dealers, who have live-cars conveniently located and can dress the fish as needed. The San Francisco and Portland fish markets are so far from the water front that the dealers can not keep the fish alive.

THE FISHING SEASON FOR CATFISH.

In California, fishing for catfish is done throughout the year, with but little variation from month to month, as the receipts of the San Francisco dealers given on page 393 will show. The catch is, however, smallest in July and August. Mr. Alexander reports that from October to June a few fishermen find employment in Oregon in taking catfish for the Portland market. During the summer months, when salmon are very abundant, there is little demand for catfish.

QUANTITY AND VALUE OF THE CATCH OF CATFISH.

As much the largest part of the catfish yield of California is consigned to San Francisco, Sacramento, and Stockton, figures showing the receipts in those cities will give a fair idea of the quantity caught. Mr. Alexander's inquiries at Sacramento and Stockton and the writer's examination of the books of the San Francisco dealers showed that in 1893 the shipments to those places were as follows:

	Pounds.
San Francisco	43,975
Sacramento	59,025
Stockton	36,000
Total	139,000

The quantity of catfish sent from the principal shipping centers on the Sacramento and San Joaquin rivers, as determined by Mr. Alexander, were as follows, the difference between these and the foregoing figures, amounting to about 33,000 pounds, representing the aggregate of a number of minor shipments of which no record could be obtained:

	Pounds.
Red Bluffs, Fremont, and Knights Landing	40,000
Courtland	13,550
Isleton	12,000
Rio Vista	2,290
Bouldin Island	23,000
Jersey Landing	15,000
Total	105,840

The catch by persons who make something of a business of fishing for catfish was not under 150,000 pounds in 1893, and fully 50,000 pounds additional would not more than cover the catch by farmers, boys, and fishermen in other branches, most of which is consumed locally.

The gross value to the fishermen of the catfish caught for market was $6,358, and the total value of the fish to the State in the year named may be estimated at $8,500, making a very moderate allowance for the catfish used for home consumption.

The quantity of catfish taken for sale in the Columbia basin in 1893 was about 90,000 pounds, with a value to the fishermen of $2,800. Comparatively large numbers were also consumed by lumbermen, farmers, and others who fished for their own use. The receipts of catfish in Portland in 1893 amounted to 75,000 pounds.

The contention of the California fish commissioners in several of their reports already cited, that the value of all the catfish caught annually and consumed as food would more than equal the annual appropriation made by the State in the interests of the fisheries and fish-culture, has probably been verified in a number of years. In 1893, when the fishery is known to have been less extensive than formerly, the appropriations exceeded the value of the catch by only $1,500.

EDIBLE QUALITIES OF CATFISH.

While the consumption of catfish in California is not large, the fish are well-liked by many people; others, however, regard them as very inferior fish. When taken from the cooler, deeper waters, they have a good flavor, and deserve to rank high among the resident fresh-water fishes of the Pacific States, but when caught in warm, shallow, muddy sloughs and ditches they naturally have little value as food.

Mr. Alexander says that fishermen, with few exceptions, have little praise to offer in behalf of the catfish. Nearly all with whom he conversed said their edible qualities were of a low grade. He believes, however, that many people think differently, and that the quantity of catfish eaten in some localities indicates that the fish are rather popular. The amount consumed can not be due to the cheapness of the fish, for at times other fish reach so much lower prices that it would seem no catfish would be bought. Mr. Alexander thinks that, while a large part of the catfish is eaten by Chinese and the poor of the numerous nationalities found on the west coast, considerable quantities must be consumed in restaurants under fictitious names, just as sturgeon and sharks are served as "tenderloin of sole."

The dealers in San Francisco and Portland do not attach much importance to the catfish and do not value its edible qualities highly, but in Sacramento they speak well of the fish.

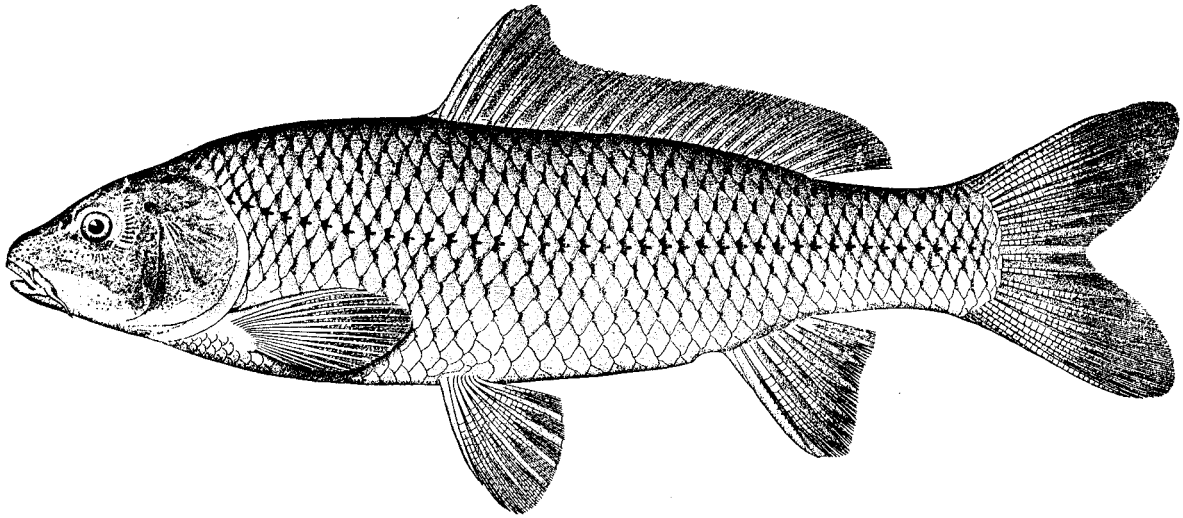
Drs. Jordan and Gilbert regard the bullhead as the best food-fish found in Clear Lake, California, with the exception of the Sacramento perch and rainbow trout.

THE CATFISH TRADE.

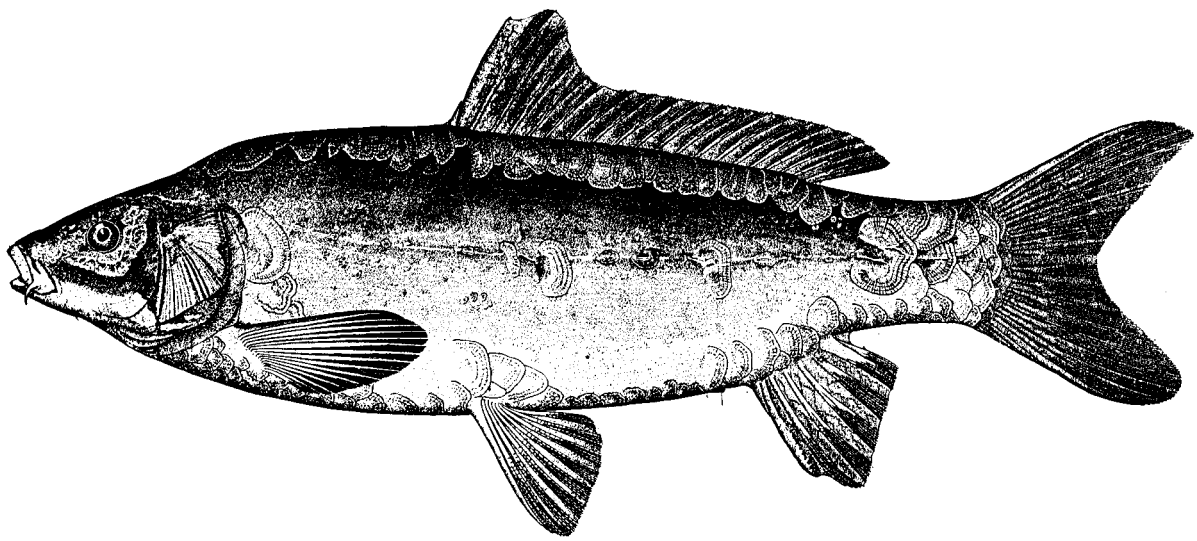
The principal marketing centers for catfish are San Francisco, Sacramento, Stockton, and Portland. The last-named place has the most extensive trade. In proportion to its population, San Francisco receives much fewer catfish than any of the other cities mentioned.

Catfish can not be said to be common in the San Francisco markets. The demand is usually very limited. At times, however, when other fish are scarce, they meet with ready sale at good prices. In 1893 the average daily receipts were less than 150 pounds, and in 1894 under 100 pounds. In no month during those two years did the daily receipts run over 250 pounds on an average, and in July and August, 1894, they were under 30 pounds a day.

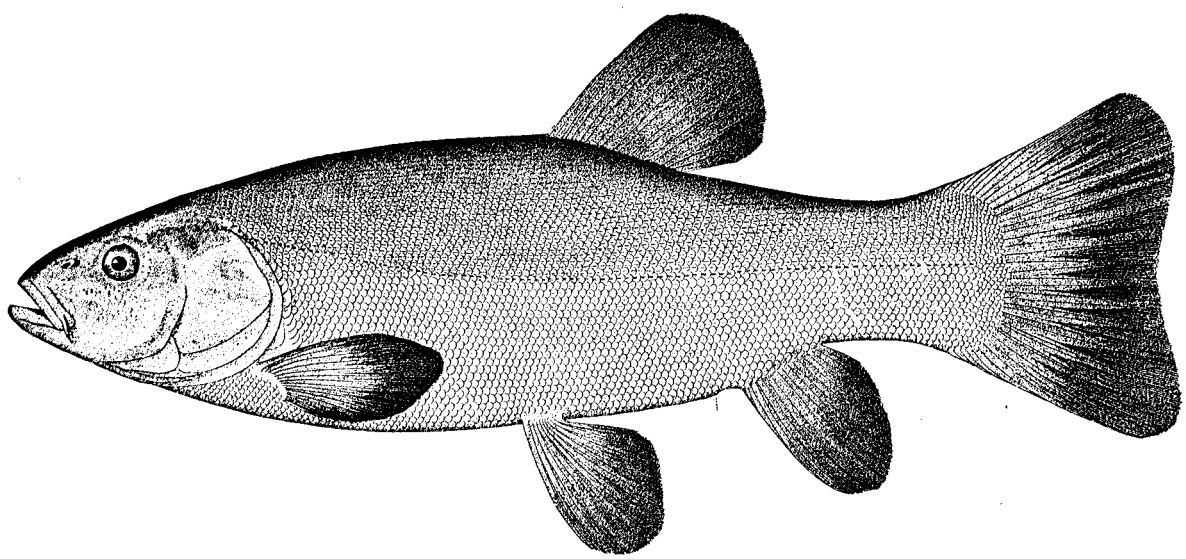
An examination of the books of the San Francisco dealers by the California fish commission and the writer showed that in 1893 the aggregate receipts of catfish were 43,974 pounds, and in 1894 were 31,055 pounds. The decrease in 1894 was due to a marked diminution in the receipts during the last six months of the year, as will appear from the following statement. In 1893 the largest quantities were handled in September, and in 1894 in April.



ASIATIC CARP; SCALE CARP (*Cyprinus carpio*).



GERMAN CARP; LEATHER CARP (*Cyprinus carpio coriaceus*).



TENCH (*Tinca tinca*).

Statement by months of the number of pounds of dressed catfish handled by San Francisco dealers in 1893 and 1894.

Months.	1893.	1894.
January	1,515	4,117
February	2,576	1,096
March	5,408	4,760
April	4,115	5,290
May	3,565	2,978
June	3,035	2,630
July	2,619	695
August	950	357
September	6,400	2,473
October	6,347	2,795
November	4,082	1,526
December	3,362	1,732
Total	43,974	31,055

There is little or no sale for round catfish in San Francisco, and those which reach the dealers in such condition are dressed by them before being exposed for sale. The fish shown in the foregoing table were dressed weights, which represent about two-thirds the original weights. The dressing consists in skinning, eviscerating, and removal of the head.

The price commanded by catfish in the San Francisco market has greatly decreased in the past few years. In 1888 the average price to consumers was 17 cents a pound; in 1889 it was 10 cents; in 1891, 7 cents; in 1892, 6 cents, and in 1893, 4 cents.

There is very little reshipping of catfish by the wholesale fish-dealers. Fully three-fourths of the receipts of catfish in San Francisco are consumed locally, and but few are sent beyond the limits of the State.

The catfish trade of Portland is comparatively large. The quantity of fish handled in 1893 was 75,000 pounds of dressed fish, with a retail value of $3,750 and a cost price of $2,250.

As elsewhere stated, the quantity of catfish handled at Sacramento and Stockton in 1893 was 59,025 pounds and 36,000 pounds, respectively, having about the same retail value per pound as in San Francisco.

THE CARP.

HISTORY OF INTRODUCTION.

The carp (*Cyprinus carpio*) has been planted in all the States of the Pacific and Rocky Mountain regions, and is now one of the most widely distributed fishes. At a comparatively early date the local fish commissioners became impressed with the desirability of planting the carp in the sloughs, bayous, and shallow waters generally, which were either destitute of fish or, to quote the California commissioners, contained only "the worthless and unpalatable fish of the warm waters of the great valleys in the interior of the State." From the outset a very active interest in the cultivation of the carp sprang up in most of the States, and numerous demands for fish for stocking local waters came from farmers and others.

The carp was first imported into California in 1872, when Mr. J. A. Poppe, of Sonoma County, brought five fish from Holstein, Germany, and put them in private

waters. These fish appear to have multiplied rapidly, and it is recorded * that Mr. Poppe did a thriving business in selling their progeny for stocking purposes.

In 1877, in exchange for eggs of the California trout, the California fish commissioners received 88 young carp from Japan; these were retained for breeding purposes.

The United States Fish Commission, in May, 1877, imported carp from Germany, and in 1879 supplied 298 fish to the California commission; 60 of these were placed in Sutterville Lake, near Sacramento, and the remainder in a private pond in Alameda County, where they were at the disposal of the State authorities.

The foregoing lots, aggregating only 394, represent all the carp from outside the State planted in California up to the time the consignment to private applicants was begun by the United States Fish Commission in 1882.

The United States Fish Commission began the distribution of carp to applicants in Idaho, Oregon, and Washington in 1882, and has continued to supply them as requested up to the present time, comparatively large consignments being made in recent years. Most of the original plants were made in private waters, but by the breaking of dams, the overflowing of ponds, and other accidents, the fish have in some localities reached rivers and other public waters.

The carp was introduced in Nevada in 1881, when the State commissioner distributed to applicants some that had been supplied by the United States Fish Commission. In the two subsequent years numerous assignments were made by the national commission, 190 fish being sent to nine applicants in 1882 and 2,285 to more than 100 applicants in 1883. Since that time there have been calls for but few fish for stocking purposes.

GENERAL RESULTS OF CARP PLANTING.

A detailed account of the early results of carp introduction in the Pacific States, based on the testimony of the recipients of fish, is given in an article entitled "Some results of carp culture in the United States," compiled by Charles W. Smiley, and published in the Report of the United States Fish Commission for 1884.

As early as 1879 the carp had become extensively acclimatized in private waters in California and furnished a large amount of food to people living in the interior of the State; this outcome was chiefly due to the distribution from Mr. Poppe's private ponds. In 1880 the commissioners reported that wherever introduced the carp had grown rapidly in size and numbers, and by 1884 they had become so generally and successfully planted in the waters of the State that few calls were made for them, and the commissioners reported that the supply was enormous, the market price at times being only 1½ cents a pound.

The history of the introduction of carp in the open waters of the Columbia basin is not known. It is probable that the fish accidentally gained access to the river by the breaking of dams or the flooding of ponds. It has become exceedingly abundant in the lower Columbia and its tributaries, especially the Willamette River. At The Dalles and Celilo the fish are also very numerous. Recent investigations by the Fish Commission have shown that the fish also inhabits the Snake River as high up as Glenn Ferry. Mr. Barnum reported the fish as abundant at Weiser, and cited its occurrence at Huntington, Ontario, Payette, and other points on the river.

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*The introduction and culture of the carp in California. By Robert A. Poppe. Report U. S. Fish Comm. 1878, pp. 661–666. Also Reports California Fish Commission, 1874–75 (p. 12), 1880 (p. 10), and 1893–94 (p. 74).

Carp have become numerous in Clear and Silver lakes, near Spokane, Wash., and are held in considerable esteem.

Marked and immediate results attended the planting of carp in Nevada. In 1884 Mr. Thomas Oliver, who had carp ponds near Carson City, was reported to have thousands of young carp for sale, the progeny of eleven small fish received two years before. The report of the Nevada fish commission for 1889–90 stated that Mr. Oliver's fish had multiplied so rapidly that he produced more than enough to supply his neighbors and the State commission with plants. An earthquake in June, 1887, however, destroyed these flourishing ponds.

Mr. Taft, of Diamond Valley, in 1890, produced fish for the Eureka market and local consumption. The Humboldt River near Winnemucca was said to have an abundance of carp in 1890, some of the fish weighing 5 pounds and upward; they were sold in the Winnemucca markets, and were rather highly esteemed.

In 1881 Hon. Thomas B. Rickey planted some carp in reservoirs and ditches connected with Alkali Lake, in Douglas County. The Nevada fish commission report for 1889–90 stated that the fish had increased beyond all expectations in Alkali Lake, from which many fish had been taken and salted for home use.

ECONOMIC IMPORTANCE, FOOD VALUE, AND INJURIOUS QUALITIES OF CARP.

In the Pacific States, as elsewhere, opinions differ widely as to the edible qualities of the carp, and as to whether the fish is not more injurious than useful. The various views entertained depend to a considerable extent on local conditions and are often based on limited observation and experience. Prejudice and preconceived ideas have also led to the formation of opinions favorable and unfavorable to the fish.

The present feeling toward the carp in California, Oregon, Washington, and Idaho is generally adverse, and seems to represent a reaction from the favorable attitude which prevailed for a number of years after the acclimatization of the carp. The most extravagant statements regarding the food value of the fish were then entertained. We find in some State reports such superlative expressions as "carp are the most delicious fish that swim"; "carp as food-fish have no superior," etc.—which excellence has hardly been claimed even by many who are thoroughly acquainted with and most favorably impressed with the edible qualities of the carp. With this high ideal in mind, it is not surprising that disappointment overtook those who stocked their ponds with these fish.

Outside of the question of its food value, the carp is, in the Pacific States, condemned on a number of other grounds, which will be mentioned.

In reservoirs and lakes, its habit of stirring up the mud and sediment makes the water roily. Reference is elsewhere made to the planting of fry of the predaceous muskellunge in Lake Merced, near San Francisco, in order to secure the destruction of the carp, which were very abundant and constantly kept the water muddy. As this lake was one of the reservoirs for the water supply of San Francisco, the matter had considerable importance. Sea lions were previously placed in this lake for the same purpose. Mr. Babcock writes as follows on this subject:

> Carp have entered the Blue Lakes in Lake County. The Blue Lakes, three in number, were formerly very striking and beautiful bodies of water. A. V. La Mott now tells me that lower Blue Lake is so muddy that its beauty is gone, the carp keeping the water roiled all the time. Lake Merced, property of the Spring Valley Water Company, in the city and county of San Francisco, was so damaged by

carp as to be almost useless to the company. The company employed 4 fishermen by the month to seine the lake, and during that time—some four months—bought 19 good-sized seals [i. e., sea lions] taken near Cliff House. These seals were placed in Lake Merced in 1891, and for a time the company employed men to go over the lake to pick up the pieces of dead carp that were so numerous as to be dangerous to the purity of the water. In the summer of 1895, at the request and expense of the water company, I engaged several Italian fishermen to go to the lake, and under our supervision they used all kinds of drag nets and seines in the lake and were unable to take any carp or any other fish than sticklebacks. The seals have grown very thin. Another effort was made in same manner with like result in fall of 1895. I am of the opinion that there are no carp, big or little, in the lake at this time. The coming season the company will try again for carp, and if none is found the seals will be killed off and large-mouth black bass placed in the lake.

A rather wide-spread opinion prevails that the carp consumes or uproots the wild celery on which wild ducks feed, and "it is reported that these game birds have diminished in numbers of late wherever in this State their feeding-grounds have been invaded by the carp."

Carp are credited with eating other and better food-fishes, but the charge seems almost too trivial to notice. The ingestion of live fish must be very rarely if ever undertaken, and is inconsistent with the anatomy and known habits of the carp.

The habit of eating the spawn of other fish is ascribed to the carp in the Pacific States, as in other parts of the country. From a statement hereafter quoted, it will be seen that by some the scarcity of Sacramento perch in California is attributed to this cause.

The San Francisco *Evening Bulletin* of May 29, 1894, contained the following editorial notice of the carp and catfish under the caption "Where the fish commission went astray." The article may be quoted to illustrate the sentiment entertained by many persons against the carp, and to show the general grounds for that sentiment.

When the fish commission a few years ago undertook to stock the rivers and sloughs of California with catfish and carp, the *Bulletin* deprecated that sort of enterprise. Pains were taken to acquire information from various sources about the value of these species as food-fish, in addition to what was personally known from observation on western rivers. It was found that these fish were relatively of small value, and that this was overbalanced by the injury they would do in decreasing the number of better fish.

The German carp had already been tried in ponds and lakes on private estates. Not a single favorable report could be obtained. The tenor of the reports were that the fish were a nuisance, and that efforts were being made to exterminate them. Ponds and small lakes were drained off, but the fish went into the mud and lived for weeks. When the water was turned on, the fish were as active as ever. They multiplied with amazing rapidity. But nobody seemed to want them, except the few who were still bent on making experiments. These fish have multiplied in the rivers and sloughs until in many places they have become a nuisance. Like the English sparrow on the land, they are beyond extermination, and are everywhere execrated.

Now comes the *Oregonian* and reports that carp have become so plentiful in the sloughs and bays along the Columbia that fishermen have offered to supply farmers with any desired quantity for manure at $5 a ton. The carp are gross feeders, consuming better food-fishes and wild celery and grasses on which wild ducks feed and fatten. It is reported that these game birds have diminished in numbers of late wherever in this State their feeding-grounds have been invaded by carp.

Then the fish commissioners made another unfortunate experiment, against the strongest protests that could be put forth. They introduced the hated and almost worthless catfish to the waters of California. These fish, like the carp, have multiplied rapidly. It was reported, in answer to the protests made at the time, that only a superior kind of catfish would be introduced, against which there could be no valid objection. But they turned out to be the same old toughs that have occupied western rivers and bayous to the exclusion of better fish. These catfish are voracious feeders on young trout and salmon. Their value is so low that very few seek them. The Chinese sell them occasionally, as they do carp, if they can find a customer. But most consumers turn away from these fish in disgust.

The fish commissioners introduced to the waters of California, among some of good quality, two species of what were called edible fish that now have come into the category of nuisances. If every one of these fish could be removed from the water to the land, and there employed as fertilizers, a substantial gain would be made.

Drs. Jordan and Gilbert, in a paper* on the fishes of Clear Lake, California, condemn the carp in severe terms. They say of this fish:

Everywhere very common; burrowing into the mud among the tules or in shallow waters, thus keeping the shoal waters roily all the time. This species is regarded as worthless for food. It destroys the eggs of the Sacramento perch and also devours the *Vallisneria* or water celery, on which the canvasback and other ducks feed. In California this species is a nuisance, without redeeming qualities.

The remarks of these writers on the Sacramento perch and the catfish in this lake are also applicable to the question of the destructiveness of the carp:

Archoplites interruptus (*Perch*). Formerly very common, but now becoming scarcer, as its spawning-grounds are devastated by the carp. The destruction of this valuable fish is one of the most unfortunate results of the ill-advised introduction of the carp into California waters.

Ameiurus nebulosus (*Catfish*). Extremely abundant and destructive to the spawn of other species. It is, however, a fair food-fish and much less objectionable than the carp.

The following statements concerning the destruction of vegetation by carp in California are from a letter from the late Mr. Ramon E. Wilson, secretary of the California fish commission, dated November 12, 1891:

I took advantage of the first opportunity presented, November 3, to visit the duck-shooting preserve of the Tule Shooting Club, located in the heart of what is known as the "Suisun Marshes," lying midway between Benicia and Suisun. These marshes for twenty years have been famous for duck shooting, and for the past ten years have been preserved by five clubs. Each of these clubs has, from year to year, supplemented the natural and indigenous growth of vegetation by planting non-indigenous seeds and grasses, until about two years ago the ponds, ditches, and sloughs had so grown up with vegetable matter that upon the opening of the season it was almost impossible to push a boat through the dense growth. Last year, the season of 1890, it was discovered that a marked change had taken place. The cause was attributed to the winter, which was a rather severe one, in that there were many overflows and freshets occasioned by heavy storms. This year the change in the respect mentioned was much greater. It was early reported in the spring that there was very little sign of vegetable growth in any of the ponds. Investigation followed, and it was found that fish in large numbers, ranging from a few inches in length to 15 pounds in weight, had invaded the grounds and taken entire possession of all the waters. These fish came, say, in May and remained until about the latter part of July—that is, the bulk, but many remained later. We are convinced that these great numbers came to spawn. About August, this great school, if you can so call it, suddenly disappeared—that is, the larger ones and the majority of the whole. Their going was not unlike the grasshopper in effect on vegetation—not a sign or remnant left. The result is that to-day, where these same ponds have heretofore afforded unlimited food supply for surface-feeding ducks in the early part of the season and a like supply of celery bulbs for the canvasbacks and redheads for the balance of the season, there is absolutely not a single sign of vegetation. At the time mentioned I carefully examined the beds of the ponds and found them positively barren of vegetable matter. Notwithstanding the emigration, if it can be so called, of the larger fish, the waters are still alive with the same fish, ranging from 2 to 8 inches in length. These ponds, heretofore quite clear, are now nothing more than mud holes. That this fish burrows in the mud there is no question. The beds of the waters are not unlike a sieve in appearance, with holes, round in form, ranging from one-half inch to 3 inches in diameter. The banks of the ponds and sloughs are quite like the bottoms. The fish have burrowed to the depth of a foot in many places, and it can be readily seen that it has been done for the purpose of getting at the roots of the vegetable growth.

Following out your suggestion, I secured three of the largest specimens of the fish. I caught

* Bulletin U. S. Fish Commission, 1894, p. 141.

them myself in one of the ponds. I should say each weighed three-fourths of a pound. I sent them to Dr. Jordan, wrote to him my experience, and am now in receipt of his reply. I quote:

"The three specimens mentioned in your letter have been received. They are, of course, the ordinary carp (*Cyprinus carpio*). I will have them opened to see if, perchance, the contents of their stomachs may throw any light on the question at issue. I should think there would be little doubt that the carp might destroy the water celery and so interfere with the food of ducks."

What I have said, as the result of my own observation, is true from evidence, by way of correspondence, which has accumulated in my office, and applies to all the marshes on the Sacramento and San Joaquin rivers for a distance of quite 100 miles. The irrigating ditches throughout the San Joaquin Valley are full of these fish, and it is no "fish story" to say that they burrow into the banks and make breaks in the levees.

The carp is very unpopular in the upper Columbia, at The Dalles and Celilo, on account of its supposed destructiveness to salmon spawn. It is used to some extent by the German families of that section and also in the fishing-camps, but the consumption is light. At Umatilla and Arlington complaints are also made of the carp.

At Huntington, on the Snake River, Oregon, some carp are caught which find a sale among the farmers of the neighborhood. Along the same river, at Payette and Ontario, some favorable mention of the carp as a food-fish is made, but the sentiment of the people is generally against it and the fish has no economic value.

At Spokane, carp are sold in limited quantities to German families at 3 to 3½ cents a pound.

Mr. Wilcox reports that carp are found constantly in the Portland market, although the abundance of the fish is such that at times it can not be sold at any price.

Mr. James Crawford, fish commissioner of Washington, reports that carp and catfish have recently begun to be recognized as of some importance as food-fishes in that State, and that in 1892 at least $2,000 worth of these fish were disposed of in local markets and in inland towns along the Union Pacific and Northern Pacific railroads.

Without desiring to ignore any injurious qualities the carp may possess, the opinion may be ventured that the fish is credited with doing much harm that it may not be responsible for, and that the evidence on which the carp is so severely condemned is, in the Western States, as elsewhere, wholly insufficient at present, whatever may be the result of an impartial investigation of the matter.

In the November 5, 1891, issue of *Forest and Stream* is the following editorial reference to carp in California:

Nearly two decades ago, and five years before the United States imported the fish from Germany, Mr. J. A. Poppe placed five small carp in one of his ponds at Sonoma, Cal. Nine months later (May, 1873) his stock had grown to 16 inches in length, and 3,000 young fish were obtained from the first breeding. The fish were sold to farmers throughout the State, and some were shipped to Central America and the Sandwich Islands. The increase of the species, especially in the marsh or "tule" lands, was remarkable, and the demand continued steady. Now a reaction appears to have set in, and a most unjustifiable style and amount of abuse is being heaped upon a really valuable food-fish, which has also long held a worthy place among the anglers' favorites in countries wherein it was best known. The qualities which led to the action of the Government in behalf of carp acclimation were the following:

(1) Fecundity and adaptability to the processes of artificial propagation.

(2) Living largely on a vegetable diet.

(3) Hardiness in all stages of growth.

(4) Adaptability to conditions unfavorable to any equally palatable American fish and to very varied climates.

(5) Rapid growth.

(6) Harmlessness in its relations to other fishes.

(7) Ability to populate waters to their greatest extent.

(8) Good table qualities.

These properties still exist and no amount of unreasoning prejudice can alter or reduce them. When we are told that the carp is a kind of sucker and "sucks the roots out of the banks of the ditches, causing the banks to wash out," we are bound to reply that California is noted for the variety and size of its suckers, but the carp is not one of them. The habit referred to is not observed in the carp, and the real culprit must be sought in some other direction. It is gravely asserted also that the food of the ducks and other wild fowl is consumed by the carp and the game birds are deserting the marshes in consequence. Again, it is charged that the salmon and trout waters are being invaded and the eggs devoured on the spawning beds. Carp in water having a summer temperature of 54° would be about as untimely as oranges on the tundra at Point Barrow. We shall next hear that the carp has utterly destroyed the salmon industry of Alaska and driven the seals out of Bering Sea. As a matter of fact, California has many native fishes of the carp or minnow family, some of which swarm in the irrigating ditches, while others inhabit trout waters, and certain of these are known to be very destructive of eggs. In the Pit and McCloud, for example, may be found a large species of *Ptychochilus,* known as the Sacramento "pike," which is really a giant minnow, growing to a length of 5 feet. This, or something like it, is probably the fish for whose sins the carp is now suffering in the estimation of many good people of California. Before passing final judgment on the subject, send some of the cold-water carp and the burrowing nuisance to some one who knows the fishes of the State for identification. Dr. Jordan, at the Leland Stanford Junior University, will settle all doubts for you, and *Forest and Stream* will take pleasure in aiding investigations of any sort into the habits of fishes.

In a letter dated September 25, 1891, Mr. Ramon E. Wilson, at that time secretary of the California fish commission, called the attention of the United States Fish Commissioner to the fact that carp had been taken at the McCloud River station of the United States Fish Commission, and that Pitt River and Squaw Creek, in the vicinity, were swarming with the fish. Mr. Wilson expressed the fear that this raid of carp in the upper waters of the most important salmon river of the State, the Sacramento, was a serious matter. In reply, the United States Fish Commissioner stated that it did not seem possible that the carp could injure the salmon, whose spawning beds are located in the cold upper portions of the streams, and that it would be contrary to all experience to find carp thriving in such situations. The Commissioner suggested that the fish reported in such numbers in the Pitt River might not all be carp, but some other members of the carp family, such as *Orthodon, Lavinia, Pogonichthys, Mylocheilus, Ptychocheilus,* etc.

In attributing to the carp the scarcity of canvasback and other ducks in a given region, there should be proof that the carp does and other fish do not eat and uproot large quantities of *Vallisneria;* and the influence of market hunters and indiscriminate killing by sportsmen must not be overlooked. The scarcity of canvasback ducks in most streams probably antedates the advent of the carp in noteworthy numbers, and, as in the Potomac, was coincident with spring shooting and with the activity of pot-hunters using swivel guns. Mr. John P. Babcock, chief deputy of the California fish commission, states that he thinks ducks in that State have changed their feeding-grounds; miles of lands in the San Joaquin Valley are now covered with ditches and miles of alfalfa now grow where a few years ago there was a desert; and the main market supply of ducks comes from that region instead of the Suisun Marshes. He thinks, however, that the carp have proved very objectionable in this region, and in a letter communicates his observations, as follows:

The carp have destroyed almost all the wild celery of the lower Sacramento and Suisun Marshes. They reach all the ponds during high water, and, as soon as celery comes up, they eat the shoots, and, in many of the best ponds on the shooting preserves, have taken roots and all of the celery. They have not destroyed the tule grass to any noticeable extent, if at all. The damage has been to the

better grasses. Many of the clubs planted wild celery in 1891, 1892, and 1893, but the carp destroyed it all, and it is claimed by observing men that the celery is entirely destroyed. The clubs resort every season to baiting their ponds with grain, and in these ponds the carp move in droves that W. P. Whittier tells me look like a tidal wave, as they move from one side to the other.

The following observations on the food and the feeding-habits of the carp have been furnished by Dr. Rudolph Hessel, who superintended the first importation of German carp by the Government in 1877, and the foremost authority in the United States on carp-culture. Dr. Hessel's remarks were prompted by the letter of Mr. Wilson previously quoted, an extract from which was submitted for an expression of opinion.

In connection with an extract from a letter of Mr. Ramon E. Wilson, California fish commission, relating to the suspected destruction of wild celery and other vegetation in the Suisun Marshes in the vicinity of San Francisco, Cal., by the carp, I will give you my observations, extending over a period of many years, regarding the habits of the carp (if I may be allowed to so term its mode of living, and the likes and dislikes of that fish), cautioning you, however, not to regard such observations as authority.

It is true that I have paid a great deal of attention to the habits of the carp in Europe and in our eastern waters, but I am not familiar with the waters of the Pacific Coast, and, for this reason, my conclusions should not be taken as final.

It is well known that the carp is not very particular as to its food. It feasts upon animal as well as upon vegetable food. It seems to be an established fact, however, that animal food is preferred, hence their persistent hunt in the mud and about the roots of water plants for worms, crustacea, and larvæ. At the earliest stages of its existence, from a few weeks to a few months old, the young carp can be seen scrutinizing water grasses and the under parts of floating leaves, etc., for diminutive and almost microscopic animals for feeding purposes. Later on they do not despise larger animal substances in the rivers; but where there is a perceptible scarcity of that kind of food in rivers and stagnant waters, they ascend into tributaries, creeks, and bayous, ostensibly going for vegetable food, in reality, however, delving, digging, burrowing, and hunting in the mud and about the roots of the water vegetation for animal food, as indicated above. No one need, therefore, be surprised if at such vigorous exertions of the carp the growth of vegetation generally will not be promoted and the water will not become any clearer. Many a plant will thus be uprooted, rise to the surface, and perish, and this may have been the case with the celery plants in the Suisun Marshes, too, to a certain extent.

The carp is very numerous and prolific in the Potomac River. There are specimens from 20 to 30 pounds, but that they go for the water celery has not been noticed here as yet. Water celery grows in abundance in places where the river flows slowly, especially about the so-called flats, but any injury to its growth, or a reduction of its density, not to speak of its total destruction, has not been heard of, as far as I know, with two exceptions only, not attributable, however, to the carp, but to high water in the spring of 1882 and 1889, when every kind of vegetation was swept away by the floods, and consequently water celery disappeared from the river during the two years subsequent to those freshets.

I must not forget to call your attention to the fact that turtles, too, are not averse to a meal of water celery. Frequently I have seen "red-bellies" and "yellow-bellies" feasting in the dense growth of Potomac celery upon that plant. Another point: For years I have kept quite a number of these species of turtles for ornamental purposes in a small pond about this station and fed them with water celery taken fresh from two ponds stocked with a great number of old and young carp, which never touched the celery, though it must be admitted that they did loosen the roots in their hunt for animal food.

In conclusion, I reiterate that I am not familiar with the fauna of the Suisun Marshes, but my impression is that, upon closer investigation, there may perhaps be found additional causes for the disappearance of the water celery and other vegetation therein, besides the undeservedly much-abused carp.

The carp may be very destructive to the spawn of certain fishes; this is probably the most serious charge that can be lodged against it. At the same time, no examinations, by competent persons, of the stomach contents of carp appear to have been made in the Pacific States or elsewhere. Even if it should be demonstrated that the carp consumes large quantities of fish spawn, it would not differ in this respect from a host of native species whose shortcomings in this respect are usually overlooked. If

we condemn the carp for this pernicious propensity, without conclusive evidence, what are we to do with the basses, trouts, salmons, sturgeons, and the entire sucker and catfish tribes, with known spawn-eating tendencies? There can be no question that in the waters of the Pacific States the large indigenous representatives of the carp family—the Sacramento pike (*Ptychocheilus*) and the squawfish or Columbia River chub (*Mylocheilus*)—are immeasurably more destructive to spawn than the carp. They are notorious spawn-eaters; the most attractive bait with which to catch them is fish spawn; and on the spawning-grounds of salmon and trout, where the character of the water is not adapted to the carp and where it is either entirely absent or quite uncommon, these fish are almost always present in large numbers and are known to subsist largely on the ova of salmonoid fishes.

