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ERRATA

Page 49, fifth line of paragraph: *Table 30* (*p. 30*) should read *Table 30* (*p. 50*).
Pages 105, 106, 107, and 108: *Richia* should read *Richiella*. In the first impressions of this paper the name *Richia* was used for the genus, but it has since been found that this name is preempted by a genus of moths; accordingly it is replaced by *Richiella*.
Page 177, line 22: *ts* should read *its*.
Page 190, line 4, paragraph 3: (*p. 199*) should read (*p. 196*).
Page 220, line 22: *Eperlanoi* should read *Eperlanio*.
Figure 5: The reference to *Figure 4* should read *Figure 7*.
Figure 6: The reference to *Figure 10* should read *Figure 5*.
Figure 9: The reference to *Figure 12* should read *Figure 8*.
Figure 10: The reference to *Figures 10, 11, and 12* should read *Figures 6, 8, and 9*.
Page 286, line 5: *Doolitte* should read *Doolittle*.
Page 314, line 5, under heading "Harmfulness of smelt": *objections* should read *objection*.
Page 343, figure 23: The reference to *Fig. 23* should read *Fig. 22*.
Page 343, figure 24: The reference to *Fig. 24* should read *Fig. 23*.
Page 375: The 1858 reference under H. R. Storer should be under D. H. Storer on page 374.

SCHIZAMŒBA SALMONIS, A NEW AMEBA PARASITIC IN SALMONID FISHES

By H. S. DAVIS, Ph. D.

Fish Pathologist, U. S. Bureau of Fisheries

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INTRODUCTION AND METHODS

During the course of an investigation on the intestinal protozoa of trout it was found that an ameba which exhibits a number of very interesting characteristics is common in these fish. Unlike the parasitic amebæ of other vertebrates, this species lives in the stomach rather than in the intestine, only the cysts being found in the latter organ. This ameba is evidently widely distributed, since it has been found in a number of localities east of the Mississippi River and on the Pacific coast. Nor is it restricted to any one species of fish, having been found in several species of trout and salmon, but it is probably confined to the Salmonidæ.

Practically all of the material for this investigation was obtained at the Bureau of Fisheries' station at White Sulphur Springs, W. Va. Since the amebæ die very quickly when removed from the stomach, nearly all my observations have been based on preserved material. For this purpose the mucus covering the epithelial lining of the stomach was scraped off with a scalpel and smeared as quickly as possible over a cover glass, which was at once dropped into a fixing solution. Worcester's formol-sublimate-acetic fluid was found to give the best results, although Schaudinn's fluid was also found to be of considerable value. Both smears and sections were stained with iron-hematoxylin, which was found to give excellent results when properly decolorized.

THE TROPHOZOITE

As stated above, the trophozoites are found only in the stomach, where the organism is often very abundant in the mucus covering the epithelial lining. The living amebæ are colorless and very transparent, showing a faintly granular structure of the protoplasm within which the nuclei are usually easily distinguishable. No

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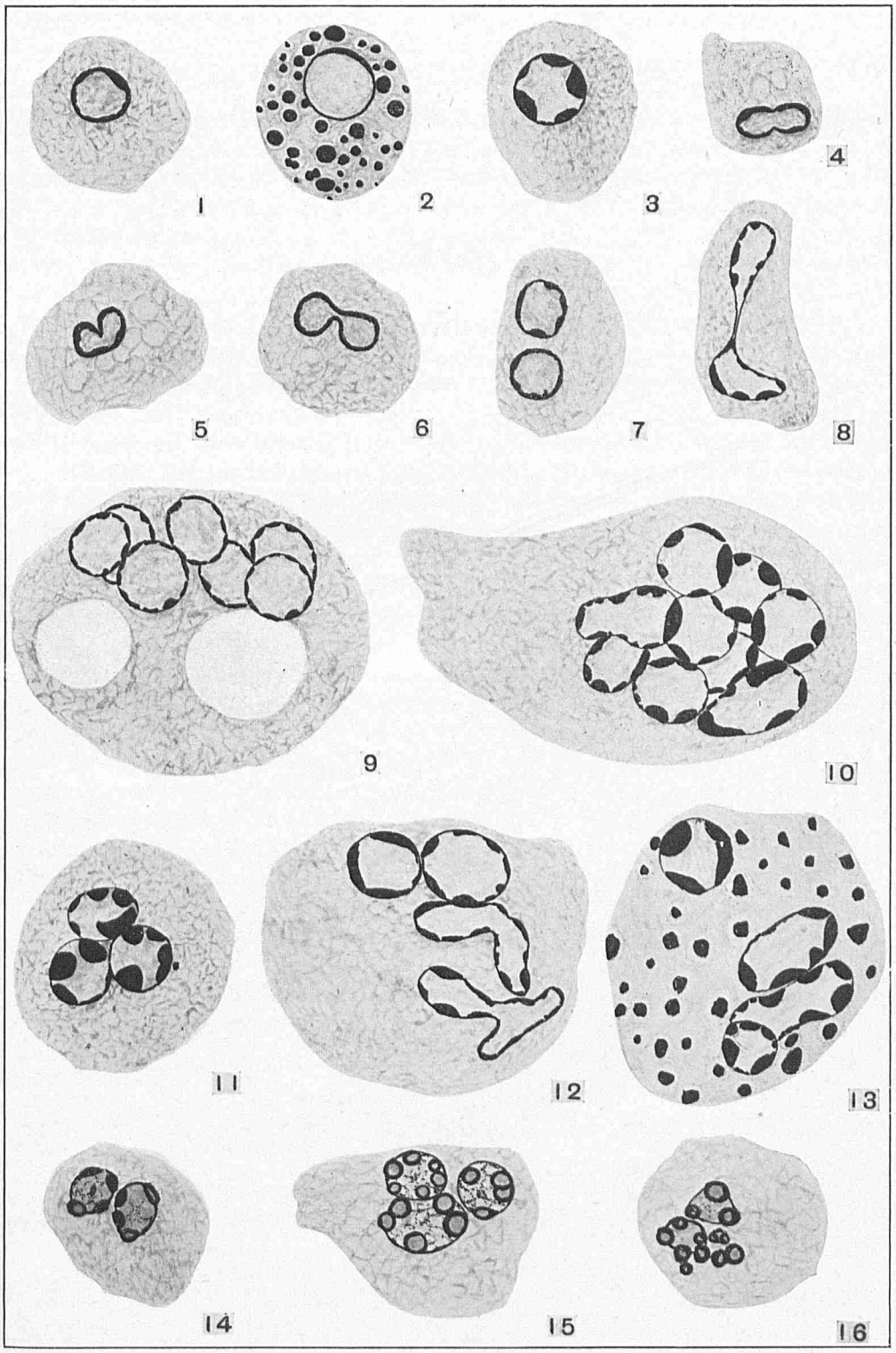
ectoplasmic layer can be distinguished, and there are usually no distinct vacuoles, although a few small fat globules are sometimes present. Treatment with iodine has failed to disclose any evidence of the presence of glycogen at this stage. No trace of ingested food particles could be found, and it is probable that the amebæ are entirely dependent on liquid food. Although somewhat irregular in shape, no ameboid movements could be distinguished, and it seems probable that even when in the stomach such movements are comparatively slow.

The appearance of the trophozoites after being stained is shown in Figures 1 to 12. They vary greatly in size, and although the majority have a diameter of about 10 to 15 microns, individuals with diameters of 20 to 25 microns are found occasionally. Usually there is only one nucleus, although multinucleate stages occur and are sometimes quite numerous. The latter are, of course, larger than the mononucleate amebæ and may contain from 2 to 10 nuclei—possibly even more, since it is very difficult to distinguish the individual nuclei when crowded closely together. However, individuals with 6 or more nuclei are very exceptional and can not be considered typical of the species. As a matter of fact, it is believed that this ameba must be looked upon as primarily mononucleate, with the occasional occurrence of multinucleate forms.

The nuclei are of the vesicular type and never possess a karyosome, the interior being filled with achromatic material that exhibits no distinct structure. The chromatin is confined to the periphery of the nucleus, where it sometimes forms a thin, nearly continuous layer attached to the nuclear membrane (figs. 1 and 2), but which in many instances can be seen to be composed of a large number of small granules (fig. 9). A similar arrangement of the chromatin has been described by several writers in other species of amebæ. Frequently, instead of forming a more or less continuous layer, the chromatin is concentrated in several large masses, as shown in Figures 3, 10, and 11. These blobs of chromatin are evidently formed by the aggregation of the granules previously referred to, and this is believed to form the first stage in the development of the cysts that will be described later.

The cytoplasm usually has a quite uniform, indistinctly vacuolated structure. Occasionally one or more large vacuoles can be distinguished (fig. 9), which in life probably contained fat globules, but such vacuoles are exceptional and in nowise characteristic. Usually a small percentage of the amebæ contain numerous chromatoidal bodies, as shown in Figures 2 and 13. These bodies usually are spherical, sometimes somewhat irregular in shape, and vary greatly in size. They are distributed uniformly throughout the cytoplasm and apparently have no relation to the nucleus. That the presence of these bodies is not due to differences in fixation or staining is shown by the fact that amebæ containing them are found side by side with individuals in which no trace of such structures can be found. It is believed that these bodies probably are composed of reserve food material, and it is an interesting fact that the protoplasm of amebæ containing chromatoidal bodies always has a dense homogeneous structure without any trace of vacuoles or a network.

Nuclear division in the ameboid stages is probably always amitotic, as is strongly suggested by Figures 4 to 8, which are by no means exceptional. In Figure 12, which is drawn from a section through a multinucleate individual, two of the nuclei



FIGS. 1 and 2.—Mononucleate amebæ showing typical arrangement of the chromatin on the inside of the nuclear membrane. In Figure 2 the cytoplasm contains numerous chromatoidal bodies. × 1640

FIG. 3.—Mononucleate ameba with the chromatin collected in large masses on the nuclear membrane in preparation for encystment. × 1640

FIGS. 4 to 8.—Amebæ showing different stages of nuclear division by amitosis. Figure 8 was drawn from a section. × 1640

FIG. 9.—Large multinucleate ameba containing two large vacuoles. × 1640

FIGS. 10 to 13.—Multinucleate amebæ showing chromatin collected in large masses on the nuclear membrane. Figures 12 and 13 were drawn from sections. Numerous chromatoidal bodies are present in the cytoplasm in Figure 13. × 1640

FIGS. 14 to 16.—Successive stages in the development of the cyst nuclei. × 1640

appear to be dividing by amitosis. That mititic division does not occur in the ameboid stage is also indicated by the fact that a careful search has failed to disclose any evidence of mitosis at this stage. This agrees with the observations of Taylor (1923), who was unable to find any evidence of mitotic division in the ameboid stage of *Amœba proteus*.

STRUCTURE OF CYSTS

Usually, in addition to the ameboid stages just described, there are numerous cysts present in the stomach which have a quite different appearance. These cysts are often more abundant than the vegetative stages, which in several instances were rare while the former were present in large numbers. On the other hand, the opposite condition may obtain, and in one noteworthy case very few cysts were found, although the ameboid stages were extremely abundant. This would indicate that cyst formation is more rapid at certain times than at others, although little evidence has been obtained regarding the factors controlling their development. The facts at hand indicate that cyst formation may possibly be correlated in some way with the amount of food in the stomach of the host.

The cysts are spherical and vary greatly in size, the diameter usually being between 15 and 35 microns, with an average diameter of 20 to 25 microns. They are surrounded by a thin transparent membrane and usually contain numerous spherical refringent bodies, which are evidently fat globules since they stain deeply with Sudan III and are unaffected by iodine. No glycogen vacuoles could be demonstrated, but since the inner half of the cysts usually stains deeply with iodine it is believed that glycogen is present in a diffused condition. In a few instances small irregular bodies staining deeply with iodine could be distinguished near the center of the cyst. After being on the slide for some time the fat globules may be squeezed out of the cytoplasm and coalesce to form a large globule in the space between it and the cyst wall.

A study of stained preparations shows that the cysts are always multinucleate, containing from three up to a large number of nuclei (figs. 20 to 22). The structure of the nuclei is very different from that of the vegetative stages, and were it not for the fact that a complete series of transition stages can be found between the two forms it would be difficult to believe that they belong to the same species. In striking contrast to the ameboid forms the cyst nuclei always contain a large deeply-staining karyosome near the center, while the nuclear wall is entirely free from chromatic material (fig. 20). The karyosome usually stains intensely and uniformly with chromatin stains, but in a few strongly decolorized specimens could be seen to be composed of closely crowded chromatic granules embedded in a lighter staining matrix. On one side of the karyosome, usually that turned toward the periphery of the cyst, is a mass of achromatic material extending from the karyosome to the nuclear wall. It does not, however, extend directly to the wall, but flares out in all directions a short distance from the karyosome to form a mushroom-shaped structure with its edges in contact with the nuclear membrane (fig. 20). Embedded in the achromatic material are numerous small deeply-staining granules, whose later history indicates that some of them, at least, are to be considered as homologous

with the centrioles and blepharoplasts of other protozoa. That they differ chemically from the chromatin of the karyosome is indicated by the fact that in very strongly decolorized nuclei they are unstained while the karyosomes still retain the stain. In fact, the appearance and abundance of these granules appears to be largely dependent on the stage to which the destaining process has been carried.

The arrangement of the nuclei in the cyst is characteristic. Except in the case of the small cysts with few nuclei they are usually arranged quite regularly in a single layer about one-half the distance from the center to the periphery of the cyst (figs. 20 and 22). This arrangement divides the cytoplasm into two regions, which present a quite different appearance. Within the nuclear layer the cytoplasm is strongly vacuolated, while in the outer zone between the nuclear layer and the periphery the vacuolated structure is much less noticeable and in the larger cysts may entirely disappear.

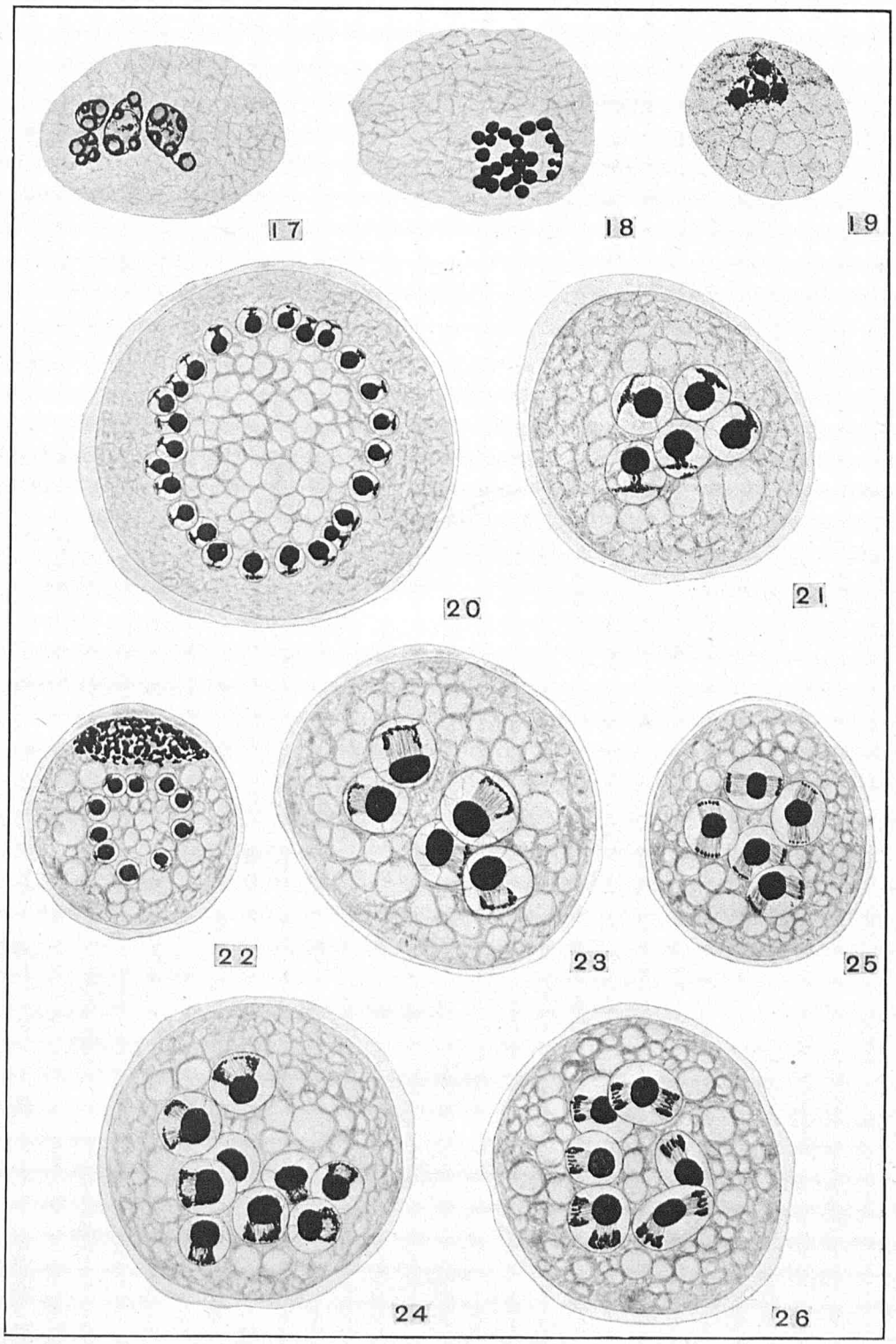
In some instances a mass of deeply staining granules is present at one side of the cyst, which is probably homologous with the chromatoidal structures of other amebæ, but in the great majority of cysts no trace of such a structure can be distinguished. The explanation of this fact is not obvious, since it can hardly be due to differences in fixation or staining.

DEVELOPMENT OF CYSTS

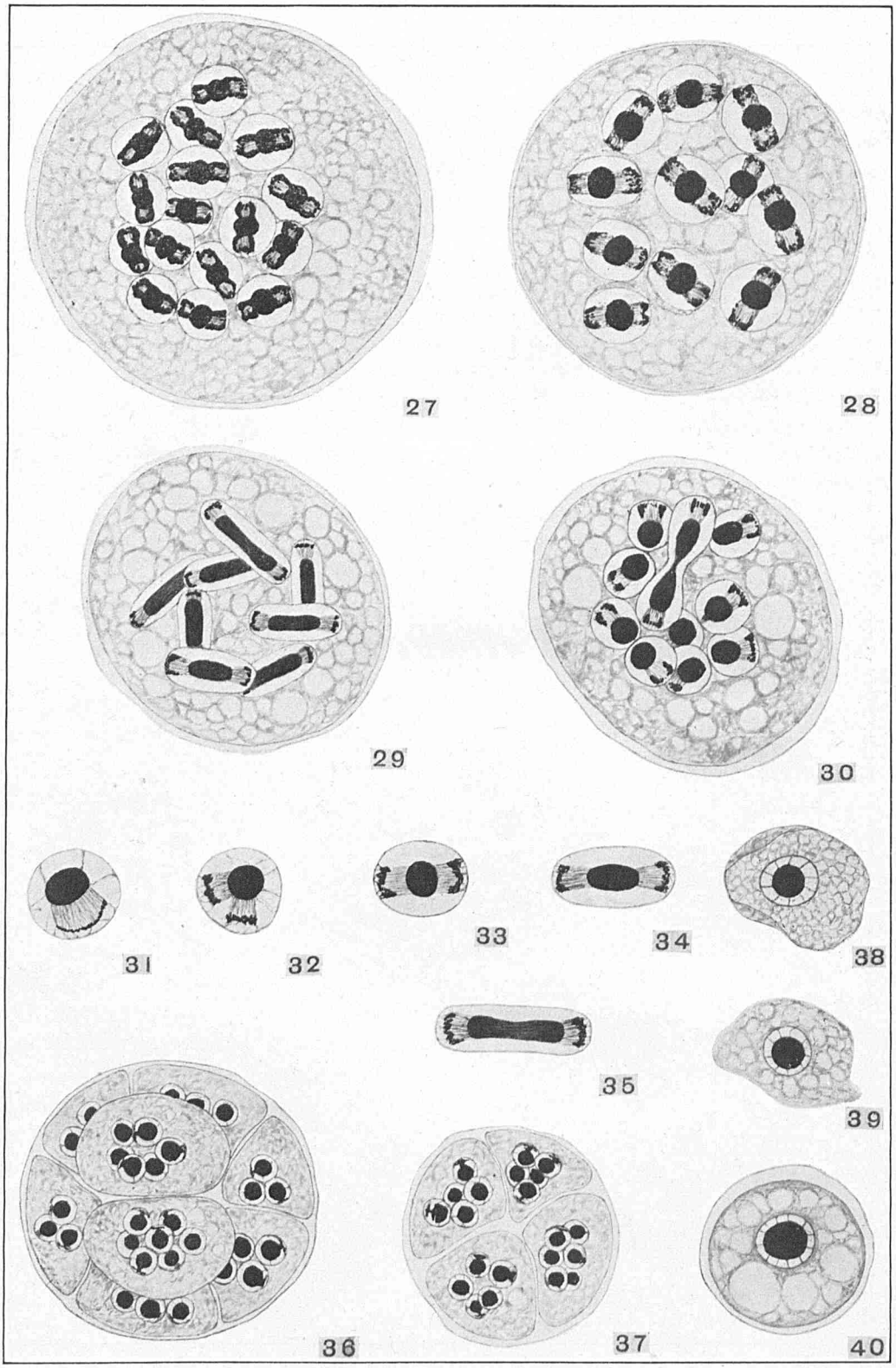
Perhaps one of the most interesting features in the life cycle of this species is to be found in the development of the cysts from the ameboid stage, since the process is quite different from that described for other amebæ. As previously noted, the nuclei of the amebæ frequently exhibit a quite different arrangement of the chromatin from that usually found. Instead of forming a thin layer, either continuous or composed of discrete granules on the inside of the nuclear membrane, the chromatin becomes arranged in large blobs, as shown in Figures 3 and 10 to 13. There are usually five or six of these chromatin masses in each nucleus, but the number is by no means constant. This arrangement of the chromatin is apparently the first step in cyst formation and may occur in both mononucleate and multinucleate individuals. Judging from their abundance, this stage lasts for some time, and the nuclei may even divide amitotically while in this condition. After a time the chromatic masses become rounded and usually exhibit a vesicular structure (figs. 14 to 17), the chromatin forming a peripheral layer around the less deeply staining center.[1] At this time the nuclear wall shows signs of disintegration and a little later entirely breaks down, leaving the chromatin spherules free in the cytoplasm (figs. 18 and 19). These spherules form the karyosomes of the cyst nuclei, losing their vesicular structure and each becoming surrounded by a nuclear membrane.

The nuclear changes involved in the development of the cysts are accompanied by corresponding changes in the cytoplasm. The organisms become rounded and are surrounded by a thin transparent membrane which is difficult to distinguish in stained specimens. The cytoplasm is distinctly vacuolated and contains numer-

[1] The vesicular structure is evident only in strongly decolorized individuals.



FIGS. 17 to 19.—Successive stages in the development of the cyst nuclei. The nuclear membrane is disintegrating in Figures 18 and 19. × 1640
FIG. 20.—Optical section of a cyst showing typical arrangement of the nuclei. × 1800
FIG. 21.—Small cyst with five nuclei drawn at a higher magnification to show details of structure. × 2700
FIG. 22.—Optical section of cyst with a mass of chromatoidal bodies on one side. × 1800
FIGS. 23 to 26.—Cysts showing successive stages in the division of the nuclei. Prophases. × 2700



FIGS. 27 to 30.—Cysts showing successive stages in the division of the nuclei. Figures 27 and 28, metaphase; Figure 29, anaphase; Figure 30, telophase. × 2700

FIGS. 31 to 35.—Nuclei drawn at a higher magnification to show successive stages in division. × 3150

FIGS. 36 and 37.—Cysts that have recently divided into a number of approximately equal parts. The cyst shown in Figure 36 contained 11 cells, three on the lower side not being shown in the figure. × 1800

FIGS. 38 to 40.—An undescribed species of ameba occasionally found in the digestive tract of trout. Figures 38 and 39 are the trophozoites from the stomach, while Figure 40 is the encysted stage from the intestine. × 1640

ous fat globules. It also stains more deeply with iodine, indicating the formation of glycogen, which is evidently present in a diffused condition.

Since the cysts may develop from mononucleate, binucleate, or multinucleate individuals, there is obviously great variation both as regards size and number of nuclei in the newly formed cysts. In fact, cysts are formed with as few as three nuclei, while others may contain a large number. However, the later history of the cysts is such as to make it impossible to determine with any degree of accuracy whether any particular cyst is newly formed or has already gone through a course of development in the encysted stage. Their further development is of particular interest, since no similar phenomena appear to have been observed in other species of amebæ. These changes take place both in the stomach and intestine, and all stages may be found in both organs. In fact, no difference could be detected in cysts from the stomach and intestines and, unlike the vegetative stages, they are apparently indifferent to the surrounding fluids.

While the newly formed cysts vary greatly in size, there is good reason to believe that the organisms continue to grow after encystment, since the percentage of large cysts with a correspondingly large number of nuclei is always much greater than that of the multinucleate vegetative forms. Furthermore, the division of the nuclei, followed eventually by division of the cysts themselves, also indicate growth during this stage. In striking contrast to the ameboid stage the cyst nuclei always divide by a primitive form of mitosis. The details of this process are shown in Figures 23 to 30. In preparation for division the karyosomes become enlarged and the chromatic material at one side develops a fibrous structure (figs. 23, 24, and 31). The chromatic granules, which in the resting nucleus are embedded in this material, become arranged in an irregular manner at the ends of the fibers nearest the nuclear membrane. A little later the group of fibers splits into two equal parts (figs. 25 and 32), which separate and eventually come to lie on opposite sides of the karyosome (figs. 27, 28, and 33). At this stage, which is evidently the metaphase, the mitotic figure extends across the nucleus with the karyosome in the middle of the spindle. The chromatic granules now form a deeply staining mass at the ends of the spindle fibers. Often they appear to be scattered along the sides of the spindle, but this may be due to the fact that the fibers are of unequal length. Shortly after this the karyosome becomes elongated and later constricted in the middle, as shown in Figures 29, 30, 33, and 34. Eventually the two parts separate, thus giving rise to two daughter nuclei similar in every respect to the original nucleus except in the matter of size. While this is evidently a form of promitosis no chromosomes could be detected in the karyosome, although it appears to have an indistinct fibrous structure when greatly elongated. The arrangement and behavior of the chromatic granules on the spindle fibers indicates that they should probably be considered as homologous with the blepharoplasts and centrioles of other protozoa.

The details of this process of promitosis appear to be quite different from anything described in the literature. In some respects there is a superficial resemblance to the nuclear division in the trophozoites of *Amœba tachypodia* (Gläser, 1912; Ford, 1914) and of *Nægleria gruberi* (Wilson, 1916). However, in both species the details of the process are quite different in several respects. The peripheral chromatin, which collects at one side of the karyosome in these two species,

appears strikingly like the granules embedded in the achromatic structure joining the karyosome to the nuclear wall in *S. salmonis*. However, it is very evident that in *salmonis* these granules take no part in the formation of the chromosomes but become arranged at the poles of the spindle during the prophase. In this respect they would appear to correspond with the chromatic polar masses, which in *Amœba tachypodia* and *Nægleria gruberi* are derived from the karyosome. Obviously, further investigations are required before it will be possible to determine the homologies of the nuclear structures in the two types of amebæ.

Coincident with the division of the nuclei there is a marked increase in the size of the cysts, which may eventually reach a diameter of 35 microns and contain a large number of nuclei. Occasionally a large cyst is found in which the nuclei, instead of being distributed quite regularly around the central portion of the cyst, as previously described, are arranged in several groups separated a short distance from each other. This arrangement of the nuclei is preparatory to division of the cyst into a number of distinct parts corresponding to the number of nuclear groups. Superficially this division has a striking resemblance to the segmentation of an egg but differs in several fundamental respects. Unlike an egg, the cyst divides simultaneously into from 4 to 11 cells of approximately equal size (figs. 36 and 37). Each cell usually contains from 4 to 8 nuclei, there being considerable variation in this respect even in daughter cells from the same cyst. The disintegration of the cyst membrane, which quickly follows, allows the cells to separate, and presumably each in turn may go through a similar course of development. Dividing cysts, while not common, have been found in a number of instances in both the stomach and intestine, and there can be no doubt that this is a normal process in the life cycle of the species.

The further development of the cysts has not been followed, but it is known that they pass out of the intestine in the excrement in the condition shown in Figures 20 and 22, and presumably germinate after being ingested by another fish

SYSTEMATIC RELATIONSHIP

It is evident that this ameba differs in several essential respects from other known species. The most striking differences are found in the encysted stage, and these are believed to be of sufficient importance to justify the creation of a new genus coordinate with other genera of the Amœbidæ. The essential characters of this genus are as follows:

Schizamœba gen. nov.

Parasitic. Trophozoites mononucleate and multinucleate. Cyst nuclei formed by fragmentation of nuclei of trophozoite, with large central karyosome connected at one side with the nuclear membrane by an achromatic structure in which are embedded numerous chromatic granules. Cysts divide into a number of multinucleate cells, each of which forms a separate cyst.

Type species **Schizamœba salmonis** sp. nov.

Trophozoite slowly ameboid, with one to several vesicular nuclei without a karyosome, and with the chromatin arranged on the nuclear wall. During encyst-

ment the chromatin collects in several large masses on the nuclear membrane, which eventually become rounded and, following disintegration of the nuclear wall, form the karyosomes of the newly-formed cyst nuclei. The karyosomes are connected at one side with the nonchromatic nuclear wall by a mushroom-shaped achromatic structure, in which are embedded numerous chromatic granules. The cyst nuclei divide several times by promitosis, during which the karyosome is divided into two equal parts without losing its identity. Eventually the cysts divide into several multinucleate cells, which separate and form new cysts like the original. The trophozoites are found only in the stomach; the cyst in both stomach and intestine of salmonid fishes.

DISTRIBUTION

That this species is widely distributed is shown by the fact that, although it has been under observation for only a short time and but little attention has been paid to this feature, it has already been found in several species of trout, including the rainbow (*Salmo shasta*), the brook trout (*Salvelinus fontinalis*), and the brown trout (*Salmo fario*), at the White Sulphur Springs (W. Va.) and Wytheville (Va.) hatcheries. The cysts of this ameba have also been found in the young of the chinook salmon (*Oncorhynchus tschawytscha*) and the silver salmon (*Oncorhynchus kisutch*) from several hatcheries on the Pacific coast. Dr. Emmeline Moore also reports that it occurs in trout at a number of the New York State hatcheries, where the cysts have been confused with those of *Octomitus salmonis*. It is very evident that this ameba is widely distributed among the Salmonidæ.