Considering the question of the relation between the carp and the scarcity of the perch in California, attention is directed to the report of the board of State fish commissioners for 1883–84, in which the decrease in the abundance of the perch is commented on and other factors than the carp assigned as the cause of the scarcity. The beginning of the scarcity of Sacramento perch dates from 1881 or 1882, and was probably antecedent to the general abundance of carp in public waters. The remarks of the fish commissioners in the report cited are as follows:

> In former years this fish was very plentiful, but has become very scarce in the last few years, owing to several causes, viz:
>
> (1) We believe the greatest cause of disappearance is due to the reclamation of our tule lands by closing the sloughs, whereby ingress and egress are stopped, causing them to deposit their spawn in the rivers, and the spawn is lost by being covered with sediment.
>
> (2) By a continual drain upon the supply by Chinese and other fishermen, who are ever on the alert to find their hiding-places.

Many people in California think catfish are to blame for the scarcity of Sacramento perch. Reference to this matter is made in the remarks on the catfish.

The fact that carp uniformly command a higher price in the principal markets of the country than do many fish with well-established reputations as good food-fishes should prevent the reiteration of the statement that the carp is of no value as food. The additional facts that in the United States the carp has greater money value and is consumed in larger quantities than any other fish taken from private waters should be conclusive evidence of its food value and economic status.

A great deal more has been expected of the carp than has ever been claimed by those whose experience entitle them to speak on the subject. In the United States, which is so bountifully provided with salt-water and fresh-water food-fishes, the chief utility of the carp lies in its adaptability to cultivation in natural and artificial waters in the lowlands and plains which are either destitute of food-fish or contain species inferior to the carp in size or edible qualities. Throughout the Western States there are closed waters, containing few or no desirable fish, in which the carp is susceptible of successful cultivation and is the equal in food value of any of the fish which are found in the same situations. It is to the stocking of such waters that the carp is eminently adapted, and it is thus being utilized by thousands of families in which it is the chief if not the only available food-fish.

The carp is preeminently a pond fish, and when reared in ponds or similarly closed waters it will have food qualities, the degree of excellence of which will depend on the character of the water. Discrimination in the planting of carp should entirely obviate any necessity for considering the injurious qualities of the fish, except as a precautionary measure.

The "Abstract of the Eleventh Census," in a table showing the extent of carp-culture in the United States in the decade ending in 1890, gives the following data for the States of California, Oregon, Washington, Nevada, Idaho, and Utah:

Number of carp-culturists	1,006
Number of ponds and other bodies of water in which carp were planted	1,241
Number of carp planted	101,617
Value of carp sold or used from private waters	$15,324

The field inquiries conducted by the Fish Commission through Mr. W. A. Wilcox showed that the sales of carp by the fishermen increased annually from 1889 to 1892. Figures drawn from the books of the San Francisco dealers for the years 1893 and 1894 indicate a continuation of the increase, the aggregate receipts in the latter year being about 20 per cent larger than in 1893. Following is a statement of the quantity and value of the carp taken for market in the Sacramento and San Joaquin rivers during a series of four years, as determined by Mr. Wilcox:

Years.	Pounds.	Value.
1889	51,214	$1,734
1890	58,113	1,974
1891	59,618	2,016
1892	65,662	2,191
Total	234,607	7,915

The foregoing fish were taken with seines and fyke nets. The average gross price received by the fishermen was a little over 3 cents a pound each year. In addition to these fish, large quantities are known to be taken for local sale and home consumption in counties remote from the coast, for which no statistics are available.

San Francisco is naturally the principal market for carp on the Pacific Coast. An examination of the records of the wholesale fish-dealers of that city by the writer and the California fish commission showed the receipts to have been 35,653 pounds in 1893 and 42,580 pounds in 1894. The largest quantity handled in any one month was 10,142 pounds in January, 1894. The figures for each month in the years named are given in the following table. In addition to these, many thousand pounds of carp are handled by the Chinese dealers, of which no accounts can be obtained. The catch of the Chinese fishermen can not be ascertained, owing to their suspicious disposition and their failure to keep any records. Mr. Babcock states that large quantities of carp are offered for sale in the Chinese markets every morning. It is likely that their aggregate trade in this fish is larger than that of all the other dealers.

Statement by months of the number of pounds of carp handled by San Francisco dealers in 1893 and 1894.

Months.	1893.	1894.
January	784	10,142
February	709	4,755
March	4,936	6,798
April	3,191	2,839
May	660	767
June	1,589	699
July	4,650	729
August	1,725	383
September	1,531	4,396
October	3,982	4,960
November	6,319	4,461
December	5,577	1,642
Total	35,653	42,580

The average retail price received by the San Francisco dealers for carp during the past few years has been about 4 cents a pound. The average weight of those exposed for sale in the city markets is 5 pounds. The largest seen by Mr. Paladini, one of the oldest dealers, weighed 30 pounds, while Mr. Cuneo, of the American Union Fish Company, has handled a fish whose weight was 33 pounds.

In discussing the striped bass, reference is made to the observations of Mr. Alexander, which showed that in the Sacramento and San Joaquin Rivers the carp constitute the principal food of the bass. Further investigation will doubtless indicate that a number of other fishes (black bass, steelhead, and Sacramento perch, for instance) also subsist, in part at least, on carp.

THE TENCH.

The tench (*Tinca tinca*) is a fish of the carp family native to Europe. It has been somewhat extensively planted in the United States by the national fish commission. In foreign countries it reaches a maximum weight of 12 pounds. The fish is covered with very fine scales and is shapely and handsome. Its habits are very much like those of the carp. The flesh is firm and white, and is considered very palatable. In 1895 a number of shipments of yearling tench were made to the Pacific States; 50 fish were placed in Older Springs, Washington County, Oreg.; 400 were put in Fourth of July Lake, Fetz Lake, and a pond in Spokane County, Wash., and 758 in Diamond Lake, a lake and a pond in Kootenai County, and a pond in Latah County, Idaho, the first-named lake receiving 500 fish. In February, 1885, 20 tench were sent to a private applicant in Virginia City, Nevada.

THE GOLDFISH.

The goldfish (*Carassius auratus*) is an ornamental fish, without value as food. Numerous plants have been made by the United States Fish Commission in private waters in the Pacific States, and the fish has, in some instances, probably escaped into lakes or larger streams and there become acclimatized. It readily interbreeds with the carp, to which family it belongs.

THE AWA.

In the report of the California fish commission for 1876–77 the following reference is made to the introduction of the Hawaiian awa (*Chanos cyprinella*) in California waters. No further mention is made of the fish in the State reports, and there is no record of their survival or capture:

> In exchange for some salmon and trout eggs, sent to the Hawaiian Islands, we received in July last nearly 100 fish called "awa." These we placed in a small stream at Bridgeport, in Solano County, where they could have free access to brackish and salt water. They are said to be the most valuable food-fish of the Hawaiian Islands, of fine flavor, and thrive in fresh, brackish, and salt water. Where they have access to salt water they grow to weigh an average of 5 pounds. We have reason to believe they will find congenial homes and grow and multiply in the waters of this State.

THE SHAD.

HISTORY OF EXPERIMENTS IN CALIFORNIA.

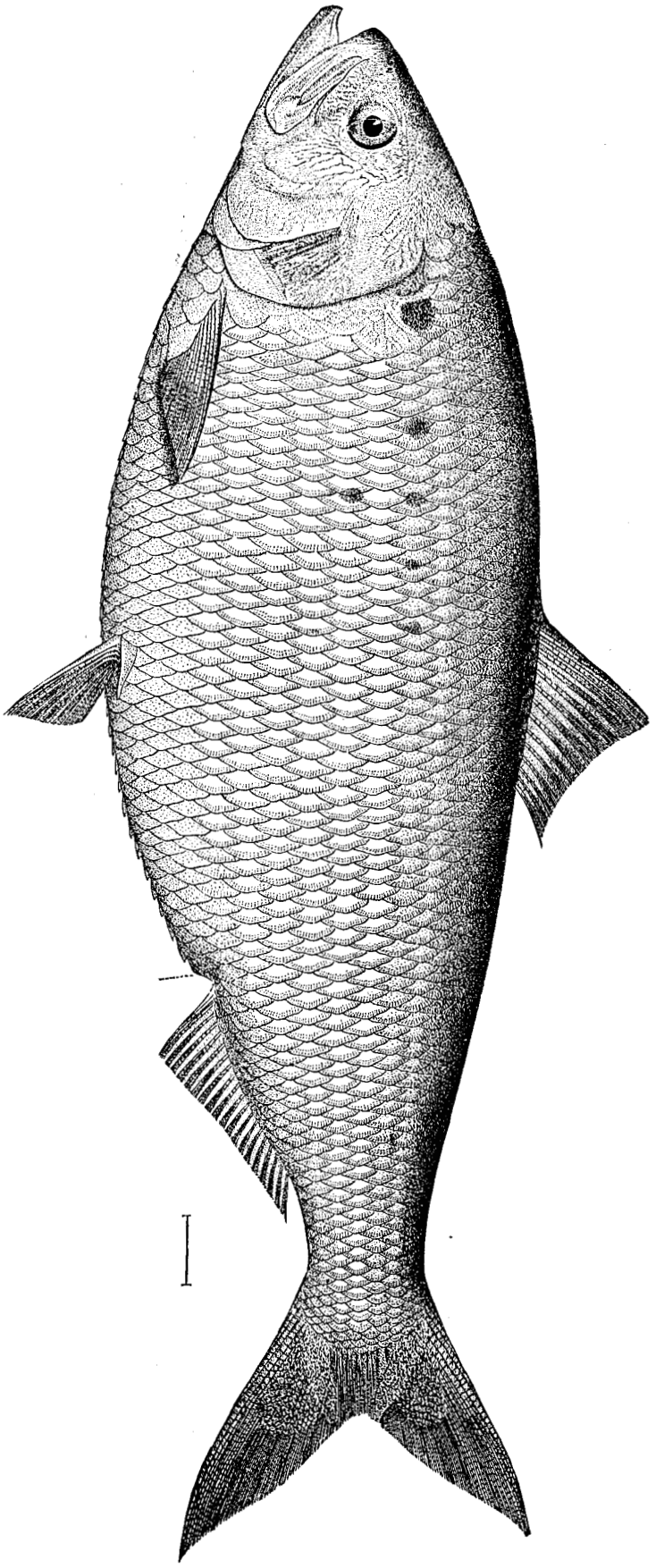
The shad (*Clupea sapidissima*) was first introduced into the waters of the Pacific Coast in 1871. The feat of transporting the fry across the continent was at the time considered so remarkable and has had such a prominent influence on fish transportation that the original accounts of the experiment, as contained in the reports of the California fish commission for 1870–71 and the New York fish commission for 1871, may with propriety be quoted at some length. The possibility and the desirability of introducing the fish into the rivers of the west coast appear to have been first suggested by the California fish commission, as may be seen from the following extract from their report:

Your commissioners made arrangements with Mr. Seth Green, the noted pisciculturist of Rochester, N. Y., for the importation of a lot of young shad to be turned into the Sacramento River. No shad proper (*Alosa præstabilis*) are found in the rivers of the Pacific Coast, while there are found several varieties of the same family, such as herring, anchovies, and sardines. As shad readily enter rivers while muddy from the spring freshets, and spawn in waters of a temperature as high as 65°, there was reason to hope that if the shad could be brought here alive and turned into the river they would find suitable food, and in time go to the ocean and return to propagate their species. As the shad is very prolific, each full-grown female yielding from 50,000 to 80,000 eggs, and as the flesh is esteemed to be nutritious and valuable food, it was deemed proper to make the first experiment of importing new varieties with the young of this fish. The eggs of the shad are hatched in from two to four days after they are spawned; therefore, if there were no other reason, time alone would prevent the importation of the eggs.

Mr. Green felt so much doubt as to the possibility of transporting the young fish for so great a distance that he determined to superintend the experiment in person. He left Rochester, N. Y., with an assistant, on the 20th of June, with 15,000 of the young fish just hatched, contained in eight tin cans holding about 12 gallons of water each. The water had to be changed at every convenient opportunity, as on a part of the journey the weather was quite warm. Constant attention had to be given to prevent the water in the cans from reaching a higher temperature than 80°. At Chicago he lost a few fish from a film of oil from the machinery of the waterworks with which the water attempted to be used was covered. At Omaha the river water killed a few. The cause of this he had not time to investigate. The water of Bear River (discharging into Salt Lake) and the waters of the Humboldt and Truckee rivers were found to agree with them and contained plenty of food.

Mr. Green arrived on the 27th of June. As it was advisable to put the young fish in the river at as high a point as practicable, for the reason that the instinct of the shad is, like that of the salmon, to return to spawn at the same place where it was hatched, they were the same day transferred to the cars of the California and Oregon Railroad and taken to the Sacramento River at Tehama. Here the temperature of the water was found to be 60° F. Upon dipping up the river water in a glass and pouring a lot of the young fish into it they were found to be lively and the water to contain large quantities of some minute substance on which they fed. All the conditions being favorable, they were turned loose in their new home.

It is expected they will remain in this river until about January, by which time they will be 3 or 4 inches long. They will then go to the ocean to return the next year weighing from a pound to a pound and a half, ready to commence the increase of their kind. Thus far the experiment has been a success. The water of the river is adapted to them. It contains the proper kind of food for their young, and the waters of our coast are filled with the sand flea, a small species of the shrimp, on which the fish feed after reaching the salt water. The only thing to be feared is that there may be in the ocean some kind of a fish which may so completely exterminate them that none will be left to come back and spawn. If, after one or two years, even one shad is taken in the river the result will be satisfactory, as it will demonstrate the fact that all the conditions are favorable to their successful



SHAD (*Clupea sapidissima*).

propagation in the waters of our rivers. We could then, at a trifling expense, fill our waters with this valuable fish. When first hatched and in a condition proper to be transported, one freight car would bring over 2,000,000 of them. If, after two years, none should be taken, it would not then be well to abandon the experiment.

Mr. Seth Green's account of his trip across the continent with the young shad, and his opinion of the success of the experiment, are as follows:

On the 19th of June, 1871, I started, at 6 a. m., from Mull's fishery, 10 miles below Albany, on the Hudson River, with 12,000 young shad in four 8-gallon milk cans. They had been hatched the night before at the establishment under charge of the New York commissioners. I arrived at Rochester at 10 p. m. and changed the water, substituting that from the Genesee River without injury to the fish. I arrived at Cleveland at 7.45 next morning, put 200 shad in Lake Erie, and changed the water again. The fish were then fresh and lively, without any signs of sickness. I again changed water at Toledo, and when I arrived at Chicago, at 7 p. m., the fish were still in good order. Here I first tried the water from the city waterworks, but found there was too much oil in it, so I went to the lake. Having tested the water and found that it would answer, I put 200 fish in Lake Michigan, and on June 21 started with cans newly filled, at 10.45 a. m., for California. I carried an extra can of water, for before me was a long stretch of almost arid land. Still I was fortunate enough to find some places between Chicago and Omaha where I could get a few pails of water and make a partial change. The fish were still in good order when we arrived at Omaha, but there I could not find any water in which they would live five minutes. The way I tested the water was by filling a tumbler and putting a few fish in it. It was easy to tell at once, by the behavior of the fry, whether the water agreed with them or not. I did not get a full change until I reached Laramie River. From Omaha I did not find any good water for 400 miles, and the only way I kept my charges alive was by drawing the water out of the cans into pails and pouring it from one pail to another until purified, this process being assisted by my getting a little ice water from the car tanks.

June 22.—Bad water all day, with the thermometer 100° in the shade from 9 a. m. to 4 p. m. I used ice water the entire day, a very little at a time, and had hard work to keep the temperature of the water below 82°. I began to feel blue and doubtful of the result. The fish suffered considerably, but the weather began to get cold toward night, and I got the temperature of the water down to 75° at 9 p. m., the fish recovering somewhat.

June 23.—I arrived at Laramie River at 5 p. m., and got a good change of water, fish doing well, and I began once more to feel hopeful and encouraged. We had a frost that night, and next morning, at 7, I changed water at Green River, where it was in proper condition. At 2 p. m. I got another change from a stream in which there were trout, and again at Ogden, where I put 200 fish in the river.

June 25.—The water was changed at the Humboldt River. The water was good and continued good all the rest of the way.

June 26.—I arrived at Sacramento, and took the fish up the river 275 miles from Sacramento, in company with Messrs. Redding and Smith, the California fishery commissioners. In their presence I deposited the fish in the Sacramento River the same night at 10 p. m. There were about 10,000, in good order.

On the sixth and seventh days out they began to be very busy, looking for food. Whenever I changed the water, they would clean up all the food there was in five minutes. They did not suffer for food as long as the sac lasted on their bellies—that is, for about five days—then they needed sustenance. If I could get a change of water often enough from running streams, I could carry them a long way, as nearly all streams are filled with small insects. With this view I examined the water of the Sacramento where I put them in, and found plenty of food for the young fry. I then went down to the Pacific Ocean, and ascertained that there were plenty of sand fleas, which are the principal food that the old shad live on in the Atlantic.

And now, in conclusion, I can only say, that if they do not have shad in the Pacific Ocean there will be but one cause—the roily water caused by washing the mountains down for gold. However, I think the fish will get through all right. I examined the river where it looked so roily, and found it quite clear on the surface for a few inches down. The tendency of the roil was to settle to the bottom. The young shad will find the clear water, and if it does not get very much worse than it was when I was there, they will succeed. But if these do not, more must be sent, for any amount of young fish can be taken to California by making the proper preparations beforehand.

The second plant of shad in the waters of California was made in 1873. In June of that year, Mr. Livingston Stone, of the United States Fish Commission, had started for California in a specially equipped car containing shad fry, together with a large number of young fishes of several other species. He had gotten as far as Nebraska, when his entire stock was lost and his car destroyed by the collapse of a railroad bridge over the Elkhorn River. On hearing of the disaster, the California fish commission telegraphed Mr. Stone to return to the Hudson River and secure another lot of shad. He obtained 40,000 fry from the New York State hatchery at Castleton, and transported them to the Pacific Coast at the expense of the United States Fish Commission. On July 2, 1873, 35,000 healthy fry were placed in the Sacramento River, near Tehama.

All the subsequent plants of shad in California waters were made directly by the United States Fish Commission, the place of deposit being the Sacramento River, at Tehama. Between 1876 and 1880, inclusive, 574,000 fry were planted, as follows: 99,000 in 1876, 110,000 in 1877, 150,000 in 1878, and 215,000 in 1880. Since 1880 no shad fry have been introduced into the State.

The total number of young shad planted in the Sacramento River was 619,000

STOCKING OF THE COLUMBIA RIVER BASIN WITH SHAD.

The first attempt to introduce shad into the waters of the northern part of the west coast was made by the United States Fish Commission in 1885, when a consignment of 900,000 fry, destined for the rivers of Washington tributary to Puget Sound, was sent out in a special car. By the washing away of a railroad bridge, so much time was expended that nearly the entire consignment was lost, and the original intention to go to the Puget Sound region was abandoned. Of the 60,000 fry that survived, 50,000 were planted in the Willamette River, at Portland, Oreg., and 10,000 in the Snake River, near its junction with the Columbia, at Ainsworth, Wash.

The following year, efforts to stock the Columbia River were continued. To guard against loss incident to delays en route, eggs as well as fry were placed on the car, which left Havre de Grace, Md., May 9, with 1,000,000 young shad, 200,000 eggs on trays, and 385,000 eggs in jars. The eggs on trays were all lost in transit and 50 per cent of the fry perished, while of the eggs in jars less than 10 per cent were lost. At Albany, Oreg., on the Willamette River, 550,000 fry were planted, and at Wallula Junction, Wash., on the Columbia River, 300,000 more deposited.

The aggregate plants of shad fry in the Columbia basin in 1885 and 1886 were 910,000. No additional shipments to that region have since been made.

INTRODUCTION OF SHAD INTO COLORADO RIVER.

In 1884, 1885, and 1886, relatively large plants of shad were made by the United States Fish Commission in the Colorado River with a view to ascertain whether the waters of that stream and its tributaries are suitable for the existence and multiplication of that fish. The reasons for expecting satisfactory results from the stocking of this river are thus stated in the report of the Commissioner for 1885:

(1) The Colorado is free from alkaline salts and of a suitable spring and summer temperature; the other physical conditions are also favorable.

(2) The Colorado empties into the Gulf of California, which extends south for 700 miles before reaching the ocean, and it is thought that the warm waters of the lower part of the gulf would be a barrier to keep the shad from being lost in the Pacific. The shad then would return to the Colorado and Gila to spawn.

The plants aggregated 2,651,000, of which 953,000 were deposited in 1884, 848,000 in 1885, and 850,000 in 1886. These fish were all planted at The Needles, in Arizona. These experiments were considered sufficiently extensive to test the adaptability of the river, and no further plants were contemplated.

It was expected that by 1887 or 1888 the results of the experiment would be known. Information has never reached the Commission, however, that adult shad have been taken in any of the tributaries of the Gulf of California, although, in the absence of special efforts with suitable apparatus, the outcome of the experiment should not necessarily, for the present, be regarded as a failure.

SHAD PLANTED IN UTAH AND IDAHO.

In 1873, while en route to California with a consignment of young shad, Mr. Livingston Stone left 5,000 fry at Ogden, to be placed in Great Salt Lake basin. The fish were deposited in the Jordan River, a few miles above its outlet in Great Salt Lake. In 1887, 984,000 more young shad were placed in the Jordan River. A plant of 1,925,000 fry was made in Utah Lake in the next year. Deposits aggregating 2,265,450 fish were made in the Weber River at Ogden, Bear River at Montpelier, Idaho, and Bear Lake, Utah and Idaho, in 1891. In 1892, 1,998,000 fry were placed in the Bear River at Cache Junction, Utah.

GENERAL RESULTS IN CALIFORNIA, OREGON, WASHINGTON, AND UTAH.

In order to insure protection to the shad in the event of the survival of the fry and the return of the mature fish, the California legislature enacted a law prohibiting, under a heavy penalty, the taking of shad prior to the year 1877. The existence of this law, which was of course entirely proper, made it difficult, if not impossible, to determine with satisfactory accuracy just when the results of the experiment were first manifested. From what can now be learned, mature shad first appeared in the waters of California in 1873. It appears that May 10, 1873, the California fish commissioners paid $50 as a reward for the first shad taken, and in their report of 1872–73 they state that while grown shad were not due in the rivers until 1874, they had, nevertheless, had three specimens in their hands and had heard of the capture of two others.

In a letter to Professor Baird, dated April 30, 1874 (published in *Forest and Stream* May 21, 1874), Mr. S. R. Throckmorton stated:

> The first shad taken on this coast, as verified by my own observation, was caught in a trap in Linsoon Bay, a branch of the harbor of San Francisco, about the 1st day of April, 1873. I purchased the fish and placed it in alcohol and presented it to the Academy of Sciences of the State of California. It is a male fish, 1 year 9 months and 20 days old, is 17 inches in length, and 3 pounds in weight. Two other shad were taken in the same locality during the summer of 1873—male fish and smaller in size.

In 1874 and 1875 sixteen full-grown shad were reported to have been taken at Vallejo and in the Sacramento River; the fish commissioners also learned of others taken in the same years.

The increase of shad in the waters of California has been uninterrupted and rapid since the first capture of the grown fish. The following important references to the appearance of shad in the Sacramento River and elsewhere in 1877 are from the report of the California fish commission for 1876–77:

> Shad, in their season, are becoming quite numerous in the Sacramento River. The experiment of their importation to this coast has resulted satisfactorily. The river is of proper temperature and furnishes an abundance of food for young fish before they go to the ocean. There can be no doubt

that the first shad brought from the Hudson River in 1871 have been to the ocean, returned, and spawned. No shad were placed in the river during the years 1874 and 1875, yet shad two years old were quite numerous this year, and they must have been the product of the first importation. It may be safely asserted that we now have shad born in the Sacramento. As it is illegal to take this fish prior to December of this year, probably there has been no systematic fishing for them, yet numbers have been accidentally caught in traps and nets; probably not less than 1,000 were thus taken during the winter and spring of 1877. They return from the ocean at an earlier season of the year than in the northern Atlantic States, in this respect corresponding to the periods when they return to the rivers of South Carolina and Georgia. The first reported this year were taken in Sonoma Creek, January 6; the latest two at Sacramento, June 20. These latter were full-grown fish, a male and a female, on their return to the ocean after having visited their spawning-grounds. * * * We are frequently urged to make larger importations of shad and fill the rivers immediately. This is impossible with the appropriation at our disposal. * * * We believe, however, that by 1878 shad will be sufficiently numerous in the Sacramento to warrant the attempt at taking ripe fish for the purpose of artificial hatching in our own waters. Should we be successful, we can save the expense and risk of importation, and all our appropriate rivers can in a few years be filled with this valuable fish. Having this in view, we would respectfully ask that you recommend the passage of a law restricting the catching of shad at all other times except between January 1 and April 1 of each year. This, if faithfully observed, would give part of the fish an opportunity to reach their spawning-places.

* * * * * * *

It is well known that salmon, after going to the ocean, invariably return to the river of their birth for the purpose of reproduction, and this was supposed to be the instinct of the shad, yet we have information of shad having been taken at Wilmington, and others in Russian River, * * * points on the coast separated by more than 400 miles. It may be possible that as these fish become more numerous they will return in schools to the Sacramento, the young following their elders who have once made the journey. Should they continue to enter different rivers on their return from the ocean, they will soon stock all on the coast that are appropriate to them.

During the spring of 1879 several thousand mature shad were sold in San Francisco, and it was reported by the fish commissioners that a few were found in the markets almost every month. In 1880 it was stated that they were beginning to increase by natural reproduction, as specimens of all sizes were found in the Sacramento River and Monterey Bay. Up to 1883 their increase was regarded as marvelous and the supply was considered as almost unlimited. During that year a law was in force forbidding their capture, but enough were incidentally taken to show their great abundance. In 1885 and 1886 numberless young shad were reported to be hatched in the tule lakes in the Sacramento-San Joaquin delta, and the supply was said to equal if not exceed the demand; the California fish commissioners estimated that a million good-sized shad were taken from the waters of the State in 1886.

At the present time the shad is one of the most abundant fishes of California, and the quantity taken, while actually less than that estimated in 1886, is enormous, and the wholesale and retail prices are less than in any other State.

In 1882 shad were taken in Rogue River, in southern Oregon, and have since been reported from time to time in other small coast rivers of the State.

Shad were taken in the Columbia River as early as 1876 or 1877. As fry were first artificially introduced into the basin of the Columbia in 1885, it is clear that the fish planted in California were the pioneers in the Columbia, although there is no reason to doubt that the large numbers of fry planted directly in that stream augmented the existing supply.

In a paper on the fishes of the Pacific Coast of the United States, published in the report of the California fish commission for 1880, Prof. W. N. Lockington refers to the taking of two specimens of the shad in the Columbia by Prof. D. S. Jordan.

About 1881 or 1882 shad became distributed along the Washington coast, and are now regularly found in all the coast bays and rivers. They appear to have reached Puget Sound in 1882. Mr. James G. Swan, of Port Townsend, communicated to the Fish Commission the information that on August 26, 1882, Mr. G. M. Haller, of Seattle, took a shad in Puget Sound in a gill net; the fish was small. Since that time shad have increased in size and numbers and are now regularly taken in Puget Sound and its tributaries, although not abundantly.

In 1891 shad reached the Fraser River in British Columbia, and in the same year they were reported from the Stikine River, near Wrangell Island, Alaska.

But meager reports have been received of the outcome of plants of shad fry in Utah and Idaho. No evidence of the survival and growth of those placed in the Jordan River has been met with, excepting an unverified statement that in 1876 a shad 3 inches long was taken in that river with a hook and line (see Report Deseret Agricultural and Manufacturing Society for 1875); there is no certainty of the proper identification of the specimen.

In November, 1888, Mr. M. P. Madsen, of Lake View, caught a 6-inch shad in the southern part of Utah Lake, about 15 miles south of the point where plants were made in the preceding June. Mr. Madsen reported the capture of another specimen in the same vicinity and of two others on the western side of the lake.* Under date of October, 24, 1889, Mr. A. M. Musser, fish commissioner of Utah, stated that another shad in fine condition had been taken in Utah Lake; its length was 13 inches and its weight 1 pound.

The following *résumé* of the results of the efforts to acclimatize shad on the west coast was given by the United States Commissioner of Fish and Fisheries in his report for 1887. Speaking of the fry deposited in the Sacramento River between 1871 and 1880, he says:

> From these slender colonies, aggregating less than 1 per cent of the number now annually planted in our Atlantic Slope rivers, the shad have multiplied and distributed themselves along 2,000 miles of coast from the Golden Gate of California to Vancouver Island, in British Columbia. They are abundant in some of the rivers, common in most of them, and occasional ones may be found everywhere in the estuaries and bays of this long coast line. Prior to our experiments on the west coast it was a dictum of fish-culture that fish planted in a river would return to it when mature for the purpose of spawning. The result of these experiments has been to demonstrate that this instinct of nativity, should it really exist, is in this case dominated by other influences, which have dispersed the shad planted in the Sacramento widely beyond the limits which we had assigned to them and in the most unexpected direction.
>
> The cause is probably to be sought in the genial influences of the Japan current, which brings the warmth of equatorial Asia to temper the extremes of Arctic climate on the southern shore of the Alaskan Peninsula, and, thence sweeping to the south, carries tropical heats to the latitude of San Francisco. Repelled on the one hand by the low temperature of the great rivers and fringe of coast waters, and solicited on the other by the equable and higher temperature of the Japan current, the shad have become true nomads, and have broken the bounds of the hydrographic area to which we had supposed they would be restricted. Following the track of the Asiatic current and finding more congenial temperature as they progress, it is not unreasonable to expect that some colonies will eventually reach the coast of Asia and establish themselves in its great rivers.

INFLUENCE OF NEW ENVIRONMENT ON HABITS OF SHAD.

The changes which have been wrought in the habits of the shad as the result of their introduction into new waters are extremely interesting and important from both biological and economic standpoints. In the absence of a special scientific inquiry,

*Deseret *Evening News*, Nov. 30, 1888.

no comprehensive remarks on this subject can be ventured, but enough is known, from even casual observation, to prove that certain well-marked habits of the shad on the Atlantic Coast have undergone noteworthy modification in Pacific waters, and the inference is proper that still further changes have occurred as a result of the new physical and thermic conditions, food supply, enemies, etc.

GEOGRAPHICAL DISTRIBUTION OF SHAD ON THE WEST COAST.

The present distribution of the shad on the Pacific Coast is from Los Angeles County, Cal., to Wrangell Island, Alaska. Following the major indentations, the known range of this fish now covers about 2,700 miles of coast line. Its distribution, considered from the standpoint of commercial importance, is from Monterey Bay to Puget Sound. It seems probable that the shad has become scattered along this extended coast as a result of the initial plants in Sacramento River. The suggestion of the United States Commissioner of Fish and Fisheries, in the report previously quoted, that the further extension of the shad's range to Asia may be expected, seems reasonable in the light of the history of the fish's movements up to this time.

On the California coast the shad regularly ranges as far south as Monterey, but the absence of suitable streams south of Monterey Bay makes its occurrence in that region probably accidental.

Several instances of the occurrence of shad as far south as Los Angeles County are known. In a "Report upon the edible fishes of the Pacific Coast, U. S. A.," by Prof. W. N. Lockington, in the report of the California fish commission for 1880, reference is made to the capture of shad as far south as Wilmington, Los Angeles County.

Mr. Arthur G. Fletcher, of the California fish commission, has made inquiries for the writer as to the recent presence of shad on the shores of Los Angeles County, and communicates the following notes: Four or five years ago (in 1890 or 1891), Harry Wallman, a fisherman, caught a 1-pound shad in a beach seine near East San Pedro; the fish sold for $1. In November, 1894, Chris. Hoffman, a fisherman, took in the same manner and at the same place two shad at one time and four at another, all 16 or 18 inches long. On December 3, 1895, a 12-inch shad was delivered to the cannery of the Hanniman Fish Company at San Pedro; it had been taken in a seine by J. Turner In a letter to Mr. Fletcher, Mr. Henry King, of Santa Monica, stated that in 1893 he caught a shad at Redondo Beach; it weighed about 1½ pounds, and was snagged with a line fished off the Redondo wharf. It is probable that other shad have been taken in this vicinity, but the fishermen as a rule are not well acquainted with the fish and might overlook it.

On the paranzella fishing-grounds off Drake Bay, north of the Golden Gate, shad are occasionally caught by the steamers; in the bay the drag-seine fishermen take small numbers at times.

In the Sacramento River the shad does not ascend as far as the salmon, and is not common above Sacramento; and in a letter dated November 26, 1895, Mr. Livingston Stone states that no shad have appeared in the upper tributaries of the Sacramento, owing to the low temperature of the water.

In September, 1894, a deputy of the California fish commission visited the Klamath River to watch the run of salmon, and obtained the following information about shad in that stream, which has been communicated by Mr. John P. Babcock,

the chief deputy: In July, 1891, two shad were taken; during July and August, 1892, seven were caught, ranging from 7 to 10 inches in length, and in August, 1894, but one was secured, which was 16 inches long.

The absence of special inquiries in the coast rivers of Oregon, south of the Columbia, makes it impossible to speak positively of the distribution and abundance of shad. They probably enter all the streams of suitable size, but as there is no fishing generally until the late fall run of salmon begins, only a few straggling shad are found, the main run having probably entered the river earlier in the season and gone out to sea by the opening of the salmon season.

In Rogue River, the southernmost stream in Oregon, a lot of shad was taken in 1883 by Mr. Charles T. Finély, of Ellensburg. Shad had also been obtained in that river in 1882, which had traveled up the coast from the Sacramento; they are now found in the river each year. In 1889 a shad was reported to have been caught in the Coquille River.

According to Mr. Alexander, very few shad are taken in any of the tributaries of the Columbia, but it is very probable that if proper apparatus were used they would be found in many places where they are not now known to exist. He says that no adult or small shad have as yet been caught in the Willamette River. Each season considerable salmon gill-net fishing is done in the river, and if there were any large shad there it is probable that one would occasionally be taken.

Mr. Malarkey, one of the largest fish-dealers in Portland, thinks the reason why shad do not go up the Willamette is that in the spring months, when they are first seen, the current of the Columbia is so swift that it forms a "back water" for several miles up the Willamette, which may have considerable influence on the movements of shad.

In the Columbia River the shad is regularly found as far as the Cascades, about 150 miles above the mouth of the river. A few appear to have gone even higher up the river, but there is no evidence that the shad occurs far above The Dalles. Mr. Charles F. Lauer, a fish-dealer at The Dalles, states that in 1893, when a Mr. Davis had a salmon wheel in position near that place, on several occasions from one to two dozen shad were caught in a day, in rather still water; and that in 1894 Mr. Davis also obtained a few shad about 2 miles above The Dalles on the Washington side of the river, in swift water. In 1893 one of the salmon wheels of Messrs Seufert Bros., at The Dalles, is reported to have taken two 6-pound shad. No one makes a business of taking shad at that point, and probably many of the fishermen do not know a shad when they catch it. Mr. I. H. Taffe, the proprietor of a salmon cannery and wheel fishery at Celilo, at the mouth of the Deschutes River, has never caught a shad at that place, and thinks these fish do not ascend the river so far. Inquiries and investigations of the Fish Commission in the upper Columbia River and in the Snake River elicited no information going to show the presence of shad. The fish is found in greatest abundance near the mouth of the river; it is caught, however, in considerable numbers wherever pound-net and drag-seine fishing is carried on.

Mr. Alexander reports that in 1893 fifteen shad were taken in traps at Point Roberts, Washington, near the mouth of the Fraser River; their average length was 15 inches and they weighed about 2½ pounds each. Mr. Charles H. Townsend, naturalist on the United States Fish Commission steamer *Albatross*, states that on September 23, 1895, Mr. Drysdale, superintendent of the salmon canneries at Point

Roberts, Washington, informed him that 300 or 400 shad were caught near that place during the summer fishing operations.

In Fraser River, British Columbia, whose mouth is near the international boundary, in latitude 49°, accounts of the occurrence of shad have been given in the annual reports of the inspector of fisheries. The report for 1891 records the capture of the first shad, as follows:

> I wish to mention the fact that a very fine full-grown shad, containing well-developed ova, was caught in the river in the latter part of July last, by one of Mr. Wadham's fishermen, and sent to me by that gentleman. I am in a position, therefore, to vouch for the excellent quality of the first shad known to have been caught in the Fraser River.