RELATION TO HOST

There is, as yet, no evidence that *Endamœba salmonis* is directly harmful to the host, although it is sometimes present in very large numbers. In fact, it has been observed in several instances that the parasites were exceptionally abundant in fish that appeared to be in excellent condition, while there were only a few amebæ in sick fish from the same lot. This difference in the abundance of the parasites was probably due to the fact that the sick fish were taking little if any food, since it has been found that the ambæ rarely occur in numbers in the stomachs of fish that have been without food for several days. But while apparently not directly injurious, at least under ordinary conditions, they are doubtless of considerable importance in nutrition, since when abundant they must consume appreciable quantities of food that would otherwise be utilized by the host.

OTHER AMEBÆ IN TROUT

In addition to *Endamœba salmonis*, another ameba has been found in the stomach and intestines of trout in several instances. As in the case of *S. salmonis*, the vegetative stages were found in the stomach while only cysts were observed in the intestine. In appearance this species is quite distinct from *S. salmonis*, especially as regards the structure of the nucleus, which always contains a prominent karyosome even in the ameboid stage (figs. 38 and 39). The protoplasm is more

sharply defined than in *S. salmonis*, and the general appearance of this species suggests that it is a typical ameboid form of the limax type. The cyst shown in Figure 40 is mononuclear and very similar in appearance to the ameboid stage.

This species has been found in only a few instances, and then in too small numbers to permit of a detailed study, but such observations as have been made indicate that it differs in no essential respect from the orthodox type of parasitic amebæ.

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OCTOMITUS SALMONIS, A PARASITIC FLAGELLATE OF TROUT

By H. S. DAVIS, Ph. D.

Fish Pathologist, United States Bureau of Fisheries

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INTRODUCTION

It is well known that when any animal is confined under unnatural conditions various difficulties are encountered, which are of little importance in nature. This principle is well illustrated in the artificial propagation of fish, which is becoming more and more important because of the rapid rate at which the fish life of lakes and streams is becoming depleted. As a result of herding together large numbers of fish at the hatcheries, various parasites, which cause little or no injury in nature, have taken advantage of the exceptionally favorable conditions for their rapid increase and now present one of the most important problems with which the fish-culturist has to deal. Unless methods for controlling the various parasites and diseases so prevalent at hatcheries can be developed, the artificial propagation and rearing of fishes is threatened with failure. This is especially true of trout, which, owing to the ease with which the eggs can be handled, are crowded together in large numbers in a very limited space.

Among the parasites of trout probably none is more important to the fish-culturist than the flagellate *Octomitus salmonis* Moore, since this species infests the young fish at an early age before they are large enough to leave the hatchery. The conditions in the hatchery troughs, where thousands of fingerlings are crowded together in a narrow space, afford an ideal environment for the development of this parasite at a time when the fish are least able to resist its ravages. These facts, coupled with its wide distribution, have made Octomitus a serious menace to the success of trout culture.

NOMENCLATURE

Octomitus salmonis was first described by Dr. Emmeline Moore (1922), who found it in several species of trout at the New York State hatcheries. Investigations of the parasite were begun almost simultaneously in the spring of 1922 by Doctor Moore and the writer, who had independently discovered it in rainbow and brook trout from the White Sulphur Springs (W. Va.) hatchery.

Octomitus salmonis belongs to the family Hexamitadæ, which, according to Alexeieff (1914), includes the four genera, Hexamitus, Octomitus, Giardia, and Trepomonas. It is not the writer's intention at this time to enter into the controversy relative to the distinctive characters of the genera Hexamitus and Octomitus. This matter has been discussed at length by Dobell (1909), Alexeieff (1914), Swezy (1915), and Moore (1922). It is believed that there are valid grounds for distinction between the two genera as pointed out by Alexeieff. This distinction should be based not on a difference in habitat, as proposed by Dobell, but on strictly morphological characters, since the three genera, Hexamitus, Octomitus, and Giardia, can be clearly distinguished by the character of the flagella. As pointed out by Alexeieff (1914), the three pairs of anterior flagella in Hexamitus arise directly from the basal granules. In Octomitus there is a short rhizoplast surrounded by a differentiated layer of protoplasm between the basal granules and the flagella, while in Giardia the rhizoplasts are much longer and better developed than in Octomitus. The second characteristic—that of the fusion of the axostyles for part of their length—is believed to be based on an error in observation, since it is very doubtful if the axostyles are ever fused in either of the three genera, although they may sometimes be so close together as to appear fused on casual observation. The writer has several undescribed species of Octomitus and Hexamitus from various fishes, but in all cases the axostyles are distinct throughout their length. Probably another characteristic of Octomitus is a specially modified region at the anterior end, which forms a primitive cytostome but without the dorso-ventral flattening so characteristic of Giardia.

It will thus be seen that Octomitus occupies an intermediate position in the phylogenetic series between Hexamitus and Giardia. Hexamitus undoubtedly represents the primitive type from which the other two genera have been developed, while in Giardia we have the forms that are most highly specialized for a parasitic mode of life.

DISTRIBUTION

Octomitus salmonis is widely distributed throughout the country, having been reported from trout hatcheries in New England, New York, New Jersey, Virginia, West Virginia, Iowa, and Missouri, and it is probable that very few hatcheries are free from the parasite. It has also been found in young salmon from hatcheries in Washington, Oregon, and California. The parasite has not yet been found in wild trout except under circumstances that indicate that the infection was probably derived from hatchery fish. However, there is no reason to doubt that it does occur naturally in wild trout, but it is probably rarely abundant under such circumstances. No doubt the hatcheries first became infected from wild fish, the

greater abundance of the parasites in hatchery fish being due to the exceptionally favorable conditions for its spread and development. This conclusion is borne out by the fact that allied species of flagellates occur in other fishes, both fresh-water and marine.

Not only is *Octomitus salmonis* widely distributed geographically, but it has also been found in a considerable variety of hosts. It evidently occurs in all species of trout, having been reported from the brook trout (*Salvelinus fontinalis*), rainbow trout (*Salmo shasta*), brown trout (*Salmo fario*), Loch Leven trout (*Salmo levenensis*), and lake trout (*Cristivomer namaycush*). The writer has also found the flagellate in considerable numbers in fingerlings of the chinook salmon (*Oncorhynchus tschawytscha*) and the silver salmon (*Oncorhynchus kisutch*).

SYMPTOMS OF THE DISEASE

The disease caused by infection with *Octomitus salmonis* and known as octomitiasis is not characterized by well-defined symptoms by means of which it can be readily distinguished from other ailments of trout. There are no external lesions, and the most common indication of the presence of the disease is the appearance of thin, emaciated fish, usually somewhat darker in color than normal, although in some instances they may be lighter. Owing to the relatively large head in comparison with the emaciated body, such fish are commonly referred to as "pinheads" by fish-culturists. Many of the "pinheads" may improve after a time and eventually resume their normal rate of growth, but others gradually grow weaker and weaker until finally death supervenes.

More rarely the disease may occur in an acute form accompanied by a heavy mortality. Dr. Emmeline Moore (1923) refers to the disease as the "whirling sickness" and states that "Balance seems easily lost and the fish turn over repeatedly with a 'whirling' or 'corkscrew' motion in the water; too weak to make headway against the current, numbers of them are found in the corners at the foot of the trough or nosing along the sides near the surface; they lie on their backs with gills distended and in feverish action." This whirling motion has been observed only rarely in our investigations, and in no case was it a prominent feature of the disease. It should be remembered in this connection that whenever fish become so weakened from any cause as to be unable longer to maintain their balance they turn on their sides, and any effort to swim necessarily results in their taking a spiral course. In one instance where the disease was exceptionally severe the dying fish were observed to lie on the bottom of the trough and bend the body from side to side in quick spasmodic movements. Similar movements were also noticed when the fish were swimming at or near the surface, but in no case did they exhibit a whirling or spiral motion.

Doctor Moore also refers to diarrhœal symptoms as being specific for the disease, but this has not been noticeable in any of the diseased fish observed by us. It is true that the intestinal contents of infected fish are usually more fluid than normal, but this is believed to be due simply to the fact that such fish take comparatively little food.

The simplest and most reliable method of diagnosing the disease consists of a microscopical examination of the contents of the anterior end of the intestine.

This should be mounted on a slide in a drop of water, in which the parasites will remain alive and active for 10 to 15 minutes. Since no other parasites are likely to be encountered, which could be confused with Octomitus, examination with the low power of a compound microscope usually is sufficient. At this magnification the parasites can be distinguished readily as colorless, minute, pear-shaped organisms darting rapidly about in all directions.

When the parasites are very abundant, the intestinal wall just behind the stomach usually is thin and transparent and distinctly yellowish rather than brownish, which is the normal color. In acute cases it may exhibit a distinctly reddish color due to congestion. However, since the appearance of the intestinal wall is to a considerable extent dependent on the character of the food, too much reliance should not be placed on the yellow transparent appearance as a diagnostic character.

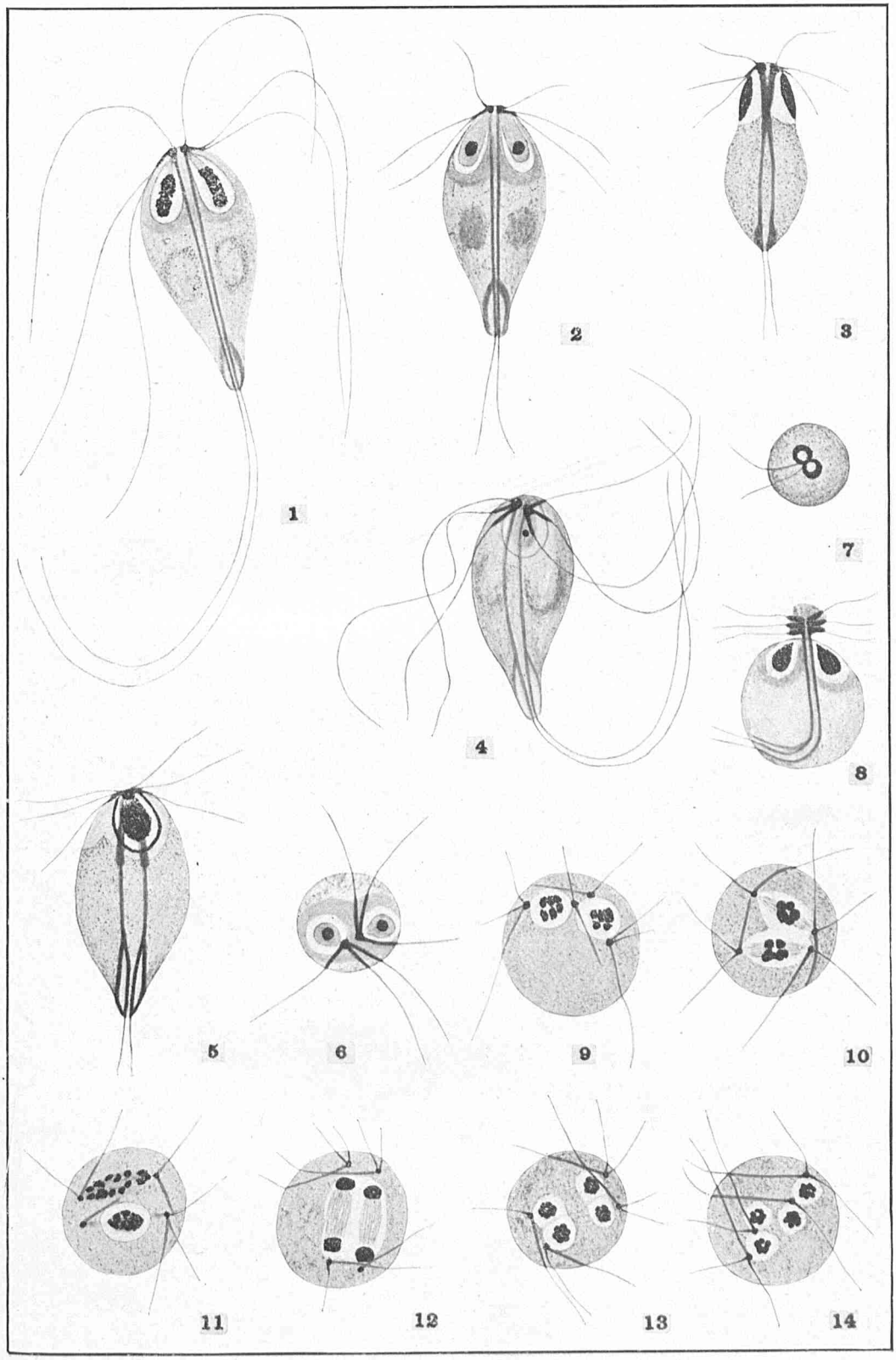
MORPHOLOGY OF THE FLAGELLATE

The flagellate usually is pyriform or ovoidal in shape, tapering gradually toward the posterior end, which is more or less distinctly truncate (figs. 1 to 4). Rounded individuals are quite common, however, and other variations in form are by no means infrequent. They vary considerably in size, also, the majority being about 6 to 8 microns in width by 10 to 12 microns long.

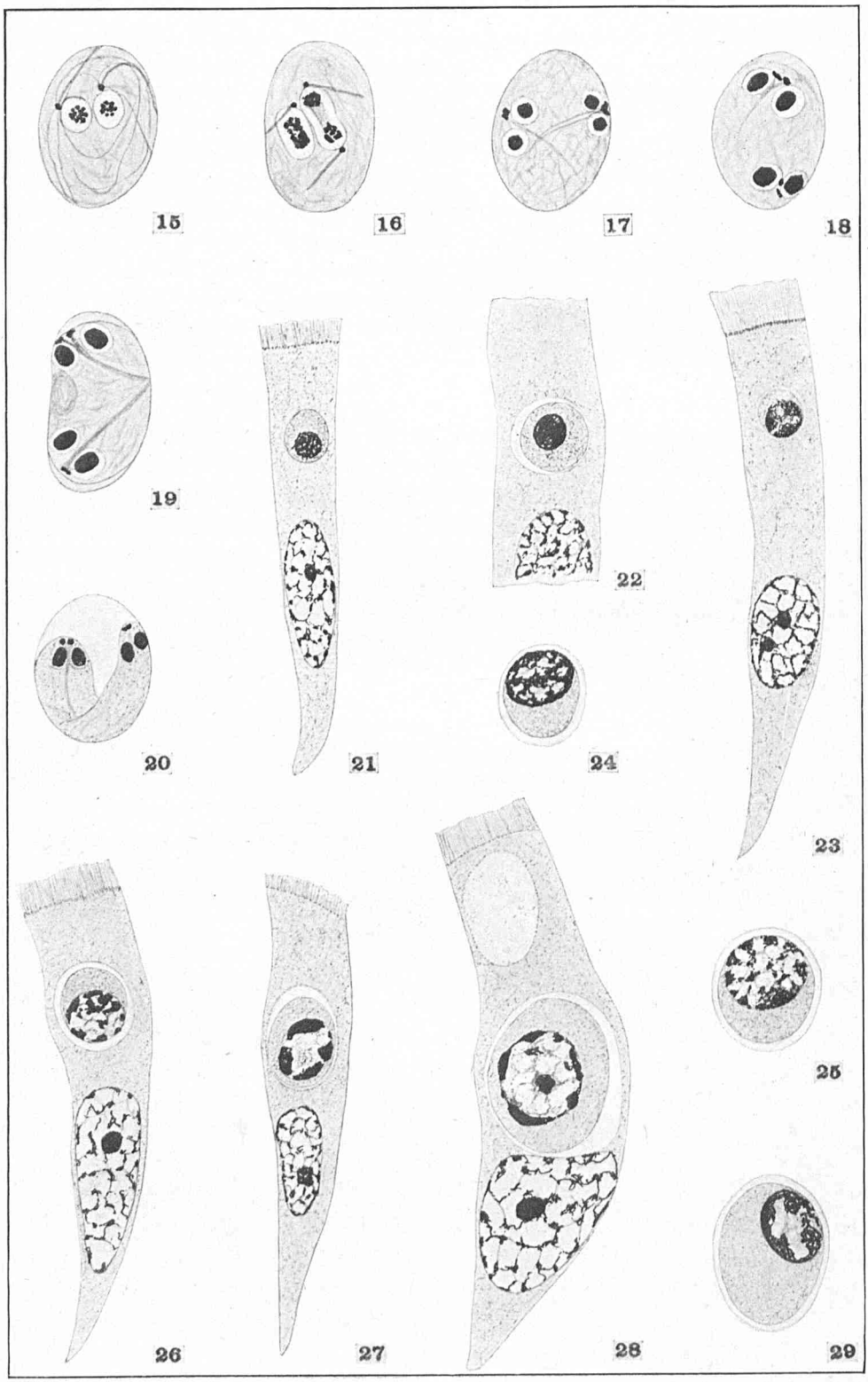
But little of the internal structure can be distinguished in the living flagellates, which are usually very active and swim swiftly about by means of rapidly moving flagella. Furthermore, the animals are so minute that even when fixed and properly stained it is very difficult to make out the finer details of their structure.

A thorough study of more carefully fixed and stained material has convinced the writer that his previous description (Davis, 1923) of the structural details was inaccurate in several respects. This is especially true of the cytostome, which was described as a slightly concave structure on one side of the anterior end. It is now believed that there is no constant flattened or concave region, nor is there a definite ventral side. On the contrary, the anterior end is usually uniformly rounded on all sides. Although there is no flattened cytostome, the protoplasm in this region has a quite different structure from the rest of the body and can be plainly distinguished in both living and stained individuals. In the former it appears as a clear hyaline region occupying the anterior third of the animal, which is sharply marked off from the more opaque and granular protoplasm composing the remainder of the body. When stained with hematoxylin, this region usually appears darker than the rest of the body, but sometimes may be lighter in color (figs. 1 to 4). In the living animal this region is very mobile and changes shape rapidly, sometimes being thrust out for some distance in front and again retracted so that the anterior end becomes enlarged and rounded. It seems probable that this mobile region has been specially modified to enable the animal to cling to the intestinal wall and possibly even to bore into the tissues. In other words, it is apparently a rudimentary cytostome and homologous with the more complex structure characteristic of Giardia. A similar mobile region has been described by Schmidt (1920) in *Octomitus intestinalis truttæ*.

When in active movement, the organism rotates rapidly on its long axis and, as noted above, there is no definite ventral side as described in a previous paper.



For explanation of figures, see page 26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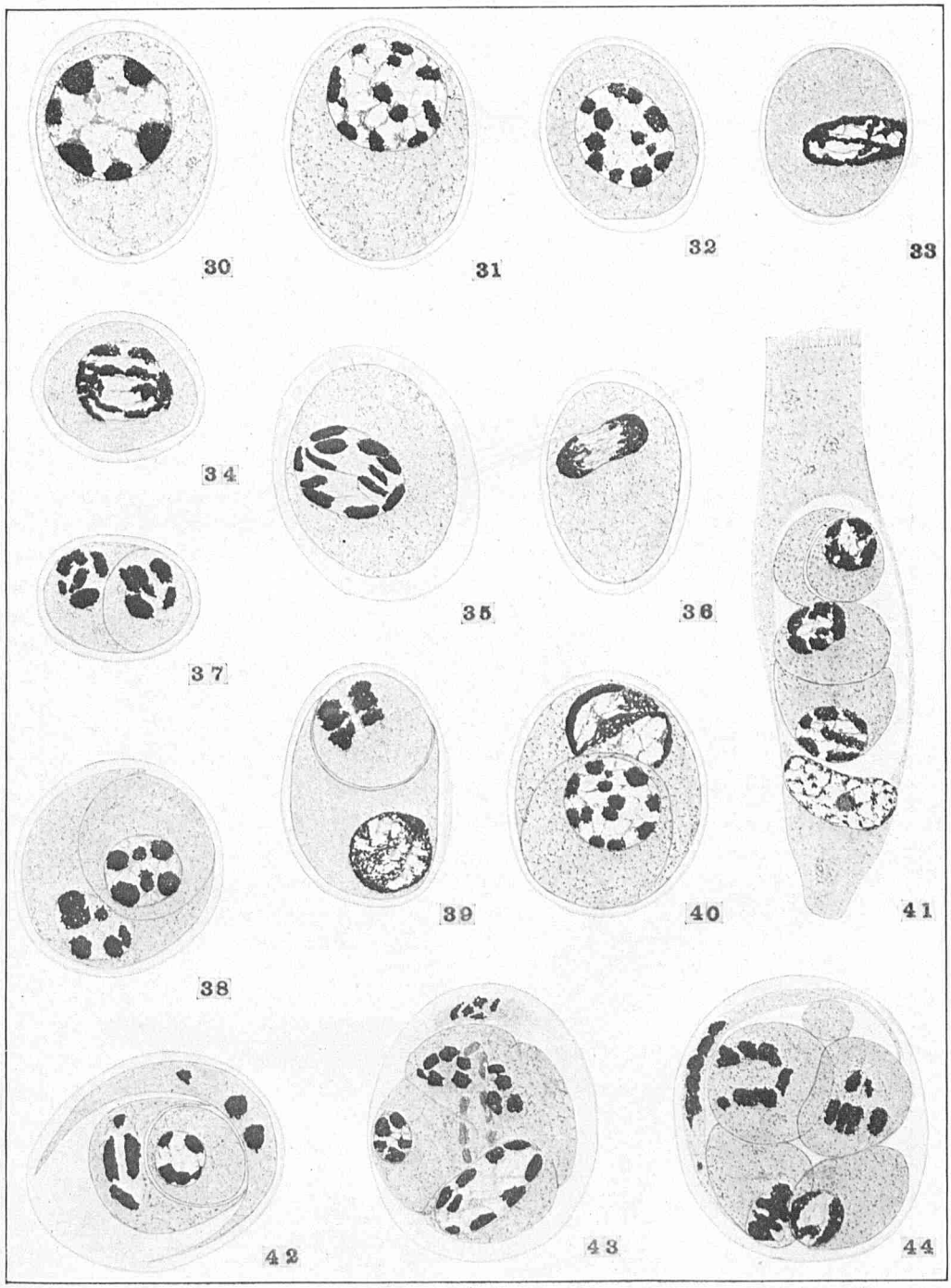
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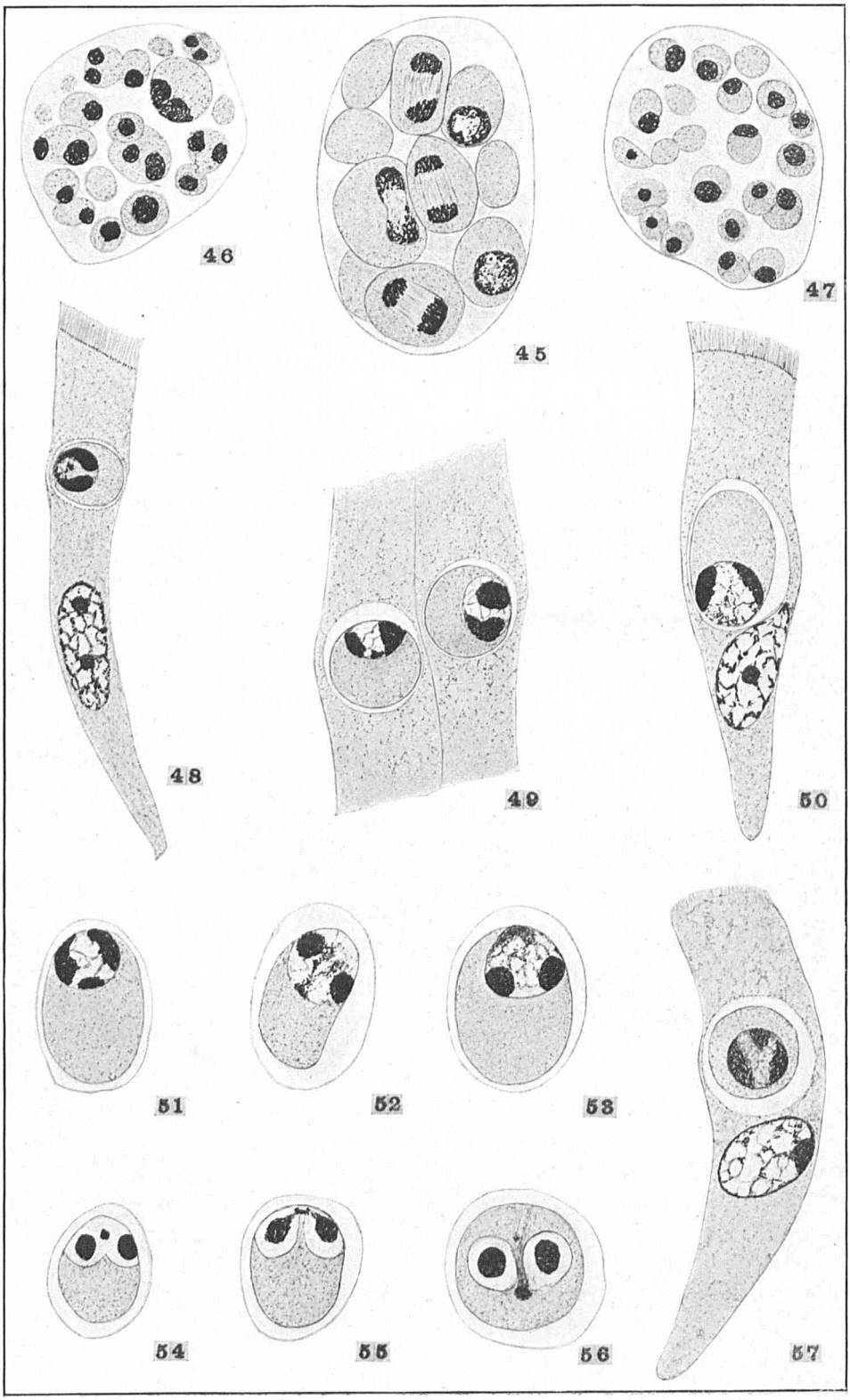
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While a ridge can sometimes be seen on one side of the body, this is evidently due to a temporary displacement of the axostyles.

Attached to the anterior end are three pairs of flagella, which vary considerably in length but are usually about one and one-half times the length of the body. These flagella arise from the blepharoplast complex attached to the anterior ends of the axostyles. Surrounding the base of each flagellum is a deeply staining layer, which extends from the axostyles to the point at which the flagellum leaves the body (figs. 4, 6, and 8). Owing to this layer, it is often very difficult, if not impossible, to distinguish a definite granule at the base of the flagella, and one gets the impression that the blepharoplast complex is formed by the greater development of the deeply staining layer at the junction of flagella and axostyles. A fourth pair of flagella arise from the axostyles at the extreme posterior end of the body. These flagella are considerably longer than those at the anterior end and trail behind the animal when it is in motion.

The axostyles are a pair of slender flexible rods which extend the entire length of the body and can usually be distinguished in the living animal. Their relative position is very variable, and while they may sometimes lie nearly parallel (figs. 1 and 2) they often extend across each other as shown in Figure 3. At the anterior end the axostyles are surrounded by a chromatic layer which in deeply stained specimens may be conspicuous (fig. 5), but is usually indistinguishable in strongly decolorized individuals. Near the posterior end is a characteristic structure, also composed of chromatic material, which is easily recognized even in strongly decolorized individuals. This structure appears as three or four granular chromatic bands extending along the axostyles for about one-third their length (figs. 1 to 5). These bands often appear to form the walls of a pair of longitudinal grooves and were so described by Moore (1922). However, when viewed from the posterior end (fig. 7) it is evident that the chromatic material in reality forms a pair of funnel-shaped structures attached to the axostyles with the smaller end pointed forward. Owing to the movements of the axostyles, the appearance of these structures varies greatly in different individuals.

At the anterior end of the body is a pair of ovoidal or egg-shaped nuclei, with the smaller end extending anteriorly to connect with the blepharoplast complex and axostyles. Surrounding the nucleus is a delicate membrane, within which a layer of chromatic granules can be seen in deeply stained individuals (fig. 5), but these readily lose the stain when the preparations are properly decolorized. Within the nucleus is a central karyosome surrounded by a clear space or halo. The karyosome is elongated and stains deeply with hematoxylin. When properly decolorized it can be seen to be composed of deeply stained granules embedded in a lighter matrix—the plastin—which extends anteriorly to connect with the blepharoplast. In strongly decolorized individuals the chromatic material is limited to a single spherical granule near the middle of the karyosome (figs. 4 and 6). When further decolorized, this chromatic body gradually grows smaller and eventually disappears.

There can often be seen, near the middle of the body, a pair of irregular, finely granular structures, which stain somewhat darker than the surrounding cytoplasm (figs. 1 and 2). These structures vary greatly in shape and appearance, and, while

sometimes quite prominent, flagellates are often seen which show no trace of them even when fixed and stained in the same way (figs. 3 and 5).

MULTIPLICATION OF FLAGELLATES

Multiplication takes place by a complicated process of binary fission, which in its essentials is very similar to that described by Swezy (1915) in Hexamitus. In preparation for division, the organism becomes rounded and the chromatin in the karyosomes collects in a number of rounded granules, which are evidently chromosomes (fig. 9). These granules are so small and close together that it is very difficult to determine the exact number, but there are probably five or six in each nucleus. The differentiated region forming the rudimentary cytostome becomes indistinguishable from the rest of the protoplasm, but the clear areas surrounding the karyosomes are a prominent feature throughout the process of division. Early in the prophase each blepharoplast and axostyle divides into two parts, which quickly separate so as to lie on opposite sides of the nucleus (fig. 9). No paradesmose connecting the blepharoplasts, as described by Swezy in Hexamitus, could be distinguished. The flagella fail to take part in this division, with the result that one of the blepharoplasts has two flagella, the other only one, and one axostyle has none. A primitive type of spindle, which extends across the nucleus connecting with the blepharoplast centrosomes outside the nuclear membrane, is then formed from the plastin of the karyosome (fig. 10). The chromosomes are at first grouped at the equator of the spindle, but later become distributed along its entire length (fig. 11). At a somewhat later stage the daughter chromosomes become grouped at each end of the spindle a short distance from the blepharoplast centrosomes (fig. 12). At first interzonal filaments can be plainly seen connecting the two groups of chromosomes, but these gradually disappear with the formation of the daughter nuclei. The telophase appears strikingly like the prophase, except that there are two pairs of nuclei instead of one, and, just as in the prophase, each karyosome is composed of five to six rounded granules embedded in a homogeneous matrix (figs. 14 and 15). All the axostyles now bear flagella, but no new ones have yet been developed from the blepharoplasts. Just when these appear has not been determined.

It will be noted that dividing individuals retain their flagella throughout the process and for that reason are actively motile. Flagellates in different stages of division have often been observed in fresh preparations, swimming about as actively as the others, but with considerably more irregularity in their movements. On one occasion a rounded individual, which was evidently in the last stages of division, was observed to separate in less than 60 seconds into two typical flagellates, which swam away in opposite directions.

It is evident from the foregoing account that fission in this species is essentially a longitudinal division very similar to the process described by various authors in Hexamitus and Giardia. It should be pointed out, however, that no evidence has been found of a multiple division such as has been described in Giardia and Hexamitus, and it is not believed that it occurs in this species.