In July, 1892, according to the inspector's report, several shad were caught in the north arm of Fraser River. In the same month a number of fine shad were taken at Rivers Inlet, north of the northern end of Vancouver Island, in latitude 51° 30′. In 1893 shad were said to be getting more plentiful in Fraser River and at Rivers Inlet.

In a letter to the late John K. Luttrell, special agent of the Treasury Department, for the protection of the salmon fisheries of Alaska, Mr. John C. Calbreath, of Fort Wrangell, Alaska, refers to the capture of two shad at the mouth of the Stikine River in 1891, and reports none as being taken in 1892 or 1893. The mouth of this river is near Wrangell Island, in latitude 56° 30′. Mr. Townsend states that while at Sitka, on September 10, 1895, an alcohol tank, that had been loaned to the Natural History Society of that place, was returned to the *Albatross*. It contained a fine shad which had been obtained at Fort Wrangell by one of the members of the society. Whether the fish was taken at Fort Wrangell or in the Stikine River could not be ascertained. This specimen is now in Washington. It is a female, 15½ inches long, and weighs about 2 pounds. These are the only references to the occurrence of shad in Alaskan waters that have been met with. Commander Z. L. Tanner, U. S. N., who was for many years in command of the United States Fish Commission steamer *Albatross* during the fishery explorations of that vessel in Alaskan waters, never found the shad while making extensive collections of fish in the rivers of the Aleutian Islands.

MIGRATIONS AND MOVEMENTS OF SHAD.

The periodic movement of shad from the ocean into the fresh-water streams of the Atlantic Coast is one of its most characteristic and well-known habits. This migration begins in the early winter in Florida and involves all suitable streams as far north as the Gulf of St. Lawrence, which is reached in midsummer. The influx in each basin proceeds gradually from south to north, and the arrival in a given locality is usually about the same time each year and can be predicted with considerable accuracy. Prior to this regular advent of the schools, no shad are in the rivers, and after the completion of the spawning process, which ensues immediately on reaching the headwaters, the adults return to the salt water, and only stragglers are found during the remainder of the season or until the following year.

In the waters of California this well-marked habit of the shad has to a great extent been lost. From the figures given showing the receipts of shad in San Francisco from the Sacramento and other rivers, and from the statements made under the subject of spawning, it will be clearly seen that shad inhabit the rivers tributary to San Francisco Bay and the coastal waters of that vicinity throughout the year. It can not be stated with certainty that the same individuals remain in Sacramento

River, or San Joaquin River, or Suisun Bay during a whole year, but the fact is established that in every month and on every day it is possible to find shad in quantities in those waters.

It seems probable that the constant supply of shad in the northern tributaries of San Francisco Bay is kept up by the arrival of new bodies of fish from the salt water, which take the place of those that have spawned and gone to sea. The movement of schools in and out of the Golden Gate is well recognized.

Monterey Bay seems to be a loitering and feeding ground for shad bound to or from the Sacramento. According to the statement of the California fish commissioners in their report for 1878–79, the shad which leave the Sacramento River follow the coast to that bay, where they are supposed to find an abundance of food, for a few are taken in the fishermen's nets every week throughout the year.

As it is only during the salmon season that shad are caught in the Columbia River, very little is known of their movements and the times of their arrival and departure. They are caught from April to July, inclusive, but after the latter part of July few are taken. It is generally supposed that most of them enter the sea about that time. Mr. Alexander says that, as no person has been interested enough to study the migratory habits of the shad in the Columbia basin, nearly all the ideas advanced concerning them are speculation, but what is now known of their habits would indicate that a much larger proportion of the shad of this river enter the sea in a general body than do those inhabiting the Sacramento.

THE SPAWNING SEASON AND GROUNDS.

The change in the spawning season of the shad incident to their introduction to the waters of the Pacific Coast is one of the most interesting features connected with the results of acclimatization. On the Atlantic Coast the spawning season of the shad rarely lasts longer than five or six weeks in a given river basin, and in places is shorter during some seasons.

In California, according to the testimony of reputable dealers, shad are found with ripe spawn from December to August. Inasmuch as the ripe roe is often taken from the fish by the San Francisco dealers and sold separate, the dealers are in position to make accurate observations on this point. May, however, is the month when most of the shad in the Sacramento region are thought to undergo the spawning process. Many shad examined by the writer in May and June, 1894, contained ripe spawn, and the roe was often seen exposed for sale in the San Francisco market during those months.

The principal spawning-grounds for shad in California are in the lower parts of the Sacramento and San Joaquin rivers, in the numerous sloughs in the delta of those streams, and in the lakes of the so-called tule lands—alluvial islands in the beds of the rivers. These tule lands were at one time under splendid cultivation, but, becoming neglected, the river broke through the embankments and formed lakes of various sizes on the sites of former plantations. Some of the tule ponds are from 10 to 15 feet deep, but the average is only 5 or 6 feet. At some places near the point of communication with the sloughs or river the tule waters are very deep; one cut on Sherman Island, which was recently surveyed, was 65 feet deep within the levee. In these tule waters the shad and striped bass are found at all seasons, and are generally believed to spawn there. They are certainly well suited for spawning-grounds, the

conditions for the development of young shad being excellent; there is a large amount of vegetable growth around the shores and in the ponds, insuring an abundance of minute animal and vegetable food. The water runs out of the tule ponds less rapidly than the tide falls in the river, so that at low tide there is quite a fall at the breaks in the embankments; and, on the other hand, when the tide is coming in the tule ponds receive the water less rapidly through the narrow entrances than it rises in the river, and consequently there is a fall from the river into the ponds.

Regarding the presence of young shad in the San Francisco Bay region, Mr. Alexander remarks:

> Young shad are observed the year round, but they seem to be more numerous in the early part of the summer, when the weather is warm. They are mostly seen in and close to lagoons, sloughs, and in shallow places in the bay. Drag-seine fishermen, when fishing for bottom species, frequently catch young shad, but a person who brings them to market is guilty of a misdemeanor and subject to a fine. In consequence of this law, young shad are not exposed for sale, but are thrown away. In this manner thousands of shad fry are said to be annually destroyed.

Monterey Bay has, by some, been regarded as a spawning-ground for shad, but the waters of the bay must offer very slight inducements to shad, owing to the absence of fresh-water streams of any importance. The largest stream, the Salinas River, is shallow, short, and at times muddy, and it is doubtful if shad ever enter it; there is no record of the capture of shad at or near the entrance to the river. It therefore seems probable that Monterey Bay is a feeding and resting ground for shad that are bound for the Golden Gate, or for fish that have withdrawn from the fresh waters of the Sacramento region.

The inquiries of Mr. Alexander in the basin of the Columbia River led him to believe that the shad in that region spawn in May, June, and July. This conforms with the testimony of fishermen, dealers, and the State fish commissioners. The spawning-grounds are said to extend from the vicinity of Grays Bay to within about 40 miles of the Willamette; at least, that is where most of the fish with ripe eggs are caught, and it is naturally presumed that this is the general spawning-ground, the water and environments being supposed to be better suited to the fecundation of the eggs than elsewhere on the river. Young shad are very numerous during the whole of the salmon season and sometimes become a nuisance to trap fishermen. Small and large fish are found together and taken in all the traps in the river from Ilwaco to the Cowlitz River, more particularly in those situated off Chinook, Grays Bay, and Knappton. At times both large and small shad are abundant off Cottonwood Island, near the mouth of the Cowlitz River.

ABUNDANCE OF SHAD ON THE WEST COAST.

The present catch of shad in the Columbia River, Sacramento River, and San Francisco Bay and tributaries affords only an imperfect conception of the quantities of the fish occurring in those centers of its abundance. Dealers and fishermen say that it would be easily possible, should occasion require it, to treble or quadruple the quantity of shad now taken, by the use of proper apparatus and by carrying on the fishery with regularity and vigor.

In the Sacramento-San Joaquin delta, in the waters between the Golden Gate and the mouth of the Sacramento River, and in the lower Columbia River, shad exist in incredible numbers. It is probably safe to say that in either the Sacramento or the Columbia basin more shad could now be taken than in any other water-course in

the United States, but whether these west coast streams would long maintain such extensive fishing as is prosecuted annually in the Potomac, Delaware, and Hudson rivers is another question.

In all the streams where the shad is regularly found, each year's run shows an apparent increase over the preceding season. Under the existing conditions of the fishery, which result in the taking of only a small percentage of this fish, their further rapid increase in abundance may be expected.

In the lower courses of the Sacramento and San Joaquin rivers, in San Francisco Bay and the bays emptying into it, the shad is exceedingly numerous and appears to be increasing rapidly. Mr. Alexander states that in 1893 many fishermen and dealers in that region assured him that shad were then five times more abundant than they were three years before. During the early part of the summer of 1891 and 1892, shad were caught in such numbers and were sent to San Francisco in such quantities that thousands of pounds were thrown away weekly.

WEIGHT AND SIZE OF SHAD IN WATERS OF THE PACIFIC.

At a very early period it became evident that the waters of California were favorable to the growth of shad. It is probably a fact that the fish there attains a larger size than on the Atlantic Coast. It is also doubtless true that the average size of the fish taken for market is greater than in the East. This may in part be due to the use of nets with large meshes.

The average weight of the shad caught for market in California at the present time is over 4 pounds. The same differences in the size of the sexes which exist on the Atlantic Coast are observed in the West. On all the fishing-grounds large numbers of relatively small fish occur, which, if caught, would reduce the average, but the use of large-meshed gill nets keeps up the average, and as long as a conspicuous part of the catch continues to be taken in nets set primarily for salmon the high average will be maintained.

No shad as large as those sometimes taken in California waters have in recent years been reported from the east coast, and it is probable that no authentic record for the Atlantic rivers surpasses or even equals several verified instances of the capture of large shad on the Pacific Coast.

In 1880, Mr. W. N. Lockington recorded a shad sold that year in the San Francisco market that was 26 inches long, 9½ inches deep, and weighed 8½ pounds. Another of the same dimensions, but somewhat lighter, was sold in 1879. In 1885, some that weighed from 8 to 10 pounds were reported to be commonly taken, and of late even larger examples have been observed.

At times in recent years comparatively large consignments of shad received at San Francisco from the Sacramento region have been made up of fish whose average weight was 6 pounds or more. A large number of shad seen by the writer in San Francisco, May 24, 1894, weighed from 6 to 7 pounds. All the fish-dealers of that city report shad weighing 10, 11, and 12 pounds.

Reports of the taking of shad weighing 16 and even 18 pounds have been received, but they can not be verified. Records of the capture in the Sacramento of several specimens with a weight of 14 pounds can, however, be relied on, although such large fish must be extremely rare.

Since most of the shad taken in the Columbia River are obtained by means of traps and seines with a relatively fine mesh, the average weight of the fish caught is less

than in the Sacramento, although it is probable that there is actually little difference in the size of fish from the two streams. According to Mr. A. B. Alexander, the average weight of the shad caught in the Columbia is 2½ pounds and the average length is 15 inches, while of the fish selected from the catch to be sent to market the average weight is 3 to 4 pounds and the average length is 21 inches. The weight of the largest shad thus far recorded was 9 pounds, although examples 6, 7, or 8 pounds in weight are not especially rare.

FOOD OF SHAD.

Very little information on this topic can be given, owing to the lack of systematic study. It may be stated, however, that, as on the Atlantic Coast, the stomachs of shad taken in the rivers contain no recognizable food. Mr. F. C. Reed, of Astoria, Oreg., formerly State fish commissioner, states that during the past five years he has examined the stomachs of hundreds of Columbia River shad and has never yet found any kind of food in them. The fishermen of Monterey Bay are of the opinion that the relative abundance and scarcity of shad are determined by the absence or presence of shrimp. Mr. Lindsey, in charge of one of the fish firms, and several other fishermen reported that they always found shrimp in the stomachs of shad; in years when shrimp are plentiful there is always a corresponding increase in shad, but when shrimp are scarce few shad may be looked for.

ASSOCIATION OF SHAD WITH OTHER FISH.

In San Francisco Bay and tributaries shad associate largely with other marketable fish. They are found with salmon, herring, anchovies, smelt, and striped bass, and are caught in drag nets and gill nets employed primarily for those species. In the Columbia River shad are caught in pound nets with salmon, sturgeon, and otherfish. Drag seines take shad at the same time that salmon are caught.

SHAD FISHERY OF MONTEREY BAY.

This is the southernmost locality on the Pacific Coast where shad are regularly caught. Fishing is prosecuted at Monterey, Capitola, and Santa Cruz, but at Monterey and Santa Cruz it is of very little consequence. Shad are taken in the bay chiefly from May to July, but they are also caught in other months in small numbers. Mr. Alexander makes the following report:

> Only a few shad are taken by fishermen at Monterey. Each season, however, a few straggling individuals are caught, but the catch has never been great enough to lead the fishermen to suppose that this species will ever strike this part of Monterey Bay in paying quantities. The lack of fresh water on the south side of the bay seemingly precludes the possibility of this fishery reaching any commercial importance. So small has the catch been that no attempt has been made to manufacture nets especially adapted for the capture of shad. The fish which have been caught from time to time have been taken in the "three mesh" or trammel net while fishing for other species. The entire catch of shad for this season [1893] amounted to only 6 fish.

Capitola is the principal shad-fishing community on Monterey Bay. In 1893 there were 28 persons engaged in taking shad here; these used 7 gill nets, having a mesh of 5¾ to 6½ inches. The grounds are 1½ to 3 miles off shore. Occasional specimens have been taken in drag seines hauled along the beach. The fish have an average weight of 4 pounds and recently have yielded the fishermen about 2½ cents a pound. The principal part of the catch goes to San Francisco, a few being consumed

locally on the shores of the bay and in the adjacent towns. At Santa Cruz 15 shad fishermen used 12 gill nets. They fished on grounds 2 or 3 miles off shore. The catch in 1893 was quite small, and was sold locally at 6 cents a pound. In 1886 and 1887 shad were more numerous here than at any other time. In 1892 they were more abundant than for several years.

Of the shad fishery of Santa Cruz, Mr. Alexander remarks:

It is not much greater in importance than that of Monterey. In 1886 and 1887 shad were more plentiful than they have ever been since. The catch has gradually been falling off since 1887, and it now amounts to very little. Fishermen no longer look for shad to visit Monterey Bay in large numbers, for the catch each year indicates that the water and general surroundings of the bay are not suited to their habits. The first shad caught at Santa Cruz brought several dollars, and for a considerable time they were sold at high prices. It was common for fishermen to get from 75 cents to $1.50 a piece for them. As soon, however, as they began to make their appearance in considerable numbers in the market of San Francisco, the price immediately fell to a comparatively small figure. Fishermen persistently demanded high prices for a long time, and not a few Italians thought that they were suddenly going to amass a fortune from catching shad, but they soon found that this fishery would yield no greater profit than other branches of the industry.

The statistical inquiries of Mr. Wilcox relating to the Monterey Bay fisheries disclosed the following catch of shad in the years named, the values given representing the gross prices received by the fishermen:

Years.	Pounds.	Value.
1889	20,264	$810
1890	24,880	995
1891	30,120	1,205
1892	35,000	1,400

Regarding the future of the shad fishery of Monterey Bay, Mr. Alexander says:

If shad should greatly increase in numbers in all parts of Monterey Bay the fishermen would derive no greater benefit than from the barracuda, mackerel, etc., and in fact not so much, for the reason that the day has gone by when fishermen can expect to get large returns for these fish. Sacramento River and San Francisco Bay can supply the State with shad at nearly all seasons, which practically precludes the possibility of fishermen situated further south from gaining more than a meager share of the trade, even if shad should become numerous south of Golden Gate. If the population within a radius of 60 miles of Monterey Bay should greatly increase, the case might be different; but at the present time and under the existing circumstances, fishermen of Monterey Bay can do fully as well if not better by occupying their time fishing for other species.

SHAD FISHERY OF SAN FRANCISCO BAY AND TRIBUTARIES.

Early history.—In the remarks on the results of the introduction of shad to the Pacific Coast, reference was made to the first fish captured in California waters. The following additional notes on the early history of the fishery have been furnished by Mr. Alexander:

In a very few years after shad were planted in the Sacramento River, fishermen began to catch them in their nets. At first only a few mature specimens were caught. Frequently several months would elapse without a single fish being taken; suddenly, however, they would again put in an appearance, each time in greater numbers than before. Shad at that time were considered a great luxury, and the price was very high. The first specimens taken brought so much that fishermen who were fortunate enough to capture even three or four in a day did a lucrative business. The use of nets having less than a 7½-inch mesh being prohibited, very few small fish were caught. This was at that time a wise provision, for it gave the shad an opportunity to grow and multiply. This law, however, has never been repealed, and to-day, on account of the large-size mesh required by the statute, a great

deal of illegal fishing is being done. Little or no notice is taken of it in the case of the shad, however, for the reason shad are so numerous at most seasons that it is thought no perceptible decrease will be caused by the methods now employed.

The high price paid for shad did not long continue, for a marked increase in the catch was the result of the small fish planted from time to time by the United States Fish Commission. Most people could not afford to purchase this food-fish while high prices prevailed, and the demand came almost wholly from first-class restaurants, hotels, and wealthy families. It was not until about 1886 that the fish began to be generally consumed, at which time the price had fallen to 10 cents a pound, a few cents higher than salmon. Previous to this, comparatively few people on this coast had ever eaten shad, and considerable effort was put forth by dealers to increase the sale, the supply being greatly in excess of the demand. People in moderate circumstances not being familiar with the food value of this newly introduced fish, it was not unnatural for them to continue to buy such species as they had always been accustomed to, namely, sturgeon, salmon, herring, smelt, and rockfish. To-day shad are in large demand, but they have not taken the place of, or, in the estimation of many, rank with, the foregoing fishes.

The fishing-grounds.—The principal shad fishing-grounds in the vicinity of San Francisco are San Francisco Bay, San Pablo Bay, Suisun Bay, Karquines Strait, Sacramento River, and San Joaquin River. The comparatively few shad taken outside the Golden Gate are caught only incidentally and do not indicate any special resorts for the fish in the waters frequented by the paranzella fishermen. The hydrographic basin which finds its outlet through the Golden Gate is the most important shad ground on the west coast and is evidently admirably adapted to the growth and multiplication of that fish.

The concentration of the shad in the San Francisco Bay region seems to be due to the absence of suitable waters elsewhere on the California coast, and does not indicate any special tendency of the fish to remain in the waters where the fry were first planted. On the entire coast of California there are no streams of proper length, depth, temperature, volume, etc., to afford spawning-grounds for shad, with the exception of the Sacramento and San Joaquin rivers.

The following interesting statement of the physical relations existing between the waters of this region and the fish fauna is from the report of Mr. W. A. Wilcox, entitled "The fisheries of the Pacific Coast" (Report United States Fish Commission, 1893):

A large part of the salt-water and fresh-water fish received in San Francisco is taken in San Francisco Bay and its tributary bays and streams. This inland water area is of large extent and well adapted to the support of a large amount and variety of animal life. The quantity of fishery products annually withdrawn from these waters is enormous, but it is doubtful if the full resources are utilized or appreciated.

In a general way the dimensions of San Francisco Bay and the smaller bays connected therewith may be stated as follows: From the southern end of San Francisco Bay, bordering on Santa Clara County, to San Francisco is a distance of 25 miles, the width of the bay being from 2 to 10 miles. Between San Francisco and the entrance of San Pablo Bay the distance is 11 miles; San Pablo Bay is 10 miles long and from 8 to 10 miles wide. Karquines Strait, which connects San Pablo Bay with Suisun Bay, is 8 miles long and one-half to 1 mile wide. Suisun Bay is 16 miles long and from one-half to 6 miles wide. The total length of these connected waters is about 70 miles.

At the northern end of Suisun Bay, in Solano County, the two largest rivers in the State have their outlets. A peculiar feature of these rivers, probably not found elsewhere in the United States, is the relation existing between their respective sources and outlets. The San Joaquin takes its rise in the semitropical section of the southern part of the State, and flows northward hundreds of miles through a warm region. The Sacramento, with its headwaters among the perpetually snow-covered Sierra Nevada Mountains, flows south many hundred miles, and, through numerous passages, mingles with the San Joaquin and is lost in the tide waters of the bay. These two streams constantly carry with them a large amount of minute animal and vegetable life, much of which must find a congenial

home in San Francisco Bay, and furnish a large and varied quantity of food for the fish life of the fresh, brackish, and salt waters.

Another interesting feature of the bay is the almost uniform temperature of the water, there being only a few degrees variation at any season of the year. That the conditions are extremely favorable to the support of aquatic life is demonstrated in the rapid increase and permanent residence of the several fine food-fishes introduced from the Atlantic Coast by the Government. Some of the fishes thus acclimatized are naturally anadromous, but in San Francisco Bay, contrary to their usually migratory habits, they do not appear to have any desire to spend much if any of their existence in the ocean.

Another feature which has its influence upon the quantity of animal life present in San Francisco Bay is the absence of fishing banks or submerged chains of mountains off the coast of California adjacent to the Golden Gate. Fishing-grounds, such as are found off the coast of the Atlantic States, do not occur within many hundred miles of the California coast. It may therefore be assumed that during very stormy weather numbers of the near-shore marine fishes would seek food and shelter inside the Golden Gate, where, finding favorable conditions, many remain.

While considerable quantities of shad are taken in San Francisco Bay, that ground is much less productive than the bays and streams which enter it on the north. One of the best fishing-grounds lies between Penole Point, at the southern entrance of San Pablo Bay, and Martinez, on Karquines Strait—a distance of about 15 miles. Another good ground is at the head of Suisun Bay. The best grounds, however, are the Sacramento River below Sacramento and the San Joaquin River below Stockton, and the numerous sloughs at the delta of those streams. At times the fish are taken as far up the San Joaquin as Banta.

Mr. Alexander states:

By experience the fishermen of the Sacramento and San Joaquin rivers have learned the points where shad are most likely to be found; each locality has its best spots, and around these the nets are set. A fisherman who finds a good fishing-ground one season will seek the same place the next year. Fishermen who have discovered good grounds in various parts of the river are very careful about letting others know the spots, and will often go a long distance out of their way rather than let it be known where their favorite grounds are.

Fishermen.—The persons engaging in the shad fishery of this section are also engaged in the market or salmon fisheries, or both, shad now constituting only a small part of their catch and receiving but little special attention. They are for the most part natives of southern Europe, a large percentage being unnaturalized.

The number of fishermen taking shad varies greatly from time to time. Some months there may be several hundred in whose nets shad are caught in noticeable numbers, but those who set nets especially for shad probably do not number more than 100. In 1893 there were 90 persons who might be called regular shad fisherman; these belonged at San Francisco and at the various fishing stations between that place and the lower courses of the Sacramento and San Joaquin rivers.

The apparatus and methods.—In the San Francisco Bay region shad are now taken in salmon gill nets, in trammel or three-mesh nets, and in shad gill nets. No pound nets or traps, such as are so extensively employed on the Atlantic Coast for shad, are used in these waters; a few fish are incidentally obtained in drag seines.

The trammel nets are employed chiefly in San Francisco Bay and, in addition to shad, take rockfish, flounders, perch, and other species. This form of apparatus is very popular with the foreign fisherman, and is usually fished in conjunction with special shad gill nets. Each boat fishing regularly carries from 4 to 6 trammel nets, with an average value of $20 each. The two outer nets composing the trammel have a mesh of 14 or 16 inches; the inner piece is provided with a $5\frac{1}{2}$ or $5\frac{3}{4}$ inch mesh.

The special shad gill nets are 60 to 70 fathoms in length and 2 to 3 fathoms deep. They have a mesh of 5½ to 6 inches. During 1893 1,500 pounds of shad netting were received from eastern manufacturers by the San Francisco Bay fishermen. About 225 pounds consisted of cotton twine worth 75 cents a pound, and the remainder linen twine worth $1.30 a pound. The nets are hung by the fishermen. The average value of the cotton nets is $25 or $30; that of the linen nets $35 to $40.

Mr. Alexander's account of the method of setting gill and trammel nets for shad is as follows:

> Several nets are generally set together. Each boat carries 3 shad nets and 4 to 6 trammel nets. The boat is made fast to one end of the string and together they drift with the current, care being taken to evade all places where snags are known to be. Two men go in a boat; in setting the string, one man throws the nets out and the other keeps the boat in position with the oars. The nets are generally set across the stream or tide, but in a short time they will swing around in the direction of the current. After drifting a certain time, or when it is known that fish are in the nets, they are hauled. In most cases one man does the hauling. As the nets come in the fish are picked out, the nets being so stowed that they may be thrown out again without additional handling. As soon as a day's fishing is over or a good catch secured, sail is made and the fish are taken to the nearest railroad or steamboat landing and prepared for shipment to San Francisco.

While a great many shad are in the aggregate secured in salmon nets, their number is small compared with those obtained with shad and trammel nets. The size of the mesh of the salmon gill net (7 inches) ordinarily permits all but very large shad to pass through. Fish of small and medium size, however, are frequently caught, especially when the nets become tangled or doubled. Formerly a large part of the shad supply was obtained in this way, but the low prices now received lead fisherman in search of salmon to often throw away the shad that may be caught.

The boats used in the shad fishery are the felucca and the ordinary salmon skiff. The former is employed in San Francisco, Suisun, and San Pablo bays, the latter in the two last-named bays and in the rivers. At times in 1893 there were over 100 boats employed in taking shad in San Francisco Bay and tributaries, principally in apparatus set for other fish. The boats from which nets were set for the purpose of catching shad numbered about 40.

According to Mr. Alexander, more shad are caught in muddy water than in clear water. In parts of San Francisco Bay, where the water is comparatively clear, a net will take but few shad in a day, even when the fish are plentiful; in such places most of the catch is made at night, but in the rivers and in bays near the mouths of streams, where the water is thick, fishing may be done at any time. The best time for shad fishing is at the "slack tide." The fishermen endeavor to have their nets down then. The last of the ebb tide and the first of the flood tide are also considered good periods in the San Francisco Bay region.

Prices of shad.—The fish all leave the hands of the fishermen in a round condition. The price received varies much with the season, the day of the week, and the quantity of other fish in the market. At times each year shad will yield the fishermen 6 to 8 cents a pound, but this price seldom lasts more than a few days. The average in 1893 and 1894 was about 2 cents a pound; often, however, the fishermen could get only 5 cents for a full-grown shad, and it was not rare for a box of shad holding 80 pounds to bring only $1.

The average price of shad in recent years has steadily declined; it was about 5 cents a pound in 1889, 4 cents in 1890 and 1891, 2¾ cents in 1892, while in 1893 and 1894 it reached a figure below which it will probably not fall, as many fishermen will

cease to catch the fish if the value declines further, and the diminished output will maintain the price.

The place where shad are taken has no influence on the price. Fish from Monterey Bay, San Francisco Bay, and the Sacramento all command the same price, as no differences in the condition or food value are attributed to fish from different waters.

A feature of the shad fishery which is noteworthy to a person familiar with the conditions on the Atlantic Coast is that fish with ripe roe command no higher prices than others, although the roe is considered a delicacy and is quite extensively eaten.

SHAD FISHERY OF THE COLUMBIA RIVER.

The first year for which complete data are available showing the amount of the shad catch of the Columbia River is 1888. Mr. Wilcox made a canvass of the fisheries of the Pacific States covering that year and reported a total catch of 10,000 pounds in the river. These yielded the fishermen $500. He reports that about 1888 the first noticeable catch of shad was taken in the pound nets of Baker Bay, near the mouth of the river. The following year quite an increase was noticed, the nets often having half a dozen at a lift. This was not enough for the fishermen to waste any time over, and the few taken were either given away to anyone wishing to sample the new fish, or were returned to the water. A few found their way to the city market at Portland and quickly found sale, 10 cents per pound being paid the fishermen. The fish slowly worked their way up the river, the haul seines about 80 miles up taking some 200 pounds in 1889.

In 1892, when Mr. Wilcox again visited this region, he found that the shad had as yet received very little attention, and were taken only in seines and pound nets set for salmon. The special features of interest in connection with the shad were the much larger incidental catch, the increase in the average size, and the decrease in market value during the years intervening between the two inquiries. The quantity and value of those taken and sold during 1889, 1890, 1891, and 1892 were ascertained to be as follows, the catch shown being taken at or near the mouth of the river in Clatsop County, Oreg., and Pacific and Wahkiakum counties, Wash.:

Years.	Pound nets.		Seines.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1889	49,800	$4,979	200	$20	50,000	$4,999
1890	84,420	6,753	610	50	85,030	6,803
1891	116,388	6,983	13,000	780	129,388	7,763
1892	174,250	5,228	37,000	1,170	211,250	6,398

Mr. S. H. Greene, of Portland, Oreg., in May, 1893, communicated the following information on the shad of the Columbia River:

Regarding the results which have attended the introduction of the eastern shad in the waters of this coast, permit me to say that the cannerymen, marketmen, and fishermen all agree that so far as the shad of the Columbia are concerned, they are prospering beyond the most sanguine expectations. Six years ago this summer a shad was taken in one of the traps at the mouth of the river that weighed a fraction over 6 pounds. It was thought to be a wanderer from the California coast, but quite a number were taken that season weighing 2 pounds or so. At that time the fishermen and shippers at the mouth of the river got 16⅔ cents a pound (gross) by sending them to the Portland market, the marketmen paying freight, as they were considered quite a curiosity. Now you can buy dressed shad in most of the markets at 4 cents a pound. This fact is indicative of the prosperous condition of the shad. Last season some of our marketmen found it necessary to salt their surplus. One Portland

firm salted about 2 tons. Shad are taken either in the fish traps or drag nets. The gill-netters do not get them. The shad run 5 or 6 pounds in weight, but the greater majority are of about 2½ or 3 pounds weight. Frank M. Warren & Co. have canneries at Cathlamet, Wash., and at The Cascades, Oregon. Mr. Warren informs me that the shad are very numerous at both places. At The Cascades of the Columbia the fish wheels take great numbers of very fine shad, and all information at hand indicates that the shad of the Columbia are in a very prosperous condition.

Mr. A. B. Alexander, who in 1893 was detailed to make inquiries regarding the shad in the Columbia River, reported as follows on the shad fishery:

The shad fishery of the Columbia has little or no history, for as yet it can hardly be called an industry. All shad brought to market are taken incidentally. They are caught by thousands in traps and turned away, there being very little demand for them. The total amount sold at all points on the river in 1893, as near as can be estimated, was 85,000 pounds. This does not include the amount given away by fishermen. It is very probable that nearly as many of these fish are given away as sold. A fisherman who brings in a hundred or more shad disposes of what he can; the rest being left on his hands, he either gives them away or throws them overboard. I am told that it often happens that a large portion of the catch is disposed of in the last-mentioned manner. Nobody buys shad at the small towns on the river, for all desired can be obtained from fishermen by merely asking for them.

Nearly all shad of the Columbia are taken in traps or drag seines, principally by the former method; a few are also caught in salmon gill nets, but the number is so small that it is hardly worth mentioning. Occasionally a shad weighing 8 or 10 pounds is caught in a large-mesh chinook gill net, but the majority of those taken in this manner are caught in nets set for the blueback and other small salmon.

Fishermen make no regular business of sending shad to market; it is only when it is thought that the last supply is sold that another shipment is made. The dealers never send orders to fishermen, as at nearly all times the shipments they voluntarily make are amply sufficient to supply the demand. A large portion of shad is taken in traps, and it is a very easy matter for a fisherman to bail out one or two thousand pounds, or as many more as are wanted, take them to the nearest steamboat landing, and send them to Portland. If he gets a fair return, he is encouraged to repeat the experiment. It sometimes happens that a good day's work is made with little or no exertion; at other times word comes back that the fish have only brought enough to pay freight charges. This, of course, is discouraging, and he has little desire to make further shipments until he is quite sure that some returns will be made to him.

No such fabulous prices have been paid for shad on the Columbia River as have been received at different times in the market of San Francisco and elsewhere in the State. The early run of shad sells for 12 and 15 cents a pound; as soon as they commence to appear in any considerable number the price immediately falls until it reaches 5 or 6 cents, which is the average price. The fishermen are paid for early shad 4 and 5 cents a pound; this price does not last long, for it falls in proportion to the number taken, and very soon 1½ and 2 cents are all that can be realized. Frequently fishermen can not get even a cent a pound; when shad reach this figure few are brought to market. The demand for shad is as yet too small to hold forth any inducements to fishermen to engage in the industry. Owing to the limited demand, the price from year to year undergoes little change. The fish shipped from San Francisco are sold at from 4 to 5 cents more a pound than those caught in the Columbia; not because they are superior, but on account of the time of year they are shipped.

Portland is the only market of importance on the river, and during the season of 1893 handled 70,000 pounds of shad; of this amount 17,500 pounds were shipped from San Francisco. About 15,000 pounds were sold at Kalama and 1,500 pounds were consumed in Astoria. At Kalama one firm has paid some attention to shipping shad to neighboring States and Territories; in 1893, 10,000 pounds were shipped from this place. All the shad consumed in Oregon and Washington during the winter and early spring months come from San Francisco. The retail value of shad shipped from San Francisco is 10 cents a pound; average value of those caught in the Columbia, 5 cents. There is no regular demand for shad from any locality, and in consequence dealers buy only a limited amount at a time. Montana, Nevada, and Utah are as far east as Portland dealers ship shad. Occasional shipments are made to cities and towns on Puget Sound, but the amount which goes north is small. It is evident that the reason why shad are not more in demand in interior towns and cities is on account of their not reaching the consumers in good condition. While the fish may, and probably do leave

the market securely packed and iced, long before they reach their destination they are in need of more ice, and when a box of shad lies 24 hours or more, even under cover, with no ice on it, the contents are sure to be in poor condition.

Smoked and salt shad are not in demand, perhaps for the reason that few people here have ever eaten them cured in such a manner. It is very probable that if some individual should try the experiment of salting and smoking them he would be rewarded for his trouble, for the people of this locality eat more salt and smoked fish than elsewhere on the Pacific Coast. In all the markets and most of the grocery stores salt mackerel, cod, smoked herring, eels, and haddock are for sale. That there is considerable demand for these fish is plainly indicated by the quality kept, which is of the best.

That there is wanton destruction of both young and adult shad on the Columbia River is acknowledged by dealers, cannerymen, and fishermen. Large numbers of shad are dumped out of seines and left to die. This destruction goes on day after day during the spring and summer months, and, from what can be learned, a much greater number of fish rot on the beaches than are saved. Many shad are also annually destroyed in traps, or rather by trap fishermen. This is due to the manner in which the fish are taken out of the traps, little or no care being used to put them back into the water alive; they are so roughly handled that a great many of them die. No notice is taken of this unnecessary killing of shad, for the reason that they have no great commercial value.

The condition of the shad fishery of the Columbia River in 1894, when it was made the subject of inquiry by the writer, did not present any specially prominent features not referred to by the other observers quoted. The abundance of the fish has continued to increase, as demonstrated by its more frequent capture in the salmon nets, but the local demand has improved but little. The relatively small quantities saved for market, as compared with the possible catch, are sent mostly to Portland, where they are regularly exposed for sale and are always found on the bills of fare of the best hotels and restaurants.

The ruling retail price of shad in Portland in 1894 was 10 cents a pound. The fishermen receive about 4 cents a pound, net, but the sales at that price are limited, and the value falls too low for profit if the supply is increased even comparatively little. At Wallace Island, near Eureka, Wash., during the early part of the salmon season of 1894, 400 or 500 pounds of shad were caught daily in a salmon seine; some attempt was made to utilize these fish by shipping them to Portland dealers, but the price dropped so low (2 cents a pound) that the fishermen could not make the venture pay.

The Columbia River shad are of excellent quality, and during the time of their greatest abundance, April 15 to July 15, one would expect a large consumption in Portland and the other cities and towns adjacent to the river, but the abundance, cheapness, and popularity of salmon, together with the general unfamiliarity of the people with the edible qualities of the fish, make it probable that a number of years will elapse before a special shad fishery on the Columbia River will have local support.

The following additional references to the economic value of the shad in the Columbia River in 1890, 1891, and 1892, respectively, are extracted from the reports of Mr. James Crawford, fish commissioner of Washington, for the years named:

There has been no regular fishing for this fish, which, in the opinion of many, is the finest fish we have. What have been caught have been taken in pound nets set to catch salmon. Still there have been 50,000 pounds of shad taken in Baker Bay during the past season, netting the fishermen 5 cents per pound. Catching of shad promises to be, in the near future, one of the most valuable industries of the Columbia. Young shad have been seen this season in both Gray's Harbor and Shoalwater Bay.—(Report 1890.)

In my last report I mentioned the wonderful increase of this fish in the waters of the Columbia River, and this season the number coming into the Columbia to spawn was much larger than ever

before known. Shad weighing as much as 9 pounds have been frequently taken, and although there has been no special effort made to catch them, and what have been taken were caught in pound nets set for salmon, 50,000 pounds is a safe estimate of the catch of 1891. This amount has been disposed of in the markets of Portland, Astoria, and the cities of Puget Sound. Five cents per pound was received for the fish, making the value of catch $2,500.—(Report 1891.)