The writer has found no reason to believe that a transverse division, as described by Moore (1924), ever occurs. Individuals showing a transverse constriction in some part of the body are quite common in some of the writer's preparations, but there is every reason to believe that such a constriction has nothing to do with division. It has been noticed frequently that when an individual is passing through a small opening the body may become strongly constricted as the animal squeezes through the narrow space. When mounted in the thick mucus from the posterior end of the intestine, numerous individuals that are worming their way through small openings of this kind can often be seen in the same field.

It is a notable fact that fission is evidently more or less periodic, since in the majority of the writer's preparations dividing forms are rare, while in a few instances they are very abundant. Just what factors are concerned in stimulating division is still somewhat doubtful, but there is evidence that there may be a sudden increase in the rate of fission when the host fishes are subjected to unfavorable conditions, such as a rise in temperature or a deficiency of oxygen or food.

DEVELOPMENT OF CYSTS

The cysts of *Octomitus salmonis* are ordinarily rare in the intestines of infected fish, even though the flagellates may be abundant, but a few can usually be found if a diligent search is made. In several instances they were present in large numbers, and it is worthy of note that these cases were all found in early spring. However, the evidence at hand is too meager to justify the conclusion that the cysts are more abundant at this season, although this may very well be the case.

When first formed, the cysts are ovoidal, rarely spherical, and are surrounded by a very thin transparent membrane. No definite structure can be made out in the living cysts, but in some cases rapid vibratile movements can be plainly seen. These are evidently due to the flagella that are retained for a short time after encystment. The axostyles are indistinguishable, but the nuclei usually can be recognized, and small vacuoles can be faintly discerned in some cases. The cysts usually stain a deep brown when treated with iodine, due to the presence of glycogen, which occurs in the form of fine granules or, in some cases, in irregular masses. This affords an easy method of demonstrating the presence of cysts, which stand out conspicuously against the more lightly stained background. It is of interest to note that ordinarily no trace of glycogen can be seen in the flagellated forms, but in one instance, when the cysts were exceptionally abundant, numerous flagellates were observed, which contained varying amounts of glycogen in the posterior half of the body, where it was evidently being stored in preparation for encystment. The cysts are usually about 7 microns wide by 10 microns long, but may reach a length of 12 microns with a corresponding decrease in the width.

Figure 15 shows a newly formed cyst in which the paired nuclei, blepharoplasts, flagella, and axostyles can be distinguished, but the texture of the cytoplasm is much looser than before encystment. This is characteristic of the cysts and is probably due to extensive formation of glycogen, which, of course, disappears as a result of the treatment to which the cysts are subjected. The flagella disappear

shortly after encystment, followed by the division of the nuclei, blepharoplasts, and axostyles (fig. 16). Since this occurs so quickly after encystment, the great majority of the cysts always contain two pairs of nuclei, either close together or some distance apart (figs. 17 and 18). Later the cysts become more elongate, with a pair of nuclei at each end (fig. 19). It is probable that the contents of the cyst is always divided into two distinct individuals at this time, but they are so closely crowded together that in most cases it is impossible to determine this with certainty. An exceptional case is shown in Figure 20, where two individuals can be clearly distinguished owing to the fact that they do not entirely fill the cavity of the cyst, as is usually the case.

Advanced stages of the cysts, such as are shown in Figures 19 and 20, are found only in the extreme posterior end of the intestine. They evidently pass out with the excrement at this stage, and their further development has not been followed. Presumably they are accidentally ingested by another fish and in this way start a new infection. It is very probable that this is the usual method by which the parasite gains entrance to a new host, although when the fish are crowded closely together it is not impossible that the flagellated forms may set up a new infection. Experiments have shown that the flagellates can live outside the host for 15 to 30 minutes, but that they are unable to survive in water for a much longer period. However, even should the flagellates gain entrance to a new host while still in active condition, it is by no means certain that they could survive in the stomach for any length of time.

INTRACELLULAR STAGES

In addition to the flagellates that are found only in the lumen of the intestine, intracellular stages are always present in the intestinal epithelium of infected fish. Ordinarily these forms are comparatively rare, but under certain conditions may become very abundant. They occur only in the epithelial lining of the pyloric cæca and the anterior end of the intestine.

The earliest stage of the intracellular parasite appears as a small rounded cell containing a relatively large deeply staining nucleus (figs. 21 to 24). They are usually found in the distal end of the cells, as shown in Figures 21 and 23, but in some cases may lie in the proximal portion of the cell below the nucleus. The parasite is almost invariably surrounded by a distinct vacuole, which is probably, in large part at least, the result of shrinkage. They grow rapidly to many times their original size (figs. 25 to 30), causing hypertrophy of the host cell, which in probably all cases is eventually destroyed. At first the nucleus is filled with a diffuse chromatic network (figs. 24 to 26), but as the organism grows there is a tendency for the chromatin to become aggregated in several large masses on the nuclear membrane (figs. 27 to 30). At first there are five or six large chromatic masses, but at a little later stage these bodies are smaller and more numerous (figs. 31 and 32). A careful study of a number of cells at this stage shows that there are always about 12 of these masses of chromatin in each nucleus. It is believed that they are formed by the division of the larger chromatic bodies that were present at an earlier stage and that they are, in reality, chromosomes that have divided pre-

cociously in advance of the division of the cells, which occurs somewhat later. At this stage the organism is usually somewhat elongated, with the nucleus at one end (fig. 31). Occasionally the host cell may disintegrate at this stage, the parasite passing into the intestinal lumen. In such cases it is apparently unable to complete its development, since, although this stage of the organism is sometimes not uncommon in the intestine, they invariably appear to be in a moribund condition and later stages have not been found.

Division of the full-grown parasite or schizont is accomplished by a very primitive form of mitosis shown in Figures 33 to 36, but which is very difficult to follow in detail. The daughter cells formed by this division (figs. 37 and 38) are unsymmetrical, and instead of lying side by side, as in ordinary division, one is partially inclosed by the other. This peculiar relation of the two cells is very characteristic; sometimes the outer cell is much flattened and almost entirely incloses the other. Often the nucleus of the enveloping cell has a quite different structure from that of the inner cell (figs. 39 and 40), and in some cases, at least, this cell may eventually degenerate. Several divisions of the inner cells follow in rapid succession until as a result of this process numbers of small spores or merozoites are formed (figs. 41 to 47), which then make their way into uninfected cells and repeat the cycle. As stated above, the enveloping cell often degenerates during the process of schizogony, but whether this is always the case is uncertain. In Figures 43 and 44 it is very evident that the cell is gradually distintegrating, but in many other instances, such as shown in Figure 41, no trace of a degenerating cell could be found. There appears to be considerable variation in the behavior of the cells during schizogony, and it is probable that many of the parasites are destroyed during the process. In many cases entire groups of cells in various stages of schizogony do not stain normally and are apparently moribund. In fact, the whole process gives one the impression that in this species the intracellular cycle is a comparatively recent development and that the organism has not yet become completely adjusted to such an environment.

It is obvious that schizogony furnishes a rapid means of multiplication, since the entire process requires but a short time, probably not more than 24 to 48 hours under favorable conditions. It has often been noticed that infection of the epithelial cells is not uniform but that here and there are groups of cells in which nearly every one is infected, while between such areas there may be only an occasional infected cell. Such a condition is evidently due to infection by merozoites that invade the surrounding epithelium, causing an intensive infestation of the cells in the immediate vicinity and in many cases the complete destruction of the epithelium.

In addition to the stages just described, other intracellular forms are sometimes met with which do not fit into the cycle of schizogonous development. A number of these forms are shown in Figures 48 to 56. It is evident that this series shows a gradual transition from the typical intracellular parasite to the flagellated form in the lumen of the intestine. In the early stages these cells differ from those previously described only in the fact that nearly all the chromatin is collected in two large masses on opposite sides of the nucleus (figs. 48 and 49) instead of being uniformly distributed, as in the majority of parasites at this stage. However, the writer is by no means convinced that all cells showing such an aggrega-

tion of chromatin develop directly into flagellates, since there is apparently a tendency for the chromatin to collect on opposite sides of the nucleus in many cells that are evidently in the schizogenic cycle. Later, as shown in Figures 50 to 53, the cells become elongated, with the nucleus at one end containing the paired chromatin masses symmetrically arranged, one at each side. Between the chromatic bodies there is always some residual chromatin, which gradually loses its affinity for stains. At a somewhat later stage the outline of the original nucleus has disappeared, and each of the chromatic bodies now forms the karyosome of a distinct nucleus (figs. 54 to 56). These nuclei show a striking resemblance to the nuclei of the flagellates, each karyosome being surrounded by a membrane separated from it by a clear area. In addition, there is usually a deeply staining body, evidently the blepharoplast, between the paired nuclei. The position of the blepharoplast suggests that it is derived from the residual chromatin left in the nucleus after the formation of the karyosomes. It has been impossible to distinguish flagella on the intracellular parasites at any stage, but in a number of instances there were structures that appeared to be developing axostyles, although in no case were they very distinct. However, in spite of the fact that no clear case of the presence of axostyles or flagella has been demonstrated, it is nevertheless believed that such a series as shown in Figures 48 to 56 can be explained only on the assumption that they represent a gradual metamorphosis of the intracellular parasites into the free-swimming flagellates.

Since no intracellular stage has previously been attributed to any flagellate at all closely related to Octomitus, it may not be out of place to briefly review at this time the evidence for the assumption that the intracellular parasites and flagellates are simply different stages in the life cycle of a single species. Undoubtedly the strongest evidence in favor of such a belief is the fact that various stages can be found among the intracellular parasites which, when arranged in series, show a gradual transition from the typical intracellular form to the fully developed flagellate. While it is true that such stages are not common, they can scarcely be regarded as exceptional, since several can often be found on the same slide.

Furthermore, it has been found that the intracellular parasites and flagellates always occur together. In no case have flagellates been found in fish in which the intestinal epithelium did not contain at least a few of the intracellular forms. It is true that the latter have been found in fish when no flagellates could be demonstrated in the intestine, but in all such cases flagellates were found in other trout from the same locality. When we take into consideration the wide distribution of Octomitus, the constant association of the flagellates and intracellular parasites becomes all the more significant. It is difficult to explain such a relation except on the ground of specific indentity.

Of special significance is the fact that an undescribed species of Octomitus occurs in the fan-tailed darter (*Etheostoma flabellare*) at White Sulphur Springs, W. Va., which, like *O. salmonis*, lives in the anterior end of the intestine. Sections of the cæca of infected fish show the presence of a few intracellular parasites (fig. 57) that are evidently distinct from those in the trout. Presumably these are the intracellular stages of the species of Octomitus peculiar to the darter.

PATHOGENESIS

The effects of the parasite on the host undoubtedly vary greatly under different conditions, and there is still much to learn in this connection. The evidence at hand is quite contradictory in some respects, but it is believed that much of this apparent discrepancy can be explained on the basis of the two cycles of development within the host. Since the extracellular and intracellular stages develop under such different conditions, it is to be expected that the effects on the host will show corresponding variations.

There can be no doubt that fish may harbor large numbers of flagellates in the intestine without exhibiting any noticeable injurious effects. In fact, it has been a source of wonder to the writer that fish on occasion may contain such numbers of flagellates and still appear to be in a healthy, vigorous condition. However, this appears to be largely a matter of age, and probably also of acquired immunity on the part of the host. Ordinarily Octomitus does not cause serious injury after the first summer, and it is a common occurrence to find yearling fish in a healthy condition in spite of the fact that they are infested with large numbers of flagellates. Since at most hatcheries practically all the fish become infected during the fingerling stage, it is reasonable to assume that these yearlings have developed more or less immunity to the effects of the parasite. However, the writer does not mean to imply that under such circumstances the parasites are harmless, for they probably interfere with the growth of the host—possibly to a greater extent than is realized.

Among the fingerlings the effects of a severe infestation by the flagellates are usually quite marked. The fish lose their appetite and become thin and emaciated, the large head and attenuated body suggesting the term "pinhead," by which they are commonly known among fish-culturists. Such fish are usually weak and listless and in late stages of the disease may become too feeble to fight the current, being finally carried against the screen at the lower end of the trough, where they soon expire.

This chronic form of octomitiasis is usually most prevalent during the spring and early summer when the fingerlings are about 2 to 2½ inches long. While the mortality is usually not very heavy at any one time, this condition may persist for several weeks or months, with the result that the total loss may be considerable, sometimes reaching as high as 50 or 75 per cent.

Of course it is not contended that all "pinheads" are due to Octomitus, since anything that will interfere with nutrition will tend to have the same effect. However, the examination of a large number of "pinheads" at several hatcheries has shown that such fish are almost invariably infected with the flagellate stage of *Octomitus salmonis*, and, furthermore, that on the average the number of flagellates present is much greater in the "pinheads" than in other fish from the same lot that are not so emaciated.

No doubt there are a number of environmental factors that tend to bring on the chronic form of octomitiasis. Among these a rise in temperature, even though comparatively slight, and overcrowding are believed to be especially important. There is also reason to think that the character of the food may exert considerable

influence on the abundance of the flagellates. We have found in a recent feeding experiment that rainbow trout on a sheep-liver diet contained, on the average, a smaller number of flagellates than trout of the same age kept under similar conditions but fed beef heart instead of liver. This is shown in the accompanying table, which indicates the comparative numbers of flagellates in the intestines of 40 rainbow fingerlings at the White Sulphur Springs hatchery. These fish were examined on August 7, 1924, and the relative abundance of flagellates indicated as correctly as possible by the familiar plus-sign method. All of the fish examined were in a fairly vigorous condition at the time, and the mortality was not excessive.

Kind	+	++	+++	++++	+++++	Total number of fish
Liver-fed fish	4	7	7	2	0	20
Heart-fed fish	3	3	3	4	7	20

While, as previously stated, the flagellates are ordinarily not a serious problem in the yearling fish, a notable exception to this rule has come to the writer's attention. The Manchester (Iowa) station has for a number of years experienced considerable difficulty with both brook and rainbow trout during the second summer when the fish are 1½ years old. These fish are stunted, grow slowly, and may develop a "pot-belly," while the mortality is considerably higher than is usually the case with fish of this age. It was found that, almost without exception, the yearlings at this station are heavily infested with flagellates; so much so, in fact, that the intestinal contents is often a squirming, seething mass of these parasites. Remarkably enough, the fingerlings of both rainbow and brook trout are not infected, and little difficulty is experienced with these fish, which are healthy and vigorous and show a rapid growth with a comparatively low mortality. Just why the fingerlings at this station do not become infected is not entirely clear. Possibly it may be due to the fact that the water supply is derived from a covered spring and there is no possibility of its becoming contaminated by fish before reaching the hatchery. The greater susceptibility of the yearling fish to the effects of Octomitus is probably due to the fact that they have had no opportunity to acquire an immunity. When the fingerlings are infected, those that survive doubtless develop a more or less complete immunity by the end of the first summer, which protects them from serious injury the following year.

While the chronic, wasting disease just described is undoubtedly the most common result of infection by *Octomitus salmonis* and is prevalent to a greater or less extent at nearly all trout hatcheries, there is good reason to believe that under certain conditions the disease may manifest itself in a quite different manner. The writer's attention was first called to this infection in the spring of 1922 by reports that the rainbow fingerlings from the White Sulphur Springs (W. Va.) hatchery did not stand up well during shipment. The loss during the first 24 hours was not excessive, but if the fish were in transit for a much longer period the mortality was exceptionally heavy, sometimes reaching 75 per cent, or even more. In an attempt to discover the cause of the trouble, a number of the fish were shipped to

Washington, and it was found that in many instances the anterior end of the intestine was badly inflamed. When sectioned, the congested portion of the intestine and cæca were found to contain intracellular parasites in such numbers that a large proportion of the epithelial cells was destroyed, which was undoubtedly the cause of the inflammation. In striking contrast to the chronic form of octomitiasis, we have here an acute disease that results in a heavy mortality within two or three days. Evidently the changed conditions to which the fish are subjected during distribution result in a sudden and rapid increase in the intracellular stages of Octomitus. That this is the case has been shown by a number of experiments in which fish have been taken directly from the hatchery troughs and placed in cans (such as are used in distribution) for 24 to 48 hours. In every case this has resulted in a noticeable increase in the number of intracellular parasites, the great majority of which were in various stages of schizogony. The picture presented in sections of such material is in striking contrast to that ordinarily found in sections from infected fish in which the intracellular parasites are not abundant and division stages are the exception.

There is still some uncertainty as to the factors involved in stimulating the development of the intracellular stages, but undoubtedly a rise in temperature, deficiency of oxygen, and cessation of feeding are among the more important, although it is not necessary for all of the factors to be present to cause increased activity among these forms. For instance, when the fish are held in cans placed in running water at the hatchery there is usually an increase in the intracellular stages although the temperature is constant. However, the increase is not as rapid as when the temperature is allowed to rise slightly. That the practice of withholding food from the fish during distribution is also a factor is indicated by some observations during the past summer. In the course of some feeding experiments at the White Sulphur Springs station it was necessary on two occasions to allow the fish to go two or three days without food, owing to delay in the usual shipments of heart and liver. In both instances there was an increased mortality after the first day, and in practically every instance an examination of the cæca of the dead fish showed that large numbers of intracellular parasites were present in an actively growing condition. Strangely enough, the mortality was greatest among fish fed on liver, although, as stated above, the flagellates were more numerous in heart-fed fish.

In addition to the mortality during the distribution of fingerlings there is reason to believe that severe epidemics, accompanied by heavy mortality, may occur under certain conditions while the fish are still at the hatchery. Such epidemics occur only sporadically and are not of regular recurrence year after year, as in the case of the common chronic form of octomitiasis. While the writer has not had an opportunity to conduct a personal investigation of such an epidemic, there is evidence that several heavy mortalities at the bureau's hatcheries in recent years were primarily due to this cause, and Dr. Emmeline Moore (1923 and 1924) states that a number of severe epidemics in the New York State hatcheries have been caused by Octomitus. Such a heavy mortality in a comparatively short time suggests that the intracellular stages may have been primarily responsible, although it is by no means certain that in some instances, at least, another organism in addi-

tion to Octomitus may not have been involved. Theoretically it is not improbable that under certain conditions the intracellular forms may exhibit a sudden and rapid increase while the fish are still in the hatchery troughs which would result in a severe mortality. Fortunately, under ordinary circumstances there appears to be little danger of such an outbreak; otherwise it is difficult to account for the fact that at many hatcheries in which the fingerlings are known to be thoroughly infected with Octomitus there has been no sudden excessive mortality for a number of years. However, given the proper conditions there would seem to be no reason why the intracellular forms might not develop as rapidly at the hatchery as in cans during distribution.

Although it is believed that there are thus two quite different forms of octomitiasis produced by different phases in the life history of the parasite, and that, as the result of environmental conditions, one or the other form may be more prominent, it is nevertheless true that in the great majority of cases we have to deal with a combination of the two types. In some instances the injurious effects appear to be due almost entirely to the flagellated stage, while in others it is the intracellular stages that are primarily responsible. Obviously the character and severity of the disease will depend on which stage of the parasite is the more abundant, although in most cases both stages are not without their influence. It is very probable that even in the chronic, wasting type of octomitiasis the mortality may to a considerable extent be due to the intracellular parasites, and a comparison of the dying fish with emaciated but fairly vigorous fish from the same lot has shown that in most instances the intracellular stages were distinctly more numerous in the former than in the latter.

As previously pointed out, fish are sometimes infected with the intracellular stages when no flagellates can be found in the intestine. This is usually true only of an occasional fish, but in one notable instance a lot of brook-trout fingerlings 1 to 1½ inches long were observed in which there was a heavy mortality, although no flagellates could be found in the intestine. The explanation of this was not apparent until it was found that the intracellular stages were abundant in the cæcal epithelium.

While apparently all species of trout and salmon may be infected with Octomitus, not all species are equally susceptible to the injurious effects of the parasite. At the bureau's hatcheries Octomitus appears to be more injurious to the rainbow trout than to other species, although according to Dr. Emmeline Moore in the New York State hatcheries it is the brook trout that are the principal sufferers. The explanation of this fact is not evident, although it is suggested that since the bureau's hatcheries at which most of the investigations on this parasite have been carried on are primarily rainbow hatcheries, it may be that a strain of Octomitus has been developed which is especially adapted to this species. The fact that the brood stock at these hatcheries consists entirely of rainbow trout may be significant in this connection.

No evidence is at hand regarding the effects of *Octomitus salmonis* on young salmon, but since considerable losses sometimes occur among the fingerlings in early spring, at about the time its effects are most noticeable in trout, it is not improbable that Octomitus may be responsible.

CONTROL MEASURES

Since *Octomitus salmonis* is so widely distributed and occurs in fish of all ages, it is believed that it will be impracticable to eliminate the parasite from the hatcheries. It is probable that many, if not all, adult fish in infected hatcheries harbor small numbers of the parasite and are thus carriers of the disease. Even when no flagellates can be found in the intestine a few intracellular forms can usually be discovered if the search is sufficiently prolonged. It is very doubtful if these parasites can be reached by any drug administered in the food, so that in order to free a hatchery from infection it would be necessary to remove all the fish and throughly disinfect the entire plant. Even were this done, it would probably not be practicable to restock with uninfected fish.

It is even doubtful if drugs could be successfully used in getting rid of the flagellates. While no experiments have been conducted along this line, the fact that attempts to get rid of Giardia (a closely related parasite in man) by this means has so far resulted in failure affords little encouragement in that direction, especially when we consider the many practical difficulties in attempting to administer drugs to trout 1 to 2 inches long.

In view of these facts it is felt that efforts to control the disease must be based almost entirely on prophylactic measures. Fortunately there is good reason to believe that by the adoption of such methods the ravages of the disease can be reduced to a point where it will no longer be a serious menace to trout culture. In this connection the fact that Octomitus is apparently not injurious to trout under natural conditions is especially significant. All the evidence at hand points clearly to the conclusion that the ravages of octomitiasis are in inverse ratio to the suitability of the environment, and that if the fish can be kept in a strong, vigorous condition they will be able to resist the attacks of the parasite.

The factors that appear to be most conducive to the development of Octomitus are overcrowding, an unsuitable water supply, especially a deficiency of oxygen and improper food. Owing to the inherent defects of artificial propagation, it is almost impossible to entirely avoid the unfavorable effects of these factors, but certainly in most cases much can be done to improve present conditions. There are, for instance, probably few hatcheries where the fish are not overcrowded at certain seasons. It is a natural tendency to attempt to increase the output by overloading the equipment. In some cases this may be successful for a time, but in others it is attended with disaster. That such a practice is ever advisable in the long run is more than questionable, since, even if not attended by heavy mortality, the fish reared under such conditions are likely to be weak and underdeveloped.

It is very probable that part of the injurious effects of overcrowding are due to an insufficient supply of oxygen, and this is, of course, especially noticeable when the water is not properly aerated before entering the troughs. With rare exceptions the water from springs is deficient in oxygen and should always be made to flow over an efficient aerating device before entering the troughs or ponds.

The third factor, that of improper food, is less easy to correct. Undoubtedly no substitute can equal natural food, but it will probably never be practicable to supply this in sufficient quantities to meet the demands of the hatcheries. To

attempt to rear trout on natural food alone would in most cases increase the cost of artificial propagation beyond all reason; but it may be possible to effect a compromise whereby the fish can be given some natural food in addition to the usual hatchery diet. Experiments have shown that such a diet will give much better results than the straight heart or liver diet commonly used.

In connection with the investigations on Octomitus we have carried on some experiments on the additions of vitamins to trout foods with very encouraging results. In these experiments cod-liver oil and dried brewer's yeast were added to the ordinary heart and liver diet to correct any deficiency of these foods in vitamins A and B. The results to date indicate that fish fed on a diet containing small percentages of oil and yeast show a greatly decreased mortality and increased growth over those fed a straight heart diet.[1]

While our experiments have not yet been sufficiently extensive to justify any general conclusions as to the effectiveness of cod-liver oil and yeast in the control of octomitiasis, it is believed that improvement in the food, either through the addition of vitamins in oil and yeast or the addition of some natural food to the diet, affords one of the most important methods of combating the disease.

It has been found that the excessive loss which frequently occurred when infected fish were held in cans for more than 24 hours during distribution can be entirely prevented by avoiding overcrowding and keeping the fish at a temperature considerably below that at which they were formerly carried. When infected fish are held at temperatures of 40 to 45° F. and given an abundant supply of oxygen, there is very little loss, even though they may be several days in transit.

SUMMARY

1. *Octomitus salmonis* is widely distributed throughout the country and probably occurs in all species of trout and salmon.

2. The parasite has two phases of development within the host—one intracellular, the other extracellular.

3. The intracellular stage is found in the epithelium of the pyloric cæca and the anterior end of the intestine. This stage reproduces by a process of schizogony, resulting in the formation of a number of merozoites, which in turn invade neighboring epithelial cells and repeat the process.

4. After a time some of the intracellular forms cease to divide and become metamorphosed into the flagellated form.

5. The extracellular or flagellated stage occurs in the lumen of the intestine and multiplies by a complicated process of binary fission.

6. The flagellates form cysts, within which they divide once by binary fission. These cysts serve to spread the infection from one fish to another.

7. Severe infestation by the parasite may result in serious injury to the fingerling fish. Excessive numbers of the flagellates may cause the fingerlings to lose their appetite and become greatly emaciated. Rapid multiplication of the intracellular stage may result in an acute form of the disease accompanied by heavy mortality.

[1] See Davis and James (1925) for further details regarding these experiments.

8. While the parasites are ordinarily most abundant in fish less than one year old, small numbers are usually present in the older fish, which become carriers of the disease.

9. It is believed that control of the disease must be based primarily on prophylactic measures. This can best be accomplished by keeping the fish under as favorable environmental conditions as possible.

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EXPLANATION OF FIGURES

FIG. 1.—View of a typical flagellate. ×3150.
FIG. 2.—Similar to Figure 1, but more strongly decolorized. ×3150.
FIG. 3.—Flagellate with anterior end restricted, causing flattening of nuclei along the side. ×3150.
FIG. 4.—Flagellate viewed at a different angle from Figures 1 to 3 to show attachment of anterior flagella. Very strongly decolorized. ×3150.
FIG. 5.—Flagellate viewed at right angles to Figures 1 to 3. Only one nucleus is shown, the other lying directly underneath. ×3150.
FIG. 6.—View of flagellate from anterior end to show origin of flagella. ×3150.
FIG. 7.—View of flagellate from posterior end. Note openings of small funnel-shaped organs. ×3150.
FIG. 8.—Flagellate with anterior end abnormally retracted. Note the deeply staining envelope around the base of the flagella. ×3150.
FIGS. 9 to 14.—Successive stages in the division of the flagellates. Figure 9, prophase; 10, metaphase; 11, anaphase; 12 to 14, telophase. ×3150.
FIG. 15.—Early stage of cyst in which the nuclei are preparing for division. ×2400.
FIG. 16.—Slightly later stage of cyst. Nuclei beginning to divide. ×2400.
FIGS. 17 and 18.—Cysts at a somewhat later stage with two pairs of nuclei. ×2400.
FIGS. 19 and 20.—Cysts at a still later stage of development with contents divided into two distinct individuals. ×2400.
FIG. 21.—Epithelial cell from cæcum of trout containing early stage of intracellular parasite. ×1640.
FIG. 22.—Portion of an epithelial cell containing parasite at about same stage as Figure 21. ×2400.
FIG. 23.—Epithelial cell containing early stage of parasite. ×1640.
FIG. 24.—Intracellular parasite at about same stage as Figure 23, but more highly magnified. ×2400.
FIG. 25.—Slightly later stage than Figure 24. ×2400.
FIGS. 26 to 28.—Epithelial cells containing successively later stages of the parasite. ×1640.
FIG. 29.—Intracellular parasite showing tendency of the chromatin to collect in large masses on the nuclear wall. ×2400.
FIG. 30.—Fully grown intracellular parasite or schizont. ×2400.
FIGS. 31 and 32.—Slightly later stages of schizont just before division. ×2400.
FIGS. 33 to 36.—Successive stages in the first division of the schizont. ×2400.
FIGS. 37 to 40.—Daughter cells formed by division of schizont. In Figures 39 and 40 the nucleus of the enveloping cell has a very different structure from that of the inner cell. ×2400.
FIG. 41.—Epithelial cell containing parasite, which is undergoing schizogony. ×1640.
FIG. 42.—Intracellular parasite at about same stage as Figure 41. Note that nucleus of enveloping cell shows evidences of disintegration. ×2400.
FIG. 43.—Slightly later stages in schizogony. Enveloping cells disintegrating. ×2400.
FIG. 45.—Somewhat later stage in schizogony. ×2400.
FIGS. 46 and 47.—Late stage in schizogony, showing formation of merozoites. ×2400.
FIG. 48.—Epithelial cell containing parasite with chromatin in two masses at opposite sides of nucleus. ×1640.
FIG. 49.—Portions of two adjoining epithelial cells containing parasites at a somewhat earlier stage than Figure 48. ×2400.
FIG. 50.—Epithelial cell with parasite at a later stage of development than Figure 48. ×1640.
FIGS. 51 to 56.—Series of stages showing transition from the typical intracellular form to the flagellate. ×2400.
FIG. 57.—Epithelial cell from the cæcum of the fantailed darter (*Etheostoma flabellare*), containing intracellular stage of Octomitus sp. ×2400.

SECOND EXPERIMENT IN TAGGING SALMON IN THE ALASKA PENINSULA FISHERIES RESERVATION, SUMMER OF 1923

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INTRODUCTION

During the summer of 1923 the writers, assisted by W. P. Studdert, carried out an extensive program of salmon tagging in the district south of the westernmost portion of the Alaska Peninsula, between the Shumagin Islands and Isanotski Strait (commonly known as False Pass). Approximately 10,000 numbered aluminum tags were attached to adult red salmon within this district, and the recaptures of such as were again taken in the ordinary prosecution of the commercial fisheries were reliably reported, as to both place and time, through the cordial cooperation of all the salmon-packing concerns in western Alaska. The program of 1923 was planned as a continuation of a similar experiment on a smaller scale which had been undertaken the previous year and has been reported on by the senior author.[1]

[1] Gilbert, Charles H.: Experiment in tagging adult red salmon, Alaska Peninsula Fisheries Reservation, summer of 1922, Bulletin, U. S. Bureau of Fisheries, Vol. XXXIX, 1923-1924 (1924), pp. 39-50.

The principal results obtained in 1922 may be summarized as follows:

1. An extensive migration of mature red salmon occurs past the shores of the Shumagin Islands and westward along the Pacific coast of the Alaska Peninsula as far as False or Isanotski Pass. This migration forms the subject of an important fishery centering at Unga Island, King Cove, Ikatan, and False Pass. In these districts in 1922 were captured 3,311,911 red salmon, which produced 225,888 cases of the packed product, each case consisting of 48 one-pound cans.