This desirable table fish continues to increase in number and size in the waters of the Columbia River, and, although no effort has been made to take them, enough have been caught to net the owners of pound nets, traps, and set nets about $2,000. They have been taken as far up the river as the Cascades, about 150 miles. The shad is not a native of the Pacific Ocean, but was first introduced by the United States Commission of Fish and Fisheries into the Sacramento; later some were placed in the Columbia River. From this beginning they have increased until they are considered a staple article among the fish-dealers. Their flavor and size will compare favorably with the shad of the Hudson River.—(Report 1892.)

STATISTICS OF THE SHAD CATCH OF THE PACIFIC COAST.

Figures are available to show the quantities of shad taken and sold in the Pacific States in each of the years 1888 to 1892, inclusive. These statistics are based on the field inquiries of Mr. W. A. Wilcox, agent of the Commission, and represent the results of the examination of records of fishermen, dealers, and transportation companies. In each State the yield shows a large annual increase since 1888, although the value of the fish to the fishermen was less in 1892 than in the previous year, when the output was over 20 per cent smaller. The yearly decrease in the average price per pound received by the fishermen illustrated by the table herewith presented (until in 1892 the average gross price was under 3 cents) suggests a reason for the diminished output in the subsequent years, which is disclosed by incomplete statistics gathered in San Francisco and elsewhere.

Summary of the quantities and values of shad sold by fishermen of the Pacific States from 1888 to 1892.

Years.	California.		Oregon.		Washington.		Total.	
	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.
1888	90,871	$6,513	10,000	$500	200	$50	101,071	$7,063
1889	263,788	10,833	29,990	2,999	21,010	2,055	314,788	15,887
1890	318,140	11,891	50,100	4,008	36,092	2,860	404,332	18,759
1891	445,006	15,856	70,500	4,230	59,900	3,590	575,406	23,676
1892	526,494	14,372	109,000	3,270	103,350	3,183	738,844	20,825

PRICES OF SHAD ON THE WEST COAST.

The first shad taken on the Pacific Coast were regarded chiefly as curiosities and brought extraordinary prices, and even after the supply became comparatively regular the market value of the fish continued very high for some years.

Mr. J. H. Kessing, who has been in the fish business in San Francisco for forty years, states that when shad were first caught in California they were in great demand and he sold them at wholesale at $10 to $15 each; many brought $1 to $1.50 per pound. These prices are confirmed in the early reports of the California fish commission. By 1880 the abundance of shad had reduced the market price to the consumer to 20 to 25 cents a pound. In 1887 and 1888 the average price was about 10 cents a pound, while at the height of the season it was sometimes as low as 5 cents. In 1889 the average retail market value of shad was 5 cents a pound; in 1890 it dropped to 4 cents; in 1891 it was 3 cents; in 1892 it was not over 2¾ cents; in 1893 and 1894 it was 2 cents or less. During the years 1893 and 1894 the prices often fell to one-half or 1 cent a pound, and thousands of fish could not be disposed of at any price. To protect themselves against

losses arising from too great a stock, the dealers were obliged to restrict their receipts. Of course, at the figures last quoted the fishermen who sell on commission get no returns.

In the Columbia River the prices for shad have never been as high as in California, although they have at times ruled almost as low. About 1887, when the fish first began to be numerous, the salmon fishermen and shippers of the lower river received about 16 cents a pound (gross price) by sending their shad to Portland. In 1893 and 1894 the general retail price in Portland was 10 cents a pound, the fishermen receiving about 4 cents a pound, net. It is only by placing a limit on the supply that these prices are maintained. Fishermen who have endeavored to utilize the shad incidentally taken in their salmon nets have, as a rule, received such low prices that no inducement was offered to continue the shipments. At times in the past three years only 2 cents a pound could be realized by the fishermen on fish sent to market, a price entirely too low to pay for time and expense.

FOOD QUALITIES OF THE SHAD.

Notwithstanding the great abundance of the shad in the vicinity of the principal seaboard cities and towns of the Pacific States, a large proportion of the people of the west coast are totally unfamiliar with the food value of the fish, and it is eaten by only a comparatively small part of the population. While the price of the shad is such that it is within the reach of everyone, the supply of other fish that have been long in popular favor is also sufficiently abundant to keep the prices relatively low. As salmon, the prime favorite of the public, is most plentiful and lowest priced at the time when the shad is found in the markets in greatest numbers, the latter meets with only a limited demand.

With the exceptions of some complaints about the bones, no one speaks in disparaging terms of the edible qualities of the shad; and if it did not have to compete with an almost unlimited supply of salmon, herring, smelt, anchovies, flounders, rockfish, and other species for which there is a strong local sentiment, there is no doubt it would occupy the very front rank in popular estimation among the fishes of the coast.

One potent reason why the shad has not advanced farther in popular esteem is the poor condition in which it reached the consumer, about the time when its remarkable abundance first brought it into notice. The lack of care in the preservation of fish which has characterized the fishing industry of the west coast naturally led to the early deterioration of so delicate a fish as the shad, and people who ate the fish a number of years ago acquired a distaste for it, which has continued. It is gratifying to note that in the past few years there has been a radical change in the state of preservation in which the shad reaches the consumer, owing to the plan of the San Francisco dealers to restrict the receipts and to purchase, as far as possible, only the quantities that they can probably dispose of before the fish become tainted, one day's catch supplying the next day's trade.

Of the opinion held regarding the edible qualities of the shad in the Columbia River region, Mr. Alexander says that the dealers consider the shad a very palatable and valuable fish, and greatly regret that the demand for it does not increase. People have so long been accustomed to eating salmon and smelts that they have formed a prejudice against all other fish. The fishermen all say that shad are excellent, and they fail to see why there should be so little call for them.

THE SHAD TRADE OF SAN FRANCISCO.

San Francisco is the principal shad market of the Pacific States, as it is for all other fishery products intended for immediate consumption. All the fish-dealers who purchase their supplies directly from the fishermen handle shad, and the amount of their trade in this product constitutes a reliable basis for estimating the extent of the shad fishery in California. The San Francisco dealers get their shad from San Francisco, San Pablo, and Suisun bays, Sacramento and San Joaquin rivers, and Monterey Bay.

In 1894 the writer made a thorough examination of the records of the San Francisco dealers, and noted the quantities of shad handled by them in the preceding year and in 1894 up to June. For the remaining months of 1894 the California fish commission, through Mr. John P. Babcock, the chief deputy, obtained similar data and courteously supplied them to the United States Commission of Fish and Fisheries. Mr. Babcock also procured some information for 1893 from several firms. The figures thus acquired permit the presentation of a table, showing for each month in 1893 and 1894 the actual quantities of shad received in San Francisco.

The aggregate receipts in 1893 were 429,136 pounds and in 1894 were 270,807 pounds, these amounts being the round or gross weights of the shad.

There is not a day in the entire year when shad may not be found in the San Francisco markets, and during nine months it is one of the commonest and cheapest fish exposed for sale in that city. During July, August, and September, when the salmon fishing is at a low ebb or totally suspended, the supply of shad is much less than at other times.

In 1893 the largest receipts were in May and November; in 1894 in January and May. The average monthly receipts in the former year were 35,761 pounds and in the latter 22,567 pounds. During the three months ending December 31, 1893, more shad were handled than in any previous period of similar length; in that time 227,874 pounds were received, an average of over 75,000 pounds per month. A detailed summary of the monthly receipts is given in the following table:

Statement by months of the number of pounds of shad handled by San Francisco dealers in 1893 and 1894.

Months.	1893.	1894.
January	6,588	41,266
February	19,185	11,767
March	19,546	17,747
April	32,389	39,115
May	80,557	57,823
June	36,184	22,027
July	3,319	7,941
August	2,796	2,029
September	698	475
October	53,652	24,229
November	96,340	38,110
December	77,882	8,278
Total	429,136	270,807

A condition of the San Francisco shad market, by no means rare, is thus referred to by Mr. Babcock, in a letter dated May 9, 1895:

The run of prime shad is on again. The markets all show fine fish this morning, and I made a canvass of them all for retail figures. Chinatown dealers offered me 6, 7, and 8 pound shad for 10 and

15 cents each; all were in good condition and fresh. The Clay-street marketmen asked only 2 cents a pound retail for dressed fish, and said they had sold but few. The Pioneer Fish Company said they had not sold 1 pound at retail this morning, and that they would have to dump their fish this afternoon; wholesale price, 1 cent a pound. In the California market, Leon was offering to deliver fish at your house for 5 cents a pound, and would sell fish over the counter for 10 cents apiece.

The receipts of shad in San Francisco could be greatly increased if the dealers did not discourage their shipment by the fishermen, owing to the very low prices which prevail when the supply is large. All the firms dealing extensively in shad are obliged to restrict the receipts in order to protect themselves and their fishermen from loss. Shad have at times been thrown away because of the impossibility of selling them, or sold at ridiculously low prices. Thus, in October, November, and December, 1893, when the preceding table shows large receipts, the prices were sometimes hardly sufficient to cover the transportation charges. A shipment of 1,500 pounds of fine shad, sent in by a Sacramento River fisherman in the third week of November, brought only $1.50, and about the same time another lot of 795 pounds sold for only $1.

At the present time, fewer shad are probably handled in San Francisco than in 1890, 1891, 1892, or 1893. The supply of salmon in that city determines the quantity and price of the shad sold. Owing to increased shipments of Puget Sound salmon to San Francisco of late, the market has been partly closed to shad; these salmon are cheap fish, which the San Francisco dealers are able to buy at 1 to 1½ cents a pound. When salmon are scarce, shad and other cheap fish are in demand.

The action of the dealers in curtailing the receipts of shad in the past two years has resulted in fewer gluts, and conditions have been altogether more satisfactory than formerly. At the present time, when the dealers desire a consignment of shad, they have only to telegraph or telephone to one of their agents on the fishing-grounds and the required quantity will be on hand the next morning. By this method the fish reach the consumer in a much better condition than where the receipts are unrestricted and the fish are held over from day to day.

Practically the entire quantity of shad handled by San Francisco dealers is sold and eaten fresh. The Chinese prepare small quantities of salt shad; the fish they utilize this way have often been on the dealers' stands for several days and can be obtained very cheaply. The fish are lightly pickled for one or two days and are then hung up to dry on the roofs of their houses. Although there are several smokehouses in San Francisco, no shad are smoked. The experiment of thus treating shad has been tried and abandoned, owing to the little demand for them prepared in this way; there is, however, some sale for smoked salmon and sturgeon.

Mr. Thompson, of Oakland, who has been engaged in the smoked-fish business for a number of years, has given more attention to smoked shad than anyone else on the west coast. In 1893 he is reported to have smoked between 11,000 and 12,000 pounds of shad, which had a retail value of $1,440, or about 12 cents a pound.

Mr. Alexander reports that about half the shad which go to San Francisco dealers are reshipped out of the city to various parts of the State. Some shipments are made to Salt Lake City, Denver, and points in Mexico. The fish are cleaned, iced, and packed in boxes holding 100 to 200 pounds. When shad are to be sent very long distances, or to a warm climate, one box is placed within another. Fish prepared for distant shipment are split down the belly and packed with ice, but those intended for local consumption are split down the back.

THE WHITEFISH.

In 1872 and 1873 Professor Baird, the United States Fish Commissioner, sent to the California fish commission from Lake Superior 50,000 eggs of the common whitefish (*Coregonus clupeiformis*) in two lots; many of these perished during transportation. The survivors (25,000 in number) were hatched in an extemporized structure on Clear Lake, in which the young were placed. Clear Lake is a large body of water in Lake county, in the Coast Range, about 80 miles northwest of Sacramento, and was selected for this purpose by the California authorities because of the supposed advantages it afforded, it containing few other fish, having a suitable temperature and other physical conditions, and being so placed that it could be readily seined.

In 1875 the United States Fish Commission sent 20,000 whitefish eggs from Lake Michigan; these were successfully hatched at Berkeley and deposited in Tulare Lake on March 29, 1875. This lake, the largest in the State, was thought by the California commissioners to have the requisite temperature, food supply, etc., for the whitefish, and the introduction of that species was much desired by the people living near the lake.

Larger plants were made in various parts of the State in 1877 and 1879, the eggs being furnished by the national fish commission. In 1877, 75,000 fry were put in Donner Lake, in Nevada County; 50,000 in Sereno and other lakes, in Placer County, and 175,000 in Lake Tahoe, in the extreme eastern part of the State, partly in Nevada. In 1879, fry were planted as follows: 70,000 in Lake Tahoe; 70,000 in Donner Lake; 60,000 in lakes in Nevada County; 225,000 in Eagle Lake, in Lassen County; 100,000 in Tulare Lake; 10,000 in Mark West Creek, in Sonoma County; 10,000 in San Jose Water Company's reservoir, in Santa Clara County; and 20,000 in Chabot Lake, in Alameda County.

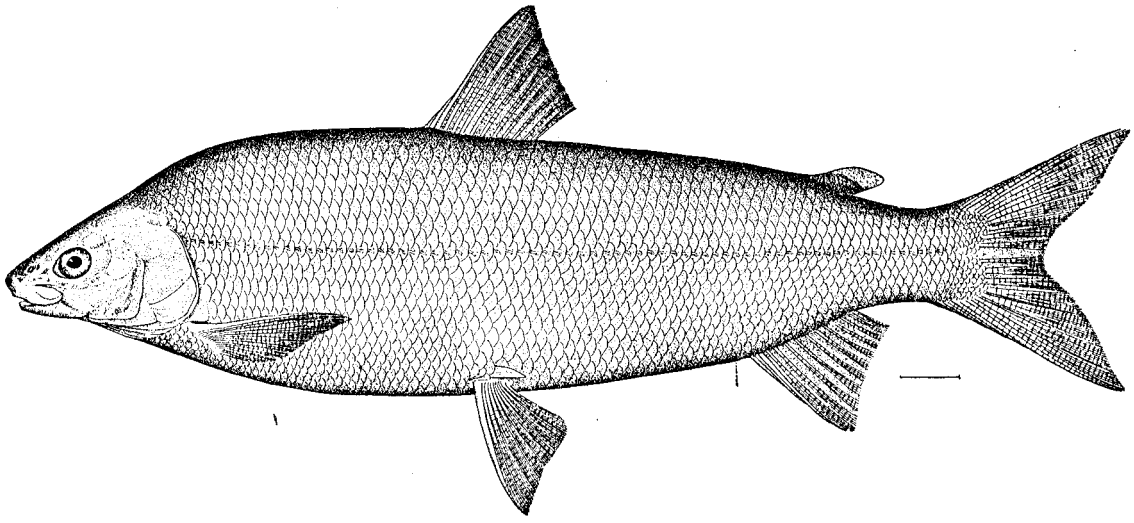
In January, 1883, the United States Fish Commission delivered 500,000 eggs at the hatchery of the California commission at San Leandro. No record of the results of this consignment has been met with.

Whitefish fry were introduced into a number of Oregon lakes in January and February, 1889, by the United States Fish Commission. The largest deposit, numbering 400,000, was made in Klamath Lake, near Linkville, at the southern end of the lake. About 100,000 fry were placed in Kullaby Lake, near Astoria; 75,000 in Chetaw Lake, in Wasco County; and 10,000 in Laddis Lake, in Multnomah County.

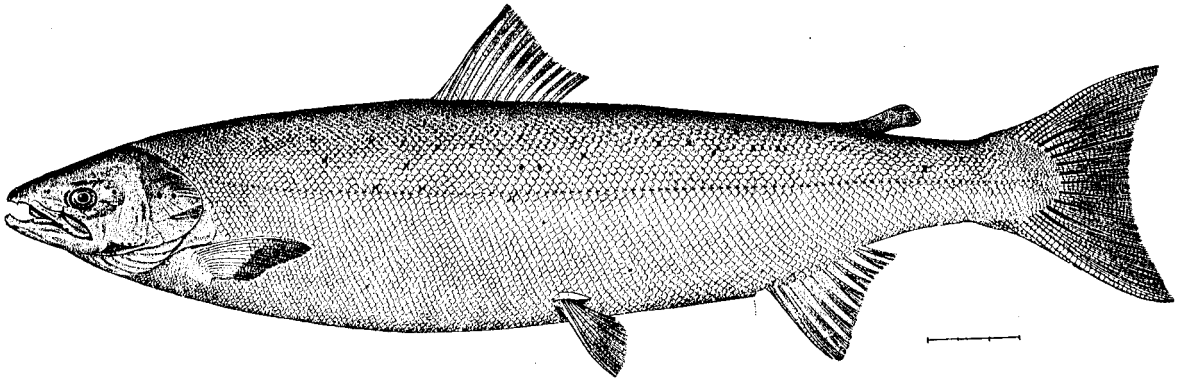
The plants of whitefish in Washington have consisted of 375,000 fry placed in Washington Lake at Seattle; 300,000 in Lacamas Lake, in Clarke County; and 10,000 in Silver Lake, at Castle Rock. These deposits were made by the United States Fish Commission in February, 1889.

In Cœur d'Alene Lake and Pend d'Oreille Lake, in Idaho, in the basin of the upper Columbia River, very large deposits of fry were made by the United States Fish Commission in February, 1889. In the former lake 1,930,000, and in the latter 1,300,000, young whitefish were planted. Hayden Lake, a small body of water north of Lake Cœur d'Alene, received 20,000 fry at the same time.

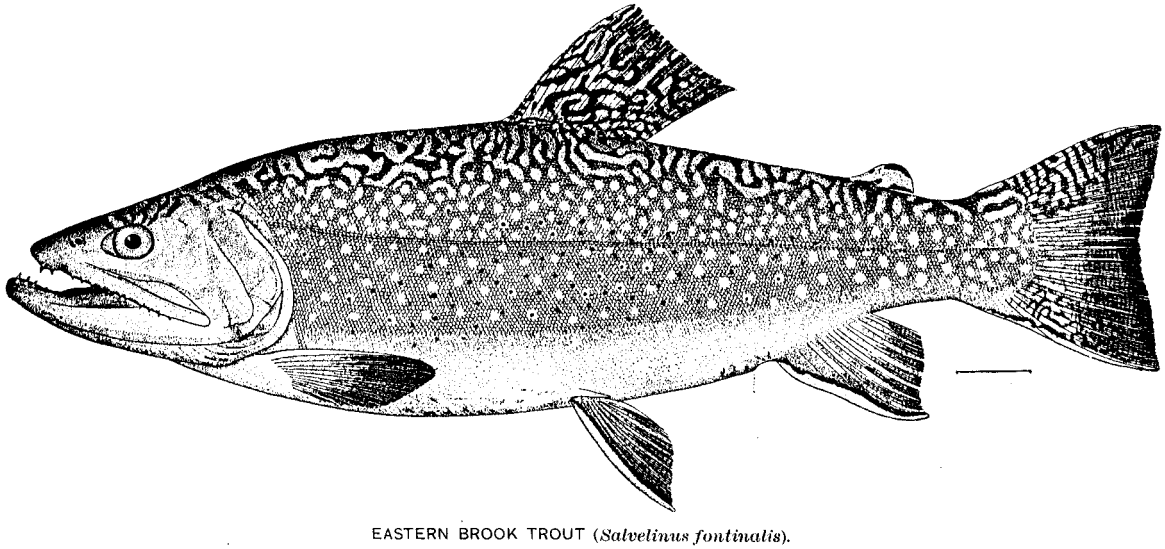
The results attending the introduction of whitefish into California waters have been extremely meager, if not altogether negative. While it is possible that the fish have in certain waters been overlooked, owing to the nonprosecution of commercial fisheries and the absence of scientific investigation, it is known that they have not attained economic importance anywhere in the State and have never been taken, in recent years, in some of the waters in which they were planted.



WHITEFISH (*Coregonus clupeiformis*).



ATLANTIC SALMON (*Salmo salar*).



EASTERN BROOK TROUT (*Salvelinus fontinalis*).

The reports of the California fish commission for the years following the first whitefish plants contained several references to the taking of large fish. The report for 1875–76 stated that several mature whitefish had been caught in Clear Lake in the winter of 1875, and in the report for 1876–77 the commissioners say of this fish:

> We believe they have lived in Clear Lake, also in Tulare. It is reported in a Lake County paper that a whitefish was taken in Clear Lake April 10, 1876, which measured a foot in length. We have no positive information that they have found a congenial home in Tulare Lake, but have heard reports that a few have been seen.

In the commissioners' report for 1878–79 it is stated that the fish had thrived and that reports of the capture of a few mature fish in Tahoe, Tulare, and Clear lakes had been received. The report for 1883–84, however, casts considerable doubt on the supposed taking of eastern whitefish in California waters. The commissioners say:

> The results accruing from the planting of this kind of fish in our waters are not fully known to the commissioners, and * * * we have no reliable data as to whether they are a success or not. There are native whitefish that are caught in lakes Bigler and Donner, which have been taken for those planted by the former commissioners. * * * There has been no showing of the eastern whitefish so far. * * * Up to August 30 (1884) not one has been taken, so far as the commissioners have any knowledge.

In the report of the California fish commission for 1893–94, which contains a review of the outcome of the introduction of non-indigenous fish, no results are said to have attended the planting of whitefish. The inquiries of the United States Fish Commission have not disclosed the existence of any eastern whitefish in California waters. In a recent report* on the fishes of Clear Lake, no species of whitefish is reported.

Mr. F. C. Reed, of Astoria, has often made inquiries about the whitefish planted in the lake in that vicinity, but has learned nothing. The fishermen have no means of catching them if the fish are really there, and would hardly know them if caught.

In Washington and Idaho a number of reports of the taking of whitefish have been received, but the possibility of mistaking the native whitefish (*Coregonus williamsoni*) for the introduced species is so great that it would require actual specimens in order to settle the question in a given locality. The fact that most if not all of the supposed eastern whitefish have been caught with a hook casts considerable doubt on the correctness of the identification. The native whitefish, which is widely distributed in the Pacific States, readily takes the hook, but the common eastern species very rarely bites at a baited hook. The average weight of the native whitefish is under 1 pound and the maximum is about 4 pounds. The eastern whitefish sometimes attains a weight of over 20 pounds, and fish weighing 10 pounds are common, although the weight is usually only 3 to 5 pounds.

Hon. George T. Myers, of Portland, has kindly interested himself and others in ascertaining the results of planting whitefish in Washington and has forwarded several communications on the subject. Mr. Myers mentions the reported capture in recent years of a number of whitefish with hook and line in lakes Washington, Sammish, and other waters where the eastern fish was planted, and states that a fisherman formerly living on lakes Michigan and Superior says that he has caught some of the fish which were identical with those he had previously taken in the Great Lakes.

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* List of Fishes inhabiting Clear Lake, California. By David S. Jordan and Charles H. Gilbert. Bull. U. S. Fish Com. 1894, pp. 139–140.

Mr. James Crawford, fish commissioner of Washington, writes as follows:

I have yet to hear of any whitefish being caught in any of the waters of the State. I have heard of some strange fish having been seen in the waters of Lake Washington, but no one knew what they were. Some whitefish were planted in Lake Lacamas in this (Clarke) county, but, although I have made repeated inquiries about them, I could never hear of any having been seen. It may be that because whitefish do not take a hook they have never been caught.

Inquiries by Mr. William Barnum in Idaho in 1895 elicited the information from several sources that eastern whitefish had been taken in lakes Pend d'Oreille and Cœur d'Alene, but the evidence is that the fish in question were of some other species. A specimen of supposed eastern whitefish obtained at Cœur d'Alene City, from the lake of that name, proved to be Williamson's whitefish.

The large, cold, deep lakes of Idaho, in which plants were made, are apparently as well adapted to the growth and multiplication of the whitefish as Lake Superior. While there may be an abundance of mature whitefish in those waters, their existence might be entirely overlooked in the absence of deep-water gill-net fishing and special scientific investigation. The inquiries of the Fish Commission representatives in 1894 and 1895 failed to throw any light on the presence or absence of the eastern whitefish in lakes Cœur d'Alene and Pend d'Oreille.

THE ATLANTIC SALMON.

The attempt to acclimatize this valuable food and game fish on the Pacific Slope was made in 1874, when the "aquarium car," in charge of Mr. Livingston Stone, of the United States Fish Commission, carried numerous species of eastern fish across the continent.* Four hundred and fifty small Atlantic salmon (*Salmo salar*) obtained in the Penobscot River, Maine, were among the consignments; of these, 305 survived and were deposited, June 12, 1874, in the Sacramento River at Redding.

In 1890, 200,000 eggs were consigned to the Fish Commission station at Fort Gaston, Cal. Of these, 194,000 were successfully hatched, and in May, 1891, the young were placed in a pond. Capt. W. E. Dougherty, the superintendent, reports that they were fed until about the last of July, when, having attained a very considerable size, they were liberated in the Trinity River.

The deposit of young fish placed in the Sacramento River in 1874 has yielded no known results. The fish undoubtedly succumbed to physical causes or were devoured by enemies, the planting being entirely too small to warrant the expectation of success. The only reference to the matter subsequent to the planting is contained in the report of the California fish commission for 1874–75:

None of the eastern salmon have been seen since they were placed in the Sacramento River. It is hardly expected that they should be as yet, as without doubt they have gone to the ocean, not to return until the spring of 1876, when we have to hear of some of them being caught on their return for the purpose of spawning. It will be interesting to learn in after years if they will cross with the Sacramento salmon and produce a new variety.

Captain Dougherty states that the salmon planted in 1891 did well, and that some of them were subsequently taken by Indians, having reached full size. No other report of these fish has been received.

* See Report California Fish Commission, 1874–75.

THE LANDLOCKED SALMON.

In January, 1878, the United States Fish Commission sent to the California fish commission, from Grand Lake Stream, Maine, 50,000 eggs of the landlocked or Schoodic salmon (*Salmo salar sebago*). These were hatched at San Leandro by the Californian authorities and in March and April deposited in various waters. In their report for 1878–79 the commissioners say:

> As the landlocked salmon are natives of the cold lakes of Maine, we have thought the most appropriate places for the distribution of the young fish would be in our mountain lakes; but, for purposes of testing their fitness to thrive in warmer waters, a portion were also distributed to lakes in the valley and on the coast, as follows: Donner Lake and other lakes near the summit, 10,000; San Francisquito Creek, Espenosa Lake, etc., 10,000; Tulare Lake, 15,000; San Leandro Creek and Lake, 2,500; Arroyo Laguna, near Sunol, 700; reservoir at almshouse, San Francisco, 1,000; Echo Lake, El Dorado County, 250.

A somewhat more detailed statement of the distribution of these fry is given in the report of the United States Fish Commission for 1881, page 894. Sereno and Chabot lakes and Laguna Honda are mentioned as receiving fry.

In the report of the California commission for 1881–82 figures are presented showing the distribution in 1881 of 20,100 landlocked salmon fry in Prosser Creek, Donner Lake, Lake Tahoe, and in various waters in Santa Cruz, Marin, San Mateo, Alpine, and other counties. These fry resulted from a shipment of 25,000 eggs from Grand Lake Stream, donated by the United States Fish Commission.

The report of the United States Fish Commission for 1881 shows that in the spring of 1882 a shipment of 10,000 Schoodic salmon eggs was sent to the California authorities; the resulting fry, 5,433 in number, were placed in Prosser Creek, Blue Lake, and Lake Honda.

In 1884 the United States Fish Commission sent 30,000 landlocked salmon eggs from Maine to the California fish commission. These were hatched with a reported loss of 7½ per cent, and the fry were distributed as follows: 5,000 in Independence Lake, 10,000 in Donner Lake, 10,000 in Bigler Lake (Lake Tahoe), and 300 in Butterfly Creek.

In 1890 the United States Fish Commission station at Fort Gaston, Cal., received 20,000 eggs of landlocked salmon from Maine. The disposition made of the fry is not known to the writer.

Thirty thousand eggs were sent to the California commission in February, 1892, and the fry were turned over to the Country Club. The eggs arrived in poor condition, and only a small percentage hatched. The fry were planted in the preserve of the club.

In March, 1895, 10,000 eggs were delivered to the Country Club of San Francisco for stocking waters on the club's preserve in Marin County; 3,000 fry were produced. At the same time, 10,000 eggs were sent to the California fish commission. These were hatched with heavy loss (60 per cent). Mr. Babcock states that the fish are retained at Sisson, but will be placed in Lake Tahoe in 1896.

A number of plants of landlocked salmon have been made in Nevada from spawn furnished by the United States Fish Commission. The nature of the early work in Nevada is obscure, and no account of the first plant or plants has been met with. In

the report of the State fish commissioner for 1881–82, the first reference to the fish is found, the commissioner there stating that in 1881 he again commenced hatching landlocked salmon. The eggs were first forwarded by the United States Fish Commission in December, 1882. From this consignment, consisting of 15,000 ova, 14,000 fry were hatched and placed in the Truckee and Carson rivers in June, 1883. In 1890, 1891, and 1892, 70,000 eggs were sent to the Nevada fish commissioner. No records are available showing the disposition made of the fry resulting from the shipment in 1890. The fry from the 1891 consignment were distributed as follows: Truckee River, 7,000; Humboldt River, 5,000; Carson River, 2,500; Lake Tahoe, 2,500. The plants in 1892 consisted of 4,500 in Truckee River, 4,000 in Humboldt River, 4,000 in Carson River, and 500 in Lake Tahoe.

The published details of the results attending the planting of salmon fry in 1878 are very meager. No reference was made to the matter in the State commissioners' reports until 1884, when it was stated that the plant in 1878 had been only a partial success; that only a few fish had as yet been taken, and that the catch had been about the same as last season, of which no mention is made. The State report for the years 1885–86 says of the landlocked salmon:

> Some small plants were made by former commissioners. The fish increased and thrived. Many large ones have been captured during the last and present year.

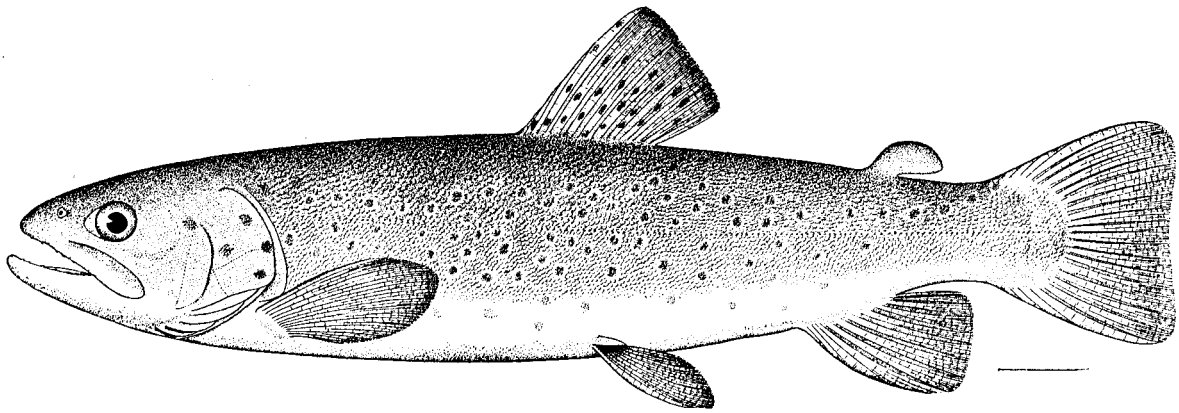
Mr. E. W. Hunt, deputy of the California fish commission, in a report dated September 30, 1891, made the following reference to landlocked salmon:

> I have been making inquiries about the landlocked salmon planted in Donner and Independence lakes. There have been two or three caught in Independence Lake during the spring and summer, weighing from 1½ to 3 pounds. The professional fishermen on the lake do not think that they hybridize. They are decreasing instead of increasing. None have ever been caught in Donner Lake that I can hear of.

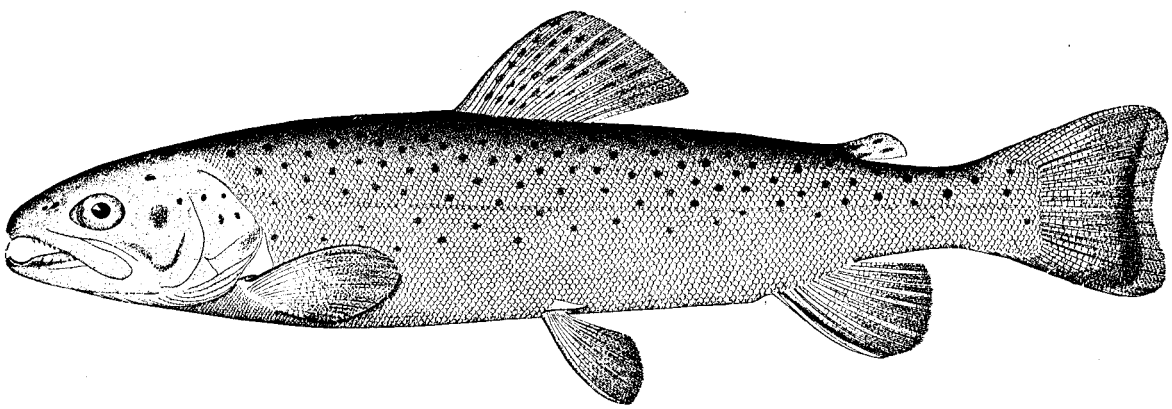
Mr. John P. Babcock states that of the fry placed in Lake Tahoe nothing had been heard up to December, 1895. Mr. Babcock thinks it possible that, as they so closely resemble the so-called "silver-side trout" of Lake Tahoe (*Salmo mykiss henshawi*), some of them may have been taken and not reported. He also furnishes the information that the fry resulting from the shipment of eggs for the Country Club in 1892 were placed in lakes on the club's preserve in Marin County, and several fine specimens were taken there in 1895. The club reports that the fish are doing finely.

In Nevada the results of the introduction of landlocked salmon seem to have been quite marked. The following quotations from the reports of the State fish commission will be sufficient to show the general outcome:

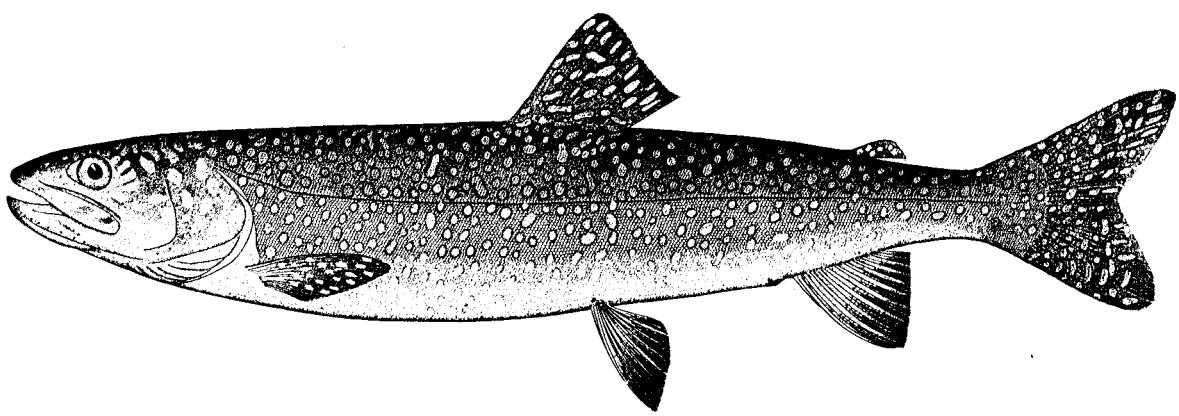
> The landlocked salmon furnished by the United States Fish Commissioner were planted in the same waters with the McCloud River salmon. The plants were small, and from the large bodies of water to be stocked I had but little hope of reporting at so early a day as this. No attempts, other than ordinary angling, have been resorted to in determining their condition. Sportsmen and fishermen have had numerous good catches of these most desirable food-fish, and an undeniable verdict as to their superiority for our waters comes from every intelligent person accustomed to the habits of fish. They do well in the Truckee and Carson, proofs of which I have in the returns made to me by fishermen this season. I await the reception of more spawn, that I may be able to introduce them into every stream in the State. (Rept. 1883–84, pp. 4–5.)
>
> Mr. H. G. Parker, while fish commissioner, made one plant in Lake Tahoe and Truckee River. During the past few years many of these fish, weighing from 1 pound up to 3½ pounds, have been taken. * * * Of my 1891 plants, several, from 2 to 10 inches in length, have been seen, thus showing our waters are adapted to their growth. (Rept. 1891–92, p. 12.)



VON BEHR TROUT OR EUROPEAN BROWN TROUT (*Salmo fario*).



LOCH LEVEN TROUT (*Salmo trutta levenensis*).



LAKE TROUT, SALMON TROUT, OR MACKINAW TROUT (*Salvelinus namaycush*).

THE VON BEHR TROUT.

The fish resulting from 25,000 eggs of the Von Behr or European brown trout (*Salmo fario*), sent from Northville, Mich., to Fort Gaston, Cal., in January, 1892, were placed in California waters in 1893 and 1894. In 1893 the plants consisted of 10,700 yearlings in Supply Mill and Fish Tang creeks, near Hoopa Valley, Humboldt County; 50 yearlings in Three Creeks, near Hoopa Valley, Humboldt County, and 178 yearlings in Redwood Creek, Humboldt County. The yearlings planted in 1894 were: 100 in Elk River, near Eureka; 981 in Larrabee Creek, a tributary of Eel River, and 2,715 in the preserves of the Country Club in Marin County. In December, 1892, 300 yearling fish from the Leadville station of the United States Fish Commission were supplied to an applicant in Idaho for planting in a private pond near Reynolds, Owyhee County. This fish occasionally reaches a weight of over 20 pounds, but the average is only 5 or 6 pounds.

THE LOCH LEVEN TROUT.

In February, 1894, 20,000 eggs of the Scotch lake trout (*Salmo trutta levenensis*) were sent to the California commission from the Northville station of the United States Fish Commission. The eggs were hatched at Sisson and the fry placed in a lake near the hatchery, to be retained as brood stock. Under date of December 6, 1895, Mr. J. P. Babcock, of the California commission, writes that the fish have done well, and in July, 1895, 250, about 3 inches long, were deposited in Webber Lake, Nevada County. Several thousand are supposed to be still on hand at Sisson. The Loch Leven trout is very similar to the brown trout in size and appearance.

THE LAKE TROUT.

Attempts have been made to introduce the lake trout (*Salvelinus namaycush*) into California and Nevada. This fish is also known as the salmon trout or Mackinaw trout. From the commercial standpoint, it is the most valuable of the so-called trouts of the United States. It is generally distributed in the Great Lakes, being especially abundant in lakes Superior, Michigan, and Huron. In 1893 over 15,000,000 pounds were taken in the Great Lakes, for which the fishermen received more than $600,000. The fish attains a large size, and is an excellent game and food fish. It is adapted to clear, cold, deep lakes, in which it has been known to reach a weight of 90 pounds.

In November, 1894, the United States Fish Commission sent 100,000 lake-trout eggs to the California fish commission. The eggs were hatched with a loss of only about 7 per cent, and in May, 1895, 65,000 fry were placed in Lake Tahoe, the remainder being retained at the Sisson hatchery.

In 1885 the United States Fish Commission sent 100,000 eggs to the Nevada fish commission. One lot of 25,000 eggs was lost in transit, but the other arrived in good condition. In December, 1889, the Nevada commissioner received another consignment of 30,000 eggs, which were hatched with little loss. The State reports do not show where these fry were planted, and no data are at hand giving the results of the early plants, but Mr. George T. Mills, fish commissioner of Nevada, states that the lake-trout fry planted in 1889 have done well and are multiplying. They were planted mostly in Lake Tahoe and are now occasionally taken by the fishermen of that lake. The largest Mr. Mills has any account of weighed 11 pounds; this is above the average of trout now taken in the Great Lakes.

THE EASTERN BROOK TROUT.

PLANTING OF BROOK TROUT IN PACIFIC STATES.

Extensive attempts to acclimatize the eastern brook trout (*Salvelinus fontinalis*) have been made in several of the States of the Pacific Slope. The first plants, made more than twenty years ago, have been supplemented in recent years, and the fish has been given a wide distribution, especially in California and Nevada.

As early as 1872 the California fish commission began their efforts to introduce this favorite game fish into the State waters, and purchased 6,000 young fish for that purpose. The plants were made in three equal installments—in the North Fork of the American River, in the headwaters of Alameda Creek, and in the San Andreas reservoir near San Francisco.

In 1875 the California fish commission purchased 60,000 brook-trout eggs in New Hampshire and hatched them at Berkeley, with a loss of 4 per cent. The fry were distributed in public waters of the State, about 20,000 being placed in lakes and streams in Mendocino, Sonoma, Napa, and Yolo counties; 20,000 in Calaveras Creek (in Alameda and Santa Clara counties) and other streams tributary to San Francisco Bay; 10,000 in Prosser Creek, Nevada County, and 10,000 in the North Fork of the American River, in Placer County. In January, 1877, 133,000 additional eggs were obtained by purchase in the East. The young fish resulting from these eggs were planted in suitable waters in Siskiyou, Contra Costa, Alameda, Placer, Nevada, Santa Cruz, San Mateo, Monterey, Los Angeles, San Diego, Yuba, and Santa Clara counties.

New Hampshire and Wisconsin furnished eggs in 1878 and 1879 to the number of 70,000. The fry resulting from these were extensively distributed, the North Fork of the American River and the Truckee River receiving the largest plants. In 1880 41,500 fry were distributed. From that time up to 1890 the reports of the California commission do not show any brook trout handled. In the latter year, however, 100,000 eggs were purchased in New Hampshire, and 83,000 fry were produced and distributed in tributaries of the Sacramento and Klamath rivers. In the same year the North Pacific Game and Fish Club privately planted 25,000 young trout in Robinson Creek.

The most extensive brook-trout propagation by the California authorities was carried on in 1892, when 317,000 fry were distributed, the eggs being taken in Marlette Lake, Nevada, where the fish had been acclimatized. The following year 251,000 fry were hatched from eggs obtained in Nevada, and in 1894 266,000 more fry were planted under the same conditions.

The aggregate deposits by the State commission numbered 1,228,000 fry, which were placed in nearly every county having suitable waters. For detailed statements of the waters stocked, the reports of the California fish commission should be consulted.

In May, 1893, the United States Fish Commission made plants of young brook trout in California, as follows: 50 yearlings in Three Creeks, near Hoopa Valley; 215 yearlings in Redwood Creek, at Berry's Crossing, and 5,900 yearlings in Supply Mill and Fish Tang creeks, Hoopa Valley. These fish resulted from a lot of 20,000 eggs from New York, which were hatched and reared at Fort Gaston (Cal.) station of the United States Fish Commission.

The brook trout appears to have been successfully introduced into Nevada waters at a comparatively early date, but a history of the matter is not at hand. The Nevada

fish commissioner, in his report for 1881 and 1882, speaks of having hatched brook trout, but no details are given and no mention of the subject is made in his two preceding reports, going back as far as 1877, implying the carrying on of private fish-cultural work before the formation of a State fish commission. In 1883 a reservoir of the Virginia and Gold Hill Water Company yielded 250,000 eggs of the brook trout, which, when hatched, were distributed to the Carson, Walker, Truckee, and Humboldt rivers, each receiving 40,000 fry. About 3,000 fry were also placed in Washoe Lake. In 1885 or 1886, 50,000 eggs were taken from the same reservoir, but the details of the distribution are not recorded. In 1887, 500,000 eggs were obtained from fish caught in Marlette Lake, and in 1888 the same number was taken in that water. The combination of the resulting fry with the young of the native trout of Lake Tahoe in the distribution tables published by the State commissioner makes it impossible to record the waters in which plants were made. Large numbers of fry were deposited in 1889 and 1890, but no details are available.

The planting of fry by the Nevada commission was continued in 1891 and 1892. In the former year 545,000 fish were allotted to private waters or public streams, the Truckee, Carson, and Humboldt rivers receiving 410,000 fry. In the latter year the plants aggregated 362,800 fry, of which 220,000 were placed in the rivers named and 65,000 in Lake Tahoe. In 1893 the State distributed 430,000 brook trout, the plants being mostly in the Truckee, Carson, and Humboldt rivers and Lake Tahoe. The eggs were taken from fish that had been introduced.

Plants of yearling brook trout were made in Oregon and Washington by the United States Fish Commission in the fall of 1894. Sixteen hundred fish were equally apportioned to the South Fork of the Umatilla River, near Gibbon, Oreg., and to a tributary of Dead Point Stream, near Hood River Station, Oreg. The fish put in Washington waters consisted of 375 yearlings in Twin Lake, 750 in Mountain Lake, 750 in Kelly Lake, 750 in Hooker Lake, 1,150 in Cranberry Lake, 1,150 in Johns Lake, and 51 in Washington Lake—a total of 4,976. All of these fish were reared at the Fish Commission station at Leadville, Colo.

STATUS OF THE BROOK TROUT IN THE PACIFIC STATES.

While detailed information is wanting regarding the outcome of the attempts to colonize the brook trout in this region, and while the results of plants in many places are unknown to the writer, enough has been recorded in the State reports and elsewhere to show that the fish has become adapted to numerous waters, where it has spawned and now constitutes a permanent addition to the list of game fishes of the section. As early as 1880 the results of brook-trout planting in California had become noteworthy. In the report of the California fish commission for that year it is recorded that—

> The South Yuba and the North Fork of the American rivers, which originally contained no fish above the high falls on each stream, are now well stocked with trout. We have also stocked other streams, which naturally contained no fish, or from which all the fish had been caught.

In the report of Mr. J. G. Woodbury, superintendent of hatcheries, published in the report of the California fish commission for 1889–90, the following references are made to the results of planting eastern brook trout in 1875, 1877, 1878, and 1879. After mentioning the waters stocked, he says:

> In all these short coast streams, which become warmer and diminish in volume as the summer advances, they have not reproduced themselves—at least I can not learn that they have been caught for a number of years past; but in all the high Sierra streams where these trout were planted they

can now be caught quite plentifully. The integrity of their characteristics in all their virgin beauty is maintained. A number of these fish were caught during the past summer in Blackwood Creek, Lake Tahoe.

About four years ago a few of these fish were planted in a small lake on the mountain side back of McKinney's place, Lake Tahoe. Last year Mr. McKinney told me that a number of eastern trout had been caught in that little lake, one of which weighed 3 pounds. He said they were fierce fighters and had a delicious flavor. Some of these eastern trout have been caught 30 miles down the river from the place where they were first planted in the North Fork of the American River. It seems to me very probable that the eastern brook trout, as they become older and larger, will drop farther and farther down the main stream, and ascend other branches to spawn, and thus becoming acclimated will gradually stock all the streams in the State accessible from the first stream in which they were planted.

Mr. John P. Babcock, in response to an inquiry, contributes the following interesting notes on the eastern brook trout in California:

The *fontinalis* has been given a very wide distribution in the streams of the State, almost every stream having been stocked at different times since the fish's introduction in 1872.

None of the plants in the immediate coast streams has been successful. In the small streams of the higher altitudes the fish has done fairly well.

Take the Truckee basin: The Nevada and California commissions have made liberal plants in Lake Tahoe. A few have been taken from the lake. Our men seining for spawning *mykiss* in spring of 1895 took one *fontinalis* that weighed 3¾ pounds. It is highly marked and of a deep, stocky build; we have it in the office. It is the only *fontinalis* taken in the lake with our seine, though we have taken many thousands of cut-throats. Of the streams that come into Tahoe from the west, Blackwood and Taylor creeks afford the best *fontinalis* fishing; the trout, though not large, are common. Very few specimens have been taken from the Truckee River proper, but in a number of its small tributaries they have been and are doing well, notably in Prosser Creek and its very small tributary, Alder Creek. A few *fontinalis* weighing over 2 pounds have been taken from Prosser Creek. In Alder Creek the brook trout predominate, as they do in Cold Stream, a small creek above the town of Truckee, but in none of the other small streams of the region does the *fontinalis* exceed 20 per cent of the catch, while the rainbow trout (*Salmo irideus*) introduced to these waters exceeds 70 per cent of the catch for the past four years.

In Lake of the Woods, a small sheet of water above and near Webber Lake, in Sierra County, specimens of *fontinalis* were taken the past season (1895) that weighed over 3 pounds, and one 2-pounder was taken from Webber Lake.

The brook trout have done well in the headwaters of American, Yuba, and Feather rivers, though they confine themselves to the smaller waters. The same may be said of the small streams in the Shasta region, the small creeks around the town of Sisson being well stocked. Large plants have been made in Sacramento and McCloud rivers, but no fish have been taken except in headwaters of small streams.

In the Klamath region they have not been a success.

In the Yosemite Valley country the plants have been very successful, and some fine fishing is to be had in Bridal Veil Creek and near Wawona in some of the lakes.

The fish placed in the King River region are reported as doing well.

In southern California, in spite of repeated efforts, they have not done well.

Speaking of the introduction of these fish in general, it can not be said to have been as successful as anticipated. They do not seem to hold their own against the natives; they have added but little to the attractions of the sportsmen, who do not consider them the equal of either the cut-throat or rainbow trout in gameness or flavor. They take the same flies as the natives. In Lake of the Woods, however, they take the spoon only, and can not be called to the surface with flies. The commission will make no further efforts to propagate these fish. We obtained the main supply of *fontinalis* spawn from Marlette Lake, in Nevada.

About 1892 a hybrid between the brook trout and the Dolly Varden trout (*Salvelinus malma*) was produced at the Sisson hatchery of the California fish commission. Two thousand eggs of the latter fish were fertilized with brook-trout milt. The experiment has been repeated each year up to the present time, and a large number of small fry is on hand. Mr. Babcock writes, under date of December 18, 1895, that

some of the specimens now at Sisson are about 7 inches long. In November, 1895, a few eggs were taken from the hybrid fish, and an effort will be made to hatch them. Mr. Babcock states that the crosses exhibit very beautiful colors.

Only meager data are at hand relating to the outcome attending the planting of the numerous trout fry in Nevada waters. It is known, however, that the fish have not only survived in most of the waters stocked, but have proved an economic commodity for sale in local markets and for home consumption. The fact that all of the spawn previously mentioned (amounting to more than 3,000,000 ova) was taken from wild fishes, is in itself sufficient evidence of the adaptability of this fish to the waters of Nevada and of its successful introduction.

The acclimatization of brook trout in the Humboldt River has been very successful; the report of the Nevada commissioner for 1893–94 states that good catches have been made and that an encouraging future awaits the fish in that stream.

Hon. George T. Mills, Nevada fish commissioner, writes as follows regarding the eastern brook trout in the Carson River and elsewhere in Nevada:

> The *S. fontinalis* do not seem to have increased in that stream. Their scarcity I attribute to their leaving the main stream for the many side streams, and from there out in irrigating ditches, where they perish. In other small streams in the State where they have been placed, they are a success beyond our expectation. With us they are extremely hardy, and the fry will stand almost anything. For example, in July of this year, I sent 20,000 to some creeks in the northeastern part of this State—12 hours by rail, 70 miles by wagon—with the loss of only one fish. This I think phenomenal.

Sufficient time has not yet elasped to determine the results of the planting of yearling trout in Oregon and Washington in 1894.

THE MUSKELLUNGE.

In May, 1893, the New York fish commission furnished to the California fish commission 100,000 fry of the muskellunge (*Lucius masquinongy*) from Chautauqua Lake. The United States Fish Commission gave free transportation of the fish to Ogden, Utah, from which place the consignment was under the auspices of the California commission. The fish reached their destination in good condition, and 93,000 were placed in Lake Merced, near San Francisco.

The introduction of this species was undertaken at the solicitation of the Spring Valley Water Company, of San Francisco, which paid half the expense of transportation from Ogden. It having been learned that the muskellunge grows rapidly, is a voracious feeder on live fish, and has excellent game qualities, it was thought to be a desirable fish to plant in the reservoirs of the company to check the proliferation of carp and afford sport. Carp existed in great abundance in Lake Merced and Palisidas Lake, which are reservoirs for the water supply of San Francisco; and these fish kept the water constantly stirred up and consequently muddy. The desirability of keeping the carp in check was probably the chief reason for the importation of the muskellunge.

The muskellunge fry were put in private water under an agreement with the water company permitting the State to take such fish for breeding purposes and distribution as might be desirable.

The planting of muskellunge in Lake Merced appears to have been a failure, although sufficient time may not yet have elapsed to fully decide the matter. In June, 1894, the California commission employed some drag-net fishermen, who made hauls in every part of the lake, but obtained no muskellunge, and the commissioners, in the report for 1893–94, express the belief that the fry have not survived.

The muskellunge is a magnificent food and game fish, sometimes reaching a weight of nearly 100 pounds. Further efforts will doubtless be made to secure its colonization in California.

THE PIKE OR PICKEREL.

On September 15, 1892, 76 yearling pike (*Lucius lucius*), sent from the station of the United States Fish Commission at Quincy, Ill., were placed in the Boise River, near Boise, Idaho. In the preceding December a plant of 400 pike was made in Lake Cuyamaca, California, near San Diego, and another of 100 in the Feather River, in Butte County, Cal. These fish were also yearlings from Quincy.

Mr. Arthur G. Fletcher, of the California fish commission, visited Lake Cuyamaca in January, 1896, and found that the pike had survived. In two hauls of a small seine near the shore, 4 fish under 8 inches long were taken; 2 of these, which were forwarded to San Francisco, were females with well-developed ova. Pike are said to be more numerous than any of the other eastern fishes—black bass, yellow perch, catfish, and crappie—that were planted in the lake at the same time as the pike. Mr. J. E. Friend, of San Diego, recently caught with rod and line 2 pike that weighed 2 pounds apiece. Professor Jordan has identified as the little pickerel (*Lucius vermiculatus*) one of the small specimens obtained by Mr. Fletcher.

THE EEL.

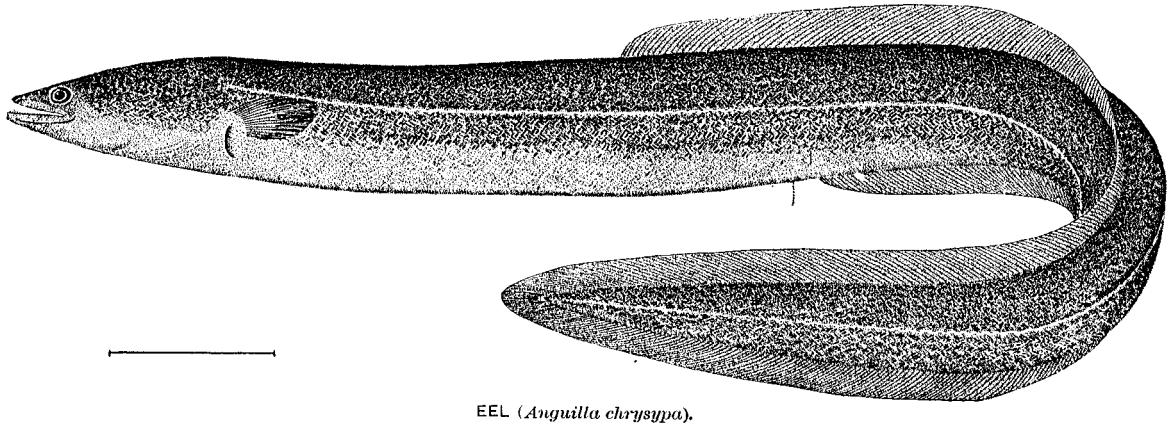
HISTORY OF INTRODUCTION.

As early as 1871 the California fish commission contemplated the introduction of the common eel (*Anguilla chrysypa*) into the Sacramento River,* and in 1873 an effort was made to import eels from the east coast. Acting in behalf of the California fish commission, Mr. Livingston Stone, of the United States Commission of Fish and Fisheries, started from Charleston, N. H., with an "aquarium car," containing, besides a large number of other fish, 1,500 eels from Martha's Vineyard, Mass., and 40,000 from the Hudson River, New York. The car passed beyond Omaha with the eels in good condition, and the prospects were favorable for the safe arrival on the Pacific Coast of between 20,000 and 30,000 eels, when the car was wrecked in a railroad accident and the entire stock was lost.

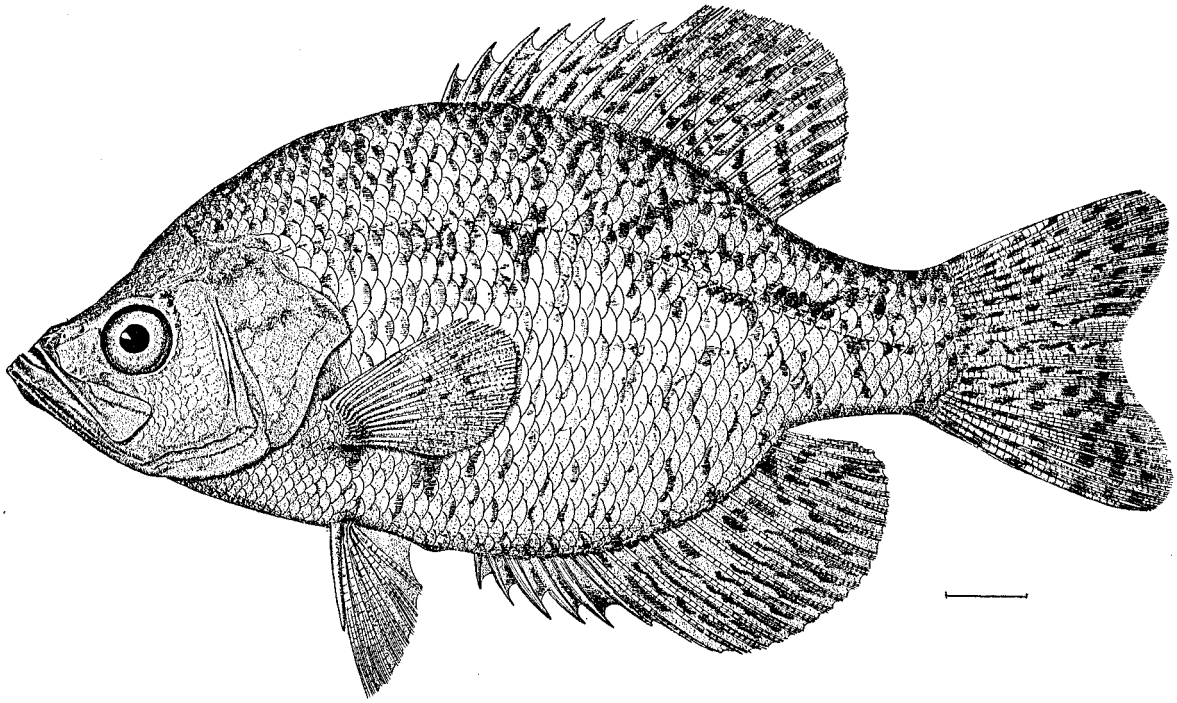
In 1874 the attempt to introduce the fish was renewed and successfully carried out by Mr. Stone in the new "aquarium car," to which frequent reference is made in this paper. The original consignment consisted of about 2,000 small "fresh-water" eels from Castleton, N. Y., on the Hudson River, and several thousand small "salt-water" eels from New York Harbor. The loss of the former lot in transit was almost complete, but the eels taken from salt water stood the journey well. On June 12 the fish from the Hudson River, then reduced to 12 in number, were placed in a slough of the Sacramento River near Sacramento. The eels from New York Harbor, about 1,500 in number, were deposited in an inlet of San Francisco Bay, near Oakland.†

* Report of the Commissioners of Fisheries of the State of California, 1870–71, p. 14.

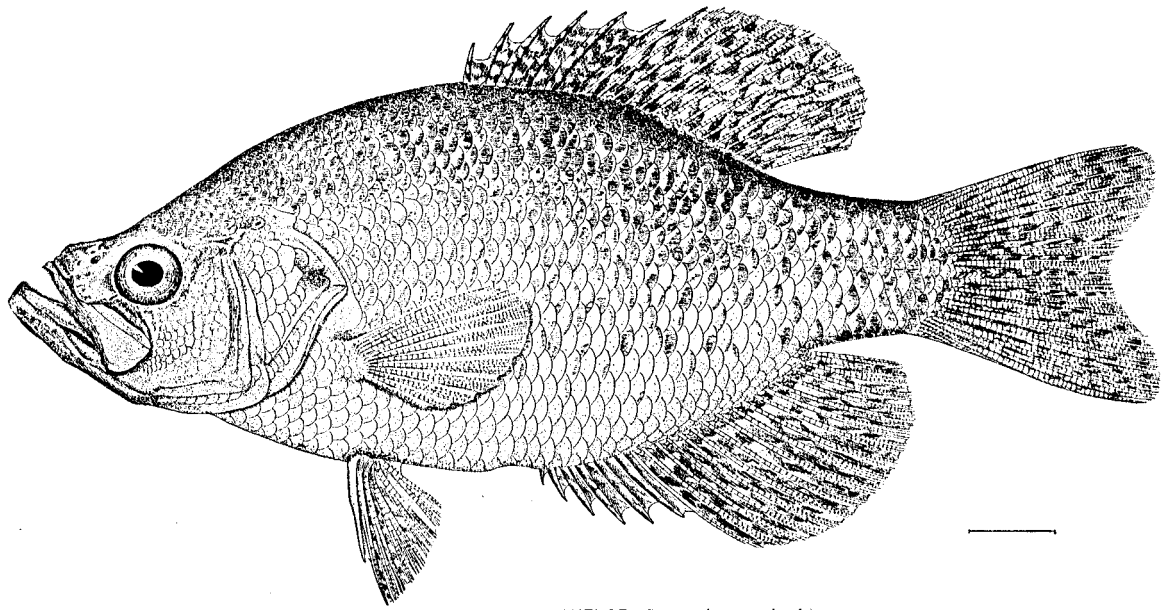
† In a tabulated statement accompanying Mr. Stone's report of the trip with the aquarium car, these eels are said to have been placed in lakes at Sutterville, a town on the Sacramento River, near Sacramento. (Rept. Cal. Fish Com., 1874–75, pp. 6, 30, 32.)



EEL (*Anguilla chrysypa*).



CRAPPY; STRAWBERRY BASS; CALICO BASS (*Pomoxis sparoides*).



CRAPPY; SAC-A-LAI; BACHELOR (*Pomoxis annularis*).

The planting of eels in waters of California was next accomplished in 1879 under the same circumstances that attended the introduction of several of the other fishes to which reference is made in this paper. The transportation of the fish across the continent was again superintended by Mr. Livingston Stone, whose report* contains all that is recorded regarding the history of the experiment. The supply of eels consisted of about 3,000 individuals obtained by Mr. Seth Green in the Hudson River, New York, and about 500 others secured by Mr. H. W. Mason in the Navesink River, New Jersey, in connection with the taking of striped bass intended for the same shipment. The tank of eels from the Hudson River was thrown away en route, as Mr. Stone saw that there was no possibility of their reaching the coast alive; the others (about 500 in number) reached Sacramento on June 18 in good condition and were deposited in the Sacramento River and Alameda Creek.

In July, 1882, Mr. J. G. Woodbury, of the California fish commission, took 10 eels from the Shrewsbury River, New Jersey, to California, in connection with the transportation of striped bass. They were carried west without loss by keeping them in a well-ventilated box in which moist eelgrass was placed. These eels were apparently larger than those in the previous plants, being from 12 to 24 inches in length. They were planted in Suisun Bay in water about a foot deep, on the edge of the tules. "On being put into the water they immediately bored straight down into the soft mud, and in a moment were all out of sight."

OUTCOME OF THE EXPERIMENTS.

The results of the introduction of eels to California waters are not fully known, and reports of the capture of the fish are unsatisfactory and somewhat contradictory. The first reference to the taking of an eel in California appears to be that given in the biennial report of the State commissioners for 1874–75. They say:

> Of the fresh-water eels placed in a tributary of the Sacramento River, we learn that one had been caught in Willow Slough, in Yolo County, which had grown to be more than a foot in length. We have no knowledge that the salt-water eels placed in Sacramento Bay have ever been seen.

In the report of the commissioners for 1876–77 it was stated that a few eels had been caught, but they had not become numerous. The next report recorded the capture of several "taken in the fresh water, near Sacramento, full grown, and 3 feet in length." In 1880 the commissioners stated:

> Occasionally we hear of an eel being captured, but as yet they have not shown an increase in proportion to that of other imported fish.

The statements regarding this fish in the report for 1883–84 conflict somewhat with the foregoing:

> Eels, placed in our waters by the former commissioners, have not been a success. It is probable that the place where they were deposited and where they have made their home has not yet been discovered; at all events, none have been taken since they were planted. It seems to us that they ought to do well in our inland waters, as they are fond of the bottoms of ponds or streams where mud prevails, as is the case in our lakes and rivers.

Under the probably erroneous caption, "The first California eel caught," the *American Naturalist* for April, 1882 (page 326), contains this note:

> The San Francisco *Chronicle* of February 8 reports the catch by George Bird of the first eel, resulting from the plant of 12,000 made by the California fish commissioners. It was caught on the easterly shore of San Francisco Bay and measured 3 feet in length.

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* Report on Overland Trip to California, 1879. (U. S. F. C. Rept. 1879, pp. 637-644.)

In 1894, when the writer visited the Pacific Coast, no eels were at any time seen in the markets of San Francisco or other cities, and the following statement, based on his observations, was printed in a report* embodying the data on certain phases of the fishing industry obtained at the time:

> Inquiries regarding the results of the attempted acclimatization of the eel (*Anguilla chrysypa*) on this coast are apt to elicit misleading information unless great care is exercised. In the San Francisco markets one learns that eels are not infrequently exposed for sale, and that both salt water and river fishermen catch them occasionally, but an examination of the reported eels usually shows them to be lampreys.

According to Mr. Charles Cuneo, of the American Union Fish Company, San Francisco, eels are occasionally caught in the vicinity of San Francisco in seines and other fine-meshed nets operated for other fish, but they are quite scarce. A few come from San Francisco Bay and a few are taken by the steamers using drag nets outside the Golden Gate. Mr. Cuneo says a steamer will sometimes bring in 10 or 12 pounds of eels. Those exposed for sale in the San Francisco markets are small, usually being only 10 to 12 inches long. The wholesale price is 10 to 15 cents a pound.

In view of the hardiness and great prolificness of the eel, it is somewhat remarkable that it has not gained a firm hold in California and become abundant. It is, of course, possible that the failure to catch more of them has been due to the absence of suitable pots or traps, but the fact that the fish are so seldom taken with the various forms of apparatus now used can only be explained by their actual scarcity, and in their last report (1894–95) the California fish commissioners regard the eel as one of the fish from whose attempted introduction "no result can be said to have come."

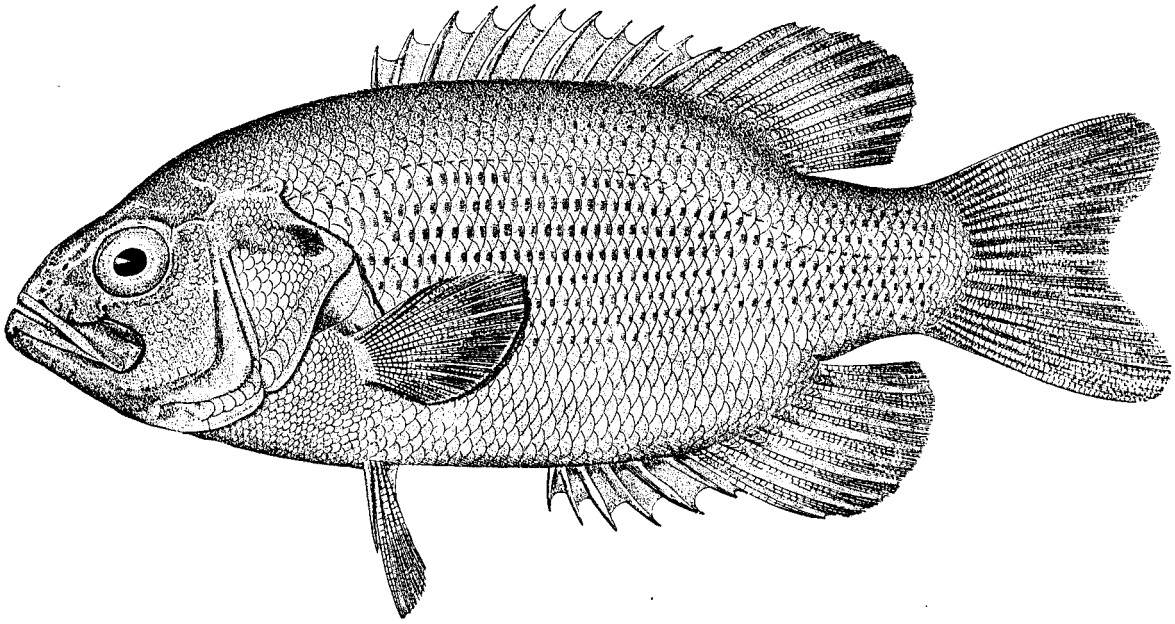
While the eel is a highly esteemed food-fish in the principal markets of the Atlantic States, is easily caught, and yields good returns to fishermen, it is perhaps fortunate, on the whole, that it has not attained abundance on the Pacific Coast. It is known to be very destructive to the spawn of shad and other important food fishes, and if it existed in large numbers in the California rivers it might seriously reduce the supply of salmon, striped bass, and other river fish by resorting to the spawning grounds and devouring the ova.

THE CRAPPIES.

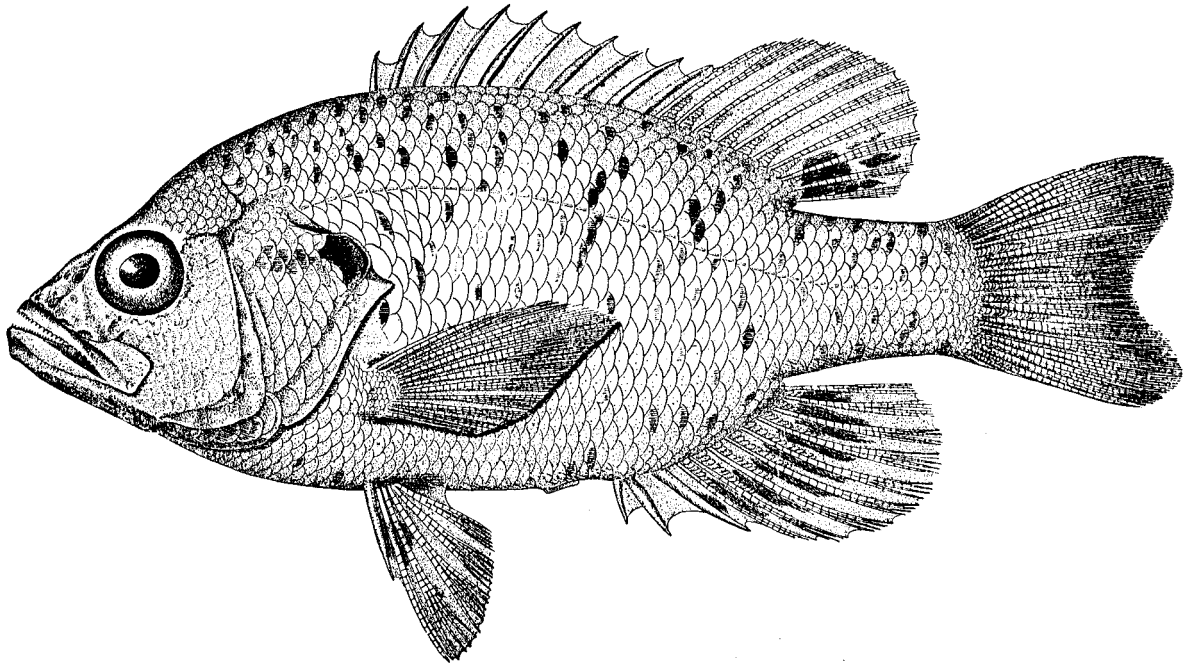
The crappy, sac-a-lai, or bachelor (*Pomoxis annularis*), and the strawberry bass or calico bass (*Pomoxis sparoides*), have been distributed in California, Washington, and Idaho, from the United States Fish Commission station at Quincy, Ill. The first plants were made in Washington. In 1890, 285 yearling crappies were placed in Lake Washington, near Seattle; the following year 220 were put in Loon Lake and 50 in Liberty Lake, near Spokane; in 1892, 25 were planted in Deer Lake near Loon Lake, and in 1893, 18 were put in Shepherd Lake. A plant of 388 yearlings was made in 1892 in the Boise River, near Boise City, Idaho. In Lake Cuyamaca, near San Diego, Cal., 285 yearlings were deposited in 1891. The largest consignment was made in 1895, when 50,000 fry were sent to the California fish commission station at Sisson. Mr. Babcock writes that none of these lived.

While most of the fish belonging to this genus which have been distributed in western waters are known to have been of the first-named species, it is certain that

* Notes on a Reconnoissance of the Fisheries of the Pacific Coast of the United States in 1894. Bulletin U. S. Fish Commission, 1894, pp. 223–288.



ROCK BASS (*Ambloplites rupestris*).



WARMOUTH BASS (*Chænobryttus gulosus*).

the plants have included some strawberry bass or calico bass (*P. sparoides*), which inhabits some of the same waters as the crappy or bachelor. Both these members of the sunfish family are valuable food and game species, attaining a length of 1 foot and a weight of 1½ pounds.

THE ROCK BASS.

Four full-grown rock bass (*Ambloplites rupestris*) obtained in the Missisquoi River, Vermont, were taken to California by Mr. Livingston Stone in 1874 and deposited in Napa Creek, a tributary of San Pablo Bay, on June 12. No known results have attended the planting of these fish, although the black bass placed in the same waters at the same time have greatly multiplied.