2. The enormous body of fish from which this highly important commercial supply was drawn consisted of individuals fresh from their feeding grounds and still feeding. This is an unusual condition in the red-salmon fisheries, which for the most part are prosecuted near river mouths, where the fish already have begun their fast—a fast that remains unbroken to the end, when they will have fulfilled their mission and have perished on the spawning grounds. The Alaska Peninsula fisheries, which formed the subject of our investigations, are peculiar in the respect that they deal largely with salmon in the midst of their migration in the sea, far from the spawning streams toward which they are directing their course. Shortly before their capture we may assume they were associated with the hosts of immature salmon, from which one, two, and three years later would be drawn the spawning runs of those seasons; but before they were taken they had separated themselves from their younger brethren and in dense formation had started along well-defined migration routes to their final destination.

3. Of the Shumagin migrants a very limited number pursued an easterly rather than a westerly course, a few being recaptured as far to the eastward as Cook Inlet. The total number taking the eastward route was so inconsiderable, however, as to convince us that no appreciable draft would be made on the salmon supply of the Chignik, Karluk, and Cook Inlet fisheries, however intense might be the fishing in the Shumagin district.

4. Of the remainder of the Shumagin fish comparatively few belonged to local races and entered one or the other of the small red-salmon streams of Unga and Popof Islands. The vast majority throughout the fishing season formed a definite westward migration. This imposing body of fish impinged on the mainland shore, notably in Morzhovoi and Ikatan Bays, and a large and important element, in common with other Morzhovoi and Ikatan fish, traversed Isanotski Strait (False Pass) and became distributed to all that unequaled group of red-salmon streams that empty along the Bering Sea shores of the Alaska Peninsula and in Bristol Bay. The fact that this wide distribution existed, constituted perhaps the most important discovery of the season of 1922.

5. The salmon tagged in the neighboring bays of Ikatan and Morzhovoi in 1922 gave no evidence of any movement to the eastward. They passed freely back and forth from one of these bays to the other, and often lingered for two or three weeks in the locality where marked. A limited number belonged to local streams, but many traversed False Pass and were reported from all the red-salmon streams in Bristol Bay and along the peninsula.

Thus far we have the results of 1922. They were obtained during a year when the Bristol Bay red-salmon run was exceptionally heavy and might be considered likely to invade territory that would be left unoccupied in years of less

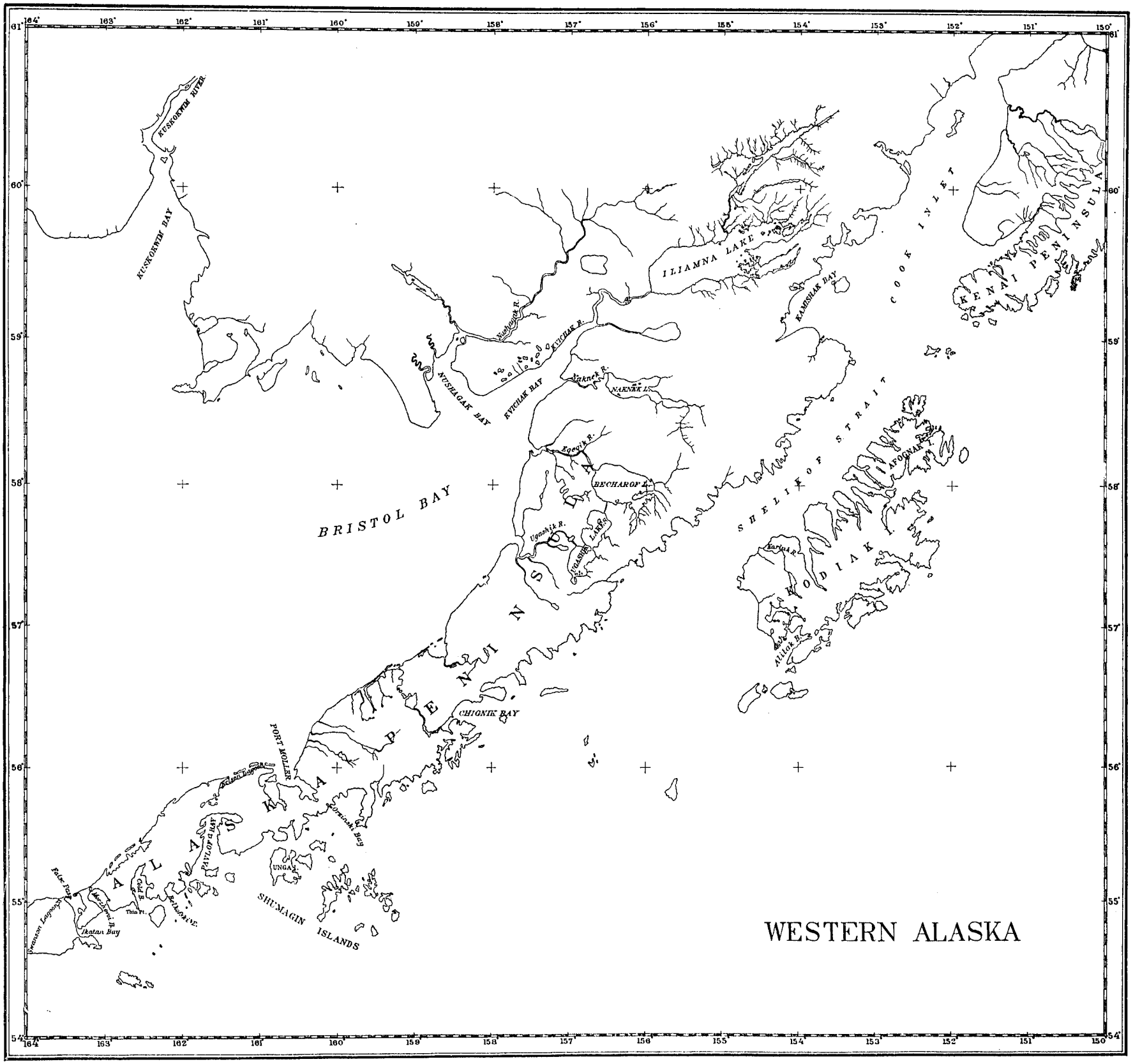

FIG. 1.—Region covered by salmon-tagging operations in the summer of 1923.

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abundance. It seemed advisable to test this by a second experiment, which might enable us to ascertain whether the extensive banks south of the peninsula served constantly as feeding grounds for Bering Sea salmon, or whether their presence on these banks in 1922 was an exceptional occurrence. It will be noted in the present report that the second experiment completely verified the results of 1922, although the season of 1923 was marked by a red-salmon run of very different character.

The methods employed in 1923 did not differ from those in use the previous year. Photographs are presented showing the character of the aluminum tags, the tongs that served to attach them to the upper portion of the base of the salmon's tail, and the method of work. The salmon were secured from three different traps on Unga Island, from four in Morzhovoi Bay, and from three in Ikatan Bay and one in East Anchor Cove. Practically all of this material was furnished by the Pacific American Fisheries, from whom we received, in addition, all possible assistance and sympathetic cooperation. We wish also to acknowledge gratefully numerous courtesies extended us at the P. E. Harris plant in False Pass.

In the prosecution of our work there was used a small seine skiff, in which we entered the spiller of the trap. The spiller was then sufficiently lifted to pen the salmon along its outer walls, where they were caught up with a dip net, tagged, and released. Four men ordinarily were employed in this process and, under favorable conditions of wind and weather, could tag and release 300 salmon in one hour. On two different occasions 1,000 fish were tagged in the course of a single day's work. Unga Island (Squaw Harbor), Morzhovoi Bay, and Ikatan cover a span about 125 miles in length, and it was desired in each of these localities to tag salmon near the beginning, the middle, and the end of the short run, which lasts only about six weeks. This program was carried out with fair success, although not infrequently our work was interrupted by the high winds for which this region is noted; but the results secured by this division of the season and the different behavior of the later fish of the season, compared with those running during the earlier and middle portions of the run, amply justified this feature of the plan.

An interesting problem which early presented itself was the extent to which the homing habit of salmon controls their movements during migration. Salmon were found associated in the same trap on Unga Island which were shown to scatter to more than 20 different streams, ranging from Cook Inlet on the south to Goodnews Bay, the Kuskokwim, and the mouth of the Yukon in the far north. The vital question which arises with regard to these is whether each of them is returning to the stream in which it had its origin—its home stream—or to what extent we may find among them strays, scattering aimlessly in search of a spawning stream. If the homing instinct prevails, we are compelled to accept at the other end of the salmon's life an extremely wide dispersal of the young to feeding grounds hundreds of miles distant from the mouths of the streams in which they were reared; and at the close of their period of growth and development, at the beginning of the season in which their eggs and milt will ripen, we must figure them leaving the feeding grounds and independently retracing the hundreds of miles which may separate each of them from its natal stream.

No landmarks have been suggested that seem in any way adequate to guide these fish in their prolonged journey through an apparently trackless sea. The

physical and chemical conditions of their immediate environment assuredly were identical for all the salmon tagged and released at a given time from a single trap. In quick succession the numbered tags are attached to the struggling fish, fresh-dipped from the trap corral. Rapidly they are restored to freedom, tossed over the trap web into the clear waters, through which their aluminum tags shine bright. For a brief while they linger outside the trap to recover from their enforced sojourn in the upper air. A dozen or more of them can usually be seen while the marking is in progress, lazily fanning their gills and recuperating their strength. But they soon disappear, and when next they come to the attention of men, bearing their tags, after the lapse of a few days or a few weeks, it is found that some have journeyed east, some north, and some west, and some have passed into Bering Sea through an obscure channel, which the navigator locates with the aid of all his instruments.

What is it that guides them in these journeys? From the same starting point, at the same moment of time, they pursue divergent paths to their destinations hundreds of miles away. How can we conceive that any elements of the common environment in which they lie immersed can so react as mechanically to lead different individuals in opposite directions? It is easy to demonstrate that they pursue their course in no haphazard fashion. Time schedules can be constructed on the basis of our recaptures, to which they conform with remarkable fidelity. We can not escape the conviction that they pass along the ocean ways with directness and speed.

That salmon possess a "homing instinct"—whatever that term may connote—that they do, in fact, wherever they may have wandered, find their way back to their native streams, has in recent years found wide acceptance. It comes as a necessary inference from facts established by a study of separate colonies of spawning fish. As each colony is stamped by certain distinctive physical characteristics, it appears impossible to account for this fact except upon the assumption that we are dealing with isolated, self-perpetuating groups with the constant habit of home-coming at maturity. This does not signify that no individuals every stray beyond the boundaries of their own groups and enter streams other than those in which they were bred. We have never succeeded in recognizing such strays even in strongly marked colonies, in which it would seem an alien should be immediately detected; but admitting the existence of strays, the inference is unavoidable that they are present in very small proportion, too small to prevent, in each colony, the formation and the maintenance of racial pecularities.

Whatever inferences concerning migrations in the sea we have felt warranted in making heretofore, based on a study of spawning colonies, we have never until now been in a position to take up the problem from the other end and to trace the operation of the homing instinct in the case of salmon about to leave their feeding grounds in the sea and to disperse widely from a common center. While there are good *a priori* reasons for believing that this dispersal is along lines that lead to their home streams, the present tagging experiments have given us our first opportunity to verify this assumption—an opportunity too unique and too valuable to be neglected. This became apparent at the close of the 1922 experiment, when the tagged individuals, to our surprise, were reported from so very extended a geographic range. It was then too late to obtain samples of their scales, so the problem could not then be taken up, for our only available means of testing the return of salmon to the streams of their nativity is through a microscopic examination of their scales and

the discovery in them of sufficiently well-marked racial pecularities to locate the migrants in the colony to which they belong.

It was in the hope of accomplishing this in some measure that, in the 1923 experiment, we made a prominent feature of collecting a full set of scales of all the salmon that were tagged. At the time each tag was attached a sample of the scales was removed and was immediately transferred to a specially prepared blank book, which was ruled in five spaces to the page, each space bearing a serial number identical with that of the tag. The material, then, includes the scales of some 10,000 red salmon, so arranged that there can be singled out for critical study those belonging to any individual recaptured at the stream it was preparing to enter, the racial affinities of which it was desired to ascertain. Other results, which we were justified in anticipating, include the following:

1. Some estimate of the intensity of the commercial fishing, based on the proportionate number of tagged fish that are recaptured. Such an estimate will of necessity be a minimum. The percentage of the run actually captured will be greater than our estimate, for some of the tags unquestionably become detached and are lost although the fish are recaptured, some tags are taken by fishermen, and others are not reported; but as a minimum record the figures still have value.

2. We may anticipate valuable information concerning the routes traversed, the association of races in a common wave of migration, and their segregation on approaching the streams for which they are bound. Still more interesting will be evidence that certain races take a distinct route from that followed by others that traverse the same general region. The existence of distinct ocean lanes for colonies still far from home opens wide grounds for speculation.

3. The rates of travel of salmon bound in different directions and the rates of those bound in the same direction in different portions of the run. It might be anticipated that the rate of travel would bear a definite relation to the exigencies of the case, causing laggards in leaving the feeding grounds to accelerate their pace in comparison with the migrants of the early part of the season.

METHOD OF TAGGING

The tags used are of a common commercial type intended originally for tagging sheep and cattle. Each consists of a flat strip of aluminum about 3 inches long, on one side of which is stamped a serial number and the initials "U. S. B. F." Close to one end a hole is cut, and the other end is flattened and sharpened into a sort of prong. The tag is then bent, as illustrated by the open tag held in the tongs in Figure 2. The photograph also shows the character of the tongs by which the tags are attached. A spring within the handles of the tongs keeps them wide open except when closed by the hand of the operator. This tool is so made that the tag snaps into place and is held by the elasticity of the tag itself, which is opened slightly wider than the tongs when fully extended. As the tongs are closed, the prong or sharpened end of the tag passes through the hole on the other end and is crimped back securely against the body of the tag. This is well illustrated by the views of the closed tag (fig. 2).

The tags were attached to the upper lobe of the caudal fin of the salmon. An attempt was made, and nearly always successfully, to insert the prong through the skin which extends back over the bases of the rays of the caudal fin. This is illus-

trated in Figure 3, taken from the report by the senior author on the results of the tagging operations of 1922.[2] The tags were almost invariably so firmly attached that it was necessary to cut the tail in order to remove them. It seems very improbable, therefore, that any considerable number were lost from the fish while they were free. Some were torn from the fish as they were brailed from traps into scows or cannery tenders, as was evidenced by occasional tags found loose on the scows or in the holds of the tenders. A very small proportion, however, was found in this manner, and the possible loss of tags as a result must be considered as negligible. A slight wearing of the tissue of the fish is sometimes caused by the tag, but no examples have come to our attention where this appeared to be serious. It can be noticed in Figure 3.

As mentioned above, the tagging was done exclusively in traps. It was found impracticable to tag at the time the traps were lifted by the fishing crews from the canneries on account of the fact that these fishing crews were nearly always anxious to complete their work as soon as possible and return with the fish, whereas the tagging operations usually consumed several hours. In ordinary practice, therefore, we found it necessary to lift the traps ourselves, an operation which was not always easy with the limited aid at our disposal. We usually had but two assistants. In this connection we wish to acknowledge the efficient aid of W. P. Studdert, who assisted in the tagging both in 1922 and 1923. His practical knowledge of boats and fishing gear and his willing and energetic activities along many practical lines made his assistance invaluable.

A small seine skiff was made use of in manipulating the traps and in doing the actual tagging. (See fig. 4.) With the top line lowered the skiff was introduced into the spiller of the trap, which was then "lifted" in the usual manner until a sufficient number of fish were collected in the pocket formed by the outer wall of the spiller. Then the bottom line was lifted above the surface of the water and was fastened to the gunwale of the skiff. The top line was then dropped, pulled in, and fastened to the gunwale near the bow of the skiff in order to facilitate the release of the tagged fish. With this arrangement the pocket formed by the side wall of the spiller remained open toward the stern of the skiff, so that the fish were easily reached by the man assigned to dip them up. A section about 4 feet long was roughly partitioned off in the stern to prevent the fish when dipped into the skiff from getting forward where the tagging was being done.

To aid in holding the fish for tagging, a number of small boxes were made, approximately 4 by 7 by 18 inches. One end was left open and the box lashed with heavy seine twine. This lashing formed a sort of handle and also strengthened the box. The fish were placed head first in these boxes. In this position only the tail and the caudal peduncle of fish of average size extended beyond the box. The peduncle was grasped by the operator holding the fish for marking, and the box so restricted the movements of the fish that holding was a comparatively easy matter.

The tags, tongs, books in which the scale samples were preserved, and a small knife used in scraping scales from the fish were arranged conveniently on one of the thwarts near the bow of the skiff. The tags were arranged on sticks in serial order and, as mentioned above, the spaces in the scale books were serially numbered to correspond with the tags. The scale samples were taken from the caudal peduncle,

[2] See footnote, p. 27.

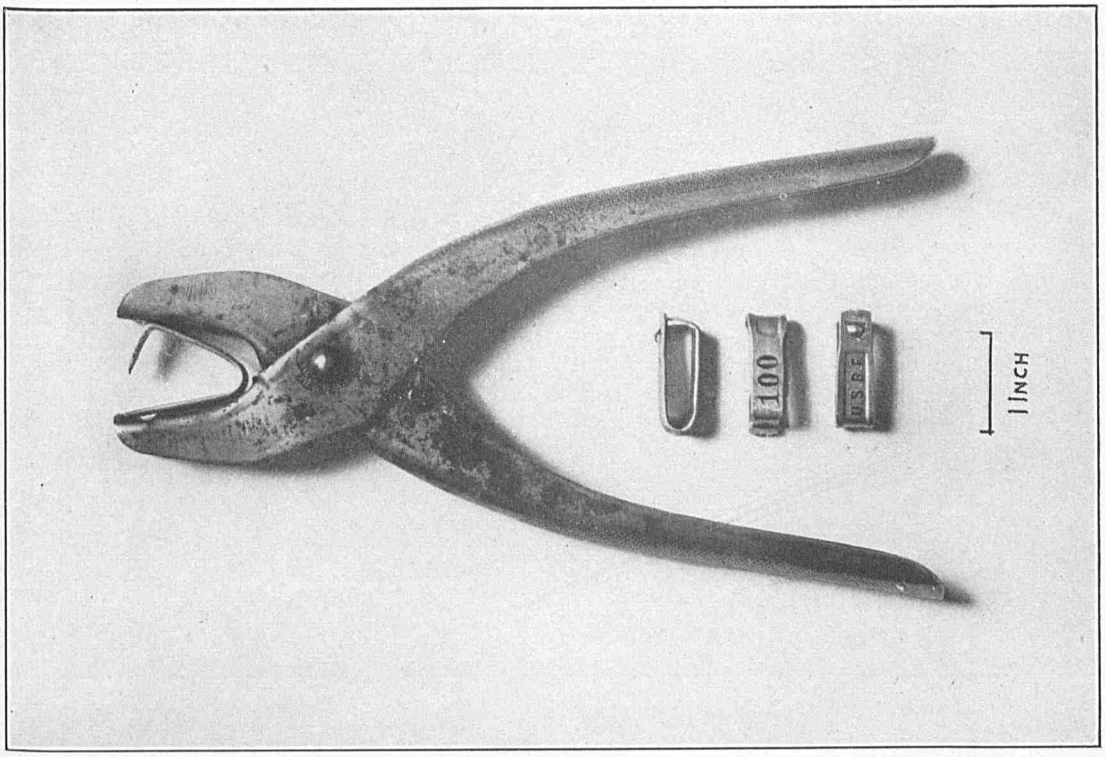

FIG. 2.—Tags and tongs

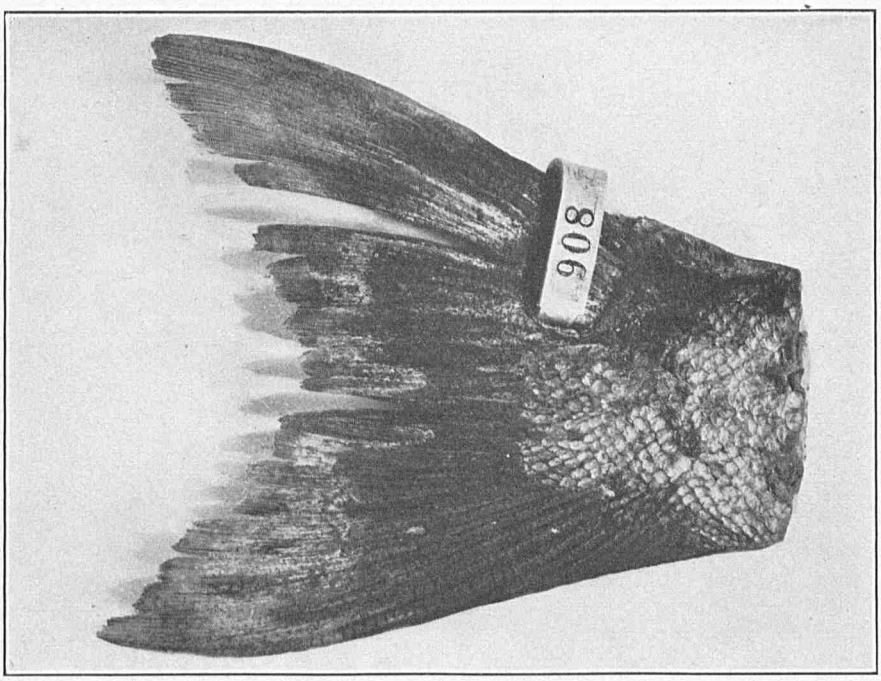

FIG. 3.—Tag No. 908, attached at East Anchor Cove, Ikatan Peninsula, June 15, 1922, and retaken July 4 at Squaw Creek, Kvichak River, Bristol Bay, distant by direct course about 350 miles from place of marking

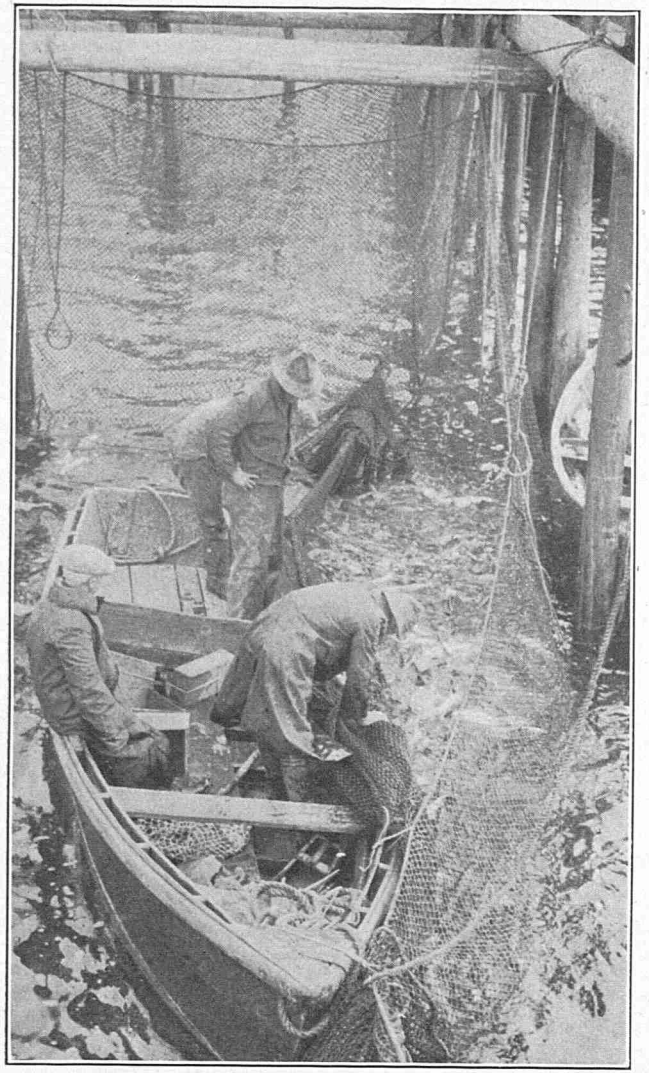

FIG. 4.—Preparing to tag. The skiff is in position, with the bottom line of the spiller over the gunwale of the boat and the top line pulled down and also fastened to the gunwale. The fish are in a pocket of the webbing by the wall of the spiller

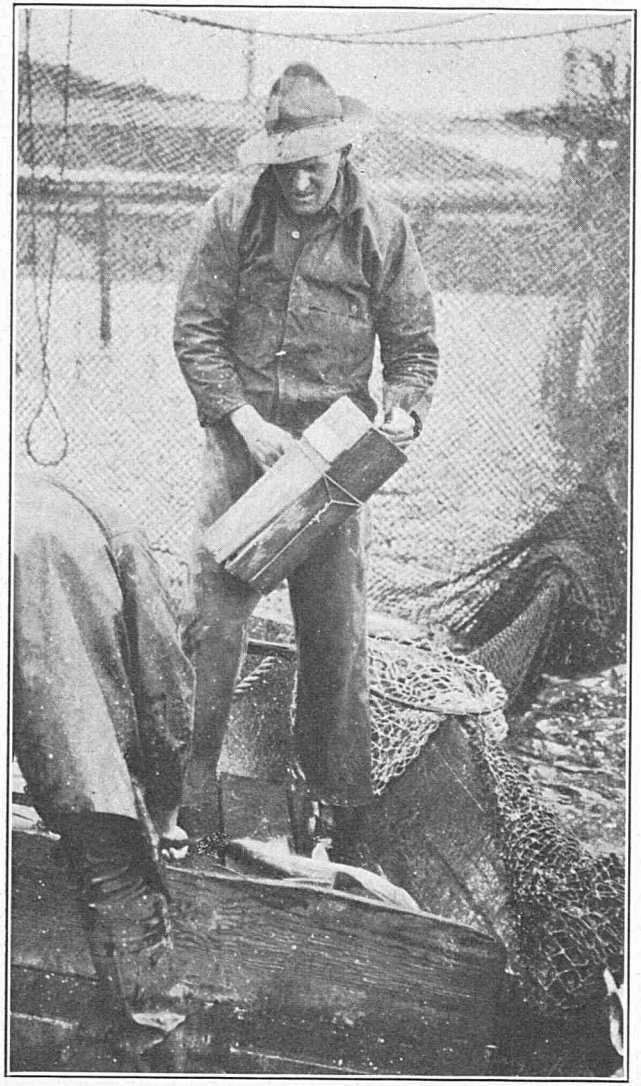

FIG. 5.—Placing the fish in the holding boxes

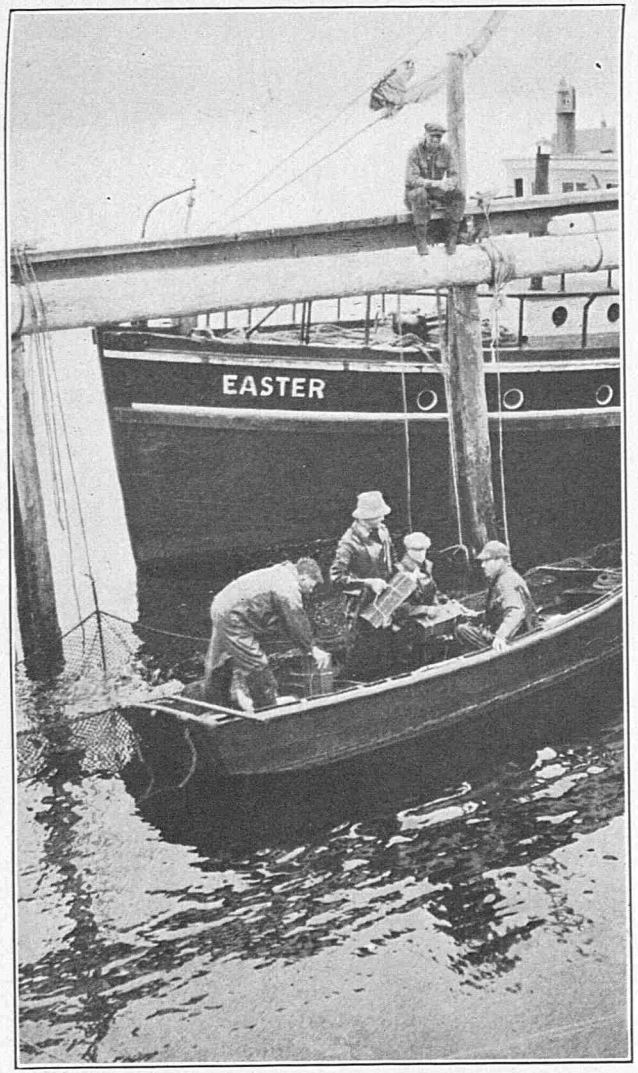

FIG. 6.—Tagging. This illustrates the usual placement of the personnel. The man in the stern of the skiff dips the fish out of the pocket of the trap and places them in the holding boxes. The man next helps to place the fish in the boxes and passes them on to the next man, who holds the fish for tagging. The man at the extreme right of the photograph attaches the tags, takes scales, and keeps the record

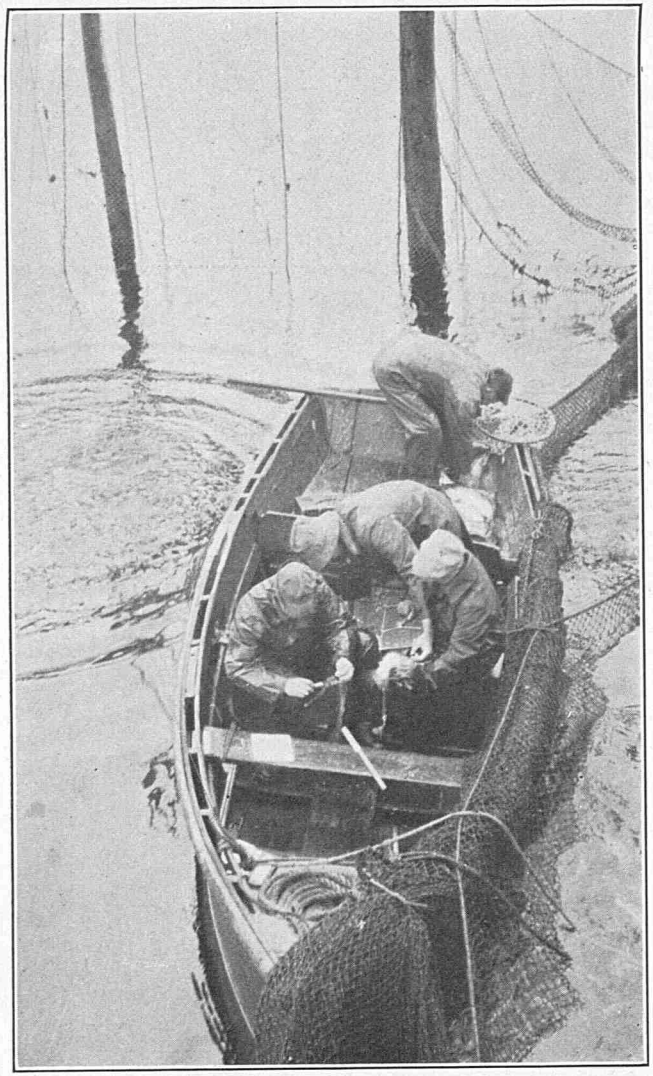

FIG. 7.—Another view, showing the tagging procedure. The tools, book for scale samples, and tags (arranged on a stick) are to be seen on the thwart just forward of the men who are doing the tagging

FIG. 8.—Here the tag is just being attached. Immediately after this has been done the man holding the fish turns slightly and allows the fish to slide out of the box into the water outside the webbing of the trap

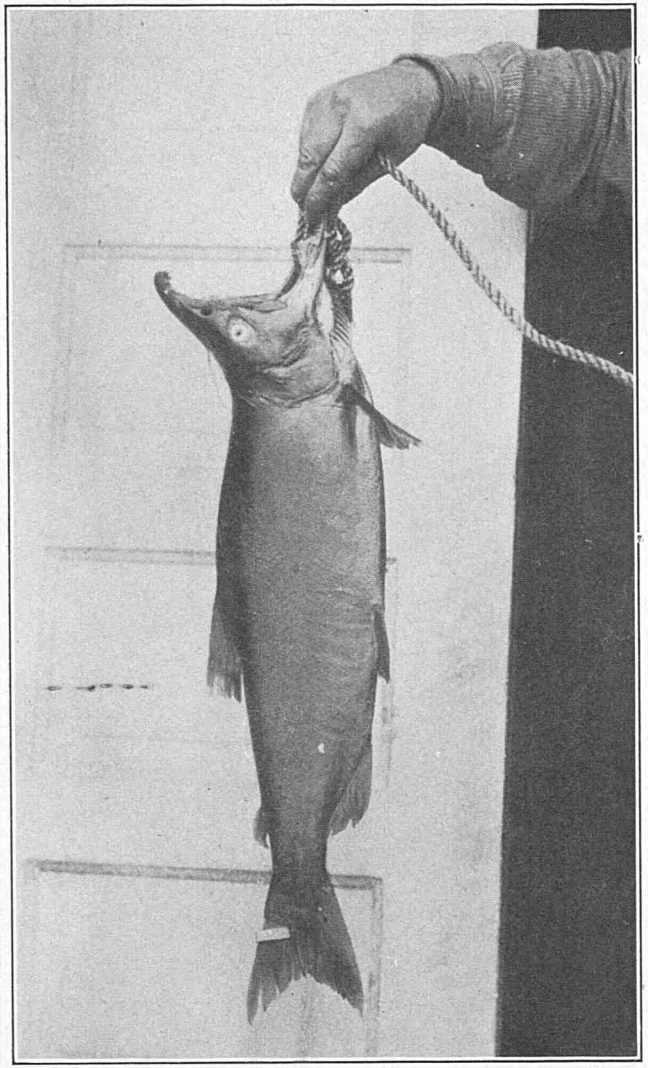

FIG. 9.—Fish bearing tag No. 4588, released from Kelly Rock trap, Unga Island, June 7, 1923, and retaken on the spawning beds in Morzhovol Lake, August 5. The appearance of the tag when attached is well shown

usually just below the adipose fin, and were placed in the books opposite the serial number corresponding to the tag.