The rock bass or red-eye perch is found in the Mississippi and Ohio valleys and in the Great Lakes. It attains a weight of 1½ pounds, is a hardy, gamy fish that takes the hook readily, and is a palatable pan-fish. Like the black bass, it builds a nest and protects its young.

THE WARMOUTH BASS.

A few small plants of this member of the sunfish family (*Centrarchidæ*), to which the black bass, rock bass, and crappy belong, have been made in California, Washington, and Idaho. It is a hardy species, adapted to quiet waters, and is naturally found in the coast States from Virginia to Texas, in the Mississippi basin, and in the Great Lakes. It closely resembles the rock bass in size, habits, food value, and game qualities.

Four hundred yearling warmouth bass (*Chænobryttus gulosus*), from Quincy, Ill., were placed in Lake Cuyamaca, near San Diego, Cal., in 1891. In the same year 100 yearlings were deposited in Feather River, near Gridley, in Butte County, Cal. A plant of 201 yearlings was made in Boise River, near Boise, Idaho, in 1892. In Loon Lake, Washington, 29 yearlings were placed in 1892. No reports from any of these fish have been received. Of 12 fish delivered to the California fish commission in June, 1895, 6 were alive in December, 1895, in a pond at Sisson.

THE SUNFISHES.

Small plants of the green sunfish (*Lepomis cyanellus*) and the blue-gill or blue bream (*Lepomis pallidus*) have been made in public waters of Washington and California by the United States Fish Commission. The Washington consignments consisted of 25 yearlings in Loon Lake and 25 in Lake Colville in 1890; 300 in Loon Lake and 150 in Deer Lake in 1891, and 9 in Deer Lake in 1892. In 1895, 12 yearlings were delivered to the California State hatchery at Sisson, 18 were put in Elsinore Lake, and 18 in the Balsa Chico River. A few sunfish were accidentally introduced with other fish into Lake Cuyamaca near San Diego in 1891.

It is not known with certainty which of the numerous species of sunfish inhabiting the United States have been taken to the Pacific States; but as the shipments were made from Quincy, Ill., and as both of the species named are common in that vicinity, it is probable that they have been introduced. Dr. Jordan has identified as *Lepomis cyanellus* specimens of sunfish obtained in Lake Cuyamaca by Mr. Fletcher, of the California commission.

THE BLACK BASSES.

HISTORY OF INTRODUCTION.

Plants of both large-mouth black bass (*Micropterus salmoides*) and small-mouth black bass (*M. dolomieu*) have been made in the Pacific States. The small-mouth fish, however, was introduced much earlier and in larger numbers. It appears to have been first taken to California in 1874 by Mr. Livingston Stone in his "aquarium car." The original lot consisted of 75 full-grown spawning bass from Lake Champlain, Vermont, and 24 small fish from St. Joseph River, Michigan. Two of the large fish and 12 of the small ones were lost in transit. The adult fish were placed in Napa Creek and the immature lot in Alameda Creek.

The probable extermination by anglers of the fish put in Napa Creek led the commissioners to renew their attempts to acclimatize the black bass, and in 1879 they had Mr. Stone take out 22 fully matured fish from the East. These were put in the Crystal Spring reservoir of the Spring Valley Water Company, in San Mateo County, with the assurances of the company that the fish would be protected and be at the disposal of the commission should they increase. Shortly before this a small lot of black bass seems to have been imported by a sporting club and placed in Lake Temescal, in Alameda County, near Oakland.*

From 1879 to 1889 no bass appear to have been planted by the California commission, although in the meantime the fish had probably been distributed privately from the waters previously stocked; thus, in 1889, it was reported as being in the Russian River. In 1889 the State authorities began the distribution of black bass from planted waters, chiefly the San Andreas reservoir, and 500 fish from 6 to 9 inches long were deposited in Clear Lake in Lake County, Thermalito Reservoir in Butte County, and Sweetwater Lake in San Diego County.

In the following year small lots of bass were put in Clear Lake, Blue Lakes, Pajaro River, Laguna de San Luis, reservoirs in Monterey and San Luis Obispo counties, and a lake at El Monte in Monterey County, the aggregate plants being 357. Some bass were taken from the reservoir of the Spring Valley Water Company in 1891 or 1892, but the number was quite small and no details of the distribution are recorded. In 1893, 155 fish were sent out by the State commission. The extent of the work in 1894 eclipsed all previous records. The State authorities sent a deputy to the Russian River, where in May the wild fish were seined. The number caught and distributed was 9,350, which were chiefly consigned to public waters not previously stocked. The

*In a report of Mr. J. G. Woodbury, California superintendent of hatcheries, printed as an appendix to the biennial report of the State fish commission for 1889–90, the following statements are made:

"Seth Green brought the first black bass to California. These were brought out at the expense of a sportsmen's club and placed in Temescal Lake, near Oakland. The second lot of black bass was brought out by B. B. Redding, for the California fish commission, and planted in the Crystal Springs reservoir, near San Mateo, with the permission of the Spring Valley Water Company."

Mr. Woodbury gives no further particulars, and is certainly in error in claiming that the two lots mentioned by him were the first and second, respectively, taken to California. He has overlooked the bass carried by Mr. Stone in 1874. The fish planted in Temescal Lake probably comprised the second lot transported to the State.

largest plants were made in Fresh-water Lake, Humboldt County (2,000); San Joaquin River, near Herndon, Fresno County (1,000); Lake Yosemite, Merced County (1,000); Stony Lake, Humboldt County (500); Keweah River, Tulare County (500); Garvey Lake, San Gabriel, Los Angeles County (500); Irvine Lake, Orange County (500). Small waters in Alameda, Los Angeles, Santa Barbara, San Bernardino, and Tulare counties also received fish.

The distribution of small-mouthed black bass by the California commission was further extended in 1895. Mr. Babcock furnishes the information that from the landlocked overflow ponds of the Russian River 25,600 fry were collected by the commission's agents, and that the fish was given a much wider distribution in the State, applications from almost all counties being filled.

The United States Fish Commission in December, 1891, placed 1,990 yearling large-mouth bass in Lake Cuyamaca near San Diego, and 620 in the Feather River near Gridley. In June, 1895, a carload lot of 2,500 large mouth bass was sent to the California fish commission. The fish were retained in ponds at Sisson. In the same month 50 fish were put in each of the following California waters: Buena Vista Lake near Bakersfield; reservoir near San Diego, and Elsinore Lake near Elsinore.

The plants of black bass in Oregon have not been numerous, although considerable interest has been manifested by anglers in securing the acclimatization of the fish in the State. In October, 1892, 500 yearling large-mouth fish were placed in the upper part of the Willamette River near Salem, and in July, 1895, 75 yearlings were deposited in Doves Lake near Salem; 25 in Mill Creek, a tributary of the Willamette River, and 75 in Big Creek, a branch of the Powder River.

Comparatively numerous plants of yearling large-mouth bass have been made by the United States Fish Commission in Washington during the past few years. In 1890 Washington, Loon, and Colville lakes received 1,220 fish; in 1891, 125 fish were sent to Loon and Liberty lakes; the following year 3,547 fish were planted in Clear, McDonald, Loon, Deer, American, Liberty, and Gravelly lakes. Clear, Padden, and Shepherd lakes, a private lake in Spokane County, and a public lake in Skagit County were supplied with 400 fish in 1893. The shipments in 1895 consisted of 625 fish, deposited in Loon, Cavanaugh, Silver, St. Clair, Welty, and Clear lakes, the aggregate plants in Washington being 5,442.

In the Boise River, near Boise, Idaho, 1,597 yearling large-mouth bass were planted by the United States Fish Commission in November, 1892.

In 1888 the Nevada fish commission exchanged 30,000 young eastern brook trout for small-mouth black bass, the other party to the transaction being the Spring Valley Water Company of San Francisco. The number of bass received is not stated in the official report, but it probably amounted to several thousand. Some were planted in Carson River and Washoe Lake, and about 1,000 were placed in a private reservoir near Carson.

The noteworthy results attending the planting of black bass in Utah warrant reference, although the general discussion of fish acclimatization in that State is not considered in this paper. In September, 1890, the United States Fish Commission delivered 300 yearling large-mouth bass to Mr. A. M. Musser, the State fish commissioner, by whom they were placed in Weber River, near Ogden. At the same time 1,418 yearlings were planted in Utah Lake, at Battle Creek. In 1893 two lots of 25 fish each were supplied to applicants in Salt Lake City.

RANGE AND ABUNDANCE IN PACIFIC STATES.

With very few exceptions, the black bass have survived and multiplied in all the waters in California in which they were planted, so that they have become one of the most widely distributed game fishes of the State. The State fish commissioners have refrained from depositing fry or yearling bass in waters already stocked with salmon or trout, but have restricted the distribution to lakes, reservoirs, ponds, and rivers in which the predaceous bass could do no damage. It seems only a question of time, however, when the bass will naturally find their way into and become abundant in all those rivers in which they have not already been planted.

Very prompt results attended the planting in Napa and Alameda creeks in 1874. In their report for 1874–75 the California commissioners stated that during the latter year black bass had been caught in Napa Creek and that large numbers of young had been observed. The fish planted in Alameda Creek were said to have been seen, but none had been taken. The report for 1876–77 stated that the fish had increased; that many had been caught, and that by June, 1878, the young could be taken for stocking other streams. The next biennial report (for 1878–79) records the probable extinction by anglers of the fish put in Napa Creek, none having been caught in the two years named.

The adult bass placed in the reservoir in San Mateo County in 1879 rapidly increased, and in 1880 the State commissioners hoped in another year to take the young for distribution. Fish imported by the Sportsmen's Club of San Francisco about the same time and placed in a lake in Alameda County had also increased and were subsequently utilized in stocking other waters. The San Mateo County reservoir served as the principal source of supply for the State commission until 1894, since which time the young for distribution have been mostly taken from the Russian River.

In the *American Angler* for April 9, 1887, Mr. Charles Kaeding records the arrival at San Francisco on March 2 of the first black bass from the Russian River. The fish was taken at Guerneville and weighed 2¼ pounds. By 1889 or 1890 the Russian River had become well supplied, although the California authorities stated that up to that time not many public waters had been stocked. Numerous applications for bass were made to the State commission in 1890, and over 800 yearlings were obtained for planting from waters that had been previously stocked. The abundance of the fish in Russian River was attested by the large number of yearlings taken for distribution in 1894 and 1895 from the overflow waters of that stream, the aggregate collections being 35,000. Large numbers of young fish were seen in the river itself in 1895. Mr. Babcock believes the stocking of the Russian River was done by private parties, as there is no record of plants made in that stream under State auspices.

In their report for 1893–94, the California commissioners said that they could quote from many letters showing the most remarkable growth of black bass in streams and lakes which had never before been stocked. Besides the numerous closed waters in which the fish are found, the following rivers, in addition to the Russian, are also stocked: Tule River, headwaters of the American River, headwaters of the San Joaquin River. A few have also been reported from the Sacramento River at Colusa. Jordan and Gilbert record the small-mouth bass from Clear Lake.

Mr. Fletcher, deputy of the California fish commission, reports that black bass are doing very well in Lake Cuyamaca, and that a great many have been taken in the last two years. Mr. J. E. Friend, of San Diego, who passed some weeks on the lake in the latter part of 1895, took 3 large-mouth black bass weighing 2½ to 3½ pounds each.

Regarding the outcome of the plants of bass in Washington waters, Mr. Alexander reports that as far as he has been able to learn nearly all the bass are thriving and are in a fair way to soon become plentiful enough to give the anglers sport and supply many tables with food.

Clear Lake, 14 miles from Spokane, is one of the waters in which the United States Fish Commission has deposited bass, plants being made in 1892 and 1895. In August, 1895, Mr. William Barnum, of the Commission, visited this lake and found the fish abundant. Silver Lake, about 2 miles distant, has also been successfully stocked, and bass were numerous in 1895. Otter Lake, a small lake in the vicinity, was privately stocked with fish from Clear and Silver lakes in 1894. The question of stocking Medical Lake with bass from Clear Lake has been under discussion for some time, and several plants of fish have been made. The peculiar character of the water in Medical Lake, however, is thought by some to militate against the success of the experiment. King Lake, near Medical Lake, has also been planted with bass from one of the neighboring lakes. In 1895 black bass were reported abundant in Loon and Washington lakes.

No information as to the outcome of planting bass in Nevada has been received since 1892. Up to that time the fishermen of Carson River and Washoe Lake had taken no fish, according to the State fish commissioner's report.

Mr. W. H. Ridenbaugh, of Boise, Idaho, has a pond connected with the Boise River, 1½ acres in extent, in which large-mouth bass are abundant. Another pond of 2½ acres was drawn off in 1892, and 2,240 bass, averaging half a pound each, were placed in the Boise River. No fishing has as yet been done in the river, and it is not known how the fish are flourishing. The eventual stocking of the Snake and Columbia rivers from this stream is not improbable. Mr. Ridenbaugh has never heard of any bass being caught by anglers or in any other way in the Boise River. He has watched for them in the irrigation ditches, especially after a break, when the water was low, but has never seen one, and is inclined to believe that the fish have gone down the Boise River into the Snake River. The latter is sluggish and deep in places, and apparently well suited to bass. Mr. Ridenbaugh thinks it will one day be a great bass stream.

Under date of December 21, 1895, Mr. Ridenbaugh informs the Commission that his first stock of black bass was obtained in St. Joseph, Mo., and shipped to Boise by express. The lot consisted of 50 fish about 6 inches long. These were placed in his smaller pond eight years ago, and during the last four years he has caught annually about 60 fish, weighing 1 to 1½ pounds. The larger pond was stocked with small fish from this pond and with bass received from the United States Fish Commission.

Large-mouth black bass are now exceedingly abundant in Utah Lake, Utah, the lake having been stocked by the single plant in 1890. The economic result of this successful introduction is more important than in any other State.

The large-mouth bass reaches a greater weight than the other species; in the Great Lakes, Mississippi Valley and Eastern States, the maximum is about 8 pounds, but in the warm southern waters a weight of 15 or more pounds is attained. The maximum weight of the small-mouth form is about 5 pounds.

As yet there is little occasion on the part of fishermen and anglers in the Western States to know the characters distinguishing the two species of basses, since only one of them has been planted in a given locality; but as the fish receive a wider distribution by natural and artificial means the two kinds will in time be sometimes found in

the same waters, and it will often be a matter of interest to anglers and others to learn which fish has been caught. The color markings and the general appearance of the two basses are usually sufficient to distinguish the species, as the accompanying figures will show, but the most satisfactory and conclusive feature by which they may be separated, whatever the age or condition of the specimens, is the number of rows of scales on the side of the head. In the large-mouth bass the scales are relatively large and in about 10 transverse rows, while in the small-mouth species these scales are quite minute and in about 17 rows.

FISHING FOR BLACK BASS.

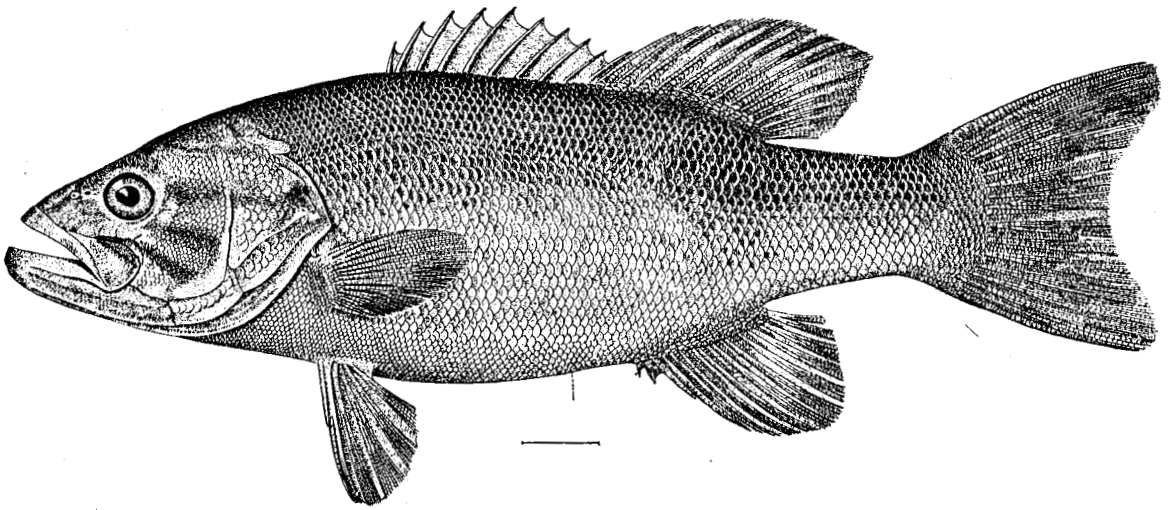
In California the black bass is not a commercial fish. It is seldom, if ever, seen in the markets of San Francisco or other large cities, and when exposed for sale is usually an indication of a violation of law on the part of some fisherman.

The only legal method of taking bass in California is with hook and line. A favorite fishing-ground is the reservoir of the Spring Valley Water Company in San Mateo County, where fishing is by permit, and only 20 bass are allowed to be caught at one time by one person. Mr. Alexander reports that the guests at the Hotel del Monte, Monterey, are permitted to fish in the lake and reservoir in the hotel grounds. The catch is limited to 12 fish to a rod. Bass a foot in length have been taken in the lake, and some 18 inches long have been caught in the reservoir at Thermalito.

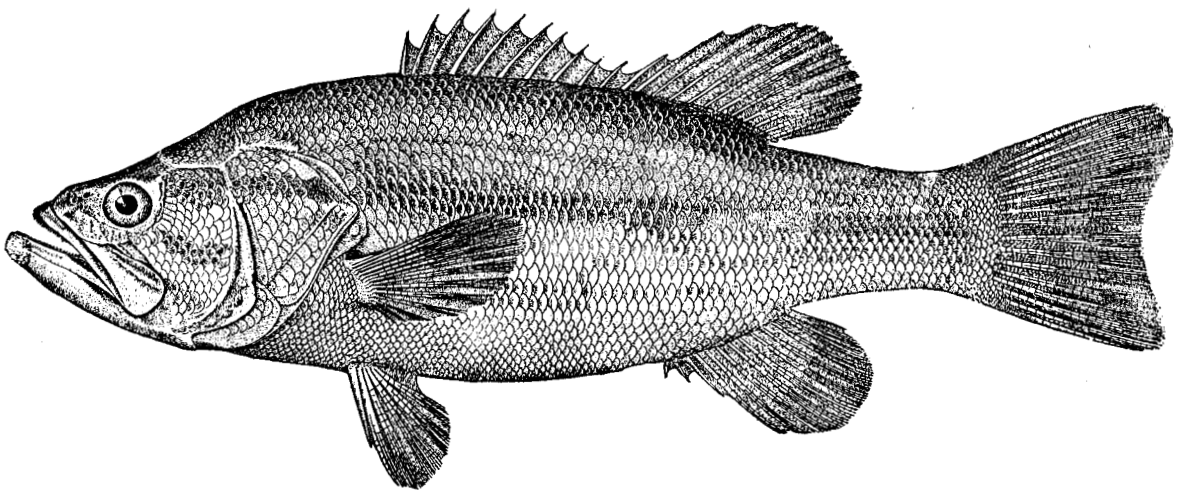
Some bass angling has been done in the Russian River, where the fish are abundant, but it is said the fishing is not good. Considerable illegal fishing has from time to time been reported in this river. Mr. Alexander states that several fishermen with drag seines made comparatively large hauls in 1894, much to the indignation of the State authorities and the people in the vicinity. In July, 1894, arrests were made and conviction had for using dynamite to kill bass. Several hundred bass were found floating in the river after the explosion of a submerged charge of powder, and dead fish are said to have lined the sides of the river and caused a strong stench for some time.

The bass in Clear Lake and other lakes near Spokane, Wash., afford fine sport to anglers. The fish usually weigh 1 to 1½ pounds. Minnows are used for bait, and even dead or mutilated ones will prove attractive lures. The black bass sold in the Spokane markets are taken in Silver and Clear lakes with hook and line, no netting being permitted. Mr. E. Michael, a fish-dealer of Spokane, reports that he pays the fishermen 12½ cents a pound for bass and retails them at 15 to 17 cents a pound. He handles about 150 pounds a week during a season of about 10 weeks.

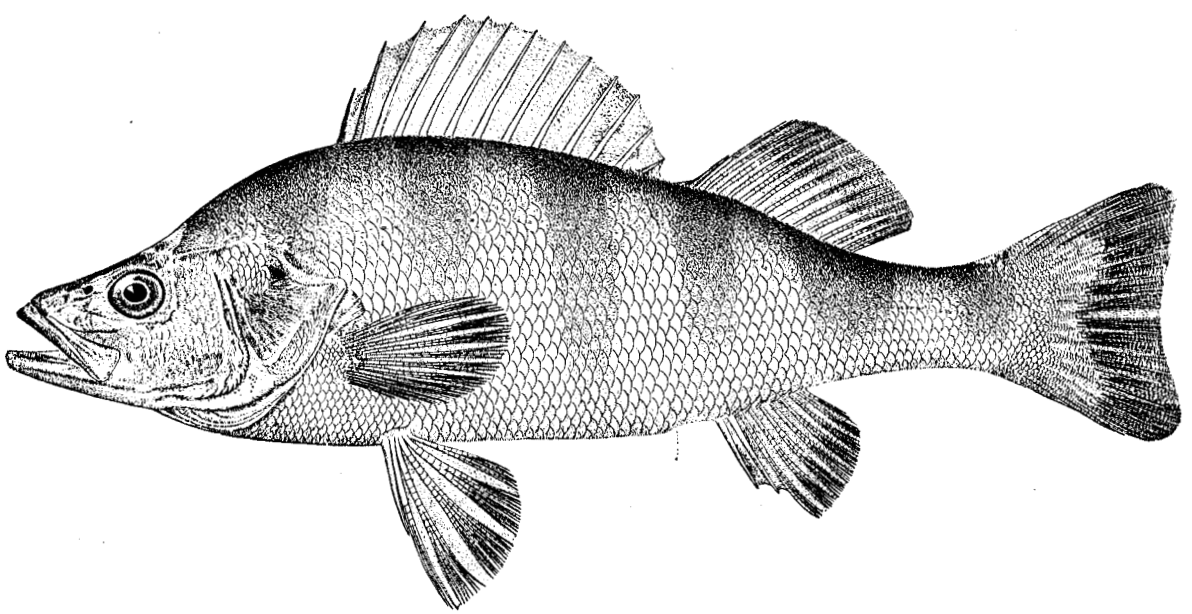
In Utah Lake, Utah, the large-mouth black bass has become a fish of considerable commercial value. In 1895 Mr. William Barnum, of the United States Fish Commission, learned at Salt Lake City that one dealer in that place was receiving about 500 pounds a week from Utah Lake. The fish are very highly esteemed, and retail readily at 20 cents a pound. The usual weight of the fish taken for market in Utah Lake is 1 to 1½ pounds, but a few specimens weigh 3 to 4 pounds. A fish weighing 4½ pounds is recorded. The bass is said to be the only high-priced fish used by the Chinese, who are very fond of it. The *Deseret Evening News* of September 26, 1895, reported that 12,000 pounds of bass had already been taken that season from Utah Lake. The report of the Utah commissioner for 1894–95 states that 60,000 pounds of black bass were caught in Utah Lake in those years, most of the fish being shipped to Colorado. Fishing is done with lines.



SMALL-MOUTH BLACK BASS (*Micropterus dolomieu*).



LARGE-MOUTH BLACK BASS (*Micropterus salmoides*).



YELLOW PERCH OR RINGED PERCH (*Perca flavescens*).

THE YELLOW PERCH.

The yellow or ringed perch (*Perca flavescens*) is one of the most important food-fishes of the Middle Atlantic States and the Great Lakes. It is also of considerable economic value in the Mississippi Valley. Its average weight is under 1 pound, but under favorable conditions it sometimes reaches a weight of several pounds. The annual output in the coast and lake States is worth over $250,000. Attempts have been made by the United States Fish Commission to acclimatize this fish in California, Washington, and Idaho, in lakes, rivers, and ponds. The results of the plants, which aggregated 7,830 yearling fish, have not been reported to the Fish Commission, with two exceptions.

In December, 1891, 3,000 yearling yellow perch were placed in the Feather River, in Butte County, Cal., and 3,980 yearlings in Lake Cuyamaca, near San Diego, Cal. This fish seems to have been successfully introduced into Lake Cuyamaca. Mr. Fletcher, of the California fish commission, reports that large numbers have been taken by anglers; specimens obtained by him have been identified by Dr. Jordan.

Some plants of yearlings were made in Washington in 1890, 1891, and 1895. In the first-named year 25 were deposited in Loon Lake and 30 in Lake Colville; in 1891, 500 more were put in Loon Lake; and in 1895, 200 were planted in South Palouse River, 50 in Loon Lake, 100 in Lake St. Clair near Tacoma, and 100 in Silver Lake.

Mr. J. A. Borden, of Spokane, who had caught yellow perch in the Potomac River, states that these fish are plentiful in Loon Lake. Mr. E. Michael, one of the principal fish-dealers in Spokane, handles yellow perch and reports that they sell well.

Newman Lake, in Idaho, received 200 fish, and private ponds near Hauser and Shoshone, in the same State, 200 more, in 1895.

In 1873 Mr. Livingston Stone attempted the introduction of yellow perch into California. His ill-fated aquarium car contained 110 specimens of this fish from the Missisquoi River, Vermont. The attempt seems to have elicited some criticism, to which the following letter of Mr. Stone, in the issue of *Forest and Stream* for March 19, 1874, was a reply. It appeared under the title, "Is the yellow perch a good fish to introduce into California?" and may be appropriately quoted in view of the subsequent successful planting of the species, as just mentioned:

I should like to ask those who are so horror-struck at the prospect of introducing yellow perch (*Perca flavescens*) into the State of California whether they suppose that any given fish is the same in quality all over the world, or that the yellow perch is a poor fish everywhere because it happens to be where they have known it. If they do, I advise them to take what spare time they have and read themselves up in natural history. They will then find that it is one of the most common facts of natural history that fish, as well as food and fur-yielding animals, vary almost indefinitely in quality with their habitat. Why does not the fur of the California mink bring as much as that of a Labrador or Lake Superior mink? The reason is obvious. The climate of California does not produce such good fur as the climate of Labrador or Lake Superior, even on the same animals. It is exactly the same with fish. Different climates, and especially different waters, produce fish of entirely different qualities, though of the same variety. The bass of our southern waters is not the same as the bass of Saratoga Lake and Lake Champlain, but a far inferior fish. So with the yellow perch. In some warm waters it is a poor fish enough, but it is not so in the cold, pure lakes of New England or northeastern New York. I will agree with my friend Mr. Mather, if he insists upon it, that the yellow perch he is acquainted with is a miserable fish and not fit to take to California. But the yellow perch of Saratoga Lake and Lake Champlain and Monadnock Lake, in New Hampshire, is an entirely different thing. Mr. Mather must come and eat some of them before he puts them down so summarily. If he will, I have no doubt that he will also agree with me that the yellow perch of these localities is a very sweet, firm, and excellent fish when in season. I am sure if he should eat some Saratoga Lake perch off the table of my friend Mr. Moon, that he would say that the yellow

perch is about as good a fish as he had ever eaten. Anyone who is in the habit of going to Saratoga Lake knows Mr. C. B. Moon, of the Saratoga Lake House, the reputation of whose game and fish dinners is world-wide, and no one who is acquainted with Mr. Moon can have a shadow of a doubt that he is an unimpeachable judge of the qualities of game and fish. I wrote to Mr. Moon for the purpose of getting his opinion on the merits of the yellow perch, and he sent me the following reply:

"Your letter is arrived making inquiries in regard to the yellow perch. I use a large quantity of these fish every season. I consider them a most excellent fish indeed. Many of my customers at the lake give them the preference above all other fresh-water fish on account of their sweetness and flavor. They increase rapidly when introduced into good waters, and I am sure they would be a hardy fish to ship, and any section of the country might well feel glad to have them introduced."

Now as to the actual charges against the yellow perch, that they are "bony and predaceous." I say, What of that? The shad is very bony, but a capital fish nevertheless. The brook trout is more predaceous than the perch, but he is the king of fresh-water fish nevertheless. Saying that the perch is bony and predaceous does not make out a case against him. The question is whether these disadvantages affect his good qualities. I think very decidedly that they do not. I reaffirm that the yellow perch of northern and northeastern waters is a very sweet and excellent fish when in good condition, and people must call them worse names than bony and predaceous before they can put them down.

Besides possessing edible qualities of an excellent character, the yellow perch has other merits. It is a hardy fish and can probably be introduced successfully where other fish would fail. It is very prolific also. Not but that other fish are equally so, but the eggs of the yellow perch will hatch under circumstances that would be fatal to other eggs, so that the perch is in consequence practically more prolific than other fish. It is also exceedingly easy to hatch the spawn of yellow perch artificially, which is another advantage.

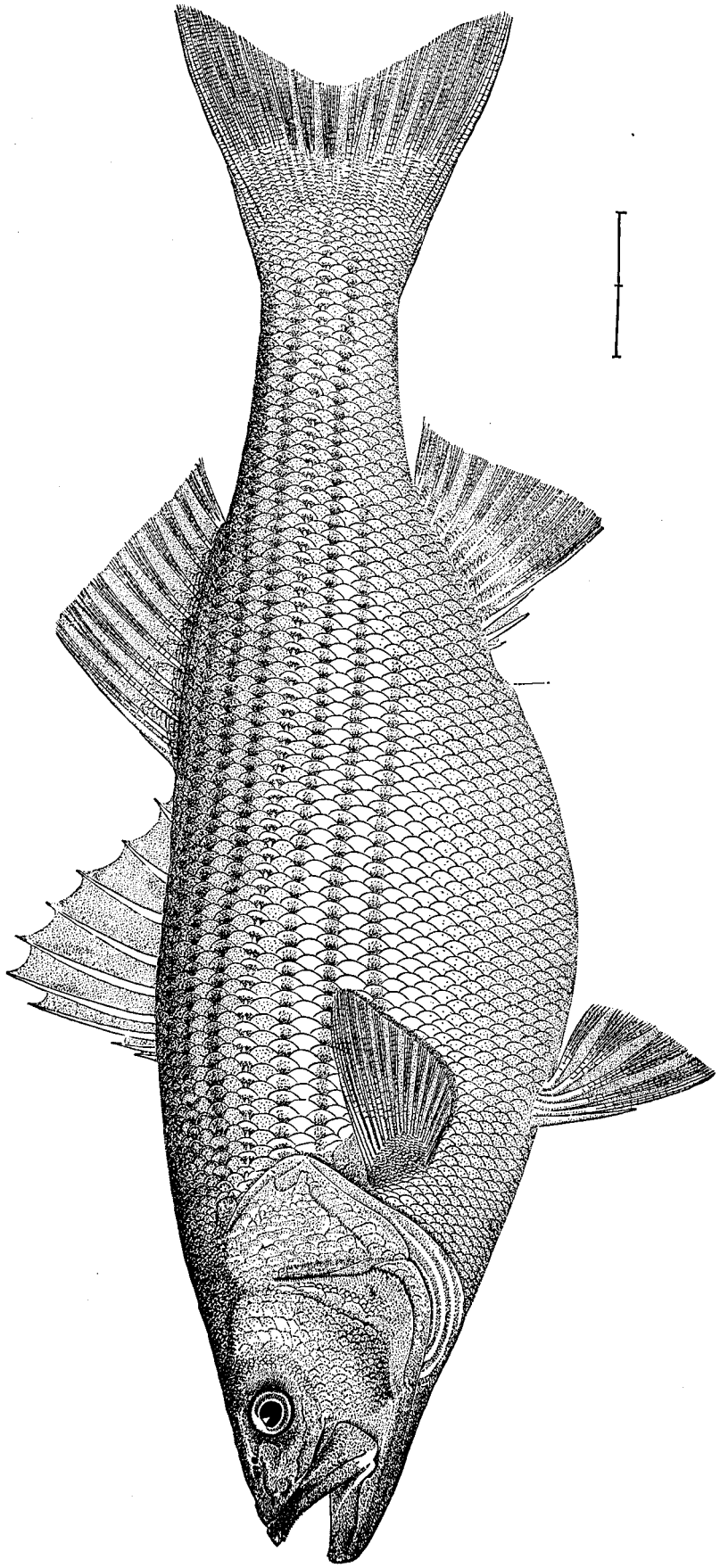
If this is not a sufficient vindication of the attempt (which, by the way, I would have it understood, had the full sanction of the California fish commission) to introduce the yellow perch into the waters of the Pacific Slope, let me add that it is at all events far preferable to most of the fish at present existing in the fresh waters of California, and even if it destroyed four-fifths of the other fish there it would replace them by a better kind.

For instance, the fish of Clear Lake are (I give the local names, for I do not yet know the scientific names) the California salmon trout, white perch, shapaulle, hitch, suckers, chy, roach, spotted sunfish, mudfish (mud suckers), blackfish, trout, bullheads, viviparous perch. The fish of the Sacramento River are trout, salmon, chubs, perch, hardheads, Sacramento pike, viviparous perch, split-tails, suckers, herrings, sturgeon, crabs, lamprey eels. The varieties of these two localities comprise most of the fresh-water fishes of northern and central California, and I think it safe to say, with the exception of the salmon, trout, and possibly the viviparous perch and blackfish, which latter is quite rare, that there is not one of these fish that is superior to the yellow perch of New England and northern New York, which it was proposed to take to California.

THE WALL-EYED PIKE OR PIKE PERCH.

In 1874 Mr. Livingston Stone transported sixteen full-grown wall-eyed pike or "glass-eyed perch" (*Stizostedion vitreum*) from the Missisquoi River, Vermont, to California, where they were deposited June 12 in the Sacramento River opposite Sacramento City. There has been no report of the survival, capture, or multiplication of these fish, with the exception of the taking of a single specimen in a slough of the Sacramento River, mentioned in the fish commissioners' report for 1874–75.

The California fish commission has been desirous of securing a large consignment of wall-eyed pike from the United States Fish Commission for introduction into certain lakes and ponds of the State, and a shipment will probably soon be made from Lake Erie. This is one of the best food-fishes of the Great Lakes, and would doubtless readily become acclimatized in some of the shallower and warmer waters of California. In the Great Lakes, it is most abundant and important in Lake Erie, the shoalest and warmest member of the system. Its maximum weight is fully 30 pounds, but the average of those taken in the Great Lakes is from 5 to 10 pounds.



STRIPED BASS (*Roccus lineatus*).

THE STRIPED BASS.

HISTORY AND RESULTS OF INTRODUCTION.

The striped bass (*Roccus lineatus*) was first introduced into the waters of the Pacific Slope in 1879, at the same time that a consignment of eastern lobsters was taken across the continent. The acclimatization of this species was undertaken at the suggestion of Mr. S. R. Throckmorton, then chairman of the California fish commission. In a letter* to Professor Baird, recounting the history of the experiment, he says:

I have long had the impression that the great bay of San Francisco, together with the bays of San Pablo and Suisun connecting with it and the number of creeks running into them, affording a variety of qualities and conditions regarding temperature and saline properties, together with feeding material, would be well adapted to the propagation and growth of striped bass.

In July, 1879, Mr. Livingston Stone, of the United States Fish Commission, made a collection of living striped bass in the Navesink River, New Jersey, for transportation to California. He obtained 132 fish from 1½ to 3 inches long and 30 medium-sized specimens. Twenty-five of these died during transportation and several were thrown away, but the remainder, about 135, reached California in good condition and were deposited in Karquines Strait, at Martinez.

The second and only other plant of striped bass in California waters was made in 1882, when Mr. J. G. Woodbury, of the California fish commission, carried about 300 fish, 5 to 9 inches long, from the Shrewsbury River, New Jersey, to Suisun Bay, where they were deposited at Army Point, about 3 miles from the preceding plant.

The results attending the attempted introduction of striped bass in California have been most remarkable, considering the very meager plants. While the second deposit of young fish undoubtedly added to the supply, the fish, in the three years intervening between the two experiments, had already gained a foothold, as the following data will show. The California authorities, however, were not certain that the fish had become sufficiently acclimatized or that enough of them had survived to insure the perpetuation of the supply.

Mr. Throckmorton, in the letter to Professor Baird before referred to, records the capture of striped bass in 1880, as follows:

Some six or seven months after the time of placing them in the water, I heard that one of 8 inches in length had been taken in the Bay of Monterey, which is about 100 miles south of this, and is an open roadstead on the Pacific Ocean. All of the circumstances were of so doubtful a character that I gave the rumor but little attention, until about the 1st of July, eleven months after the planting of the young fry, at the time about 1½ inches in length, in the Straits of Karquines, there was brought to me a very handsome striped bass taken in this harbor, measuring 12½ inches in length and weighing 1 pound. The fish was in the highest condition, the milt full and ripe, and the flavor fully up to the best specimens of the fish at the East. The exceedingly rapid growth indicates the adaptability of the waters of this bay to its development.