The procedure in tagging was as follows: An assistant, provided with a long-handled dip net, was stationed in the stern of the skiff and dipped up several fish, usually from two to five, and deposited them in the stern section mentioned above. This same assistant then placed the fish as rapidly as possible in the holding boxes, which were next taken by another assistant, who passed them forward to one of the operators seated on the outer side of the skiff, who held the fish while the second operator attached the tag and took the sample of scales. Then the first operator released the fish and returned the box to where it could be conveniently reached by the assistant who placed the fish in the boxes. By the time this was done another fish was usually ready for tagging. Figures 4 to 9 illustrate the process.

Only a few seconds were required for tagging each fish. Even when several fish were dipped up at once it was seldom that any one of them was out of water for more than a minute. With good weather and smooth water from 250 to 300 fish were tagged in an hour. When released, the fish seldom showed any distress and usually disappeared within a very short time, apparently uninjured. There may have been some slight mortality due to the handling they received, but we have no evidence that such was the case.

RETURNS

The following list gives the numbers of the tags attached at various times and places during 1923 and also indicates the species of salmon used. Out of the 10,000 fish tagged only about 800 were other species than red salmon.

TABLE 1.—*List of tags attached, 1923*

Lot number	Serial number	Number of fish	Species	Locality	Date
1	4001-4122	[1] 120	Red	Unga Island, Kelly Rock trap	June 2, 3, and 5.
2	4123-4700	575	do	do	June 7.
3	4701-5500	799	do	Ikatan Bay, P. A. F. No. 7	June 18.
4	5501-6300	800	do	Morzhovoi Bay, P. A. F. No. 8	June 20.
5	6301-6800	499	do	Unga Island, Kelly Rock trap	June 23
6	6801-7300	499	do	do	June 26.
7	7301-7438	137	do	Unga Island, Coal Harbor trap	June 27.
8	7439-8300	[2] 859	do	Unga Island, Big Valley trap	Do.
9	8301-8896	592	do	Morzhovoi Bay, P. A. F. No. 8	June 30.
10	8897-9300	403	do	Morzhovoi Bay, P. A. F. No. 5	Do.
11	9301-10000	[3] 699	do	Ikatan Bay, P. A. F. No. 2	July 1.
12	10001-10300	300	do	Ikatan Bay, P. A. F. No. 11	July 2.
13	10301-10466	110	do	Unga Island, Coal Harbor trap	July 4.
14	10467-11500	55	Dog	Unga Island, Big Valley trap	July 6.
		633	Red		
		190	Dog		
		199	Humpback		
		10	Silver		
15	11501-11936	436	Red	Morzhovoi Bay, P. A. F. No. 3	July 8.
16	11937-12046	110	do	Morzhovoi Bay, P. A. F. No. 5	Do.
17	12047-12178	131	do	Ikatan Bay, P. A. F. No. 13	July 10.
		1	King		
18	12179-12510	326	Red	Ikatan Bay, P. E. H. No. 5	Do.
		1	King		
19	12511-13000	447	Red	Ikatan Bay, P. A. F. No. 2	July 11.
		36	Dog		
		6	Silver		
20	13001-13453	279	Red	Morzhovoi Bay, P. A. F. No. 5	July 13.
		171	Dog		
		3	Silver		
21	13454-13800	[2] 170	Red	do	July 18.
		[2] 172	Dog		
		3	Silver		
22	13801-14000	198	Red	Morzhovoi Bay, P. A. F. Nos. 3, 8, and 2	July 20.
		2	Dog		

[1] This and other similar discrepancies are due to the loss or breaking of some of the tags.
[2] One previously tagged was taken and released and is included here.
[3] Three previously tagged were taken and released and are included here.

In Tables 2 to 29 are given in detail the results obtained from each tagging experiment listed above. The actual date of recapture (or, more properly, the date on which the recapture was reported) is given for each locality, and at the bottom of each column is given the total number reported from each locality, the percentage of the total number tagged taken in that locality, and the average time that elapsed between the time of tagging and the reported recapture. Careful consideration has been given to the relative advantages of calculating the percentage returned from each locality on the basis of the number tagged in each experiment and on the basis of the total number returned from each experiment. If these percentages are based on the number returned, it is implied that the fish tagged and, in fact, all the fish found with them at the time of tagging were distributed only to the localities from which tags were reported and in the percentages given. This does not give consideration to the possibility that fish may have gone to localities were no fishing is conducted and from which no returns could be expected. Furthermore, the percentage of fish taken in a given locality may be profoundly affected by extreme variations in the percentage taken in another locality if these percentages are based on the number of fish returned. By basing these calculations on the number tagged these difficulties will be avoided and the results of the separate experiments are strictly comparable. Accordingly, this has been done.

In determining the average time en route the median has been selected as the measure of central tendency best describing the average time required by the fish in passing from point to point. The median seems best for the purpose, since it gives less weight to extreme measures than does the mean, yet is not subject to the instability of either the empirical or the theoretical modes. The median seems especially appropriate for use in handling such data as we have to work with in this paper, in which a few of the frequency distributions are extremely skewed (those provided by the returns from points close to the place where the tags were attached), while others are approximately normal. The returns from some localities are numerous and from others we have only a few.

The interpretation of the median as used for this purpose is very simple. It may be given thus: At the expiration of the median time as given in the tables one-half of the total number of returns reported from that particular point had been taken.

TABLE 2.—*Returns from 120 red salmon tagged June 2, 3, and 5, 1923, at Kelly Rock trap, Unga Island. Recaptures, 13 (10.8 per cent)*

Date	Locality of recapture				
	Unga Island	Ikatan-False Pass	Egegik	Naknek	Kvichak
June 8	1	1			
June 11*		2			
June 14*		1			
June 16*		1			
June 17		1			
June 22*			1		
June 26*					3
June 29*			1		
July 25*				1	
Total	1	6	2	1	3
Percentage returned	0.8	5.0	1.7	0.8	2.5
Median time in days	3	8.5	21.5	52	23

NOTE.—In this and subsequent tables the asterisk is employed to indicate a break in the continuity of the table. It indicates that one or more dates have been omitted from the table just preceding the date thus marked. No returns were recorded on these omitted dates.

TABLE 3.—*Returns from 575 red salmon tagged June 7, 1923, at Kelly Rock trap, Unga Island. Recaptures, 105 (18.3 per cent)*

Date	Locality of recapture												
	Unga Island	Morzhovoi Bay	Morzhovoi Lake	Ikatan-False Pass	Nelson's Lagoon	Bear and Sandy Rivers	Egegik	Naknek	Kvichak	Nushagak Egushik	Kuskokwim River	Chignik	Afognak
June 8	1												
June 11*				21									
June 12				12									
June 14*		13		5									
June 15		6		2									
June 16		3		4									
June 17				1									
June 18		2		1									
June 19		2											
June 22*											1	1	
June 26*								2	1				
June 27									1				
June 28									3				
June 29					1		2			1			
June 30		1							1	2			
July 1													1
July 2				1									
July 4*								1					
July 5									1				
July 6								3					
July 8*					1								
July 9						1							
July 18*									1				
July 22*										1			
July 25*								1					
August 5*			1										
August 8*	1												
No date									1				
Total	2	27	1	47	2	1	2	7	9	4	1	1	1
Percentage returned	0.3	4.7	0.2	8.2	0.3	0.2	0.3	1.2	1.6	0.7	0.2	0.2	0.2
Median time in days	(1)	7.58	59	4.7	26.5	32	22	28.8	[2] 21.1	23	15	15	24

* Indicates a break in the continuity of the table.
[1] The two returns are at such extremes that an average has no significance.
[2] Calculated from the 8 for which dates are given.

TABLE 4.—*Returns from 799 red salmon tagged June 18, 1923, at Ikatan Bay, Pacific American Fisheries trap No. 7. Recaptures, 217 (27 per cent)*

Date	Locality of recapture										
	Ikatan-False Pass	Morzhovoi Bay	Swanson's Lagoon	Bear and Sandy Rivers	Ugashik	Egegik	Little Becharoff Lake	Naknek	Kvichak	Nushagak	Kuskokwim River (Bethel)
June 18	6										
June 19	45										
June 20	22	11									
June 21	9	17									
June 22	15										
June 23	11										
June 24	17										
June 25	1	4									
June 26	4										
June 27	2	1									
June 28	1										
June 29	1	1		1							
June 30				1							
July 2*	2		1		1						
July 3		1		2							
July 4	2			1				1	1		
July 5				3							
July 6									1		
July 7						1		2	1		
July 8										1	

* Indicates a break in the continuity of the table.

TABLE 4.—*Returns from 799 red salmon tagged June 18, 1923, at Ikatan Bay, Pacific American Fisheries trap No. 7. Recaptures, 217 (27 per cent).*—Continued

Date	Locality of recapture										
	Ikatan-False Pass	Morzhovoi Bay	Swanson's Lagoon	Bear and Sandy Rivers	Ugashik	Egegik	Little Becharoff Lake	Naknek	Kvichak	Nushagak	Kuskokwim River (Bethel)
July 9						1		1	1	2	
July 11 *				1				1			
July 12									4		
July 13								2			
July 14								2		1	
July 15									2		
July 16									1		
July 17								1			
July 20 *									1		
July 23 *								1			
July 24								1			
Aug. 11 *							1				[1]
No date									1		
Total	138	35	1	9	1	2	1	12	13	4	1
Percentage returned	17.3	4.4	0.1	1.1	0.1	0.2	0.1	1.5	1.6	0.5	0.1
Median time in days	2.32	2.88	14	16	14	20	54	25	[2]24	21	?

* Indicates a break in the continuity of the table.
[1] Recorded as taken June 22. As this is most improbable, the record has been placed with those for which no date was given.
[2] Calculated from the 12 for which dates were available.

TABLE 5.—*Returns from 800 red salmon tagged June 20, 1923, at Morzhovoi Bay, Pacific American Fisheries trap No. 8. Recaptures, 187 (23.4 per cent)*

Date	Locality of recapture												
	Morzhovoi Bay	Ikatan-False Pass	Nelson's Lagoon	Bear and Sandy Rivers	Bear Lake	Ugashik	Egegik	Little Becharoff Lake	Naknek	Kvichak	Nushagak	Cold Bay	No locality
June 21	2	1											
June 22		5											
June 23		5											
June 24		34											
June 25	11	4											
June 26		15											
June 27	9	8											
June 28		4											
June 29	2	4											
June 30		1											
July 2*		1											
July 3		3	1										
July 4		3		1									
July 5									1	1			
July 6											2		
July 7	1			1		1			1	1			
July 8	1		1	1			1		2	3			
July 9		1		2			1		2	1			
July 10							2		1	1		1	
July 12*							1			3			
July 13		1					1			1			
July 14							1		1	1			
July 15							1		1	1			
July 16			1						1	1			
July 17									4				
July 18									2	1			
July 20*		1							1	1			
July 21									1				
July 23*									2				
July 24										1			
July 25									6	3			
July 26										1			
Aug. 22*								1					
No date					1								1
Total	26	91	3	5	1	1	8	1	26	21	2	1	1
Percentage returned	3.2	11.4	0.4	0.6	0.1	0.1	1.0	0.1	3.2	2.6	0.2	0.1	0.1
Median time in days	6	4.62	18	18		17	21	63	27.25	23	16	20	

* Indicates a break in the continuity of the table.

TABLE 6.—*Returns from 499 red salmon tagged June 23, 1923, at Kelly Rock trap, Unga Island. Recaptures, 213 (42.6 per cent)*

Date	Locality of recapture											
	Unga Island	Pavlof and Volcano Bays	Morzhovoi Bay	Ikatan-False Pass	Nelson's Lagoon	Ugashik	Egegik	Naknek	Kvichak	Illiama Lake	Nushagak	Chignik
June 26	6											
June 27	4		13	6								
June 28	1		15	20								
June 29	2		23	27								
June 30			11	3								
July 1	1			7								
July 2				7								
July 3	1		3	7								
July 4		1		2								
July 6*				1								
July 8*				1							1	
July 10*									1			
July 11					1		1		1			
July 12									1		3	
July 13	1							6	2			
July 14						1	2	1	1		2	
July 15								1				
July 16											1	
July 17								4	1		1	
July 18												1
July 19											1	
July 20									1	1		
July 21									1			
July 22	1						1					
July 25*	1							1	2			
July 26	1										[3] 1	
July 31*												
No date								1	1	[1] 1		
Total	21	1	65	81	1	1	4	14	12	2	10	1
Percentage returned	4.2	0.2	13	16.2	0.2	0.2	0.8	2.8	2.4	0.4	2	0.2
Median time, in days	5	11	5.67	6.06	18	21	21	21	21	[2] 27	20.75	25

* Indicates a break in the continuity of the table.
[1] Reported as taken in July.
[2] From the one complete record.
[3] Taken 100 miles up the river.

TABLE 7.—*Returns from 499 red salmon tagged June 26, 1923, at Kelly Rock trap, Unga Island. Recaptures, 110 (22 per cent)*[1]

Date	Locality of recapture												
	Unga Island	Pavlof and Volcano Bays	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Nelson's Lagoon	Bear and Sandy Rivers	Ugashik	Egegik	Naknek	Kvichak	Nushagak Egushik	Chignik
June 29	1			1	4								
June 30				1	1								
July 1					1								
July 2					11								
July 3			2		8								
July 4					3								
July 5					1								
July 6					2								
July 7					1								
July 8					1						1		
July 9							1						
July 10							1						
July 11						1	2						
July 12							1		1			1	
July 13					1						1	1	

[1] In addition to those tabulated, one tag was taken in Good News Bay in August and another on July 10 in the Togiak River.

TABLE 7.—*Returns from 499 red salmon tagged June 26, 1923, at Kelly Rock trap, Unga Island. Recaptures, 110 (22 per cent)*—Continued

Date	Locality of recapture												
	Unga Island	Pavlof and Volcano Bays	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Nelson's Lagoon	Bear and Sandy Rivers	Ugashik	Egegik	Naknek	Kvichak	Nushagak Egushik	Chignik
July 14						1				1	1	1	
July 15		1								2	4	3	
July 16										7	2	1	
July 17										3	2	2	
July 18										1	2	3	
July 19											2		
July 20										1	3		
July 21											1	1	
July 22												2	
July 23										2	1		
July 24								1					
July 25										1		1	
July 29*				1							1		
Aug. 10*													1
No date											2		
Total	1	1	2	3	34	2	5	1	1	18	23	16	1
Percentage returned	0.2	0.2	0.4	0.6	6.8	0.4	1	0.2	0.2	3.6	4.6	3.2	0.2
Median time, in days	3	19	7	4	6.5	16.5	14.75	28	16	20.36	[2] 21.25	21	45

* Indicates a break in the continuity of the table.

[2] Calculated from the 21 complete records.

TABLE 8.—*Returns from 137 red salmon tagged June 27, 1923, Unga Island, Coal Harbor trap. Recaptures, 53 (38.7 per cent)*

Date	Locality of recapture											
	Unga Island	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Bear and Sandy Rivers	Ugashik	Naknek	Kvichak	Nushagak	Good News Bay	Orzinski	Cook Inlet Kamishak
July 1	1			5				[1] 1			1	
July 2	1			8								
July 3		1		6								
July 4				1								
July 5												
July 6	1			1								
July 7			1									
July 8			1	1								
July 9	2									1		
July 10												
July 11	1				1							
July 13*				1								1
July 14							1	2	1			
July 15						1		1				
July 17*												
July 18	1							1				
July 21*				1					2			
July 22							1					
July 23							1					
July 24								1				
July 25												
Total	7	1	2	24	1	1	3	[2] 6	4	1	1	1
Percentage returned	5.1	0.7	1.5	17.5	0.7	0.7	2.2	4.4	2.9	0.7	0.7	0.7
Median time, in days	11.75	7	10.5	6.37	14	20	26	20	21.5	13	4	16

*Indicates a break in the continuity of the table.

[1] Doubtless an error. Not included in calculating the median time.

[2] In addition one tag was taken in Lake Clark during July.

TABLE 9.—*Returns from 859 red salmon tagged June 27, 1923, at Big Valley trap, Unga Island. Recaptures, 277 (32.2 per cent)*

Date	Locality of recapture													
	Unga Island	Pavlof and Volcano Bays	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Nelson's Lagoon	Bear and Sandy Rivers	Egegik	Naknek	Kvichak	Nushagak	Chignik	Karluk	Cook Inlet
June 27	2													
July 2*	1				20									
July 3	2		2	1	23									
July 4					40									
July 5			1		7									
July 6			1		32									
July 7				8	5									
July 8		1		3	8					1				
July 9	1				3		2							
July 11*					2		2							
July 12							2			1				
July 13	2				3	2				1				
July 14								2	1	2	1			1
July 15		1			1				6	5			1	
July 16							1		16	4	1			
July 17							2	4	12	2	1	1		
July 18									3	3	1			
July 19									1		3			
July 20									1	1		1		
July 21								2	1	2	1			
July 22									1					
July 24*									1	1				
July 25									3	2				
Aug. 14												1		
No date										4				
Total	8	2	4	12	144	2	9	8	46	29	8	3	1	1
Percentage returned	0.9	0.2	0.5	1.4	16.8	0.2	1.0	0.9	5.4	3.4	0.9	0.3	0.1	0.1
Median time in days	5.75	14.5	7	10.12	7.22	16	14.75	20	19	19.12	21.5	23	18	17

*Indicates a break in the continuity of the table.

TABLE 10.—*Returns from 592 red salmon tagged June 30, 1923, at Morzhovoi Bay, Pacific American Fisheries trap No. 8. Recaptures, 250 (42.2 per cent)*

Date	Locality of recapture										
	Morzhovoi Bay	Ikatan-False Pass	Bear and Sandy Rivers	Bear Lake	Ugashik	Egegik	Naknek	Kvichak	Nushagak	Thin Point	Cold Bay
July 2		92									
July 3	5	43									1
July 4		27									
July 5		1									
July 6		13								1	
July 7	1	6									
July 8		3									
July 9		1								1	
July 12*			1					1			
July 15*		2					1	2			
July 16	1		3				10	3			
July 17							8				
July 18							1	2	1		
July 19							1	1			
July 20						1					
July 21						1		1			
July 22							1		2		
July 25*							2	1			
July 30*						1					
July 31					1						
No date				1			4	1			
Total	7	188	4	1	1	3	28	12	3	2	1
Percentage returned	1.2	31.8	0.7	0.2	0.2	0.5	4.7	2.0	0.5	0.3	0.2
Median time in days	3.2	2.54	15.8	------	31	21	16.62	16.17	21.75	7.5	3

* Indicates a break in the continuity of the table.

TABLE 11.—*Returns from 403 red salmon tagged June 30, 1923, at Morzhovoi Bay, Pacific American Fisheries trap No. 5. Recaptures, 228 (56.5 per cent)*

Date	Locality of recapture										
	Morzhovoi Bay	Ikatan-False Pass	Nelson's Lagoon	Bear and Sandy Rivers	Egegik	Naknek	Kvichak	Nushagak	Thin Point	Cold Bay	Pavlof Bay
July 2		100									
July 3	7	42							5	1	
July 4		23					[1] 1		3		
July 5		1									
July 6		7							1		
July 7		2									
July 8		3		1							
July 9		1		1					2		
July 10										1	
July 11			1							4	
July 12				1							
July 13									1		
July 15*						1	2				
July 16				1		4	1				
July 17						1	1				
July 18					1			1			
July 19										1	1
July 21*						1					
July 24*						1					
Aug. 7*										1	
No date							1				
Total	7	179	1	4	1	8	6	1	12	8	1
Percentage returned	1.7	44.4	0.2	1.0	0.2	2.0	1.5	0.2	3.0	2.0	0.2
Median time in days	3	2.39	11	10.5	18	16.25	15.5	18	3.83	11	19

* Indicates a break in the continuity of the table. [1] Doubtless an error. Not included in calculating the median time.

TABLE 12.—*Returns from 699 red salmon tagged July 1, 1923, at Ikatan Bay, Pacific American Fisheries trap No. 2. Recaptures, 308 (44 per cent)*

Date	Locality of recapture									
	Ikatan-False Pass	Morzhovoi Bay	Nelson's Lagoon	Bear and Sandy Rivers	Egegik	Naknek	Kvichak	Nushagak	Thin Point	Belkofski Village
July 2	99									
July 3	57	10								
July 4	38									
July 5	4									
July 6	14									
July 7	11	7							1	
July 8	4	5	1							
July 9	3								1	
July 13*	2	1	1							
July 14				1						
July 15						3	2	2		
July 16			1	1		2	1	2		
July 17					1		1	1		
July 18							1	1		
July 19						6	2	1		
July 20						3	3	1		
July 21						2				
July 22				1				4		
July 23						1				
July 24	1									1
No date					1		2			
Total	233	23	3	3	2	17	12	12	2	1
Percentage returned	33.4	3.3	0.4	0.4	0.3	2.4	1.7	1.7	0.3	0.1
Median time in days	1.8	5.7	12	12	[1] 16	18.08	[1] 17.5	17.5	7	23

*Indicates a break in the continuity of the table. [1] Calculated from those with definite data only.

TABLE 13.—*Returns from 300 red salmon tagged July 2, 1923, at Ikatan Bay, Pacific American Fisheries trap No. 11. Recaptures, 220 (73.3 per cent)*

Date	Locality of recapture					
	Ikatan-False Pass	Morzhovoi Bay	Bear and Sandy Rivers	Egegik	Naknek	Kvichak
July 2	36					
July 3	96					
July 4	41					
July 5	5					
July 6	20					
July 7	4	2				
July 8	2	1				
July 9	4					
July 11*			1			
July 12	1					
July 14*						1
July 16*					2	
July 18*		1		1		
July 20*					1	1
Total	209	4	1	1	3	2
Percentage returned	69.6	1.3	0.3	0.3	1.0	0.7
Median time in days	1.21	5.5	9	16	14.25	15

*Indicates a break in the continuity of the table.

TABLE 14.—*Returns from 110 red salmon tagged July 4, 1923, Unga Island, Coal Harbor trap. Recaptures, 43 (39.1 per cent)*

Date	Locality of recapture								
	Unga Island	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Nelson's lagoon	Bear and Sandy Rivers	Naknek	Kvichak	Nushagak
July 7	1		1						
July 8	8								
July 9				1					
July 10				1					
July 12*				1					
July 13	1			3					
July 14	2							1	
July 15				1					
July 16					1				
July 17		1							
July 18	1							2	
July 20*								2	1
July 21						1	4		
July 22							1		
July 23							1		
July 24								3	
July 25							1	1	
July 29*	1								
No date							1		
Total	14	1	1	7	1	1	8	9	1
Percentage returned	12.7	0.9	0.9	6.4	0.9	0.9	7.3	8.2	0.9
Median time in days	4.25	13	3	8.66	12	17	[1] 17.37	16.25	16

* Indicates a break in the continuity of the table.
[1] Omitting one with incomplete data.

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TABLE 15.—*Returns from 55 dog salmon tagged July 4, 1923, Unga Island, Coal Harbor trap. Recaptures, 19 (34.6 per cent)*

Date	Locality of recapture								
	Unga Island	Pavlof and Volcano Bays	Morzhovoi Bay	Ikatan-False Pass	Naknek	Kvichak	Nushagak	Togiak River	Pankara River, Karagin, Kamchatka
July 7	1								
July 8		1							
July 9	1								
July 15 *		2							
July 16				1					
July 18 *		2							
July 19		1					1		
July 20						1	1		
July 21					1				
July 22							1		
July 27 *		1	1						
July 30 *							1		
Aug. 18 *									1
Aug. 20 *								1	
Total	2	7	1	1	1	1	4	1	1
Percentage returned	3.6	12.7	1.8	1.8	1.8	1.8	7.3	1.8	1.8
Median time in days	4	13.75	23	12	17	16	17	47	45

* Indicates a break in the continuity of the table.

TABLE 16.—*Returns from 633 red salmon tagged July 6, 1923, Unga Island, Big Valley trap. Recaptures, 172 (27.2 per cent)*

Date	Locality of recapture																
	Unga Island	Pavlof and Volcano Bays	Cold Bay	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Bear and Sandy Rivers	Ugashik	Egegik	Naknek	Kvichak	Nushagak	Togiak River	Orziuski	Chignik	Alitak	Cook Inlet
July 7	7																
July 8	4																
July 9	3					2											
July 10	4					3											
July 11	5		1	3		4											
July 12	1																
July 13	3			1		16											
July 14	2		1	1		1					2						
July 15		2				2										1	
July 16					9	3					1						
July 17				1		3				1					3		
July 18	1	1			1	3	1				1				1		
July 19				1				2	1								
July 20	3					2	2		2	1	5						
July 21										7	5	2					
July 22	1							1	1	4	1			1			
July 23										1	3	1					
July 24										1	1				1		
July 25	1							2		8	2						
July 26											1	1					
Aug. 1*	1															1	
Aug. 3*																	1
Aug. 20*													1				
No date										1	3						
Total	36	3	2	7	10	39	3	5	4	24	25	4	1	1	5	2	1
Percentage returned	5.7	0.5	0.3	1.1	1.6	6.2	0.5	0.8	0.6	3.8	4.0	0.6	0.2	0.2	0.8	0.3	0.2
Median time in days	4.5	9.25	6.5	7.0	10.05	7.15	14.25	16.0	14.0	[1]16.12	[1] 14.9	16.0	45	16.0	11.33	17.5	28.0

*Indicates a break in the continuity of the table. [1] Specimens with incomplete data omitted in making these calculations.

TABLE 17.—*Returns from 190 dog salmon tagged July 6, 1923, Unga Island, Big Valley trap. Recaptures, 45 (23.7 per cent)*

Date	Locality of recapture						
	Unga Island	Pavlof and Volcano Bays	Thin Point	Morzhovoi Bay	Ikatan-False Pass	Nushagak	Yukon
July 7	1						
July 8	2						
July 9	2						
July 10	2						
July 12*		2					
July 13					2		
July 15*		3					
July 16				1			
July 18*		12					
July 19		2					
July 21*		2					
July 23*		1	1	2			
July 25*		1					
July 27*		3					
July 29*				1			
July 31*		1					
Aug. 1			1				
Aug. 3*			1				
Aug. 8*						1	
No date							1
Total	7	27	3	4	2	1	1
Percentage returned	3.7	14.2	1.6	2.1	1.1	0.5	0.5
Median time in days	8.75	12.20	26.0	17.0	7.0	33.0	(?)

*Indicates a break in the continuity of the table.

TABLE 18.—*Returns from 199 humpback salmon tagged July 6, 1923, Unga Island, Big Valley trap. Recaptures, 26 (13 per cent)*

Date	Locality of recapture					
	Unga Island	Pavlof and Volcano Bays	Belkofski Bay	Thin Point	Morzhovoi Bay	Ikatan-False Pass
July 7	9					
July 8	7					
July 9	1					
July 10						1
July 11				1		
July 13 *						1
July 15 *		2				
July 17 *			1			
July 18					1	
July 23 *					1	
July 31 *				1		
Total	17	2	1	2	2	2
Percentage returned	8.5	1.0	0.5	1.0	1.0	1.0
Median time in days	1.44	9	11	15	14.5	5.5

* Indicates a break in the continuity of the table.