In their report for 1880, the California commissioners give some additional notes on the occurrence of the fish:

The 150 striped bass brought in 1879 and placed in the waters of the Straits of Karquines are probably increasing. One of these fish was caught in the bay near Sausalito and brought to market and identified. We have heard of a few others having been captured at Monterey and near Alameda.

* Bull. U. S. Fish Commission, 1881, pp. 61–62.

Subsequent reports of the California commission contain a number of references to the presence and capture of striped bass. The following extracts may be given as bearing on the growth, distribution, and multiplication of the fish:

Striped bass have been taken in the Bay of San Francisco weighing 4 pounds, and one taken in the Bay of Monterey in September, 1883, weighed nearly 17 pounds. It will be some time before striped bass will be very plentiful, as the immense area in which they travel will have to be well stocked before any one place would have any considerable numbers for the fishermen to work upon. In October, 1883, one was caught in the Sacramento River weighing 16 pounds. This and other catches are strong evidence that the striped bass will propagate in our waters. March 3, 1884, a striped bass weighing 4 pounds was for sale in a San Francisco market. March 11 there was one offered for sale that weighed 18½ pounds. (Report for 1883-84.)

Quite a number have been caught from year to year, increasing in weight every year. Last year several were caught weighing over 20 pounds, and during the past winter one was caught weighing 35 pounds. I have been watching for the young fish, the progeny of those brought out in 1882, and during the past spring I heard that they were being caught by the thousands and offered for sale in the market. I hurriedly went up to the market to see if it were true. I found there a lot still unsold, averaging from a half to three-quarters of a pound in weight. I was delighted to see them, knowing that those brought out from New Jersey must have kept together in the muddy waters of our bay till they matured and spawned and their young had been successfully reared. But, knowing that the young striped bass run in schools, I became alarmed lest the many Chinese nets in our bay and the lower Sacramento and San Joaquin rivers would soon destroy the greater part of them. I immediately visited the newspapers and they kindly published a notice of the arrival of the numerous strangers, of their great importance, and the danger of their destruction if they were not protected. Your honorable board petitioned the board of supervisors to pass an ordinance to prohibit catching them under 8 pounds in weight. This they quickly did. A similar petition would be advisable to the boards of supervisors of Marin, Sonoma, Solano, Contra Costa, Alameda, San Joaquin, and Sacramento counties. The young bass will most certainly visit the waters of all these counties, and their protection for a few years is of vital importance.

I have since learned from the marketmen that from three to four thousand of these fish were sold in the market before the ordinance was passed, and that it has since been in the newspapers that these fish have been caught and sold in other counties around our bay. The arrival of so many young of this fish at one time in our markets shows conclusively that the striped bass have successfully reproduced themselves in our waters. (Report of superintendent of hatcheries, in report for 1888-90.)

DISTRIBUTION OF STRIPED BASS.

The known range of this fish in the Pacific States includes only California. It has distributed itself so widely on the California coast, however, that its occurrence in Oregon and even Washington waters is probably only a question of time, supposing that it does not already occur there.

The center of the fish's abundance is San Francisco Bay and its tributaries. It is found all over San Francisco Bay, Suisun Bay, San Pablo Bay, and the lower course of the Sacramento and San Joaquin rivers. The bass regularly ascends the San Joaquin River for a distance of 20 miles above Bouldin Island. During a visit to the upper San Joaquin, in November, 1895, Mr. Babcock learned that a catfish fisherman at Grayson, about 100 miles above the mouth of the river, had for two years been taking a number of 1-pound and 2-pound striped bass in a slough near that place. They go up the Sacramento River as far as Sacramento, but were not common at that point at last reports. In 1893 Mr. Alexander learned of their capture near Fremont, about 7 miles above Sacramento.

On May 30, 1894, in Suisun Bay Slough, a number of bass weighing 4 pounds and upward were taken with minnow bait on a regular angling rod. Several examined contained anchovies and file worms. This is a new locality for the fish, although several years ago they were reported to occur there.

In Tomales Bay the fish occur sparingly. According to Mr. Babcock, of the California fish commission, they are quite numerous in Creamery Slough, a very small slough between Tomales Bay and Russian River. The water is made extremely salt by evaporation, and no other salt-water fish of commercial importance are found in it.

In Russian River the striped bass is now plentiful. It made its appearance there about 1890. In that year a 6-pound fish was taken on a hook baited with a minnow, and in 1891 the salmon gill-net fishermen began to catch the fish. One weighing 16 pounds has been taken by them within a few years. The species ascends the Russian River a distance of 20 miles, to Guerneville.

The striped bass is found regularly but not abundantly in Monterey Bay. At Monterey a half-pound specimen was taken by the *Albatross* in 1890, which was supposed by Mr. Charles H. Townsend* to have been the first caught south of the Golden Gate. As early as 1880, however, they had been reported from that locality. In 1893 only one was taken at Santa Cruz, according to Mr. Alexander's inquiries. In that year the first striped bass were taken by Capitola fishermen.

Until 1894 the striped bass was not known to range south of Monterey Bay. In September of that year, however, two were taken in a seine at Redondo Beach, Los Angeles County, thus extending their distribution about 360 miles, following the coast line. Each weighed about 6 pounds.

Reports of a more extended coastwise range of the striped bass than that assigned have been made. In April, 1887, in a letter to Professor Baird, Mr. Horace D. Dunn, of San Francisco, stated that he was informed that these fish had been taken at places as widely separated as San Diego and the Oregon line.† In the report of the California fish commissioners for 1883–84 it is said "bass have been taken as far north as British Columbia." While there is no reason why this fish should not be found as far north and south as the points given, no records of its capture, except as before stated, are available, and the inquiries of the agents of the United States Fish Commission, covering the years 1888 to 1894, inclusive, failed to disclose the occurrence of striped bass as far south as San Diego or north of California.

MIGRATIONS, MOVEMENTS, SCHOOLING, ETC., OF THE STRIPED BASS.

Although striped bass may be taken in the waters between San Francisco and the Sacramento delta at any time during the year, they are more abundant in certain months than in others, and there is no doubt that the migratory habits which characterize the fish in its native waters have not been entirely lost on the Pacific Coast. They are sometimes observed schooling in and off the mouths of sloughs. A dozen or more may often be noticed playing and circling near an eddy. At times, Mr. Alexander says, they will hover persistently about places where two strong currents meet, to the discomfiture of the fishermen, whose nets are liable to injury if set in such places. They often go in large schools. In referring to their abundance, mention is made of the presence of a numerous body of fish on the Berkeley Flats, in San Francisco Bay, in June, 1894, and in the San Joaquin River in December, 1893.

The bass seem to prefer the waters of the San Joaquin to those of the Sacramento, the former being warmer and clearer. The water in the sloughs that connect the two rivers all flows from the Sacramento into the San Joaquin. Striped bass are scarce in the Sacramento, and some of the salmon fishermen of that stream have never caught them. Salmon are much more plentiful in the Sacramento than in the San

* *Forest and Stream* May 8, 1890.

† Bull. U. S. Fish Com. 1887, p. 50.

Joaquin. Nearly all of the fish which begin the ascent of the latter stream finally get into the Sacramento by way of the sloughs.

Mr. Alexander could learn of the capture of no striped bass distant from the California shores. The fish seems to follow the coast closely. If it wandered far to sea, either in schools or in scattered bodies, the fishermen would probably soon know of it, as hundreds of trammel nets are set in the open waters off the Golden Gate. The felucca fishermen who resort to the grounds around the Farallone Islands, about 30 miles offshore, have never reported striped bass in that vicinity.

SPAWNING SEASON AND GROUNDS.

The observations thus far made on the spawning of the striped bass in California waters are not conclusive, but what has been determined indicates a protracted spawning period such as characterizes the shad in the same region. The inquiries of Mr. Alexander and the testimony of dealers and fishermen seem to show that the principal spawning time is from April to June; but Mr. Babcock, of the California fish commission, who has devoted considerable attention to this fish, has found striped bass in the San Francisco markets containing ripe spawn in each month between December and May. On May 26, 1894, he examined a large fish with fully matured ova, and during the same month the writer saw a number of specimens, in the San Francisco markets, from which the eggs were running.

The delta of the Sacramento and San Joaquin rivers undoubtedly includes the principal breeding-grounds of the striped bass. The tule waters, the sloughs, and the lagoons are well adapted to the fish. In the tule waters, to which reference was made in treating of the shad, striped bass are found at all seasons and are generally believed to be there for the purpose of spawning. At Jersey Landing, on the lower San Joaquin River, the fishermen find bass nine months in the year and always get more fish there than in the united stream below Black Diamond.

Small striped bass 4 to 5 inches long are frequently caught in drag seines in and off the mouths of sloughs, and Chinamen also catch them in their fyke nets, according to Mr. Alexander.

The California fish commissioners, in their report for 1891–92, state that the striped bass should be protected while on their spawning-grounds and that their capture under 2 pounds in weight should be prohibited.

ABUNDANCE OF THE STRIPED BASS.

The increase in the abundance of the striped bass in San Francisco Bay and tributaries has been uninterrupted and rapid. While the fish is far less numerous than the shad and will probably never rival that species in abundance, the appearances are that in a few years the supply will exceed the demand. Between 1889 and 1892 the yield of striped bass in California increased 250 per cent. In 1893 the quantity handled by the San Francisco dealers was 5 times greater than the entire catch of the State in 1889 and 1½ times greater than the total output in 1892. In 1894 the receipts of the dealers were over 80 per cent greater than in the previous year.

An idea of the abundance of the fish may be gained from the following statement communicated by Mr. Babcock: On June 19, 1894, the fishermen struck a school of striped bass on the Berkeley Flats in San Francisco Bay; on June 20 one boat caught 1,500 fish and the other boats made large hauls. These fish weighed on an average 6

pounds apiece. The fishermen reported that until two weeks before that time not a great many bass had been taken in the bay. It is doubtful if in recent years at any point on the Atlantic Coast so large a catch of striped bass—9,000 pounds—has been taken by one boat in one day's fishing. The great abundance of striped bass at that time led Mr. Babcock to think that in ten years they would equal the shad in numbers.

Another illustration of their abundance may be given. Between December 15 and 25, 1893, Mr. William Crane, of Bouldin Island, on the San Joaquin River, and another fisherman using a seine caught and shipped to San Francisco 6,000 pounds of striped bass. These fish were taken in San Joaquin, Middle, and Old rivers.

WEIGHT OF STRIPED BASS.

The average weight of the striped bass now caught for market in California is between 10 and 12 pounds; those weighing 15, 18, and 20 pounds are common; many weighing 20 to 30 pounds are found, and larger fish are sometimes taken. A very careful examination of the receipt books of the San Francisco dealers made by the writer in May, 1894, yielded accurate data and disclosed the capture of some larger fish than had previously been recorded. The average weight of 1,461 fish was found to be 11 pounds, as shown by the following detailed statement, by months, for 1893 and part of 1894, giving the number of fish on the dealers' books whose weights were entered:

Table showing by months the average weights of 1,461 striped bass handled by San Francisco dealers.

1893.	Number of fish.	Total weight.	Average weight.	1894.	Number of fish.	Total weight.	Average weight.
		Pounds.	*Pounds.*			*Pounds.*	*Pounds.*
January	35	253	7	January	143	1,456	10
February	45	338	7½	February	31	334	10⅝
March	151	1,219	8	March	10	114	11⅜
April	50	648	13	April	29	435	15
May	56	731	13	May	31	435	14
June	1	9	9				
October	22	312	14⅛	Total	244	2,774	11⅜
November	208	2,534	11⅜				
December	649	7,305	11¼	Grand total	1,461	16,123	11
Total	1,217	13,349	11				

The largest striped bass heretofore recorded from California waters weighed 45 pounds. It was taken in San Francisco Bay on June 16, 1889, and was noticed in *Forest and Stream* of July 11, 1889. In the issue of the same paper for November 20, 1890, mention is made of the capture of a striped bass of 40 pounds' weight, and reports of others of similar size have been received. In May, 1893, one was sold in San Francisco that weighed 49 pounds, which is the largest reported up to this time. There is no reason to doubt, however, that the California striped bass will attain the size reached on the Atlantic Coast—over 100 pounds.

Comparatively few of the striped bass shown in the preceding tabulation had their individual weights recorded on the dealers' books, the entries usually being for a number whose aggregate weight only was given. Separate entries for five that weighed over 30 pounds each were found in the records for 1893. These were as follows: May, one weighing 49 pounds; October, one weighing 37 pounds; November, one weighing 40 pounds and one weighing 39 pounds; December, one weighing 32 pounds.

FOOD OF STRIPED BASS.

The introduced carp appears to be the principal food of the striped bass in California, and in the fresh waters is the almost exclusive food. Mr. Babcock has opened hundreds of bass for the purpose of ascertaining the nature of their food, and has never seen any other fish than carp in their stomachs. He has heard, however, of small catfish being found in them. Mr. Alexander's examinations of many bass in the San Francisco market showed that whenever food of any kind was present in the alimentary tract it was in nearly every instance carp. A 10-pound carp is said to have been found in the stomach of one bass. His conclusions are that, taking the season through, carp will be found in the stomachs of 7 out of every 10 bass sold in San Francisco or caught in the rivers.

At Capitola, on Monterey Bay, crabs have been taken from the stomachs of bass, and it is probable that in the salt water a great variety of fish food is ingested.

ORIGIN OF THE STRIPED BASS FISHERY.

It was just ten years after the planting of striped bass in California waters that a special fishery for them was inaugurated. While they had been taken in considerable numbers during the five or six preceding years, it was not until 1889 that the fishermen directed any special effort toward their capture. Even at the present time comparatively few of the many fishermen in the San Francisco Bay region are provided with apparatus specially adapted to the taking of striped bass, but their increasing abundance is yearly resulting in drawing more attention from the fishermen, and it seems only a question of a few seasons when this fishery will have attained considerable magnitude.

THE FISHING-GROUNDS FOR STRIPED BASS.

The striped bass is found in greatest abundance and is taken in largest quantities in the lower part of the San Joaquin River. It abounds in the ponds, marshes, and sloughs connecting with the river, and is there found at nearly all seasons.

According to Mr. John P. Babcock, chief deputy of the California board of fish commissioners—and his opinion is borne out by the testimony of the fishermen—the striped bass appears to remain in the delta of the San Joaquin and Sacramento rivers throughout the year. When the run of salmon begins in the spring, and the waters of Suisun Bay below the mouths of the rivers are filled with salmon nets, only a few striped bass are taken, perhaps not more than one to three daily by the entire fishing force, while at the same time, in the San Joaquin River, at Jersey Landing, Antioch, Bouldin Island, and other places in the lower course of the stream, the salmon fishermen take striped bass at every tide or at every haul of their nets.

The San Joaquin fishermen have found that a northerly wind makes the striped bass more numerous in the main river. The explanation of this phenomenon—which appears to be well recognized—is that the relatively shallow water in the sloughs and ponds is made roily or is too much agitated by the wind, and the fish seek the deeper water of the river.

Striped bass are taken in the Sacramento River, but, as elsewhere mentioned, in much smaller quantities than in the San Joaquin River. Good fishing is at times done between the mouth of the Sacramento River and San Francisco, in Suisun and San Pablo bays, and the northern part of San Francisco Bay.

Mr. Alexander reports that early in fall the fishing is carried on principally in the northern part of San Francisco and Suisun bays, and that as the season advances striped bass gradually move up the river, the fishermen endeavoring as far as possible to keep with them. In the winter the main body of the fish is found in the waters constituting the delta of the Sacramento and San Joaquin rivers. The fishing is at its height between October and February, attaining its maximum in December. The fish appear to be found in larger numbers in San Francisco Bay adjacent to San Francisco in summer than at other times.

In Monterey Bay there are no regular fishing-grounds for striped bass, the few taken being caught only incidentally. At Monterey and Santa Cruz only a small number have ever been obtained. None was taken at the former place and only one at the latter in 1893. More are found at Capitola than elsewhere in the bay. In 1893, which was the first year in which striped bass were caught by the fishermen of that place, 25, weighing 260 pounds, were obtained in a drag seine in September.

APPARATUS AND METHODS EMPLOYED IN CAPTURE OF STRIPED BASS.

In San Francisco Bay and the waters tributary thereto gill nets and purse seines are employed in the capture of striped bass. Drag seines used for other fish and salmon gill nets also take striped bass incidentally.

In 1893 there were 31 regular striped-bass fishermen in California. These used 12 boats, worth $1,400; 24 gill nets, worth $600, and 3 purse seines, worth $450.

The striped-bass gill net is from 60 to 70 fathoms long and 25 to 30 meshes (or about 14 feet) deep. It has a mesh of $6\frac{1}{2}$ or $6\frac{3}{4}$ inches. The cost is about $25.

The purse seine was introduced in 1892, and is said by Mr. Alexander to give satisfaction to the few fishermen who use it. The seine is like a small mackerel seine, being 200 to 225 feet long and 14 feet deep. The cost is $150. The comparatively small size of this seine makes it adapted to use in the sloughs and similar waters where a full-sized purse seine could not well be handled.

The purse-seine fishermen set their seines only when striped bass are visible. As soon as they are observed schooling or playing at the surface, the boats are put in motion and the seine is set. The seine, being small, is quickly set, pursed, and made ready for another trial, and many hauls may be made in the course of a day. Three men usually go in each boat, and sometimes two boats are employed to set a seine, but this is often done from one boat.

When the day's fishing is over, the fishermen take their catch to the nearest steamboat landing or railroad station, most of the fish being shipped by water. Nearly all the steamers plying between Sacramento, Stockton, and San Francisco make numerous stops in the fishing districts and take on board the striped bass, shad, salmon, and other fish that have been brought in. The principal dealers in San Francisco have packing boxes at the different landings, which are used by the fishermen in making their consignments, each dealer usually receiving all the fish caught by certain fishermen. The fish are packed without being cleaned or iced.

ANGLING FOR STRIPED BASS.

The anticipation of fine sport with the striped bass which the California anglers entertained when the successful introduction of the fish was assured has not been fully realized. Up to the present time comparatively few bass have been taken with the rod, and the fish has not evinced the gamy disposition which characterizes it on

the Atlantic Coast. In May, 1890, a 6-pound fish was taken in Russian River with a minnow bait. In May, 1894, some weighing 4 pounds and upward were caught with minnows in Suisun Bay Slough. Other captures might be reported, but the number taken has been out of proportion to the trials made. Whether they do not bite so readily as in its native waters or whether the California fishermen have not used the proper gear, at the proper time, and in the proper places, is not known.

STATISTICS OF THE CATCH OF STRIPED BASS.

Following is a statement of the quantities of striped bass caught and sold by California fishermen in 1889, 1890, 1891, and 1892, as determined by Mr. W. A. Wilcox, field agent of the United States Fish Commission. The values given represent the gross prices received by the fishermen.

Summary of the striped-bass catch of California in 1889, 1890, 1891, and 1892.

Years.	Pounds.	Value.
1889	16,296	$4,073
1890	20,119	4,021
1891	30,674	4,602
1892	56,209	6,488

Complete figures for later years are not available, but the catch for 1893 and 1894 may be approximately determined by the receipts of these fish by the San Francisco dealers. In 1893 the estimated yield of striped bass was 90,000 pounds, valued at $10,000, and in 1894 it was not less than 170,000 pounds, for which the fishermen were paid $16,100.

The aggregate value of the striped bass taken in California up to and including the year 1894 was between $45,000 and $50,000. The practical importance of the introduction of this fish to the Pacific is further emphasized when the foregoing figures are contrasted with the cost of its acclimatization. The entire expense connected with the matter was only a few hundred dollars. The investment now yields an annual return of $15,000 or more, and may be expected to greatly increase from year to year. Few achievements of fish-culture in public waters are comparable to the financial success of this experiment.

FOOD QUALITIES OF THE STRIPED BASS.

The very high price which the striped bass commanded, even after it ceased to be a curiosity in the San Francisco market, is evidence of the esteem in which it is held in California. It is generally regarded as one of the choicest fish of the State, and its addition to the food-fish supply is much appreciated by the public, the fishermen, and dealers. It is in demand throughout California and is consumed along the entire Pacific Coast of the United States and in most of the interior States of the West.

Mr. Babcock furnishes the interesting information that in May, 1895, Mr. J. P. Haller, manager of the Sacramento River Packers' Association, canned several hundred pounds of striped bass as an experiment. The fish were selling at 2 cents a pound at Black Diamond, and 500 to 600 pounds could have been obtained daily from salmon fishermen making Black Diamond their headquarters, while the fishermen above that place took many more fish than the Black Diamond men. The manager reported to Mr. Babcock that he was much pleased with the canned bass; that it was fully equal

to the white Alaska salmon, and that he thought the association would in a year or two make a regular pack of striped bass. Through the courtesy of Mr. Babcock, the writer had an opportunity to sample a can of striped bass and was much pleased with the flavor of the fish as thus prepared.

THE STRIPED BASS TRADE OF SAN FRANCISCO.

Probably seven-eighths or more of the striped bass caught in California are sent to San Francisco, where the larger part of the yield is consumed; but a somewhat important trade in this fish is carried on by the San Francisco dealers with other cities and towns of the West. The wholesale dealers sell to retail dealers, hotels, and restaurants in San Francisco, and make consignments to Oregon, Washington, Utah, Nevada, Arizona, New Mexico, and Mexico, as well as to numerous California towns. The entire striped bass catch reaches the consumer in a fresh condition. The only people who eat the fish salted are the Chinese, and the quantity they consume is not large. Mr. Alexander remarks on this point:

> The Chinese are heavy buyers of striped bass, but they, as a rule, purchase fish inferior in quality, which have lain in the market much longer than they ought. Such fish can be bought comparatively cheap, on an average from 5 to 7 cents a pound. The Chinese method of dressing striped bass which are to be salted is to split them down the back, the head being left on. They are then washed and salted in barrels, where they remain for a week or ten days, at the end of which time they are taken out and dried on flakes or hung on lines arranged on the tops of houses or in back yards. This is the usual way Chinese cure all kinds of fish not eaten fresh.

The inquiries of Mr. Wilcox in 1892 showed that the receipts of striped bass by the San Francisco dealers were about 5,000 pounds in 1890, 25,000 pounds in 1891, and 50,000 pounds in 1892; these figures are based on estimates furnished by the different dealers. Data for 1893 and 1894 were obtained from the books of the dealers by Mr. Babcock, of the California fish commission, and the writer. The actual quantity handled by wholesale dealers was 80,793 pounds in 1893 and 149,997 pounds in 1894. The dealers' receipts, by months, are shown in the following table, which illustrates the times when the fish are most abundant:

Statement of the number of pounds of striped bass handled by San Francisco dealers in 1893 and 1894.

Months.	1893.	1894.
January	3,448	14,177
February	3,087	12,572
March	5,403	9,002
April	8,351	9,638
May	7,232	9,413
June	4,353	4,820
July	2,950	7,521
August	2,655	6,863
September	8,507	10,218
October	6,820	23,192
November	10,473	17,950
December	17,514	24,631
Total	80,793	149,997

PRICES OF STRIPED BASS TO FISHERMEN AND DEALERS.

The prices first paid for striped bass were, like those for shad, very high. Even as late as 1888 the ruling price in the San Francisco market was $1 per pound. By April, 1890, however, on account of the increasing abundance of the fish, the price

dropped to 18 cents a pound and has since ruled lower each year. At times in 1893 and 1894 striped bass could be bought at prices that were within the reach of even the frugal Chinese. Referring to the San Francisco market, Mr. Alexander states:

> In the month of September, which is the close season for salmon, striped bass command a good price, but it is only for a short time, for as soon as salmon begin to appear again the price drops to a low figure. It can not be said that salmon alone causes the price to fall, for it is partly due to striped bass being caught in considerable numbers at that time, and it is a combination of circumstances which makes it possible to buy the fish at most seasons at a reasonable figure.

From 1889 to 1892 the average price received by the fishermen fell from 25 cents to 11½ cents a pound. During 1893 and 1894 the prices received by the San Francisco dealers ranged from 4 to 30 cents a pound, the average price being about 10 cents. The average net price to the fishermen was 2 to 3 cents less.

In December, 1893, when large consignments of bass were received at San Francisco, the prices fell to a very low figure. A dealer who made returns at only 3 cents a pound incurred the great displeasure of the fishermen. On June 21, 1894, the day following the large catch on the Berkeley Flats in San Francisco Bay, the wholesale price in San Francisco was 3½ cents and the retail price 7½ cents a pound.

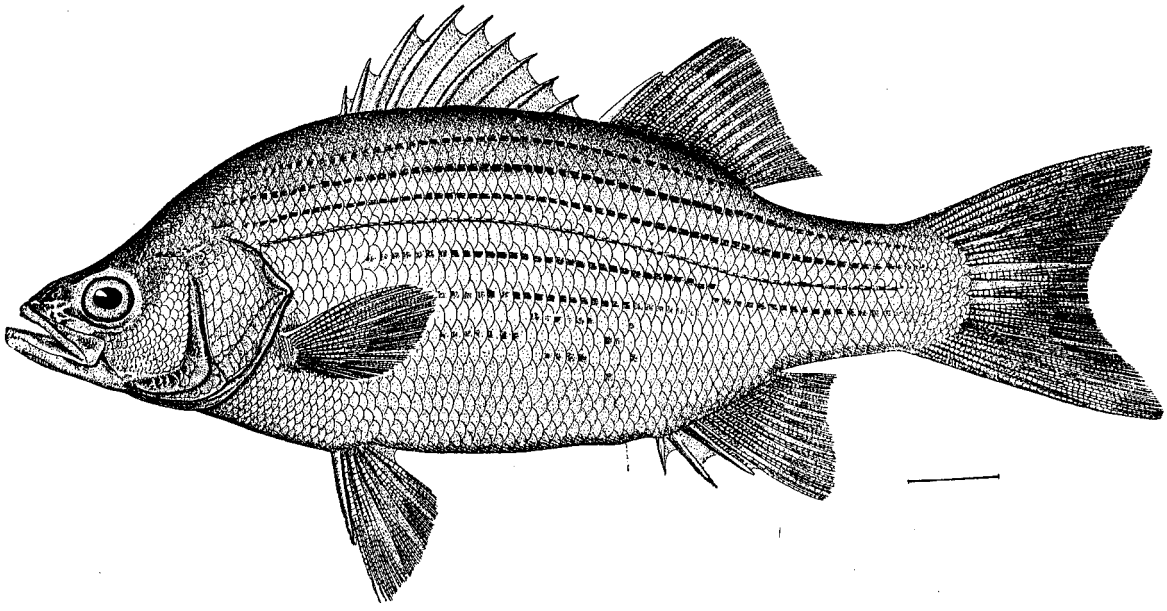
Writing under date of July 24, 1895, Mr. Babcock says that striped bass did not yield the fishermen over 5 cents a pound taking the year through, and that the San Francisco dealers had undersold the New York dealers every month, as shown by the quotations in the *Fishing Gazette*. During November, 1895, the receipts were very heavy, and on November 9 the retail price in San Francisco was only 6 cents a pound.

THE WHITE BASS.

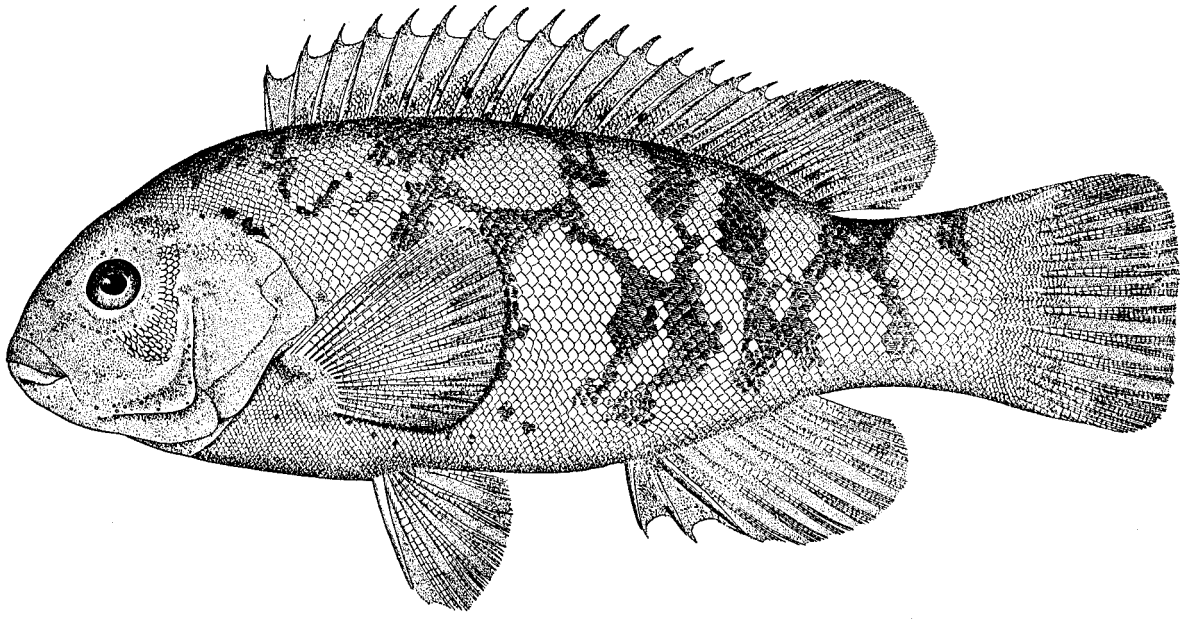
Twelve yearling white bass (*Roccus chrysops*) from Quincy, Ill., were delivered to the California fish commission at Sisson in June, 1895, at the time the carload of large-mouth black bass was sent to that State by the United States Fish Commission. Five of these were alive in December, 1895, and will be retained for breeding purposes. This fish, which is abundant in the Great Lakes and the Mississippi Valley, may be regarded as a landlocked striped bass and is an excellent food-fish. It is doubtless well suited to the warmer lakes, sluggish streams, and bayous of the Pacific States. It is adapted to cultivation, reaches a weight of 3 pounds, and is quite gamy.

THE TAUTOG.

Mr. Livingston Stone, of the United States Fish Commission, carried specimens of the tautog (*Tautoga onitis*) from the Atlantic to the Pacific coast in his aquarium car. The fish were obtained at Woods Hole, Mass., and were deposited in San Francisco Bay near Oakland, June 12, 1874. They were of small size, and the number planted was 23. There is no evidence that anything ever came of this small deposit of fish in this large body of water. In the report of the California fish commission for 1876–77, it is stated that some tautog had been reported to have been seen in the San Francisco market, but no subsequent references to their appearance have been met with. In 1873 Mr. Stone included tautogs in the collection of live fishes which he attempted to carry to California, but they were lost in the wreck of the transportation car.



WHITE BASS (*Roccus chrysops*).



TAUTOG (*Tautoga onitis*).

THE AMERICAN LOBSTER.

HISTORY OF PLANTS.

A full account of the planting of eastern lobsters (*Homarus americanus*) in the Pacific Ocean has been given in the paper by Mr. Richard Rathbun, entitled "The transplanting of lobsters to the Pacific Coast of the United States," published in the Bulletin of the United States Fish Commission for 1888. The following notes on the history of the plants are largely abstracted from Mr. Rathbun's report, to which recourse should be had by those desiring a more detailed discussion of the subject than is given in the present paper.

Five attempts have been made to introduce eastern lobsters to the Pacific Coast. The first trial was a failure, owing to a railroad accident; the others were successful to the extent of reaching the coast with live lobsters and depositing them in suitable waters.

The first attempt to transport live lobsters across the continent was made in 1873 by Mr. Livingston Stone, who represented the United States Fish Commission and the California fish commission in the matter. Lobsters constituted only a small part of the contents of the aquarium car, which had been stocked with a number of eastern fresh-water and marine fishes. The start was made with 162 lobsters obtained from Woods Hole and Massachusetts Bay. By the breaking of a railroad bridge over the Elkhorn River near Omaha, the aquarium car was wrecked and the contents lost. Forty lobsters had survived the journey to that point.

In 1874 Mr. Stone undertook the transportation of another lot of lobsters, under the auspices of the California fish commission. The consignment consisted of 150 egg-bearing lobsters procured in Boston. The losses en route were very large, only four lobsters reaching the coast alive. These were deposited in San Francisco Bay, at Oakland, on June 12. At Salt Lake City, Utah, two lobsters were put in Great Salt Lake.

Efforts in this direction were not renewed until 1879, when, under Mr. Stone's direction, the United States Fish Commission made the third attempt to introduce lobsters into the Pacific Ocean. The lot consisted of 22 females, to which were attached about 400,000 eggs nearly ready to hatch. Between Boston and Albany 40,000 eggs hatched. The trip to California was made with the loss of only one lobster, the remainder being deposited in excellent condition off Bonito Light-house in a sheltered position a few miles outside of the Golden Gate.

Nine years later the Fish Commission sent a relatively large number of adult and embryo lobsters to California, in a special car in charge of Mr. J. Frank Ellis. The lobsters, which were collected at Woods Hole, consisted of 254 males and 360 females, 8 of the latter carrying eggs on the swimmerets; 150,000 loose eggs were also added to the consignment. The losses on this trip were quite large, amounting to 282 adults. In Mr. Rathbun's opinion the heavy mortality was due to the weak condition of the lobsters incident to the spawning and molting conditions. Of the eggs, 75 per cent reached the west coast safely. The place selected for the planting of the lobsters was Monterey Bay. On June 23, 162 lobsters were placed in the sea about three-fourths of a mile off shore from Pacific Grove, in water 12 fathoms deep with rocky bottom. A second plant of 95 lobsters was made July 1, a mile off Point Lobos, to

the south of Carmel Bay, in water 30 fathoms deep with rocky bottom. The remaining lobsters, 73 in number, which were being retained in a floating car at Monterey, were chiefly intended for planting at some point on the northern coast of California. One of the bottom boards of the car having become detached by the heavy swell, all but 30 of the lobsters rapidly made their escape into Monterey Bay. On July 4 the steamer *Albatross* left San Francisco with the 30 lobsters on board, the lot consisting of 13 males and 17 females. These were planted the following day in 13 fathoms of water off Trinidad Light-house, this point having been selected because of the favorable conditions of temperature, bottom, and water, which were thought to more closely resemble those of the lobster's natural home than any other place on the California coast. The eggs were hatched on the grounds, and 104,000 young lobsters obtained, 2,000 of which were planted in San Francisco Bay and 102,000 in and off Monterey Bay.

The last shipment of lobsters to the Pacific Coast was made in January, 1889, the season for the trial being different from that of the previous experiments. The lobsters were collected at Woods Hole, and numbered 279 males and 431 females, 63 of which carried eggs. The shipment was made in a United States Fish Commission car, in charge of Mr. J. Frank Ellis. These lobsters were intended for the Washington and Oregon coasts. The start was made from Woods Hole January 14, and the lobsters were planted January 22. Owing to the failure of a part of the arrangements, the lobsters destined for Yaquina Bay, Oregon, could not be deposited in that place, and the entire plant was consequently made on the coast of Washington. Of the 710 lobsters with which the journey was begun, 233 survived the trip and were placed as follows: 88 off Cape Disappointment, at the mouth of the Columbia River; 22 in Shoalwater Bay, and 123 in Puget Sound, near Port Townsend.

The following table is a recapitulation of the plants of lobsters on the Pacific Coast. The aggregate deposits of adults amounted to 590, a large number of which were egg-bearing females.

Summary of the American lobsters planted on the Pacific Coast of the United States.

Year.	Localities.	Adults.	Embryos.
1874..	San Francisco Bay	4	.....
1879..	Pacific Ocean, near Golden Gate	21	.....
1888..	Pacific Ocean, off Monterey	162	93,000
	Pacific Ocean, off Point Lobos	95	.....
	Monterey Bay	45	9,000
	Pacific Ocean, off Trinidad Light-house	30	2,000
1889..	Pacific Ocean, off Cape Disappointment	88	.....
	Shoalwater (Willapa) Bay	22	.....
	Scow Bay, Puget Sound	24	.....
	Off Hudson Point, Puget Sound	25	.....
	Off Wilson Point, Puget Sound	74	.....
	Total	590	*104,000

*In addition to these, the female lobsters planted had attached to them several hundred thousand eggs.

DESIRABILITY OF INTRODUCING LOBSTERS TO THE PACIFIC COAST.

The Atlantic lobster would unquestionably be a very acceptable and important addition to the fishery resources of the Pacific States. The spiny lobster, locally called crawfish, which now takes the place of the lobster in the markets of the coast States, is a valuable food product; but it has only a limited distribution, not occur-

ring north of Point Conception, California, and is probably inferior in quality to the true lobster. The long stretch of coast line north of Point Conception is destitute of crustacea which now have economic value, with the exception of the large crab (*Cancer magister*). Mr. Rathbun, in the paper already cited, says:

The omission of the true lobster from the aquatic fauna of the Pacific Coast has been considered by the inhabitants of that region a great misfortune, and while its absence causes neither suffering nor affliction, it is much desired both as an article of commerce and as an added variety to the food supply. The scheme [to attempt its colonization] has received the approval of high authorities, and the benefits to be derived from the introduction of so useful a species are generally admitted.