TABLE 19.—*Returns from 436 red salmon tagged July 8, 1923, Morzhovoi Bay, Pacific American Fisheries trap No. 3. Recaptures, 110 (25.2 per cent)* [1]

Date	Locality of recapture									
	Morzhovoi Bay	Morzhovoi Lake	Ikatan-False Pass	Ugashik	Egegik	Naknek	Kvichak	Thin Point	Cold Bay	Pavlof and Volcano Bays
July 8						[2] 1				
July 9			6							
July 10			6					1		
July 11			5							
July 12			1							
July 13			3					1		
July 14									1	
July 15			1		1	1				
July 16	3		4			1				
July 17			3							
July 18	5									
July 19						1		1		
July 20			2		2		1			
July 21				1	3	2	3		1	1
July 22			1	1	2	2	2			
July 23					1	6	1		2	
July 24							2			
July 25						7	1			
July 26			1							
July 30 *							1			
July 31			1							
Aug. 8 *	1									
Aug. 11 *										1
No date		12					2			
Total	9	12	34	2	9	21	13	3	4	2
Percentage returned	2.1	2.7	7.8	0.5	2.1	4.8	3.0	0.7	0.9	0.5
Median time in days	9.8		3.5	13.5	13	15	[3] 14.25	5	14	23.5

* Indicates a break in the continuity of the table.
[1] In addition to those tabulated one tag was reported taken in Bear Lake.
[2] Obviously an error, not included in calculating time en route.
[3] Returns for which no date is given were not included.

TABLE 20.—*Returns from 110 red salmon tagged July 8, 1923, at Morzhovoi Bay, Pacific American Fisheries trap No. 5. Recaptures, 52 (47.3 per cent)*

Date	Locality of recapture								
	Morzhovoi Bay	Ikatan-False Pass	Bear and Sandy Rivers	Naknek	Kvichak	Nushagak	Thin Point	Cold Bay	Pavlof Bay
July 9		1					3		
July 10		2					7		
July 11		1					5	6	
July 13 *		1					4		
July 14							1	1	
July 16 *	1								
July 17							1	1	
July 18	3								1
July 19									1
July 21 *				1	1		2	1	
July 22			1	1	1	1			
July 23				1				1	
July 24							1		
Total	4	5	1	3	2	1	24	10	2
Percentage returned	3.6	4.5	0.9	2.7	1.8	0.9	21.8	9.1	1.8
Median time in days	9.8	2.25	14	14	13.5	14	2.9	3.33	10.5

* Indicates a break in the continuity of the table.

TABLE 21.—*Returns from 131 red salmon tagged July 10, 1923, Ikatan Bay, Pacific American Fisheries trap No. 13. Recaptures, 51 (39 per cent)*

Date	Locality of recapture						
	Ikatan-False Pass	Morzhovoi Bay	Morzhovoi Lake	Naknek	Kvichak	Nushagak	Thin Point
July 10	6						
July 11	10						
July 12	1						
July 13	11						
July 15 *	3				1		
July 16	2	2					
July 17							1
July 18	1	1					
July 20 *							1
July 21						1	
July 22					1		
July 23				2			
July 24					1		
July 26 *	1						
No date			4	1			
Total	35	3	4	3	3	1	2
Percentage returned	26.7	2.3	3.0	2.3	2.3	0.8	1.5
Median time in days	2.54	0.25	(over 50)	[1] 13	12	11	8.5

* Indicates a break in the continuity of the table.

[1] Omitting one without date of capture.

TABLE 22.—*Returns from 326 red salmon tagged July 10, 1923, Ikatan Bay, P. E. Harris trap No. 5. Recaptures, 110 (33.7 per cent)*

Date	Locality of recapture								
	Ikatan-False Pass	Morzhovoi Bay	Morzhovoi Lake	Bear and Sandy Rivers	Egegik	Naknek	Kvichak	Nushagak	Belkofski village
July 11	3								
July 12	3								
July 13	30								
July 14						1			
July 15	4								
July 16		4				1			
July 17						1			
July 18				1			2		
July 19				3					
July 20				1	1		5		
July 21					3	5	4	1	
July 22				1		5	3		
July 23						6	1		
July 24						4	4	1	
July 25						5	4		
July 30 *					1				
Aug. 4 *									1
No date			1						
Total	40	4	1	6	5	28	23	2	1
Percentage returned	12.3	1.2	0.3	1.8	1.5	8.6	7.1	0.6	0.3
Median time in days	2.96	6	(over 50)	9.16	11.0	12.66	11.66	12.5	25

* Indicates a break in the continuity of the table.

TABLE 23.—*Returns from 447 red salmon tagged July 11, 1923, Ikatan Bay, Pacific American Fisheries trap No. 2. Recaptures, 299 (66.9 per cent)*

Date	Locality of recapture									
	Ikatan-False Pass	Morzhovoi Bay	Morzhovoi Lake	Bear and Sandy Rivers	Ugashik	Egegik	Naknek	Kvichak	Nushagak	Cold Bay
July 11	12									
July 12	24									
July 13	197	1								
July 15 *	11							1		
July 16	14	6								
July 17	2						2			
July 18	2	1					1			
July 19	1									
July 20	1			1						
July 21							2	1		1
July 22					1		2	1		
July 23	1						1		1	
July 24							2	2	1	
July 25							2			
No date			2			1	1			
Total	265	8	2	1	1	1	13	5	2	1
Percentage returned	59.3	1.8	0.4	0.2	0.2	0.2	2.9	1.1	0.4	0.2
Median time in days	1.99	5		9	11		[1] 11.0	11.0	12.5	10.0

* Indicates a break in the continuity of the table.

[1] Omitting one without date of capture.

TABLE 24.—*Returns from 36 dog salmon tagged July 11, 1923, Ikatan Bay, Pacific American Fisheries trap No. 2. Recaptures, 18 (50 per cent)*

Date	Locality of recapture			Date	Locality of recapture		
	Ikatan-False Pass	Morzhovoi Bay	Volcano Bay		Ikatan-False Pass	Morzhovoi Bay	Volcano Bay
July 11	1			July 23 *			1
July 13 *	9			July 25 *		1	
July 16 *	1	1					
July 17	1			Total	14	2	2
July 18	1			Percentage returned	38.9	5.5	5.5
July 19			1	Median time in days	2.16	9.5	10.0
July 20	1						

* Indicates a break in the continuity of the table.

TABLE 25.—*Returns from 279 red salmon tagged July 13, 1923, Morzhovoi Bay, Pacific American Fisheries trap No. 5. Recaptures, 135 (48.4 per cent)*

Date	Locality of recapture							
	Morzhovoi Bay	Morzhovoi Lake	Ikatan-False Pass	Little Becharoff Lake	Nushagak	Thin Point	Cold Bay	Pavlof Bay
July 13			1					
July 14			5					
July 15			4					
July 16	25		4					
July 17			1			9	3	
July 18	9		3			4		1
July 19			2			5	5	6
July 20			1			2		
July 21						1	4	
July 22			1					
July 23	3					1	4	
July 24			1			5		
July 25	8				1	1	1	
July 27*								1
Aug. 1*						1		
Aug. 4*				1				
Aug. 6*	1							
Aug. 18*							1	
No date		9						
Total	46	9	23	1	1	29	18	8
Percentage returned	10.5	3.2	8.2	0.4	0.4	10.4	6.5	2.9
Median time in days	3.42		2.87	22	12	5.83	7.75	6.0

* Indicates a break in the continuity of the table.

TABLE 26.—*Returns from 171 dog salmon tagged July 13, 1923, Morzhovoi Bay, Pacific American Fisheries trap No. 5. Recaptures, 62 (36.2 per cent)*

Date	Locality of recapture				
	Morzhovoi Bay	Ikatan-False Pass	Thin Point	Belkofski Bay	Pavlof and Volcano Bays
July 16	10				
July 17		1			
July 18	7	1			4
July 19		1			1
July 23*	7		1	1	2
July 25*	14				1
July 26		1			
July 27	2				1
July 28			1		
July 29					2
July 31*					1
Aug. 4*					2
Aug. 16*					1
Total	40	4	2	1	15
Percentage returned	23.4	2.3	1.2	0.6	8.8
Median time in days	9.93	5.5	12.5	10.0	12.0

* Indicates a break in the continuity of the table.

TABLE 27.—*Returns from 170 red salmon tagged July 18, 1923, Morzhovoi Bay, Pacific American Fisheries trap No. 5. Recaptures, 80 (47 per cent)* [1]

Date	Locality of recapture						
	Morzhovoi Bay	Morzhovoi Lake	Ikatan-False Pass	Thin Point	Cold Bay	Belkofski Bay	Pavlof Bay
July 20			1				
July 21				1			
July 23*	3		1	6	7	1	
July 24			1	9			
July 25	8			7	5		1
July 26			3	2			
July 27	4		1				
July 28				1	2		
July 29	1						
July 31*			1	3			1
Aug. 1				1			
Aug. 3*				1			
Aug. 6*	1						
Aug. 7			1				
Aug. 9*				1			
No date		4					
Total	17	4	9	32	14	1	2
Percentage returned	10.0	2.4	5.3	18.8	8.2	0.6	1.2
Median time in days	7.18		8.0	6.5	6.0	5.0	10.0

* Indicates a break in the continuity of the table.
[1] In addition to those tabulated, one tag was taken in Bear Lake.

TABLE 28.—*Returns from 172 dog salmon tagged July 18, 1923, Morzhovoi Bay, Pacific American Fisheries trap No. 5. Recaptures, 63 (36.6 per cent)*

Date	Locality of recapture				Date	Locality of recapture			
	Morzhovoi Bay	Ikatan-False Pass	Thin Point	Pavlof and Volcano Bays		Morzhovoi Bay	Ikatan-False Pass	Thin Point	Pavlof and Volcano Bays
July 20	2	1			Aug. 1			1	
July 21				1	Aug. 3*			1	
July 22		1			Aug. 4			1	
July 23	12				Aug. 8*	1			
July 24		5			Aug. 16*				1
July 25	20			2					
July 26		1	1		Total	38	9	5	11
July 27	2			3	Percentage returned	22.1	5.2	2.9	6.4
July 28			1		Median time, in days	6.75	6	14	9.33
July 29	1			2					
July 30		1							
July 31				2					

* Indicates a break in the continuity of the table.

TABLE 29.—*Returns from 198 red salmon tagged July 20, 1923, Morzhovoi Bay, Pacific American Fisheries traps Nos. 8, 3, and 2. Recaptures, 63 (31.8 per cent)*

Date	Locality of recapture							
	Morzhovoi Bay	Morzhovoi Lake	Ikatan-False Pass	Bear Lake	Naknek	Thin Point	Cold Bay	Volcano Bay
July 23	6		1		1		1	
July 24			8					
July 25	5					4	2	
July 26			3			2		
July 27	5		1					1
July 28			1			1		
July 29	3							
July 31*						1		
Aug. 1						1		
Aug. 3*					1			
Aug. 4								1
Aug. 6*	2							
Aug. 8*			2				1	
Aug. 9						1		
Aug. 16*	1							
No date		4		3				
Tagged in No. 3	10	3	4			2	3	
Tagged in No. 8	9		11		2	5	1	1
Tagged in No. 2	3	1	1			3		1
Total	22	4	16	3	2	10	4	2
Percentage returned	11.1	2	8.1	1.5	1	5	2	1
Median time, in days	6	(Over 50)	4.37		8.5	6	5	11

* Indicates a break in the continuity of the table.

RED SALMON

ROUTES TRAVELED

In order to simplify the interpretation of the data given in Tables 2 to 29, other tables have been prepared combining the data obtained from the various experiments begun in each main locality. Thus, the results obtained from each experiment begun in the Kelly Rock and Big Valley traps on Unga Island are presented in Table 30 (p. 30). This table gives the percentage recaptured in each locality from which recaptures were reported, the time, in days, between tagging and recapture, and in the last two columns the total number of recaptures reported from each locality and the percentage of the total number tagged taken in each locality. The same has been done for the experiments begun in the Coal Harbor trap on Unga Island (Table 31, p. 52), Ikatan Bay (Table 32, p. 53), 3 traps (Pacific American Fisheries traps Nos. 8, 3 and 2) on the western and northern shores of Morzhovoi Bay (Table 34, p. 56), and from one trap (Pacific American Fisheries trap No. 5) located on the eastern shore of Morzhovoi Bay (Table 35, p. 57.) This particular grouping of experiments was made as a result of a careful inspection of the data, which showed that the results from these various localities were distinct enough to justify their separation, and that the results from the experiments that have been thrown together were similar enough to justify such treatment.

The localities from which recaptures were reported have been arranged in each of these tables as nearly as possible in the order of their proximity to the point

where the tagging was done. As the fish traveled in various directions, it was impossible to follow strictly such an arrangement. We have, therefore, arranged the localities, first in the order presented as the fish were going to Bristol Bay (where the great majority were apparently bound), and then we have given the localities to the eastward of the place of tagging. In Table 30, therefore, the localities appear in order of proximity to Unga Island, following along the south shore of the Alaska Peninsula, then along the northern shore of the Peninsula to Bristol Bay, and northward from Bristol Bay as far as the Kuskokwim. Following this, other localities where tags were taken are given in the order of their proximity to Unga Island, going in an easterly direction as far as Cook Inlet.

KELLY ROCK AND BIG VALLEY TRAPS, UNGA ISLAND

The returns from the various experiments begun at this place are given in Table 30. The two traps are those where tagging was done during the season of 1922, and, with minor variations, the results were the same.

TABLE 30.—*Returns of red salmon from each tagging at Kelly Rock and Big Valley traps, Unga Island. Percentage taken in each locality and median time en route in days*

[Number of fish tagged, 3,185]

Locality of recapture	Approximate distance (standard miles)	June 2, 3, and 5—120 tagged, 13 returned		June 7—575 tagged, 105 returned		June 23—499 tagged, 213 returned		June 26—499 tagged, 110 returned	
		Per cent returned	Time in days	Per cent returned	Time in days	Per cent returned	Time in days	Per cent returned	Time in days
Unga Island		0.8	3	0.3	(1)	4.2	5	0.2	3
Pavlof Bay [2]	65					.2	11	.2	19
Cold Bay	110								
Thin Point	105							.4	7
Morzhovoi Bay	120			4.7	8	13	6	.6	4
Morzhovoi Lake	125			.2	59				
Ikatan Bay	120	5	8	8.2	5	16.2	6	6.8	6
Nelson's Lagoon	255			.3	26	.2	18	.4	16
Bear River	295			.2	32			1	15
Ugashik	430					.2	21	.2	28
Egegik	455	1.7	21	.3	22	.8	21	.2	16
Naknek	480	.8	52	1.2	29	2.8	21	3.6	20
Kvichak	480	2.5	23	1.6	21	2.4	21	4.6	21
Iliamna Lake	610					.4	27		
Nushagak	465			.7	23	2	21	3.2	21
Good News Bay	415							.2	
Togiak	415							.2	14
Kuskokwim	560			.2	15				
Orzinski Bay	40								
Chignik	150			.2	15	.2	25	.2	45
Karluk	290								
Alitak	290								
Afognak	430			.2	24				
Cook Inlet	480								
Total		10.8		18.3		42.6		22	

[1] See Table 3.
[2] Including also Volcano Bay.

TABLE 30.—*Returns of red salmon from each tagging at Kelly Rock and Big Valley trap, Ungo Island. Percentage taken in each locality and median time en route in days*—Continued

Locality of recapture	June 27—859 tagged, 277 returned		July 6—633 tagged, 172 returned		Total number returned	Percentage returned	Average time in days [3]
	Per cent returned	Time in days	Per cent returned	Time in days			
Unga Island	0.9	6	5.7	4	69	2.17	5.1
Pavlof Bay [4]	.2	14	.5	9	7	.22	12.4
Cold Bay			.3	6	2	.06	6.5
Thin Point	.5	7	1.1	7	13	.41	7
Morzhovoi Bay	1.4	10	1.6	10	117	3.68	6.9
Morzhovoi Lake					1	.03	59
Ikatan Bay	16.8	7	6.2	7	351	11.03	6.6
Nelson's Lagoon	.2	16			7	.22	19.4
Bear River	1	15	.5	14	18	.56	15.6
Ugashik			.8	16	7	.22	
Egegik	.9	20	.6	14	21	.66	
Naknek	5.4	19	3.8	16	110	3.45	
Kvichak	3.4	19	4	15	101	3.17	
Iliamna Lake					2	.06	
Nushagak	.9	21	.6	16	42	1.32	
Good News Bay					1	.03	
Togiak			.2	45	2	.06	29.5
Kuskokwim					1	.03	15
Orzinski Bay			.2	16	1	.03	16
Chignik	.3	23	.8	11	11	.34	19.1
Karluk	.1	18			1	.03	18
Alitak			.3	17	2	.06	17.5
Afognak					1	.03	24
Cook Inlet	.1	17	.2	28	2	.06	22.5
Total	32.2		27.2		890	27.93	

[3] For reasons given in the text the average time is not given for Bristol Bay points.
[4] Including also Volcano Bay.

The general movement of the body of fish found in the region of the Shumagin Islands is westward to Ikatan and Morzhovoi Bays, thence into Bering Sea—undoubtedly through False Pass (Isanotski Strait)—northeasterly along the shores of the Alaska Peninsula and to Bristol Bay. A little over 2 per cent of the fish were taken again in the same traps from which they were liberated, but these, of course, throw no light on the migrations. It should be noted, however, that the percentage of fish recaptured in the immediate vicinity of the place of liberation was considerably higher in these experiments than in those of 1922. In 1922 only 1 fish out of 861 tagged in these same two traps was retaken in these traps, while in 1923, 69 were taken out of a total of a little over 3,000 tagged. The difference is considerable, but no explanation of it can be offered. In 1922 no fish were taken on local fishing grounds around the Shumagin Islands, but in 1923 a number were taken in Red Cove, a small bay on the south shore of Popof Island, where some beach seining is conducted. Evidently the fish are inclined to linger somewhat among the channels of the Shumagin group, but not to the extent that they remain in the region of Ikatan and Morzhovoi Bays.

The fish taken along the main route of migration (Morzhovoi Bay, Ikatan Bay, and Bear River) and in the Bristol Bay region from Ugashik to Nushagak form over 24 per cent of those tagged. Only 18 fish (less than six-tenths of 1 per cent) went to the eastward, and most of these—that is, 11 fish—were taken at Chignik. A few were taken in local spawning streams between the Shumagin Islands and Bristol Bay. These included Pavlof Bay, Cold Bay, Thin Point, Morzhovoi Lake, and Nelson's Lagoon. A total of less than 1 per cent was returned from these

streams. It is very apparent, therefore, that the fish found about the Shumagin Islands are very largely Bristol Bay residents.

With one exception no very striking differences are to be observed in the percentage of the returns from different experiments taken in any given locality. This exception is the case of returns from Morzhovoi Bay. Relatively large percentages of the fish tagged on June 7 and June 23 were taken in Morzhovoi Bay—4.7 per cent and 13 per cent, respectively. After this last date apparently fewer fish visited Morzhovoi Bay on their migration to Bristol Bay. A similar difference is not noticeable in the case of Ikatan Bay, which is practically at the entrance to False Pass. It seems reasonable to conclude, therefore, that during the latter part of the season the fish go more directly from the region of the Shumagin Islands to Isanotski Strait and through this to Bristol Bay. Additional evidence of this will be presented in the section dealing with the rate of travel.

COAL HARBOR TRAP, UNGA ISLAND

On account of the position of the Coal Harbor trap in Unga Strait, on the north shore of Unga Island, it has been of interest to compare the results of tagging at this point with those obtained from the tagging at the Kelly Rock and Big Valley traps, which are located on the eastern shore of Unga Island near the extreme southern part of Popof Strait. Only two experiments were undertaken at the Coal Harbor trap, mainly because of the fact that this trap, which was new, did not prove successful and took but a few salmon at any time during the season. The results of these two experiments are given in Table 31.

TABLE 31.—*Returns of red salmon from each tagging at Coal Harbor trap, Unga Island. Percentage taken in each locality and median time en route in days*

[Number of fish tagged, 247]

Locality of recapture	Approximate distance (standard miles)	June 27—137 tagged, 53 returned		July 4—110 tagged, 43 returned		Total number returned	Percentage returned	Average time, in days[1]
		Per cent	Time in days	Per cent	Time in days			
Unga Island	----------	5.1	12	12.7	4	21	8.50	6.7
Thin Point	105	.7	7	.9	13	2	.81	10.5
Morzhovoi Bay	120	1.5	10	.9	3	3	1.21	8
Ikatan Bay	120	17.5	6	6.4	9	31	12.55	6.9
Nelson's Lagoon	255	----------	----------	.9	12	1	.40	12
Bear River	295	.7	14	.9	17	2	.81	15.5
Ugashik	430	.7	20	----------	----------	1	.40	----------
Naknek	480	2.2	26	7.3	17	11	4.45	----------
Kvichak	480	4.4	20	8.2	16	15	6.07	----------
Lake Clark	650	.7	----------	----------	----------	1	.40	----------
Nushagak	465	2.9	21	.9	16	5	2.02	----------
Good news Bay	415	.7	13	----------	----------	1	.40	13
Orzinski Bay	40	.7	4	----------	----------	1	.40	4
Cook Inlet	480	.7	16	----------	----------	1	.40	16
Total	----------	38.7	----------	39.1	----------	96	38.86	----------

[1] See footnote 3 in Table 30.

A comparison with Table 30 shows that there was practically no difference in the returns obtained from these experiments and those begun at Kelly Rock and Big Valley. A somewhat larger percentage of the fish liberated from the Coal Harbor trap was taken in the vicinity of Unga Island—mainly in the other two traps

and in Red Cove. Evidently the fish in Unga Strait traversed Popof Strait to the southward in considerable numbers. No evidence was obtained to show that the reverse was true and that the fish found in the region of Kelly Rock and Big Valley passed northward through Popof Strait. It seems probable, therefore, that the majority of the salmon that escape the traps in the region of Kelly Rock skirt the south shore of Unga Island on their way to Morzhovoi and Ikatan Bays and False Pass.

IKATAN BAY

The data obtained from the various experiments in Ikatan Bay are given in Table 32.

TABLE 32.—*Returns of red salmon from each tagging in Ikatan Bay. Percentage taken in each locality and median time en route, in days*

[Number of fish tagged, 2,702]

Locality of recapture	Approximate distance (standard miles)	June 18—799 tagged, 217 returned		July 1—699 tagged, 308 returned		July 2—300 tagged, 220 returned		July 10—P. A. F. No. 13,131 tagged, 51 returned	
		Per cent	Time in days	Per cent	Time in days	Per cent	Time in days	Per cent	Time in days
Ikatan Bay		17.3	2	33.4	2	69.6	1	26.7	3
Morzhovoi Bay	20	4.4	3	3.3	6	1.3	5	2.3	6
Morzhovoi Lake	30							3.0	50+
Swanson's Lagoon	25	.1	14						
Nelson's Lagoon	130			.4	12				
Bear River	170	1.1	16	.4	12	.3	9		
Ugashik	300	.1	14						
Egegik	330	.2	20	.3	16	.3	16		
Little Becharoff Lake	400	.1	54						
Naknek	350	1.5	25	2.4	18	1.0	14	2.3	13
Kvichak	350	1.6	24	1.7	17	.7	15	2.3	12
Nushagak	340	.5	21	1.7	17			.8	11
Kuskokwim (Bethel)	430	.1	?						
Thin Point	30			.3	7			1.5	8
Cold Bay	50								
Belkofski Village	50			.1	23				
Total		27.0		44.0		73.5		38.9	

Locality of recapture	July 10—P. E. H. No. 5, 326 tagged, 110 returned		July 11—P. A. F. No. 2, 447 tagged, 299 returned		Total number returned	Percentage returned	Average time, in days [1]
	Per cent	Time in days	Per cent	Time in days			
Ikatan Bay	12.3	3	59.3	2	920	34.05	1.9
Morzhovoi Bay	1.2	6	1.8	5	77	2.85	4.4
Morzhovoi Lake	.3	50+	.4	50+	7	.26	50.0
Swanson's Lagoon					1	.04	14.0
Nelson's Lagoon					3	.11	12.0
Bear River	1.8	9	.2	9	20	.74	12.6
Ugashik			.2	11	2	.07	
Egegik	1.5	11	.2	?	11	.41	
Little Becharoff Lake					1	.04	
Naknek	8.6	13	2.9	11	76	2.81	
Kvichak	7.1	12	1.1	11	58	2.14	
Nushagak	.6	12	.4	12	21	.78	
Kuskokwim (Bethel)					1	.04	
Thin Point					4	.15	7.7
Cold Bay			.2	10	1	.04	10.0
Belkofski Village	.3	25			2	.07	24.0
Total	33.7		66.7		1,205	44.60	

[1] See footnote 3 to Table 30.

In full accord with the results obtained in 1922, these experiments show that a very high percentage of the returns were taken in Ikatan Bay where the fish had been liberated, and that, next to Ikatan Bay, the greatest number of tagged fish was reported from Morzhovoi Bay. In the report on the experiments of 1922 the senior author stated that "Recaptures from all the tagging experiments, without exception, indicate that the salmon tarry in this vicinity for a considerable period, often from two to three weeks, passing back and forth from Ikatan to Morzhovoi Bays and repeatedly running the gauntlet of all the traps."

It is interesting to compare the results obtained in the tagging done at the P. E. Harris trap No. 5 on July 10 with the results obtained in the five experiments for which fish were taken from traps operated by the Pacific American Fisheries. This experiment was made at the suggestion of Superintendent Nicholls of the P. E. Harris Co. The trap (P. E. Harris No. 5) is located very near the southern entrance to False Pass—in fact, is as near to the entrance as the extremely strong tidal currents will permit. In this location it is natural to suppose that the fish taken were approaching the entrance of the strait with the intention of passing through. Favorable currents would be expected to facilitate their passage through, and the tagging was therefore done on the beginning of the flood tide which sweeps up through the pass and is only met by the flood tide from the Bering Sea side well toward the northern entrance.

Although there is no appreciable difference in the time required for the fish tagged in this experiment to reach Bristol Bay (see Table 32, p. 53), there is a very significant difference in the percentage of fish that ultimately reached Bristol Bay when compared with the results of other experiments started in Ikatan Bay. It is apparent that a much larger percentage of the fish tagged in the P. E. Harris trap No. 5 escaped the traps of Ikatan Bay and proceeded through False Pass and on to Bristol Bay. The percentages are as follows:

TABLE 33.—*Fish tagged in Ikatan Bay, recaptured there and in Bristol Bay*

Point where tagged	Number tagged	Ikatan Bay		Bristol Bay	
		Number	Percentage	Number	Percentage
Other traps in Ikatan Bay	2,376	880	37	111	4.7
P. E. Harris trap No. 5	326	40	12.3	58	17.8

It is instructive to compare the results of this experiment with those obtained from the tagging done in the Pacific American Fisheries trap No. 13 on the same date and in the Pacific American Fisheries trap No. 2 the next day (July 11). These two Pacific American Fisheries traps are located some distance from the southern entrance to the pass. The two experiments were started so nearly simultaneously with the one in P. E. Harris trap No. 5 that they might reasonably have been expected to yield approximately the same results. However, the percentage of fish returned from Ikatan and Morzhovoi Bays is approximately twice as great in the case of the experiments started in the Pacific American Fisheries traps, while

the returns from Bristol Bay are only about one-fourth as great. The evidence clearly indicates that this trap (P. E. Harris No. 5) catches a large percentage of fish that have successfully evaded the fishing gear located in Ikatan and Morzhovoi Bays and which are just ready to enter False Pass on their way to Bristol Bay.

It is interesting to note that all of the fish reported from the local spawning grounds in Morzhovoi Lake and which were tagged in Ikatan Bay were tagged on July 10 and 11.

One of the fish tagged in Ikatan Bay was taken in Swanson's Lagoon on the north shore of Unimak Island, a short distance west of the northern entrance to False Pass. There was no established fishery in Swanson's Lagoon, so that no real opportunity was offered for collecting tags at this point. The one returned was secured by Mr. Wingard, of the Bureau of Fisheries, at the time of a brief inspection of the spawning grounds in this locality. It may be that a considerable percentage of the fish that enter Swanson's Lagoon for spawning feed in the north Pacific Ocean and pass through Isanotski Strait just as do the fish bound for Bristol Bay.

Three tags were reported from Nelson's Lagoon on the northern shore of the Alaska Peninsula and approximately 100 miles eastward from False Pass. Twenty were taken in the region of Bear and Sandy Rivers, about 20 miles east of Port Moller. Only a very few fish were taken at points to the eastward of Ikatan and Morzhovoi Bays along the southern shore of the peninsula. Of these, four were taken at Thin Point, one in Cold Bay,[3] and two were reported from Belkofski village and were probably taken in nets near that point. This again fully agrees with the results obtained in 1922.

MORZHOVOI BAY, PACIFIC AMERICAN FISHERIES TRAPS NOS. 8, 3, AND 2

During 1923 four traps were operated in Morzhovoi Bay, all under the control of the Pacific American Fisheries. Three of these—Nos. 8, 3, and 2—were located along the western and northern shores of the bay and one—No. 5—on the eastern shore. The results obtained from the various experiments in No. 5 were so different from the results obtained from the experiments conducted at the other traps that they have been tabulated separately. The results from the experiments in traps Nos. 8, 3, and 2 are given in Table 34.

[3] The following data were received as the paper was in press, too late to insert in the tables and text: Seven tags taken at Cold Bay, recorded under date of Aug. 1, 1923. Two were attached in Ikatan Bay, July 10; one in Morzhovoi Bay, trap No. 5, July 13; two at the same place, July 18; and two at the traps on the western shore of Morzhovoi Bay, July 20. Since these data would not materially change the conclusions reached, no attempt has been made to accomplish the revisions necessary to include them. (W. H. R.)

TABLE 34.—*Returns of red salmon from each tagging in Morzhovoi Bay, Pacific American Fisheries traps Nos. 8, 3, and 2. Percentage taken in each locality and median time en route in days*

[Number of fish tagged, 2,026]

Locality of recapture	Approximate distance (standard miles)	June 20—800 tagged, 187 returned		June 30—592 tagged, 250 returned		July 8—436 tagged, 110 returned		July 20—198 tagged, 63 returned		Total number returned	Percentage returned	Average time in days [1]
		Per cent	Time in days	Per cent	Time in days	Per cent	Time in days	Per cent	Time in days			
Morzhovoi Bay		3.2	6	1.2	3	2.1	10	11.1	6	64	3.26	6.2
Morzhovoi Lake	5					2.7	50+	2	40+	16	.79	50 (?)
Ikatan Bay	20	11.4	5	31.8	3	7.8	3	8.1	4	329	16.24	3.3
Nelson's Lagoon	150	.4	18							3	.14	18
Bear River	190	.6	18	.7	16					9	.44	17
Bear Lake	210	.1		.2				1.5		6	.30	
Ugashik	320	.1	17	.2	31	.5	13			4	.20	
Egegik	350	1	21	.5	21	2.1	13			20	.99	
Little Becharoff Lake	420	.1	63							1	.05	
Naknek	370	3.2	27	4.7	17	4.8	15	1	8	77	3.80	
Kvichak	370	2.6	23	2	16	3	14			46	2.27	
Nushagak	360	.2	16	.5	22					5	.25	
Thin Point	25			.3	7	.7	5	5	6	15	.74	6
Cold Bay	40	.1	20	.2	3	.9	14	2	5	10	.49	9.9
Pavlof Bay	90					.5	23	1	11	4	.20	17.2
Total		23		42.3		25.1		31.7		[2] 609	30.16	

[1] See footnote 3 to Table 30.

[2] One other tag was returned but with no data.

In general, there is no great difference between the results obtained here and those obtained from the experiments in Ikatan Bay. Similar high percentages of recapture were reported from Morzhovoi Bay, Ikatan Bay, and Bristol Bay. More fish were reported from Ikatan Bay than from any other locality (16 per cent), although it might have been expected that, since the fish were tagged in Morzhovoi Bay, more returns would have been reported from that locality. On the contrary, but 3 per cent were from Morzhovoi Bay, as compared with the 16 per cent taken in Ikatan Bay. A somewhat higher percentage of return was reported from local spawning grounds and from points to the eastward of Morzhovoi Bay than was the case with the experiments in Ikatan Bay—nearly 1.43 per cent, as compared with less than 0.26 per cent.[4] This fact will be more readily understood, however, in connection with the discussion of the returns from trap No. 5.

MORZHOVOI BAY, PACIFIC AMERICAN FISHERIES TRAP NO. 5

A striking difference is observed in the results (presented in Table 35) obtained from the experiments conducted at this point. These are remarkable in that a comparatively small percentage of return was reported from Bristol Bay, while nearly 17 per cent came from local fishing grounds to the eastward of Morzhovoi Bay. In none of the other experiments begun in Ikatan and Morzhovoi Bays was more than a relatively insignificant percentage of the returns reported from these local fisheries, while considerably higher percentages were in all cases reported from Bristol Bay. This difference is not due to differences in the time of tagging, since other experiments, begun at approximately the same dates but in other traps in Morzhovoi and Ikatan Bays, show the usual high percentage of returns from Bristol Bay and few returns from points to the eastward. It is quite apparent that the

[4] See footnote 3, page 55.

fish running on the eastern side of Morzhovoi Bay represent races seldom found in the other districts. Some admixture is apparent, since a few fish from trap No. 5 went to Bristol Bay and a few from other traps went eastward, but the proportions are so distinctly different that there can be no question as to the essentially different character of the two streams of migrants.

TABLE 35.—*Returns of red salmon from each tagging in Morzhovoi Bay, Pacific American Fisheries trap No. 5. Percentage taken in each locality and median time en route in days*

[Number of fish tagged, 962]

Locality of recapture	Approximate distance (standard miles)	June 30—403 tagged, 228 returned		July 8—110 tagged, 52 returned		July 13—279 tagged, 135 returned		July 18—170 tagged, 79 returned		Total number returned	Percentage returned	Average time in days [1]
		Per cent	Time in days	Per cent	Time in days	Per cent	Time in days	Per cent	Time in days			
Morzhovoi Bay		1.7	3	3.6	10	16.5	3	10	7	74	7.69	4.6
Morzhovoi Lake	5					3.2	50+	2.4	40+	13	1.35	50(?)
Ikatan Bay	25	44.4	2	4.5	2	8.2	3	5.3	8	216	22.44	2.7
Nelson's Lagoon	150	.2	11							1	.10	11
Bear River	190	1	10	.9	14					5	.52	11.2
Bear Lake	210							.6		1	.10	
Egegik	350	.2	18							1	.10	
Little Becharoff Lake	420					.4	22			1	.10	
Naknek	370	2	16	2.7	14					11	1.14	
Kvichak	370	1.5	15	1.8	13					8	.83	
Nushagak	360	.2	18	.9	14	.4	12			3	.31	
Thin Point	25	3	4	21.8	3	10.4	6	18.8	6	97	10.09	5.1
Cold Bay	40	2	11	9.1	3	6.5	8	8.2	6	50	5.20	6.9
Belkofski Bay	50							.6	5	1	.10	5
Pavlof Bay	90	.2	19	1.8	10	2.9	6	1.2	10	13	1.35	8.3
Total		56.4		47.1		48.5		47.1		495	51.42	

[1] See footnote 3 to Table 30.

Inspection of the tables also shows that the local fish constituted a much larger percentage of the fish tagged toward the end of the season. Very few fish taken locally were tagged during June, but they form a conspicuous item in the returns from experiments started during July. In the case of 37 individuals taken in Morzhovoi Lake, but one was tagged during June (June 7 at Kelly Rock trap). Twelve of those recovered in Morzhovoi Lake were tagged in Morzhovoi Bay on July 8, 5 at Ikatan on July 10, 2 at Ikatan on July 11, 9 in Morzhovoi Bay on July 13, 4 on the 18th, and 4 on the 20th. It is quite apparent that this run of fish, which spawns in Morzhovoi Lake, appears in the vicinity of Ikatan and Morzhovoi Bays late in the season after the Bristol Bay run has passed on. It is not possible to state whether these local fish actually come into these bays later in the season or whether they are there along with the others but form such a small element in the total population that the chance of tagging many of them is slight. It is possible that the influx into the coastal waters of the tremendous shoals of salmon bound for Bristol Bay may either obscure the lesser runs or may tend to keep them out and away from the coast where the fishing gear is operated. It is also possible that the fish bound for local streams do not normally seek the shore as early as those bound for the more distant spawning areas. Whatever the ultimate explanation may be, it is certain that the local fish do not constitute a conspicuous percentage of the fish taken in this region until well along in July.

In the first experiment, started June 30, over 44 per cent of the fish tagged were taken in Ikatan Bay. This is correlated with a correspondingly low percentage of returns from points to the eastward (5.2 per cent). With this exception, comparatively few of the fish tagged here were reported taken in Ikatan Bay. This is additional evidence that of the fish found in Morzhovoi Bay those that are destined to enter local streams, both in Morzhovoi Bay and to the eastward, are found along the eastern shore of the bay and mainly during the latter part of the season.

RATE OF TRAVEL

In making an analysis of the rate of travel it has become apparent that certain facts affect the reliability of the returns from Bristol Bay. These will therefore be discussed after the returns from other localities have been examined. The data will be found in Tables 30 to 35.

It is obvious that the rates of travel, as determined from the elapsed time between tagging and the reported recapture, will be only a minimum rate. In the first place, the assumption that the fish travel in the most direct line is not reasonable. Then, too, there will necessarily be some delay between the time that the fish is first taken in the trap and the time that it is found and the recapture reported. Traps are seldom lifted more than once a day (frequently a much longer interval elapses), and since the fish may enter the trap at any time during the 24 hours or more between one lift and the next, it follows that the elapsed time between liberation and reported recapture will be, on the average, at least 12 hours longer than was actually required by the fish to make the journey. It is certain, therefore, that the actual rate of travel of these fish is somewhat higher than our figures show, but just how much higher it is impossible to say.

FROM THE SHUMAGIN ISLANDS

The important migration from Unga Island to Ikatan and Morzhovoi Bays, composed, as we have seen, largely of fish bound to Bristol Bay, requires approximately 7 days. After each tagging at Unga Island fish were reported from Ikatan and Morzhovoi Bays, or both, within 4 or 5 days, occasionally in 3 days, and were reported thereafter for about 2 weeks. Tagged fish were taken in the greatest numbers within 5 or 6 days after the tagging, the numbers diminishing gradually until only an occasional tag was reported later than 2 weeks after the experiment was begun.

An inspection of some of the more typical tables will show clearly the extremely skewed type of frequency distribution given by these data. Not infrequently there were more recaptures reported on the first or second day than on any subsequent date. (See returns from Ikatan in Tables 3 and 6.) No conspicuous difference is noticeable in the time required for the fish to go from Unga Island to Ikatan or to Morzhovoi Bay, nor is there any indication that the rate of travel varies in any regular manner during the season. The weighted means of the median times found in the tables are, from Unga Island to Ikatan Bay, 6.6 days, and to Morzhovoi Bay, 6.9 days. The distances are approximately equal—about 120 miles—so that if we assume that the fish traveled by the shortest and most direct route their rate of travel was not less than about 18 miles per day.

The rate of travel to other near-by spawning grounds along the southern shore of the peninsula is considerably slower. From Unga Island to Pavlof Bay required an average of 12.4 days; to Thin Point, 7.4 days; to Cold Bay, 6.5 days (2 individuals); to Orzinski, 10 days (2 individuals); and all of these places are much nearer Unga Island than are either Ikatan or Morzhovoi Bay. The inference is that the fish bound for the local spawning grounds are traveling more leisurely or less directly, perhaps ranging more widely on their way, than are the fish bound for Bristol Bay.

The fish tagged in the Shumagin Islands, and which went to the eastward as far as Chignik, Kodiak, and Afognak Islands and Cook Inlet, required still more time in which to make the journey. All of the tags reported from these localities were attached in the Shumagins. The average time to Chignik was about 19 days. This is about the same distance from Unga Island as Ikatan Bay—125 miles—yet the elapsed time is nearly three times as great. The rate of travel is correspondingly diminished and amounts to only about 6.5 miles per day—assuming, again, a uniform rate of speed by the shortest and most direct route. It is interesting to note that the fish that went to Cook Inlet (a distance of 450 miles, approximately the same as to Bristol Bay) traveled at a much faster rate, arriving at their destination about the same time as did the fish taken at Chignik. As will be shown later, the fish going to Bristol Bay travel at about the same rate as those that went to Cook Inlet, and they had just about the same distance to go. In these cases the rate of travel was approximately 20 miles per day. Evidently the fish having the longest distance to go travel at a faster rate.

Twenty tags attached at Unga Island were taken near the Bear and Sandy Rivers, some 15 miles east of Port Moller, on the northern shore of the peninsula, and distant from Unga about 280 miles. The fish required a little less than 16 days to go this distance—a rate of about 18 miles per day. Eight tags were taken in Nelson's Lagoon, where there are local spawning grounds, once of considerable importance but now seriously depleted. The average time required was 18.5 days. The distance is approximately 250 miles, hence the rate was 13.5 miles per day. Again, it is apparent that the fish bound for the more distant spawning grounds of Bering Sea travel more rapidly than do those going to near-by regions along the southern shore of the peninsula.

FROM IKATAN BAY

More of the tags attached in Ikatan Bay were taken in that same locality than anywhere else (34 per cent). From Bristol Bay 6.25 per cent were reported (to be discussed below), 2.8 per cent from Morzhovoi Bay, and 1.4 per cent from local spawning grounds on both the northern and the southern shores of the peninsula. The average time required to make the journey from Ikatan Bay to Morzhovoi Bay was 4.4 days, indicating a very slow rate of travel, as the distance is only some 20 miles. One tag was recovered in Swanson's Lagoon, on the northern shore of Unimak Island, 14 days after tagging; 3 were taken in Nelson's Lagoon, 125 miles distant, after an average time of 12 days; and 20 were taken near Bear and Sandy Rivers after an average time of 12.6 days. This last locality is about 160

miles from Ikatan Bay. The rate of travel to Nelson's Lagoon was about 10 miles per day and to Bear River about 13 miles per day.

So few fish tagged at Ikatan were taken at points to the eastward along the southern shore of the peninsula that the data can not be considered at all conclusive. The indications are, however, that from 8 to 10 days are required for the journey from Ikatan Bay to Thin Point or Cold Bay, either of which is about 30 miles distant.

FROM MORZHOVOI BAY

The most abundant returns from the experiments begun in Morzhovoi Bay were from Ikatan Bay, where many of the fish tagged in Morzhovoi Bay are evidently bound on their way to Bristol Bay through False Pass. Ikatan Bay is only some 20 miles distant, and the average time required to make the trip is close to 3 days.

A few tags attached in Morzhovoi Bay were taken at Nelson's Lagoon and Bear River. Those fish tagged from the traps on the western and northern shores of the bay required an average of 17 or 18 days to make the trip, but those tagged in trap No. 5, on the eastern shore, required only about 11 days. This last figure is approximately the same as for the fish tagged in Ikatan Bay. Although the general impression gained from these figures is that the fish tagged in Morzhovoi Bay require a somewhat longer time to go to Nelson's Lagoon and Bear River than did those tagged in Ikatan Bay, the data are too few to warrant definite conclusions.

It was pointed out above that there is a distinct migration from Morzhovoi Bay to local spawning grounds to the eastward along the southern shore of the peninsula and especially to Thin Point and Cold Bay. The fish tagged in trap No. 5 particularly entered into this migration. The distance to Thin Point is only about 20 miles, but the time required was 6 days from the traps on the west side of the bay and 5.1 days from trap No. 5. This indicates a rate of travel of only about 4 miles per day. To Cold Bay required, from the traps on the west side of the bay, an average of approximately 10 days and from trap No. 5 nearly 7 days. The distance to the point in Cold Bay where most of the fishing is conducted is approximately 40 miles. The rate of travel was therefore about the same as to Thin Point. This illustrates again the fact noted above, that the rate of travel to near-by spawning grounds is distinctly slower than to those more distant.

The extent to which the fish linger about the place where they have been liberated is indicated by the average length of time elapsing between the time of liberation and the time of recapture in the same locality. In the case of the fish tagged at Unga Island in the Kelly Rock and Big Valley traps this was 5.1 days. Fish tagged in the Coal Harbor trap lingered about the Shumagin Islands for an average of 6.7 days. Those tagged in the traps on the western and northern shores of Morzhovoi Bay remained in that bay for an average of 6.2 days, and those from the trap on the eastern shore for 4.6 days. The average time between liberation and recapture in Ikatan Bay was about 2 days. It appears probable that the shorter delay in Ikatan Bay is associated with the nearness of False Pass, through which the fish pass in large numbers to the spawning grounds of Bering Sea.

TO BRISTOL BAY

The preceding discussion of the rate of travel has not included those fish that went to Bristol Bay. As noted above, consideration of this migration has been reserved for separate treatment, since the results are seriously affected by the closing of the season in Bristol Bay on July 25. Early in the season the average time required is about 20 days; later it is about 10 days; but this fact alone is not conclusive evidence that the fish are actually traveling faster, since the slower fish from the later experiments are eliminated from the records by the closing of the season in Bristol Bay. The result is that the average time required later in the season is certain to be less, even though the fish were not traveling faster. It has been possible, however, by other methods, to show that there is actually an acceleration of the rate of travel toward the latter part of the season. Tables 36, 37, and 38 show the time required for the fish to go to Bristol Bay from, respectively, Unga Island, Morzhovoi Bay, and Ikatan Bay. The results from various experiments are given in separate columns, and it is easily seen that the upper parts of the distributions were cut off by the closing of the season on July 25. The heavy line at the lower end of the columns indicates this date. Very few returns were reported after this date, and the few that were reported later than July 25 were probably tags that had been retained by fishermen and were not turned in previously.

In studying the comparative rate of travel during different parts of the season it has been necessary, in order to eliminate the error resulting from the closing of the fishing season on July 25, to consider only the first few fish to be reported in Bristol Bay from each tagging. In order that the number actually caught might not affect the results, the numbers which we have taken from each distribution have been based on the number tagged, not on the number retaken. Several methods of analysis were tried, but with practically identical results. The simplest and most obvious thing to do was to take the time required for the trip by the first arrival. In addition to this we took the time that elapsed before 1 per cent of the total number tagged were taken in Bristol Bay and the same for 2 per cent and 3 per cent; then we took the *average* time required before 1, 2, or 3 per cent of the total number tagged had reached Bristol Bay. We thus had 7 different series of data from each of 3 localities in which tagging was carried on, or 21 in all.

These data all told the same story, showing conclusively that the fish were actually traveling at a faster rate later in the season. Figures 10 to 12 present graphically the data on the time required by the first arrival and the time required for 2 per cent of those tagged to arrive. The time of first arrival is naturally the most variable, but is important, since it is subject to no possible error due to the closure of the season. The time required for 2 per cent of those tagged to arrive was selected from among the other series of data on account of the fact that it appeared to be the most stable. The curves shown on the graphs have been drawn in "by eye," as the character of the data did not seem to warrant more refined methods of curve fitting. The data on which these graphs are based are given in Table 39, which also shows the median time required for the journey from the various points of tagging to Bristol Bay and the rate of travel in miles per day.

Table 36. - Time to Bristol Bay from Unga Island

Number of days en route	Date and locality of tagging							
	June 2-5 Kelly Rock	June 7 Kelly Rock	June 23 Kelly Rock	June 26 Kelly Rock	June 27 Coal Harbor	June 27 Big Valley	July 4 Coal Harbor	July 6 Big Valley
1								
2								
3								
4					[1]1			
5								
6								
7								
8								2
9								
10							1	1
11						1		1
12				1				1
13								3
14							2	8
15			1			1		14
16				2		1	3	7
17			1	2	1	6	4	5
18	1		2	3	4	11	1	2
19		3	4	9		21	1	12
20		1	8	10	2	19	3	[2]2
21		3	7	7	1	7	2	
22	3	3	1	6		4		
23		3	1	2		2		
24			6	4		6		
25	1			2	2	1		
26			1	2	1			
27		1	1	3	1	2		
28		1	1	1	1	5		
29		3	1	2				
30								
31								
32			3					
33				[2]1				
34								
35								
36								
37								
38				CLOSED				
39								
40				SEASON				
41		1						
42								
43								
44								
45		1						
46								
47								
48		1						
49								
50								
51	1							

[1] Probably an error. Omitted in calculations

[2] Probably taken earlier but not reported until after the close of the season

Table 37. - Time to Bristol Bay from Morzhovoi Bay

Number of days en route	Date and locality of tagging							
	June 20 No. 8	June 30 No. 8	June 30 No. 5	July 8 No. 3	July 8 No. 5	July 13 No. 5	July 18 No. 5	July 20 No. 8
0				[1]1				
1								
2								
3								1
4			[2]1					
5								
6								
7				2				
8				1				
9								
10								
11				1				
12		1		3		1		
13				9	2			
14				7	3			[3]1
15	2	3	3	8	1			
16	2	13	5	2				
17	3	8	2	8				
18	6	4	2					
19	4	2						
20	4	1						
21		2	1					
22	4	3		[3]1				
23	2							
24	3		1					
25	3	3						
26	2			CLOSED				
27	4							
28	3				SEASON			
29								
30	2	[3]1						
31	1	[3]1						
32								
33	2							
34	1							
35	9							
36	1							

[1] Undoubtedly an error. Not considered in making calculations
[2] Probably an error. Not considered in making calculations
[3] Probably taken earlier but not reported until after the close of the season

Table 38. - Time to Bristol Bay from Ikatan Bay

Number of days en route	Date and locality of tagging					
	June 18 P.A.F.No.7	July 1 P.A.F.No.2	July 2 P.A.F.No.11	July 10 P.A.F.No.13	July 10 P.E.H.No.5	July 11 P.A.F.No.2
1						
2						
3						
4					1	1
5				1		
6					1	2
7					1	1
8					2	
9						
10					6	3
11				1	13	4
12			1	1	8	2
13				2	7	5
14	1	7	2	1	9	2
15		5			9	
16	2	3	1			
17		2				
18	1	9	2			
19	4	7				
20	1	2			[1]1	
21	5	4				
22		1				
23	1					
24	4					
25	2					
26	3					
27	2		CLOSED			
28	1					
29	1		SEASON			
30						
31						
32	1					
33						
34						
35	1					
36	1					
37						

[1] Probably taken earlier but not reported until after the close of the season

TABLE 39.—*Time, in days, required to travel to Bristol Bay from various tagging stations*

Locality and date	Elapsed time before—		Median time	Approximate rate of travel (miles per day)[1]	Locality and date	Elapsed time before—		Median time	Approximate rate of travel (miles per day)[1]
	First arrival	First 2 per cent arrived				First arrival	First 2 per cent arrived		
Unga Island:					Morzhovoi Bay—Contd.				
June 2 to 5	18	22	22.2	20.3	July 8 (trap No. 5)	13	14	13.8	25.4
June 7	19	23	22.7	19.8	July 13	12			
June 23	15	20	20.9	21.5	July 18				
June 26	12	19	20.6	21.8	July 20	4			
June 27 (C. H.)	17	18	20.2	22.3	Ikatan Bay:				
June 27 (B. V.)	11	18	19.6	23	June 18	14	24	23.6	14
July 4	10	14	17.1	26.3	July 1	14	16	17.8	18.5
July 6	8	14	15.4	29.2	July 2	12	18	15	22
Morzhovoi Bay:					July 10 (P. A. F. trap No. 13)	5	12	12.5	26.4
June 20	15	19	24.2	14.5	July 10 (P. E. H. trap No. 5)	4	10	12.1	27.2
June 30 (trap No. 8)	12	16	17	20.6	July 11	4	11	11.2	29.5
June 30 (trap No. 5)	15	17	16.3	22.9					
July 8 (trap No. 3)	7	13	14.2	24.6					

[1] Based on median time and considering the distance to Bristol Bay from Unga Island as 450 miles, from Morzhovoi Bay as 350 miles, and from Ikatan Bay as 330 miles.

NOTE.—When two experiments were started on the same date, the traps are indicated.

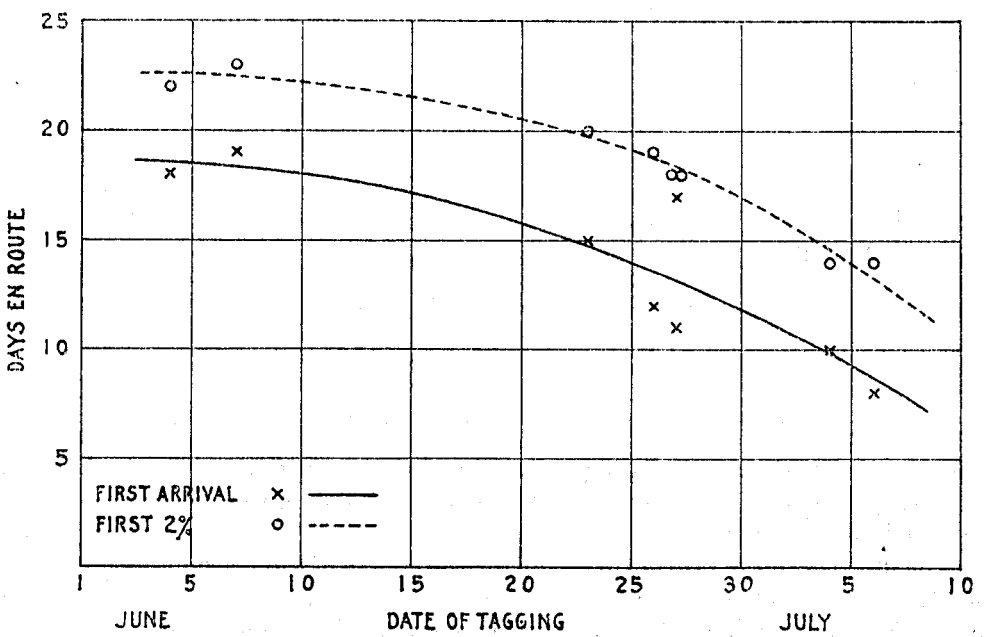

FIG. 10.—Showing time required for red salmon to travel from Unga Island to Bristol Bay

Having established the fact that the rate of travel increases markedly during the season, it remains to determine what the average rate of travel is at different times. The data given above in connection with the discussion of the comparative rate of travel does not, of course, give the average time required, since we have considered only a certain variable percentage of the total number retaken. In the case of at least the first few experiments it may be assumed that the returns from Bristol Bay were complete and were not affected by the closure of the season.

This is apparent from the distributions of the returns shown in Tables 36, 37, and 38. In most of the early distributions the frequencies gradually rise to a fairly well-defined maximum and then fall—a good indication that the distributions are approximately complete. If these distributions are then complete, we may fairly compare the median time required for the journey to Bristol Bay with the time required for 2 per cent of those tagged to reach Bristol Bay, and from this comparison can arrive at some conclusion as to the relative values of these two measures of the time required. From the data given in columns three and four of Table 39 it is very apparent that the values of these two measures are so nearly identical that for all practical purposes they may be so considered. The average difference of the times given in these two columns is exactly one day, the median time being the longer. It is furthermore apparent that even in the case of the later experi-

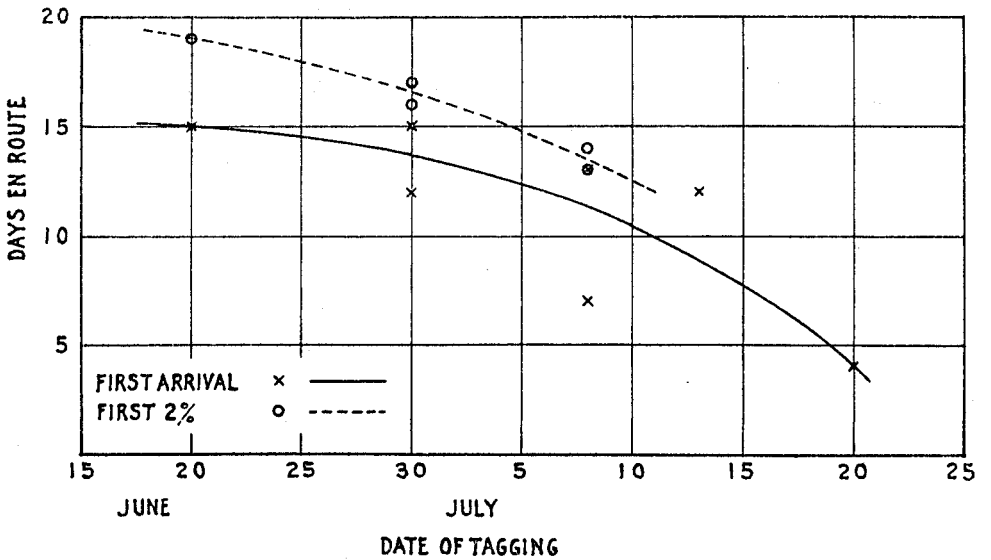

FIG. 11.—Showing time required for red salmon to travel from Morzhovoi Bay to Bristol Bay

ments the median is a satisfactory measure of the average time required to make the journey. The rates of travel shown in the last column of the table are therefore based on the median.

The increase in the rate of travel during the course of the season is very apparent from the figures given in the last column of Table 39. With but one exception the rate for each tagging is higher than for the preceding experiment. Early in the season the rate is approximately 20 miles per day, and toward the end of the season it rises to nearly 30 miles per day. Inspection of the table shows that for experiments begun on approximately the same dates the rate of travel is nearly the same in the case of Ikatan and Morzhovoi Bays, but that the rate is several miles a day faster in the case of the experiments begun in the region of Unga Island. This is, of course, in complete accord with the fact frequently noted before that the fish farthest from their spawning grounds travel at the fastest rates.

It has been of interest to compare the results obtained in these experiments with those of 1922. From the tables given in the report on the marking of 1922 by

the senior author we have determined the median time required for the journey to Bristol Bay from Ikatan and Unga Island. The data are as follows:

TABLE 40.—*Median time required for tagged fish to travel from Ikatan and Unga Island to Bristol Bay in 1922*

Locality and date of tagging	Median time to Bristol Bay	Number of tags returned
Ikatan:		
June 14	20	13
June 18	21	8
July 6	19	1
July 10	12	6
Unga Island:		
June 30	20	6
July 1	15	5

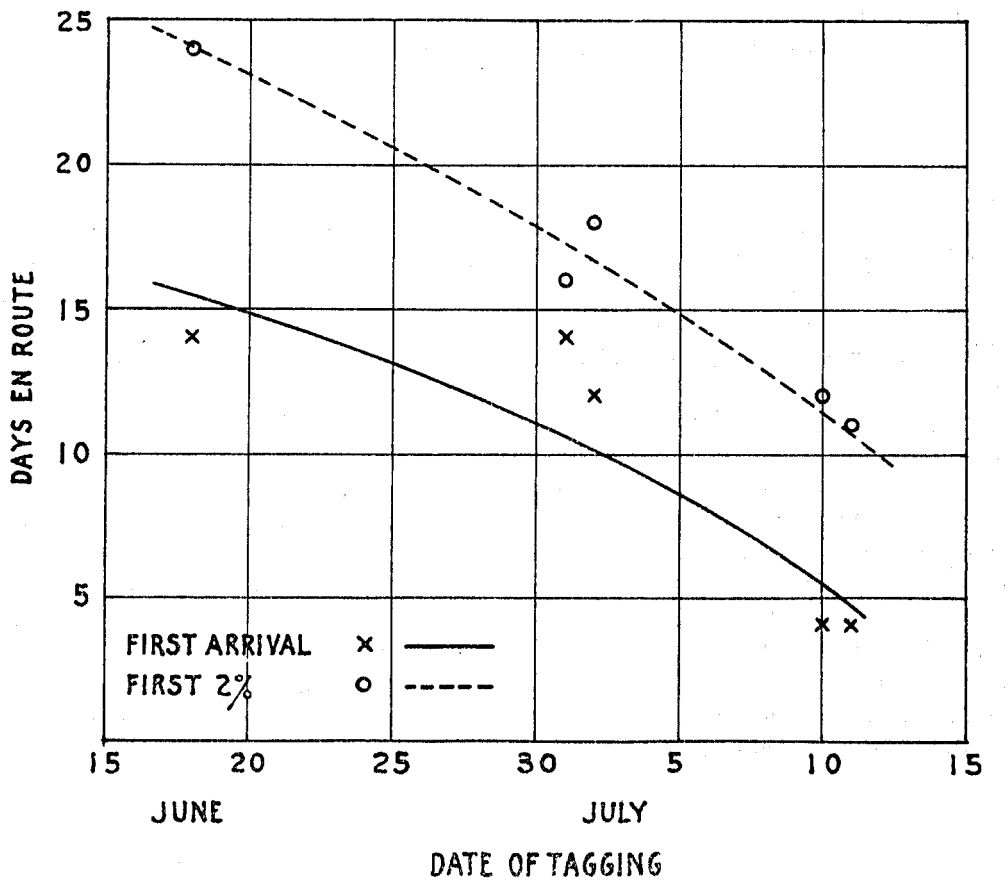

FIG. 12.—Showing time required for red salmon to travel from Ikatan Bay to Bristol Bay

The tagging of 1922 was on a much smaller scale than that of 1923, and as a consequence comparatively few returns were obtained from Bristol Bay. The total number was only 39, and the greatest number secured from the tagging of any one

day was 13. Under these circumstances it is to be expected that the variation in the median time required to make the trip would be much greater in 1922 than in 1923. In spite of this greater variability it is quite apparent that in general the results obtained in the two years are fairly similar. Experiments started on approximately the same dates in the two years gave results so similar as to leave no doubt that the conclusions drawn apply to the migration each year.

What determines the rate at which salmon travel in the ocean during their migration from the feeding grounds to the spawning grounds? It has been shown repeatedly that the rate of travel is distinctly more rapid in the case of those fish having a longer journey to make. The data on the migration to Bristol Bay has shown, further, that with the same distance to go the fish travel more rapidly with the approach of the spawning season. It seems possible to conclude, therefore, that the rate of travel is the resultant of two main forces—the relative maturity of the sex products and the distance from the spawning grounds. Other factors may possibly affect the rate of travel, but of these we know nothing at present, and it seems more than likely that the two mentioned are of primary importance.