SUITABILITY OF PACIFIC COAST WATERS TO THE EASTERN LOBSTER.

In the paper by Mr. Rathbun before referred to, that writer considers in detail the question of the suitability of the west-coast waters to the existence of the lobster. His remarks on this subject are so opportune that they may be appropriately quoted:

The North Atlantic and North Pacific oceans have much in common with respect both to their physical and biological characteristics. Identical species of fishes and marine invertebrates inhabit the northern parts of both oceans, and the number of related forms in the two regions is very great. The natural resorts of lobsters on the eastern coast—rocky, gravelly, and sandy bottoms, covered in places with kelp and rockweed, and with an abundance of aquatic life suitable for food—occur throughout the North Pacific region from California to Alaska. Temperature, however, is probably to be regarded as the most important factor determining the fitness of the region for this new food product, and it is the only one which we can now pretend to measure, although we have little data respecting it for the western coast.

On the Atlantic Coast the lobster ranges from Delaware to Labrador, being most abundant between the Cape Cod region of Massachusetts and the Gulf of St. Lawrence and Newfoundland. Its bathymetrical distribution is from the littoral zone (in some localities) to depths of probably 50 to 60 fathoms, but the fishery is chiefly carried on inside of a depth of 30 fathoms. It apparently does not migrate up and down the coast to an appreciable extent, but moves off into deeper water with the approach of winter in order to escape the severe cold.

This writer next enters into a discussion of the water temperatures of the two sides of the continent, comparing the mean temperature of a number of localities on the Atlantic Coast with that of San Francisco and Cape Disappointment. A chart is introduced which shows for the entire season the water temperature at San Francisco and Vineyard Sound light-ship. Mr. Rathbun's statements on the adaptability as regards temperature of the places in which plants were made are as follows:

The water temperature at Monterey is probably not very different from that at San Francisco, while Trinidad Light-house is intermediate in position between San Francisco and Cape Disappointment. At both of these observing stations the records indicate ranges of temperature falling within those of the New England coast, and therefore presumably favorable to the existence of lobsters. * * * By reference to the chart it will be seen that the temperature is far more equable at San Francisco than in Vineyard Sound, having a range of only about 10° in the one case and of over 30° in the other. The yearly range at San Francisco corresponds to that in Vineyard Sound from May 20 to the last of June and from the first part of October to the middle of November, seasons during which the lobsters are on the inshore grounds, the former being also the regular hatching season. In case lobsters become colonized on the coast of northern California it will therefore be interesting to observe if the more equable temperature of that region has any influence in bringing about a change in their customary habits. Will their offshore migrations be less pronounced and their breeding season prolonged? Another matter which the temperature comparison suggests is as to whether the more severe cold of the eastern winters is essential to their welfare or not. There is nothing to prove the case one way or the other, but the fact that lobsters seek shelter from the extreme cold would rather indicate that they might not suffer from its absence. An additional question of interest to the biologist concerns the effect upon the existing fauna of the introduction of the eastern lobster on a large scale. Will it to any extent disturb

the general balance of life in that region, reducing the prominence of some species and perhaps aiding others in their struggle for existence? Only the future can decide this matter, but in any event the addition of the lobster to the Pacific waters could produce no harm for which the inhabitants would suffer.

Mr. A. B. Alexander, fishery expert on the Fish Commission steamer *Albatross*, thinks that some parts of the Alaskan coast afford better conditions for the lobster than exist on the shores of the Pacific States. He writes as follows on this point:

The geographical position, temperature of water, and general character of the bottom in many parts of Alaska are, in the opinion of the writer, much better suited to the requirements of the lobster than that part of the coast lying below or south of Cape Flattery. The whole archipelago of southeastern Alaska contains many places where the lobster would be more likely to live and multiply than at any place on the Pacific Coast.

The temperature and other environments of this region correspond more closely to the home of the lobster on the Atlantic Coast. It is quite evident that lobsters require a great change in temperature of water, far greater than they would find off the Pacific Coast below 50° north latitude, from the fact that they are only found in latitudes where the water undergoes such a change.

The coast of southeastern Alaska is cut up into hundreds of islands, both large and small, forming numerous bays, channels, and estuaries, very similar to the coast of Maine and some parts of Nova Scotia and Newfoundland. From Massachusetts to the Gulf of St. Lawrence is where lobsters abound in greatest numbers, and in this region the water in summer is comparatively warm and in winter extremely cold, elements perfectly congenial to this crustacean. In Alaska the water annually undergoes, to a much less degree, the change which takes place in the latitudes above mentioned. All things considered, no great mistake would be made in planting lobsters in the waters of southeastern Alaska. The harbor of Sitka would be an excellent place to try the experiment; also at Hooniah. There are many localities equally as good above Prince of Wales Island, namely, Howkan, Nichols Bay, and Shakaan; or at Loring, Revillagigedo Island, and several more points farther up the Behm Canal.

RESULTS OF EXPERIMENTS IN PLANTING LOBSTERS.

No economic results have attended the planting of lobsters on the Pacific Coast, and, although the capture of several adult lobsters in years subsequent to the plants has been recorded, no specimen of lobster from the Pacific Ocean has been preserved, or identified by a scientific authority.

The reasons for the absence of results are unknown. Whether the negative outcome has been due to the nonadaptability of the Pacific waters to the lobster, the destruction of the plants by natural enemies before propagation had ensued, the failure of fishermen to catch the lobsters, or the scattering of the relatively small plants over a large area and the failure of the sexes to come together, can not be determined. It may be that it is yet too soon to expect noticeable results, at least from the plants made in 1888 and 1889, while the small deposits in the earlier years may be dismissed from consideration. The following extract from Mr. Rathbun's report bears on this question:

The lobster is, to the best of our knowledge, a slow-growing species, not attaining a length of 10 inches within at least 5 or 6 years from the time of leaving the egg, and by some it has been computed that the growth is even less rapid. The 565 lobsters recently planted on the coasts of California and Washington can not in themselves be regarded as a direct addition to the food supply. They are only a breeding stock, and any increase in their numbers must be derived from the growth of their progeny, also taking into account the young embryos placed in the water off Monterey in 1888. The number of embryos planted by the Fish Commission was about 100,000. Supposing that they all lived, we could not at the end of five or six years have an addition of more than that number of adult lobsters in the Monterey region, and until that time there would be no additions to the original stock of breeding lobsters. At the end of the first year, or during the first breeding season following their introduction, a maximum of 1,800,000 eggs and embryos would be all that could be expected from the

original lot of females planted, under the most favorable circumstances, and provided they all lived that long. Prolonging these conditions, the maximum number of eggs would not be increased from year to year before the fifth or sixth year. It is probable, however, that the original stock of adult lobsters will not keep entirely together, and some will undoubtedly become the prey of fishes. Moreover, lobster embryos are subject to great mortality, and only a very small percentage reach maturity. If at the end of six or even ten years a few thousand only compose the colony off Monterey, the experiment may be considered as successful, but when once it has been firmly established on so large a basis the annual increase will be much more rapid.

Mr. Rathbun states that during 1889 a few of the adult lobsters deposited in the Monterey region had been seen in shallow water, and that young lobsters about 4 inches long were reported to be observed from time to time. Of the reported occurrence of the latter he remarks that full credence can not be given the statements until the specimens have been examined by someone competent to identify the species.

During the past few years several reports of the capture of lobsters on the Pacific Coast have been circulated. In 1893 notice of the taking of lobsters in the vicinity of Monterey was published. Mr. Alexander diligently investigated the matter and reported on it as follows:

Reports are frequently circulated that lobsters have been taken by the fishermen of Monterey, but each time the investigation which has followed has proved the story false. Those not familiar with the lobster easily mistake the fresh-water crayfish for that animal. During the past season a report was circulated through the press of this coast that several small eastern lobsters had been caught at Monterey, and, to add strength to the story, it was stated that samples had been sent to the Fish Commission for identification and word had been sent back that the samples received were the genuine eastern lobster. Such reports are very misleading and have caused considerable inquiry to be made concerning the lobsters planted on the coast in 1888.

The writer has had occasion to interview the fishermen of Monterey several times during the past four years, but has never been able to find a man who was certain he had caught a lobster. Prof. Charles H. Gilbert saw the specimens that were taken this summer, and states that they were fresh-water crayfish.

That several of the lobsters planted at Monterey have been caught there is little doubt. Captain, Nichols, of the United States Navy, says that several years ago he ate a lobster which was purchased at a market in Oakland; being an eastern man, and having taken an interest in the fisheries all his life, it is to be presumed that he is correct in what he says. The questions arise, Who caught the lobsters? and, Have they been exterminated? The white fishermen say they have never been guilty of saving what they supposed to be lobsters, but are of the opinion that the Chinese have caught and sold many specimens, but of this there is no direct proof. From what can be learned it would seem that the lobsters planted here were either caught before they had time to increase, or the character of the bottom and general surroundings was not suited to them for propagating.

No traces of the lobsters planted off Trinidad, Cal., have ever been found. The fishermen of that locality have made diligent search for them with such appliances as they had, but to no purpose. Captain Nichols, in charge of the light-house board of California, has had lobster pots made and set on and near the spots where they were planted. This kind of apparatus has also met with negative results.

The following very positive references to the lobster on the coast of Washington are found in the report of the State fish commissioner for 1890:

I have endeavored to ascertain if any young lobsters have been seen since. I find that quite a number have been seen by fishermen in Port Townsend Bay, and also in Shoalwater Bay. I met two gentlemen on Grays Harbor who had each taken one, one being taken at the mouth of the Hoquiam River, and the other near Peterson Point, close to the entrance of Grays Harbor. As both these gentlemen were from States bordering on the Atlantic, they were perfectly familiar with the lobster in all its different stages of growth, and both agreed that it was a genuine young lobster they had taken. The gentlemen, after examining them, returned them to the water. From this evidence there can be no doubt that the effort to transplant lobsters into the waters of our State has been successful, and in a few years will have stocked the Puget Sound as well as Shoalwater Bay and Grays Harbor. As the lobster requires about five years to mature, the present legislation for their protection is ample.

THE EASTERN OYSTER.

WHEN AND WHERE INTRODUCED.

The shipping of live eastern oysters (*Ostrea virginica*) from the Atlantic seaboard to the Pacific Coast quickly followed the completion of the first transcontinental railroad. It is stated that the first oysters were taken to California in or about 1870 by Mr. A. Booth, of Chicago. The business rapidly increased, and has continued to be of great importance up to the present time. It is recorded* that the first shipment consisted of three carloads of large oysters and that the market was overstocked, so that the consignees, to avoid loss, were obliged to plant in San Francisco Bay all the stock that were not promptly disposed of. This enforced planting of oysters resulted favorably, and was the beginning of a business which has since grown to large proportions.

It is probable that the first consignments consisted of oysters intended for immediate consumption, but in a very short time the practice was inaugurated of importing seed oysters for planting in San Francisco Bay, and this eventually became the ruling custom. Recently, however, a new company has been shipping marketable oysters to San Francisco.

The necessity for shipping eastern oysters to the Pacific Coast arose from the small size and poor quality of the native species (*Ostrea lurida*). This has a very objectionable coppery flavor, which greatly diminishes its food value, although the comparatively large consumption indicates that a taste for it may be acquired.

The supply of eastern oysters on the west coast is kept up by large shipments from the East. In recent years from 50 to 100 carloads have been sent annually to California and planted in San Francisco Bay, where they remain until they attain a suitable and profitable size for marketing. The oysters are shipped in freight cars holding 80 to 90 barrels and are usually three weeks on the cars. The business is carried on chiefly in the fall months, and losses en route are quite small. One-year and two-year old seeds are planted on the grounds in the southern part of San Francisco Bay for three and two years respectively. Their growth is considered rapid, and they retain their original flavor to a large extent, or, at least, do not acquire the metallic taste of the native oyster.

Full accounts of the conditions and methods of the eastern oyster industry of San Francisco Bay will be found in the report by Captain Collins referred to and in the article by Mr. Charles H. Townsend in the Report of the United States Fish Commission for 1889–1891. The special interest in this connection which the paper of Mr. Townsend possesses is the reference to the question of the propagation of the eastern oyster in the waters of California, for unless natural reproduction ensue the species can hardly be considered as acclimatized. The opinion has been generally entertained and is still quite prevalent that the eastern oyster does not and will not propagate in San Francisco Bay, owing to the supposed unfavorable physical and other conditions.

*Report on the Fisheries of the Pacific Coast of the United States. By J. W. Collins. <Report U. S. Fish Com., 1888.

Some remarks of Mr. Townsend on this point will be quoted. His complete report should be consulted by those desiring to fully investigate the matter:

The interesting fact that oysters do propagate in San Francisco Bay, in certain favorable localities at least, calls for some explanation as to the long acceptance by the public of the statement that there has been no natural increase. * * * During occasional visits to the oyster beds in 1889, I found proof of considerable natural propagation of the eastern oyster in the southern part of San Francisco Bay, and transmitted evidence of the same to the United States Commissioner of Fish and Fisheries, who directed that an examination be made in order to determine to what extent this had taken place. * * * The investigations of this subject have simply disclosed the facts that the oyster has to some extent adapted itself to the new habitat in common with the other introduced species, and that in spite of many unfavorable conditions it is slowly increasing.

* * * * * * *

Not only are the chances for the fixing of spat diminished by the use of ground in some places where there are very few old shells upon the bottom, but almost all of the shells of *Ostrea virginica* are returned from the marketmen to the principal oyster company, who sell them for the manufacture of lime instead of using them for the improvement of the beds. These shells of eastern oysters, if returned to the beds where they were grown, or to other portions of the bay, would certainly increase the chances for the fixation of spat set free from the beds where adult oysters are growing. It is probable that careful attention to this matter of increasing the fixing surface required by the young oyster might make just the difference between rapid self-propagation and the present slow increase.

One of the first indications I had of the natural propagation of the oyster was the finding of young oysters six months or a year old upon beds where those three or four years old were kept. They were in most instances attached to clusters of dead shells of the small native oyster. Very few were to be found attached to adult specimens of *Ostrea virginica*, but this may be explained by the fact that such oysters are frequently handled and "laid out" to keep them well upon the surface and prevent any settling in the mud. The handling is done in order to select and clean the largest for market, the others being also cleaned of the ever-accumulating native oysters, which would involve the destruction of such small eastern oysters as might be among them upon the shells of the large oysters.

The fact of young eastern oysters being attached to anything is proof that they grew in the bay where they were found, for oysters do not have the power of fixing themselves a second time. All these small oysters are knocked off the large shells with a small cleaning hatchet, and the operation is a necessary one, as the extremely productive natives cluster upon the larger species in such numbers as to greatly interfere with their growth.

In October, 1891, I discovered some oysters of large size in certain sloughs of the south bay, where they had long escaped the stingrays in consequence of bars which shut off the sloughs from all but the highest tide. These were the largest oysters ever seen at San Francisco, and had evidently lain there for several years. More recently I obtained a quantity of oysters, apparently two years old, in Oakland Creek. As the oyster beds maintained there several years ago by Mr. Doane, now of the Morgan Oyster Company, have long since been abandoned and the stakes removed, it is evident that a limited number of oysters have found conditions suitable for their development and growth, even in this muddy place. They are no longer found on the mud flats, where they were originally kept, but live in the mud of the channel, from which I obtained them with tongs.

Mr. Cleaveland Forbes, of the Spring Valley Water Company, informed me that several years ago he found full-grown eastern oysters upon the piles of an old narrow-gauge railroad trestle, across a slough, near Dumbarton Point, and that the men of his party frequently found many upon banks composed of shells of the native species, near where the pipes of the company cross the bay.

Mr. H. D. Dunn has recently reported, through the press, the discovery of a full-grown eastern oyster near Mile Rock, in the Golden Gate.

It is possible that during the long time eastern oysters have been kept in the bay they have become in a measure acclimated, and that there is a constantly increasing tendency to propagate—that is, the progeny of oysters grown here become hardier with each generation and better adapted to the colder but more equable waters.

During my latest examinations of the bay (May and June, 1891) eastern oysters, very large and old, were found in the following places near the sites of former oyster beds: Several adhering to the piles of the narrow-gauge railroad trestle across San Leandro Bay; a few upon the rocks at the extreme

north point of Sheep or Brooks Island, near low-water mark; a few upon the rocks at Point San Pedro (at entrance to San Pablo Bay). Those from San Leandro Bay doubtless originated as spat from the oyster bed near the entrance to that bay, at the end of the bay northwest from the island. Those from Sheep Island had merely drifted as young across the half mile of distance from the old beds near Ellis Landing, while the San Pedro oysters originated upon the beds between Marin Island and Point San Quentin, a couple of miles distant.

Mr. H. D. Dunn informed me that wild eastern oysters had been reported to him from some other place near Point San Pedro, but I did not discover them, being without a pilot. These finds are very interesting, as showing not only the breeding of the oyster in various parts of the bay, but that the species began breeding several years ago when oysters were laid out in those northern parts of the bay. At Point San Pedro oysters are directly exposed to the influences of the Sacramento River. But the largest and most important tract of oyster propagation is in the region of the natural shellbanks of native oysters along the east side of the bay, beginning at Bay Farm Island and extending well southward and off into deep water. Here wild eastern oysters may be found during the low tides that expose the outer portions of the shellbanks. At this place they are numerous, and when the tides are sufficiently low it is possible to gather them by the score, ranging in size from yearlings to those several years old. This deposit is at least 4 miles removed from the nearest site of a former oyster bedding-ground, and there is no doubt about the oysters upon the whole tract being of volunteer growth. A channel several feet wide separates this tract from the old bed on the north, while it is nearly 10 miles to the nearest beds on the south.

Examination of two or three hundred oysters gathered in this region shows the fixing surface for the spat to have been the shells of the native oyster (*Ostrea lurida*). Indeed, there is nothing on this whole bank but clean shells of the native species. The bank is exposed to heavy seas during the season of strong winds, and many eastern oysters doubtless become buried beneath the easily drifted shells of the small natives. It is probable that there is a very great production of eastern oysters here that we know nothing of, as the whole tract is accessible to stingrays, which prey upon every kind of shellfish outside of the stake-protected beds. It is also probable that the heavy seas which at times sweep across this shallow section of the bay and actually break up the clusters of native oysters by rolling them toward the beaches, have an injurious effect upon newly fixed eastern spat by burying them beneath the drifting shells.

Considerable quantities of wild eastern oysters are annually gathered upon this and other shellbanks in the bay. They are retailed in Oakland and Alameda at $1.50 per 100, or sold to the oyster companies who lay them out on their fenced beds for further growth. They are obtained when unusually low tides happen to expose them. No tonging or dredging is done, the oysters being gathered by hand. The work is performed chiefly by boys. I have no means of knowing the quantity of oysters derived from this source.

It appears, therefore, that there are other parts of San Francisco Bay as good for oyster-culture as those now inclosed, and that the increase of wild oysters now growing there would be more rapid if they were inclosed and afforded similar protection from heavy seas, stingrays, etc.

Several attempts have been made to acclimatize oysters on the Washington coast. Mr. Townsend reports that many years ago two sacks of eastern oysters were placed in Budd Inlet, Puget Sound, near Olympia. They are known to have lived for several weeks, but were soon lost sight of. A few sacks of oysters were also planted in Willapa (Shoalwater) Bay, near Oysterville, a number of years ago. They lived, but no increase in their numbers was ever observed.

In 1894, pursuant to urgent solicitations of the people of the State, the United States Fish Commission sent a carload of eastern oysters to Willapa Bay. The consignments consisted of 80 barrels of large oysters from Raritan Bay, Princess Bay, Newark Bay, Keyport, East River, and Chesapeake Bay. The oysters arrived in excellent condition and were planted near Bay Center on November 11, Mr. Townsend superintending the planting. These will be carefully protected until sufficient time has elapsed to demonstrate the adaptability of this bay to the growth and multiplication of the species.

EXTENT OF THE TRADE IN EASTERN OYSTERS.

The business of planting eastern oysters in San Francisco Bay, and of taking them up for market when they have attained sufficient size, is one of the most important branches of the fisheries on the Pacific Coast. In 1888 the quantity taken from beds in San Francisco Bay and sold was 117,000 bushels, and the output has increased annually since that time. Over 100 persons are employed, and nearly $300,000 is invested in vessels, shore property, cash capital, and oyster-grounds.

The inquiries of Mr. W. A. Wilcox, agent of the United States Fish Commission, have shown the quantity and value of the yield of eastern oysters from 1888 to 1892 inclusive to have been as follows, the figures for the last four years named being extracted from Mr. Wilcox's paper* in the Report of the United States Fish Commission for 1893:

Years.	Bushels.	Value.
1888	117,000	$465,375
1889	120,000	480,000
1890	125,000	500,000
1891	130,000	520,000
1892	146,000	584,000

THE SOFT CLAM.

The existence of the soft clam or long clam (*Mya arenaria*) of the Atlantic Coast on the shores of California was first suggested in 1874, when Dr. W. Newcomb described it from San Francisco Bay as a new species under the name *Mya hemphillii*, recognizing that it was distinct from the native *Mya* of the Puget Sound region. It is interesting to observe that it is also found on the coast of Japan.

In a paper entitled "*Mya arenaria* in San Francisco Bay,"† by Dr. R. E. C. Stearns, it was shown that since 1874 this clam had become abundant along the eastern side of San Francisco Bay, although it was not known north of that bay. The author had, however, received specimens from Santa Cruz, on Monterey Bay, 72 miles south of the Golden Gate.

In discussing the origin of the clam in San Francisco Bay, Dr. Stearns gives the opinion that the original mollusks were accidentally taken to the Pacific Coast with carloads of eastern oysters destined for planting near San Francisco. He writes as follows on this point:

> From whence came the seed which has produced the abundance of this species which has spread and is now spreading rapidly along the shores of San Francisco Bay?
>
> Examine the ancient shell heaps and mounds found hereabout, and one may find the thin broken valves of the *Macomas*, but not a fragment of the shell of *Mya*. One may find the shells of the native *Haliotis* and *Olivella* and the beads and money or ornaments made from them; the bones of the common California deer, of the whales, and perhaps other animals, all of which are still to be found in the neighborhood or not many miles away, but not a piece of *Mya*. The ancient clam-diggers, whose kitchen middens are met with in many places on the Alameda and other shores of the bay, whose skeletons and implements are sometimes exhumed or discovered, had "passed over to the majority"

*The Fisheries of the Pacific Coast, 166 pages, 14 plates.

†American Naturalist, xv, 1881.

centuries before the advent of *Mya arenaria* in California waters. To proceed to the question, Was the seed of this mollusk introduced from the waters of the Asiatic shores of the North Pacific or from the American shores of the North Atlantic? If artificially introduced, of which there can be no doubt, from which direction does the extent and character of the traffic of our commercial intercourse make it most probable that the species came or was brought? By water on the steamships from Japan, or by railroad 3,000 miles overland from the Atlantic seaboard?

With the completion and operation of the transcontinental railroad, our oyster men, many of whom have a large capital invested in the business, commenced the importation of small oysters (*O. virginica*) from the Atlantic side by the carload, for planting in San Francisco Bay, where in a season or so they attain a merchantable size, growing exceedingly fat. * * * There is no similar traffic with Japan, and it is hardly possible that the fry of *Mya arenaria*, if it did adhere to the bottom of the Japanese steamers in Japanese ports, would be able to hold on for so long a time or for so great a distance with the friction of the water against the bottom of the steamer constantly operating to sweep it off. Native oysters are also imported from various points in Washington Territory and planted in the bay, but we have no knowledge of the *Mya* existing at any point in the region from whence these latter oysters are brought.

The soft clam has attained great economic importance in California. As early as 1881, as Dr. Stearns shows, it was the leading clam in the San Francisco and Oakland markets and had superseded to a great extent the native clams (*Macoma nasuta* and *Tapes staminea*). That writer referred to the value of the soft clam and the desirability of its further distribution in the following words:

In the presence of the fact of the rapid increase of this truly excellent edible—next to the oyster the most valuable, either as human food or fish bait, of any of this class of food—and the inference from its spreading so readily in San Francisco Bay that other places along the coast might prove equally congenial to it, it would be a wise, public-spirited act if the captains of our coasting vessels would take the trouble and incur the slight expense attending the planting of this clam at such points as their vessels touch at in the ordinary course of business.

In the report of the California fish commission for 1885–86 the commercial value of the soft-shell clam is thus referred to:

During the last few years soft-shell clams have been taken in great quantities. The spawn is supposed to have been brought to this coast with the eastern oyster. They have covered the flats surrounding San Francisco Bay. The number taken by bushels can not be obtained, as they are marketed in San Francisco by the box, each box holding about 2 gallons of solid meat. Two hundred and fifty boxes, or 500 gallons, are consumed daily, making the annual consumption 156,500 gallons.

The inquiries of the agents of the Fish Commission, covering a continuous period from 1888 to 1892, have shown the extent of the soft-clam fishery and trade of California in those years. The great bulk of the output is sold in San Francisco, and the quantity handled by the dealers of that city, as shown in the following table, represents approximately the quantity taken in the State. The unit of measure is a box holding about 50 pounds of clams in the shell. The receipts of soft clams are seen to be increasing, while the consumption of native clams has varied but little in recent years. The ruling price to the consumer has been about $1 a box for several years.

Table showing the quantity of soft clams handled by San Francisco dealers.

	Boxes.
1888	31,200
1889	18,500
1890	25,000
1891	30,000
1892	40,000

According to Mr. Charles H. Townsend,* naturalist on the Fish Commission steamer *Albatross*, a large part of the soft-shell clam supply comes from San Pablo Bay, where *Mya arenaria* is found to the exclusion of all other mollusks, and where "this species is apparently as abundant as if it had always existed in these waters."

In 1884 the existence of the soft clam in great abundance in Shoalwater Bay, Washington, was shown. The history of the presence of the eastern clam in that locality was given by Dr. Stearns in the following letter to Professor Baird, published in the Bulletin of the United States Fish Commission for 1885:

I have examined the box of clams which just came to hand from Donald Macleay, esq., president of the Board of Trade, Portland, Oreg. Mr. Macleay states that they are the eastern clams, and found at Shoalwater Bay, Washington Territory, which is correct as to their original (indirectly) and present habitat. I was aware of the presence of these clams at the locality given by Mr. Macleay some months ago, and it would be wise to put the matter on record. Captain Simpson, a public-spirited citizen of San Francisco, of the firm of Simpson Bros., extensively engaged in the lumber trade, employing a great many vessels in their business, informed me that he had at one time (or at various times) sent up the coast by their captains a quantity of *Mya arenaria* for planting in Shoalwater Bay, and it, *Mya*, had multiplied wonderfully, and now (at the time of our conversation, May, 1884) this clam was abundant there. The clams planted by the direction of Captain Simpson were obtained by him in San Francisco, where *Mya* now "rules the roost," its increase in San Francisco Bay and excellent quality having nearly superseded the native clams, the latter being now seldom seen on the stalls of the fish markets.

Mr. Townsend says that the soft clam has been introduced into Puget Sound from Shoalwater Bay. It is stated that about six or seven years ago the original plants were taken from Shoalwater Bay by the engineer of a coasting steamer and deposited near Tacoma. They are reported to have greatly multiplied and to have been taken in large quantities for food.

OTHER ANIMALS SUITABLE FOR INTRODUCTION.

FISHES.

The remarkable success which has attended the attempts to acclimatize fishes in the Pacific States naturally suggests a continuance of the experiments. While there is a great abundance of valuable native food-fishes in the fresh, brackish, and salt waters of the Western States, and while the introduction of additional fishes is not generally needed, nevertheless it is doubtless true that it is desirable to augment the existing food supply of some sections by transporting several valuable eastern fishes which would be very welcome to the people of the West.

There are, in all the Pacific States, but more especially in Oregon and Washington, lakes and other waters now barren of food or game fishes, into which the introduction of native species or of eastern fishes could be readily accomplished.

A number of fishes, the introduction of which has already been attempted and has either proved a failure or only a partial success, might with propriety be given a further trial in waters now destitute of desirable species. Among these are the rock bass, the Atlantic salmon, the muskellunge, and the pike perch.

Care should be exercised in transplanting fishes to avoid the introduction of predaceous species into waters already containing desirable fish. The putting of black bass or pike perch in a trout stream, for instance, should be discouraged, as should the liberation of black bass or other sunfishes in salmon streams.

* Report on observations respecting the oyster resources and oyster fishery of the Pacific Coast of the United States. Rept. U. S. Fish Comm., 1889–1891.

Dr. C. H. Eigenmann, in a paper on the food-fishes of the California fresh waters, contained in the report of the California fish commission for 1888–1890, calls attention to the comparative scarcity of species in the fresh waters of the State. He says:

There is comparatively a very limited variety of fishes in California. A stream which in the Mississippi Valley would harbor 75 or 100 different species of fish would in California scarcely contain 20. This is due to two causes:

(1) Many of our streams become entirely dry during the summer, and no species that does not migrate to the sea, or the lower or higher water courses, can exist in them.

(2) It is a law in the distribution of fresh-water fishes that the greater the water system the larger the number of species of fish found in any of the tributaries. The tributaries of the Sacramento thus have much fewer species than the tributaries of the Mississippi, and the tributaries of the Mississippi much fewer than the tributaries of the Amazon. To be more precise, one naturalist has caught as many species of fish in one of the tributaries of the Mississippi in a day as there is known from the entire region west of the Sierra Nevada.

By saying that the number of species of fresh-water fishes is limited, I do not wish to imply that the food-fishes are less in number or inferior in quality, merely that we have less variety—a defect which can be remedied by introducing other species. The most prominent food-fishes of the Mississippi Valley which are not indigenous to California are the various catfishes, the buffalo, pickerels, most of the sunfishes, especially the black bass, perches, and the bass. Several of these have already been introduced.

Mr. A. B. Alexander, fishery expert on the *Albatross*, regards mackerel (*Scomber scombrus*), bluefish (*Pomatomus saltatrix*), and haddock (*Melanogrammus æglifinus*) as among the most desirable fishes that could be introduced into these new waters. He says:

The species of deep-sea Atlantic fish that would be most appreciated by the Pacific Coast people, in the opinion of the writer, are the mackerel, bluefish, and haddock. It is quite evident that no other fish would meet with such sale as these, for the reason that all three species are best when eaten fresh, which would suit the tastes of the inhabitants of every city on the west coast. Salt fish are in no great demand, and as a rule those which are brought to market in any other state except fresh are seldom called for.

The haddock, if successfully planted on the Pacific Coast, would meet with a demand equal to any salt-water fish brought to market. The haddock is a profitable fish to buy as compared to the red rockfish and cultus-cod, there being less waste to it.

The mackerel is in demand the world over, and if introduced on the Pacific Coast would be appreciated by fisherman, buyer, and consumer. There is little doubt that mackerel would live and propagate on that part of the coast from Monterey Bay southward. Monterey Bay would be a good locality to plant young fry, for the reason that the Pacific mackerel are found in that bay as numerous as anywhere on the coast, and it is but reasonable to suppose that where one species is found the other would live, as both species are found in the Atlantic, and some years in the same locality.

It would not be advisable to make a planting of haddock farther south than the latitude of San Francisco. It is very probable that in the vicinity of Cape Flattery would be a better place.

The well-known predaceous habits of the bluefish might be regarded as a drawback to the transplanting of the fish, although there can be little doubt it would prove a highly esteemed addition to the food and game resources of the coast. The hake (*Phycis chuss*), the cusk (*Brosmius brosme*), and the pollock (*Pollachius virens*) could also be acclimatized as easily as the haddock, but as they are less valuable as food they need not be further considered.

The scup or porgy (*Stenotomus chrysops*) would unquestionably find a congenial habitat in San Francisco Bay and in other shore waters of the coast, and it would also be a well-received addition to the fresh-fish supply of the region. As a food-fish, it is superior to the viviparous perches now so extensively consumed in San Francisco.

The following correspondence, which passed between the California fish commission and the United States Fish Commission regarding the acclimatization of alewives, is self-explanatory:

[Letter of California Fish Commissioners, dated May 10, 1895.]

We have had some correspondence with reference to the introduction of the alewife into California waters, and would be glad to have your opinion as to the advisability of such a step. We are informed that the young fish can be taken in great numbers in Maine waters when going to sea from the spawning-grounds, and if such is the case it would not be a difficult matter to secure the right kind of fish for transportation. Do you consider them a desirable fish for our waters, and would the conditions here be favorable to their development?

[Letter of United States Commissioner of Fish and Fisheries, dated May 16, 1895.]

Regarding the transplanting of alewives from the east coast to California, permit me to say that there is little doubt that the waters of your State are adapted to the alewife, and there is every reason to believe that the introduction of the fish would prove as successful as that of the shad. At the same time this commission is not satisfied that the acclimatization of the fish is necessary or even desirable. As food-fish, both the branch alewife (*Clupea pseudoharengus*) and the glut herring or summer alewife (*Clupea æstivalis*) are inferior to the shad, and the low estimation in which the latter fish is now held in San Francisco suggests that the smaller and less valuable alewives would meet with little favor on the part of the fishermen, fish dealers, and the general public. If introduced into the Sacramento River and San Francisco Bay they would doubtless be excellent food for the striped bass and other fish-eating species; but there is already a great abundance of carp, which are known to constitute the principal food of the striped bass, and the introduction of the alewives for this purpose does not seem to be demanded. While it is the habit of these fish to return to the sea, like the salmon and shad, the branch alewife at least is susceptible of cultivation in landlocked lakes and other waters, where it might have economic value or furnish food for black bass or trout.

Alewives are found along the entire eastern coast of the United States north of Florida, and there are important fisheries in North Carolina, Maryland, and Massachusetts. Fish for transplanting could therefore doubtless be as readily secured in other States as in Maine. This Commission does not propagate these fish. It is not possible to transport the adult fish across the continent, and it would probably be unfeasible to carry yearlings, and, in the opinion of this Commission, the acclimatization of the alewives in California could only be accomplished by means of fry.

THE DIAMOND-BACK TERRAPIN.

There is probably no fishery product of the Eastern States whose introduction to the west coast could be more easily consummated and prove more welcome than the diamond-back terrapin (*Malaclemmys palustris*). The wide distribution of the animal on the Atlantic seaboard—from Rhode Island to Mexico—suggests that it would probably live along the entire coast of California and possibly farther north.

In an article* on the fisheries of the Pacific Coast prepared by the writer the following reference to the diamond-back terrapin and the west coast native terrapin is made:

The question is often asked by eastern fishermen and dealers whether the diamond-back terrapin is found on the Pacific Coast; and, if not, whether there is an acceptable substitute therefor.

The diamond-back terrapin (*Malaclemmys palustris*) does not exist on the west coast, and the genus is not there represented. The California terrapin (*Chelopus marmoratus*), the only member of the order which has yet attained commercial prominence on the coast, is much inferior to the diamond-back in food value. The conditions seem excellent for the successful introduction of the diamond-back terrapin to the west coast. The extensive salt marshes around San Francisco Bay and in other places would doubtless supply a suitable habitat for the animal, whose high food value would in time bring it into active demand and stimulate cultivation and a profitable trade.

* Notes on a reconnoissance of the fisheries of the Pacific Coast of the United States in 1894. Bulletin United States Fish Commission 1894, pp. 223–288.

THE BLUE CRAB.

The writer believes that the introduction of the common crab (*Callinectes hastatus*) of the Atlantic Coast to the waters of the Pacific States would not only prove a valuable addition to the food resources of the region, but would be very acceptable to the fishermen, dealers, and consumers, and would serve as an important substitute for the large crab (*Cancer magister*) now so extensively utilized on the west coast.

It can not be said that the introduction of the small eastern crab is demanded by any present scarcity of the native crabs. The principal reason for its transportation would be to afford a new variety of cheap food and to offer a new object of capture to the fishermen. It would also doubtless serve an important function in supplying food to various fishes, and also in furnishing, as on the east coast, an important bait in line fishing.

Of the relative merits of the east and west coast crabs as to food value, there is room for little difference of opinion. The smaller species has a much more delicate and palatable flesh. Another reason why the importation of the blue crab may be desirable is the advent of large numbers of visitors from the Eastern States, to whom their native soft-shell and hard shell crabs would prove very acceptable.

As to the feasibility of transplanting crabs from the Atlantic to the Pacific seaboard there can be little question. The introduction could doubtless be accomplished with facility. The crabs are fully as hardy as the lobster and are more easily handled.

The adaptability of the waters of the Pacific Coast to the crab will at once suggest itself to anyone who will study the thermal and other physical conditions of the two coasts. On the Atlantic seaboard the blue crab ranges from Cape Cod to Mexico, and it would thus seem to be better suited to the waters of California than is the lobster.

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