PERCENTAGE OF RETURNS

The percentage of returns serves, although very imperfectly, as a measure of the intensity of fishing. If, out of 1,000 fish tagged and liberated in a given locality on a certain date, 500 are subsequently recaptured, it is fair to assume that approximately 50 per cent of the untagged fish found in that locality at that time were also taken. It must not be forgotten, however, that this is, at best, a minimum figure; that various factors are at work which keep the percentage of returns down and which, so far as we can see, will never raise it above the percentage captured of untagged fish with which they were associated at the time of liberation. These factors have been mentioned before and include the possible mortality of fish that have undergone the experience of being tagged, the retention of tags by fishermen and others as souvenirs, the loss of tags as a result of being detached between the time of tagging and recapture, and the failure on the part of the men engaged in handling the fish to notice the tags. In so far as our understanding of the intensity with which the important commercial runs of salmon are fished is concerned, these figures are also affected and reduced by the fact that some of the fish go to small streams in which no commercial fishery is maintained.

In spite of the fact that the figures can not be considered fully reliable as a measure of the intensity of fishing, certain very interesting facts are apparent from the data given in Table 41.

TABLE 41.—*Percentage of returns from each experiment, red salmon only*

Date and locality of tagging	Number tagged	Number returned from Bristol Bay	Number returned from other places	Total number returned	Percentage returned from Bristol Bay	Percentage returned from other places	Total percentage returned	Percentage of tagged salmon, not taken elsewhere, which were taken in Bristol Bay
Kelly Rock, June 2 to 5	120	6	7	13	5.0	5.8	10.8	5.3
Kelly Rock, June 7	575	22	83	105	3.8	14.5	18.3	4.5
Ikatan, June 18	799	33	184	217	4.1	23.1	27.2	5.4
Morzhovoi, June 20	800	59	128	187	7.4	16.0	23.4	8.8
Kelly Rock, June 23	499	43	170	213	8.6	34.0	42.6	13.1
Kelly Rock, June 26	499	59	51	110	11.8	10.2	22.0	13.2
Coal Harbor, June 27	137	14	39	53	10.2	28.5	38.7	14.3
Big Valley, June 27	859	91	186	277	10.6	21.6	32.2	13.3
Morzhovoi, June 30	592	47	203	250	7.9	34.3	42.2	12.1
Morzhovoi, trap No. 5, June 30	403	16	212	228	4.0	52.5	56.5	8.4
Ikatan, July 1	699	43	265	308	6.2	37.8	44.0	9.9
Ikatan, July 2	300	6	214	220	2.0	71.3	73.3	7.0
Coal Harbor, July 4	110	18	25	43	16.4	22.7	39.1	21.2
Big Valley, July 6	633	62	110	172	9.8	17.4	27.2	11.8
Morzhovoi Bay, July 8	436	45	65	110	10.3	14.9	25.2	12.1
Morzhovoi Bay, trap No. 5, July 8	110	6	46	52	5.4	41.9	47.3	9.4
Ikatan Bay, July 10	131	7	44	51	5.3	33.7	39.0	8.0
Ikatan Bay, P. E. Harris trap No. 5, July 10	326	58	52	110	17.8	15.9	33.7	21.1
Ikatan Bay, July 11	447	22	277	299	4.9	62.0	66.9	13.0
Morzhovoi, trap No. 5, July 13	279	2	133	135	0.7	47.7	48.4	1.4
Morzhovoi, trap No. 5, July 18	170	----------	80	80	----------	47.0	47.0	----------
Morzhovoi, July 20	198	2	61	63	1.0	30.8	31.8	1.5
Total	9,122	661	2,635	3,296	7.25	28.88	36.13	10.2

From the figures given in this table it is evident that the drain on the body of fish found during the fishing season in the region under discussion is so considerable that any further exploitation would be decidedly dangerous. Of the total number tagged 36.13 per cent were later recaptured and recorded. It has been mentioned above that this figure is a minimum; the actual drain on the salmon schools is therefore in excess of this figure. In other localities it has been found desirable to restrict the catch of fish to 50 per cent of the total run, and it is evident that the drain on the salmon resources of this region is so close to this figure that for practical purposes it may be considered equivalent. It is impossible to say whether these fish represent a unit of the Bristol Bay run, segregated more or less sharply from the remainder, or whether they represent merely a portion of an entirely mixed lot of fish that find their feeding grounds, in part at least, in the north Pacific Ocean. If they do represent a unit it is obvious that the fishery is being prosecuted with an intensity approximating that which obtains in the case of the fisheries at Karluk and Chignik, where a 50 per cent escapement is required.

Certain apparently significant differences appear in the percentages of returns obtained from the experiments started in the Shumagin Islands and in the region of Ikatan and Morzhovoi Bays. An especially good comparison can be made between the returns from 1,994 red salmon tagged at Unga Island June 23 to 27 and an exactly equal number tagged in Ikatan and Morzhovoi Bays June 30 to July 2. This tagging was all done during the height of the season, and there is no reason to think that the data obtained are not strictly comparable. It is very suggestive, therefore, that the experiments begun at Unga Island show a distinctly lower percentage of

recapture at other places than Bristol Bay and a distinctly higher percentage of returns from Bristol Bay even when, as shown in the last column of Table 41, the percentage is figured on the number remaining after the fish taken in other places than Bristol Bay are taken out. This was a necessary procedure since the returns from Bristol Bay are seriously affected by the capture of fish in other localities, especially close to the point where the tagging was done. Both of these facts point to the same conclusion, namely, that not all of the fish bound for Bristol Bay and found in the region of the Shumagin Islands during the height of the fishing season pass close to the shores in Ikatan and Morzhovoi Bays on their migration. There is plenty of reason to believe that a considerable proportion of the fish found south of the Alaska Peninsula do traverse these waters, but it seems probable, at least, that not all of them do so. It is possible that the fish enter Bering Sea through some one of the passages farther to the westward, or they may pass through the center of Ikatan Bay on their way to False Pass and thus avoid the traps. If some of the fish tagged in the Shumagin Islands went directly through Ikatan Bay and False Pass, or through some one of the western channels, it would account for the differences noted in the returns from these experiments and those begun in Ikatan and Morzhovoi Bays. No such migration through the western channels has ever been reported, however.

While it is felt that the figures given in Table 41 give a fairly acceptable minimum measure of the total intensity with which the schools of the Ikatan-Shumagin Island district are fished, and are, furthermore, sufficiently accurate for comparative purposes, it is not thought that the percentages taken in Bristol Bay give a reliable measure of the intensity of fishing at that point. All of the factors that tend to reduce the percentage of returns will continue to operate throughout the season, and will therefore be more effective in reducing the returns from Bristol Bay than from points nearer the place of tagging. The tagged fish actually reported from Bristol Bay form 7.25 per cent of the total number tagged. However, this figure is obviously affected by the fact that a large number of fish, undoubtedly bound for Bristol Bay, were taken in the Ikatan-Shumagin Island district, where they were tagged. If we take from the total number tagged those which were recaptured in other localities than Bristol Bay and calculate the percentage of the remainder which were taken in Bristol Bay, the result is very close to 10 per cent. It seems practically certain, however, that more than 10 per cent of the total run to Bristol Bay are taken by the fishery. The results are, of course, affected materially by the closing of the season in Bristol Bay on July 25, but it is not likely that this accounts in any great measure for the small number of returns. It is possible that this low percentage taken in Bristol Bay indicates that races bound for small local streams form a more important item in the Ikatan-Shumagin Island schools than is supposed.

The tagging experiments in 1922 and 1923 have agreed in demonstrating that the red-salmon colonies of the Chignik and Karluk Rivers, of Olga Bay, and Cook Inlet do not extend their range in any numbers as far to the westward as the Shumagin Islands and are therefore not at all involved in the fisheries of Morzhovoi and Ikatan Bays. No salmon tagged in either of these bays in 1922 or 1923 were captured even as far eastward as the Shumagin Islands. Only among those tagged

at Unga Island were eastern representatives found, and these in such limited numbers as possessed no practical significance. In 1923 there were tagged at Unga Island 3,432 red salmon. Only 20 of this number, as shown in Tables 30 and 31, were captured east of Unga, 11 being taken at Chignik, 1 at Karluk, 2 at Alitak, and 2 in Cook Inlet.

On the basis of the 1923 experiments, we are justified in repeating that no appreciable draft will be made on the salmon supply of the Chignik and Karluk Rivers and Cook Inlet by fisheries located in the Shumagin Islands and in Morzhovoi and Ikatan Bays. The red-salmon fisheries of these localities are recruited largely from the streams that enter Bristol Bay, and they should be subjected to whatever restrictions are elsewhere found necessary to protect the Bristol Bay runs.

OTHER SPECIES

Although attention was focused on a study of the migration of the red salmon, 624 dog and 199 humpback salmon were also tagged. A very few silver salmon were included, as well as two king salmon. Neither of the kings was reported and but four of the silvers. Two of these were tagged in Ikatan Bay on July 11 and were recovered in the same place on the 13th. Two were tagged in Morzhovoi Bay on July 18, one of which was recovered in Ikatan Bay on the 24th and the other at Chignik on August 15. Data on the number of silver salmon tagged will be found in the list given on page 33. Since only 22 individuals in all were tagged, it is obvious that no reliable conclusions can be drawn.

Humpback salmon.—On July 6 there were tagged 199 humpback salmon from the Big Valley trap on Unga Island. The results of this experiment are given in Table 18. None of these fish were taken elsewhere than in the traps near where they were released and in the local fisheries along the southern shore of the peninsula. Although the number tagged is small, it seems probable that the humpbacks are very largely, if not exclusively, of local origin. It is well known that many of the small streams of this region support large runs of humpbacks, so that these results are not at all surprising. The returns amount to 13 per cent of the number tagged, and of this 8.5 per cent were taken on Unga Island. It would not appear from this that the fishery for humpback salmon was particularly intensive during 1923, but the intensity of the fishing for this species varies greatly from year to year, depending to a considerable extent upon the success of the red-salmon fishery. It is not safe to conclude, therefore, that the humpback runs can withstand any great increase in the present intensity of fishing.

Dog salmon.—Six hundred and twenty-four dog salmon were tagged in five different experiments. The returns are tabulated in detail in Tables 15, 17, 24, 26, and 28, and the more essential data are collected in Table 42. In addition to those tabulated, two individuals were tagged in Morzhovoi Bay on July 20 and both were subsequently taken—one in Morzhovoi Bay on the 29th and the other in Ikatan Bay on the 24th.

TABLE 42.—*Returns from dog salmon. Percentage of total returns taken in each locality and median time en route, in days*

Locality of recapture	Coal Harbor trap, Unga Island, July 4—55 tagged, 19 returned		Big Valley trap, Unga Island, July 6—190 tagged, 45 returned		Pacific American Fisheries trap No. 2, Ikatan Bay, July 11—36 tagged, 18 returned		Pacific American Fisheries trap No. 5, Morzhovoi Bay, July 13—171 tagged, 62 returned		Pacific American Fisheries trap No. 5, Morzhovoi Bay, July 18—172 tagged, 63 returned		Total number returned
	Per cent	Time in days	Per cent	Time in days	Per cent	Time in days	Per cent	Time in days	Per cent	Time in days	
Unga Island	3.6	4	3.7	9							9
Pavlof Bay	12.7	14	14.2	12	5.5	10	8.8	12	6.4	9	62
Thin Point			1.6	26			1.2	12	2.9	14	10
Morzhovoi Bay	1.8	23	2.1	17	5.5	9	23.4	10	22.1	7	85
Ikatan	1.8	12	1.1	7	38.9	2	2.3	5	5.2	6	30
Naknek	1.8	17									1
Kvichak	1.8	16									1
Nushagak	7.3	17	.5	33							5
Togiak	1.8	47									1
Yukon			.5								1
Kamchatka	1.8	45									1
Belkofski Bay							.6	10			1
Total	34.6		23.7		50.0		36.2		36.6		207

In general, it is apparent that the dog salmon are distributed from the Ikatan-Shumagin Island district over much the same territory as are the red salmon. Tags were reported from various points along the southern shore of the peninsula, from Bristol Bay, and from rivers to the north of Bristol Bay. It is interesting to note that this wide distribution only obtains in the case of the fish tagged near Unga Island; those tagged in Ikatan and Morzhovoi Bays were only taken locally. It may be that this is the result of a segregation of races—that the dog salmon bound for more distant streams do not enter Ikatan and Morzhovoi Bays—or it may be due to the fact that the Unga Island experiments were begun somewhat earlier in the season. It has been shown in the case of the red salmon that a much larger percentage of the fish found in Ikatan and Morzhovoi Bays late in the season are bound for local streams than is true during the height of the season. On account of the comparatively small number of dog salmon tagged the data are not sufficient to warrant definite conclusions on this point. Although, in so far as the general distribution is concerned, the dog salmon found in this district go to many of the same streams to which the red salmon found with them go, the percentage going to the more distant streams is apparently much lower, a much higher percentage being taken in local fisheries along the southern shore of the peninsula Here again, however, the data are not sufficient to warrant final conclusions.

A unique and very interesting record is that of a fish tagged in the Coal Harbor trap on Unga Island and taken in the Pankara River, Kamchatka. The data were forwarded to the bureau by the director of the Far Eastern Fishery Board, Vladivostok. Regarding the recovery of this tag he states:

On August of this year, in the river Pankara in the district of Karagin, on the eastern shores of the peninsula of Kamchatka, a fish with the mark "U. S. B. F. No. 10358" was caught. The local residents did not pay any attention to this mark, and the fish was cleaned and salted, and in this form it was discovered by the agents of the Far Eastern Fishery Board at Vladivostok.

This fish, as far as we can judge in its salted state, was of the family *Oncorhynchus keta*, in all probability a male. The length of the fish is 59 centimeters, and it was in the spawning stage, as it was in "wedding dress" (changed color) and had grown teeth.

The record is important in that it indicates the possibility of a mingling, on the feeding grounds, of salmon from both the Asiatic and American shores of the north Pacific.

The data indicate that there are certain differences in the rate of travel of dog salmon when compared with red salmon. A comparison of the results of the experiment with dog salmon begun at Unga Island, July 6, with the results obtained with red salmon tagged the same day, shows that the two species required almost the same time to make the trip to Bristol Bay—about 16 days. In the case of the fish taken in local fishing areas along the southern shore of the peninsula, however, the dog salmon took a noticeably longer time, especially for the migration to Ikatan and Morzhovoi Bays. This may possibly be explained on the ground that most of the red salmon taken locally were actually bound for Bristol Bay and were therefore traveling more rapidly.

HOMING INSTINCT IN TAGGED RED SALMON

Sufficient evidence had been obtained previous to this tagging experiment to demonstrate the practical unanimity with which salmon return to their native stream at spawning time. The most direct evidence has been derived from numerous marking experiments performed on fingerling salmon before they had left fresh water. The recapture of these, when they have returned to spawn on reaching maturity, has been invariably in the stream in which the marking experiment was conducted. Such cases number many hundreds and comprise a body of evidence in itself conclusive.

A less direct but equally important line of evidence is found in the fact that the salmon of different streams often possess obvious distinguishing characteristics, which mark them off as distinct races. The individuals of one race may be much smaller than those of another even when they are of the same age, or they may be longer and more slender; one may be consistently darker in coloration even when in the ocean, or the flesh may be redder and have more oil. Such differences could have arisen only by virtue of such a high degree of isolation and continuous inbreeding as would permit and foster divergence.

Among the other differences which thus arise are distinctive growth habits, which may register themselves in the structure of the scales and can be recognized when these are subjected to miscroscopic examination. These growth habits include amount and rapidity of growth both in stream and sea, the length of residence in fresh water, the final age at maturity, and many others.

As our experiments have shown, red salmon that were schooling in the vicinity of the Shumagin Islands and in Morzhovoi and Ikatan Bays preparatory to their spawning migration found their way when tagged to a large number of different rivers, some of which were located along the southern shores of the Alaska Peninsula, others along its northern shores in Bering Sea. That the majority of them were bound for Bristol Bay was but a corollary from the fact that Bristol Bay produces by far the most extensive red-salmon runs of these northern waters.

Tagged salmon were captured with the spawning runs of the Ugashik, Egegik, Naknek, Kvichak, and Nushagak Rivers, comprising all the red-salmon streams of Bristol Bay, and they were taken in sufficient numbers to warrant an inquiry as to

their racial status. Samples of the scales of each salmon had been taken when the tag was attached. It remained to group these samples in accordance with the streams in which the salmon were captured and to compare the characteristics of the groups thus formed. In localities where few recaptures were reported, as in Cook Inlet, Karluk, Alitak, Chignik, and others, the material was not adequate for such a study; but in all the rivers of Bristol Bay and in certain red-salmon streams along the southern shores of the Peninsula, in its western portion, considerable numbers of tagged salmon were captured. In all these cases examination of the scales affords conclusive evidence that the fish were returning to the streams in which they were spawned, and that they manifested the characteristics of the colonies of their native streams.

It is not to be overlooked that the data afforded by our experiment were of necessity very incomplete for a determination of racial differences. Such differences include many characteristics—as average size, color, and richness of flesh—which were unavailable to us. The only data afforded by the scales were associated with methods of growth, ages at maturity, amount of growth, and length of sojourn in fresh water, and other minor characteristics of development which can record themselves on the growing scale.

The most tangible of these consist in the proportions in which different year classes occur in the runs. Two streams in close proximity at their mouths often differ widely in this respect. The Nushagak and the Kvichak colonies furnish a well-marked example. As we have learned from previous examination of these races, a considerable percentage of the Nushagak fingerlings always descend to the sea when but 1 year old, and they mature and return to spawn at the age of 4 or 5 years. On the other hand, the Kvichak fingerlings are practically all 2 or 3 years old when they enter salt water, and they mature mostly at the age of 6 or 7 years. If the tagged fish recovered in the Nushagak had failed to register such a difference in early growth and total age as compared with the tagged fish recovered in the near-by Kvichak, we should have grounds for doubting in their case the operation of the homing instinct; but an examination of Table 43 indicates clearly the existence of these differences.

TABLE 43.—*Percentages of the different year classes among tagged red salmon recaptured in different streams of the Alaska Peninsula and Bristol Bay*

Year classes	South side Alaska Peninsula				Bristol Bay				
	Pavlof and Volcano Bays	Cold Bay	Thin Point	Morzhovoi Lake	Ugashik	Egegik	Naknek	Kvichak	Nushagak
One year in lake:									
Four years old	9	25	7	66			1	2	4
Five years old	52	72	75	31	8	1	5	2	54
Six years old			4						
Two years in lake:									
Five years old	22		2	3	67	37	54	57	30
Six years old	17	3	11		17	46	35	27	12
Three years in lake:									
Six years old			1		8	8	3	12	
Seven years old						8	2		
Total	100	100	100	100	100	100	100	100	100

In the 71 Nushagak recaptures 58 per cent had, in their early history, left their native lake and descended to the sea when 1 year old and 42 per cent when 2 years old. Among the 228 Kvichak recaptures only 4 per cent belonged to the one-year-in-lake type, 84 per cent to the two-years-in-lake type, while 12 per cent had remained three years in the lake before migrating. The Nushagak is thus sharply distinguished from the Kvichak, and it is equally well marked off in the above respect from all the other streams in Bristol Bay. Examination of the table indicates that none of the other Bristol Bay streams showed any considerable number of tagged fish recaptured which belonged to the one-year-in-lake type. It is a growth habit for the young red salmon in all these other streams to remain at least two years in fresh water. The Ugashik recaptures contained only 8 per cent of the one-year-in-lake group, the Egegik 1 per cent, the Naknek 6 per cent, and the Kvichak 4 per cent. When it is considered that the fishes that were recaptured in these different streams had been tagged at the same places south of the Alaska Peninsula and on the same dates in a series throughout the fishing season, their final segregation to the different streams on any basis, such as their early history as fingerlings, can have but one significance. In certain of the streams this has been verified by a study of the fingerlings themselves on their way to sea. They agree with the scales of the adult fish that return to the same streams, and all lines of inquiry point to the same inevitable conclusion.

Three localities given in Table 43—Morzhovoi Lake, Thin Point, and Cold Bay—are located on the south side of the peninsula near its western extremity. The tagged sockeyes recaptured in these localities differed from all the Bristol Bay groups in the almost total absence of the two-years-in-lake type. Even the Nushagak, it will be recalled, had 42 per cent of this class; but Morzhovoi Lake, among 38 specimens, had but 1 per cent; Thin Point, with 130 specimens, had but 14 per cent; and Cold Bay, with 61 individuals, but 3 per cent. Yet Pavlof and Volcano Bays, also on the southern side of the peninsula a little farther to the east, had 39 per cent of the two-years-in-lake type.

On the basis of the limited evidence available to us, therefore, we are brought to the conclusion that red salmon captured in any trap in the Shumagin Islands, in Morzhovoi Bay, or in Ikatan Bay on any day during the fishing season contained an assemblage of individuals that had originated in diverse streams, some of which were far distant from the point of capture and others nearer at hand, and that when liberated these salmon proceeded each to the stream of its origin. The theory widely entertained by those engaged in the commercial fisheries—that the salmon constituting the runs to Bristol Bay form an undifferentiated lot and pass into one or the other stream in accordance with the direction of the wind or other external circumstance—is thus seen to be wholly without foundation. There is nothing difficult or abstruse in this problem. The facts speak for themselves to anyone who will take the trouble to examine the evidence. It can not be too soon realized by those interested in the continuance of our salmon industry that each stream is an independent unit, that its salmon runs are maintained if sufficient numbers are reserved for seed and are destroyed if this is not done. The Ugashik, the Egegik, the Nushagak, the Naknek and the Kvichak—each depends for its maintenance as an important salmon stream on the fish that are permitted to spawn within its own watershed.

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DISTINGUISHING CHARACTERS OF TWO SPECIES OF RED SNAPPERS OF THE ATLANTIC COAST OF NORTH AMERICA

By

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Some doubt exists as to the number of species of red snapper occurring in the tropical and subtropical waters of the Atlantic Ocean, and more than one species has been described. Some American authors, however, have claimed that only one species exists.

The first account of which cognizance is to be taken under the international rules of scientific nomenclature of what appears to be a red snapper was published by Bloch.[1] This description was based on that of Prince Marcgrave, whose fish was said to have been obtained in Brazil. This fish is reported to have been known at that time in Brazil under the common name of *Acara aya*, and Bloch gave it the scientific name *Bodianus aya*. Just what this *B. aya* is is difficult to determine from the description, which seems to be inaccurate in some important details. This may perhaps be determined by a study of the fish called *aya* in Brazil, if it is still known there under that name. Most American authors, however, have come to regard this fish as identical with the common red snapper of the West Indies. This assumption may be allowed to stand until the contrary is proved. The question, however, remains. Is there only one species of red snapper in the Caribbean Sea, and is the red snapper from the Caribbean identical with the common one from the Gulf of Mexico?

Poey[2] described a species of red snapper, giving it the scientific name *Mesoprion campechanus*. It is not stated in the description where the specimen on which it is based was obtained. Judging from the description, this species differs from the common red snapper of Pensacola in having a larger eye, finer scales, and 8 instead of 9 soft rays in the anal.

Cope[3] described a fish that may have been a red snapper, from the island of St. Kitts, under the name of *Lutjanus torridus*, but the description is not detailed enough to admit of ready identification, and until a careful comparative study of the type is made it is not possible to state which species this author had.

[1] Bloch, Marc Éliéser: Ichtyologie, ou Histoire Naturelle, générale et particulière, des Poissons. Part VII, p. 33, Pl. CCXXVII. 1797. A Berlin chez l'Auteur.

[2] Memorias sobre la historia natural de la isla de Cuba, Tome 2, 1856–1858 (1860), p. 149. Habana.

[3] Transactions, American Philosophical Society, new series, vol. 14, 1871, p. 468.

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Goode and Bean[4] described the common red snapper of the Gulf of Mexico, from the vicinity of Pensacola, under the name *L. blackfordii*. In the paper cited these authors make the following statement:

> The well-known red snapper of our southern coast has, strangely enough, never been scientifically described. This is due to an erroneous identification of this species with a common West Indian form (*Lutjanus aya*) from which it differs in several particulars, notably in the size of the eye and of the scales. * * *.
>
> This species is closely allied to the *L. torridus* of Cope, but differs in several particulars, notably (1) in the smaller eye, (2) the greater number of dorsal and anal rays, (3) the smaller and more numerous scales, (4) the less emargination of the tail, (5) the shorter ventral fin (according to figure of Cope), (6) the higher occipital crest, and (7) in coloration.

Goode,[5] in a catalogue of the fishes of Bermuda, calls the red snapper found in those waters *L. aya*. Although not directly stated by him, it seems that this author still regarded the Bermuda red snapper as distinct from the Pensacola red snapper, because in a list of species common to Bermuda and the West Indies, given on page 13 of the same paper, this red snapper is included, but it is not included in a similar list of species common to Bermuda and the coast of the United States which is also given in the same paper.

Jordan and Swain [6] described a red snapper under the name *Lutjanus vivanus* (Cuvier and Valenciennes). These authors evidently were of the opinion that there was only one species of red snapper, as they put the *Mesoprion campechanus* of Poey, the *L. torridus* of Cope, and the *L. blackfordii* of Goode and Bean in the synonymy of *L. vivanus*. They also placed the name *Bodianus aya* of Bloch in the synonymy of *L. vivanus*, prefacing it, however, with a query. The following quotations indicate the opinions of these authors regarding the identification of the red snapper.

> We place here with doubt the names *aya* and *ruber*, based on the *Acara aya* of Marcgrave. This is said to be a red *Lutjanus*, 3 feet in length, and with a red circle around its iris. It is therefore much more likely to have been this species than the *Lutjanus profundus*, with which it has been identified by Cuvier. It seems to us, however, that this identification is too uncertain to warrant the use of the name for either species.
>
> The name *vivanus* is based on two young specimens which Professor Jordan has examined and which he considers to belong to this species, although, as already stated, these specimens are for this species unusually slender.
>
> The type of *Mesoprion campechianus* is a stuffed skin of a young fish apparently belonging to this species. In this specimen the eye is larger than it should be in a red snapper of that size, it being, as Poey has correctly stated, 4 in head. This large size is, however, probably due to the shrinkage of the orbit in drying.
>
> Poey also counts "65 scales above the lateral line and 53 below," a larger number than others count in this species. This difference is doubtless dependent on the method of counting.
>
> *Lutjanus torridus*, loosely described and poorly figured by Cope, seems to be also the red snapper. We have examined Professor Cope's type of *L. torridus* in the Museum of the Academy of Philadelphia. It is 11 inches in length and in poor condition, but it apparently belongs to this species. * * *.

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[4] "Descriptions of two new species of fishes, *Lutjanus blackfordii* and *L. stearnsii*, from the coast of Florida." Proceedings, U. S. National Museum, Vol. I, 1878 (1879), p. 176. Washington.

[5] "Catalogue of the fishes of Bermuda." Bulletin, U. S. National Museum, No. 5, 1876, p. 55.

[6] "A review of the species of Lutjaninæ and Haplopagrinæ found in American waters." Proceedings, U. S. National Museum, Vol. VII, 1884 (1885), pp. 453–455.

The type of *L. blackfordii* is, of course, specifically identical with the specimens which form the basis of the above descriptions. The description published under this name by Goode and Bean is the first tolerable account of this most valuable food fish. We regret, therefore, our inability to retain the appropriate name which these authors have bestowed on the species.

Jordan and Fesler [7] were also of the opinion that there was only one species of red snapper to which they apply the name *Lutjanus aya*. The name *L. vivanus* is applied by these authors to the silk snapper, the *pargo de lo alto* of the Cubans, and *L. torridus* of Cope is placed in the synonymy of the last-mentioned species.

Jordan and Evermann [8] were also of the opinion that there is only one species of red snapper. In a footnote to their description of the red snapper they state:

The type of *Mesoprion campechanus* examined by us at Habana is a stuffed skin of a young fish, apparently belonging to this species. In this specimen the eye is larger than it should be in a red snapper of that size, it being, as Poey has correctly stated, 4 in head. This large size is, however, probably due to the shrinkage of the orbit in drying. Poey also counts "65 scales above the lateral line and 53 below," a larger number than others count in this species. This difference is doubtless dependent on the method of counting. The type of *Lutjanus blackfordi* is, of course, the present species, and the first good description of the species is that published by Goode and Bean under this name. We are forced, however, to adhere to our original view that the name *campechanus* certainly belongs to the same fish, and the still older name *aya* is as well authenticated as the names given by Bloch are likely to be. We can not, therefore, make use of the name *blackfordi* as the specific name of the red snapper.

By a direct comparison of specimens the present writers find that there are at least two species of red snapper. The characters of the larger eye and finer scales are real and serve well to separate a red snapper found in the Caribbean Sea (and probably in other West Indian waters) from the common red snapper of Pensacola. There are other important characters by which these two species differ, as will be shown presently. The name *Lutianus campechanus* is here applied to the Caribbean red snapper, as it seems to agree with the original description of that species in all important details, and it seems to be the same fish which Poey had when he described that species, while the Pensacola red snapper must stand as *L. blackfordii*. In view of our study, it seems best to hold the name *aya* in abeyance, insofar as our red snappers are concerned, until a direct comparison is made of the Brazilian fish of that name with the more northern red snappers.

The Bureau of Fisheries has recently received, through the courtesy of F. W. Wallace, editor of the Fishing Gazette, and J. F. Taylor, president of the Warren Fish Co., Pensacola, Fla., a fine specimen of red snapper caught in the Caribbean Sea off the coast of Honduras. The expedition on which this fish was caught was superintended by F. W. Wallace and was for the purpose of seeking new fishing banks. In a letter accompanying the specimen Mr. Taylor stated:

We are shipping to the Bureau of Fisheries a specimen of red snapper caught in the Caribbean Sea on a recent trip of our vessel, *A. F. Warren*. As the species seems quite different from the ordinary, we thought it might prove interesting to you on examination, and we would be pleased to have your views after making this examination. The flesh of the fish appears to be much firmer, the scales smaller, and its contour different from the fish caught on Campeche Banks and offshore here.

[7] "A review of the sparoid fishes of America and Europe." Report, U. S. Commissioner of Fish and Fisheries, 1889–1891 (1893), p. 447. Washington.

[8] "The fishes of North and Middle America." Part II. Bulletin, U. S. National Museum, No. 47, Part II, 1898, p. 1264.

In this letter Mr. Taylor points out the striking differentiating characters which may be noted by a surface examination of the two species.

For the purpose of making a direct comparison of specimens the bureau has received, through the courtesy of the Warren Fish Co., a specimen of the common Pensacola red snapper of about the same size. We also had for study a specimen of red snapper caught at Rebecca Shoals, near Key West. The following descriptions and comparisons are based on these specimens.

Lutianus blackfordii Goode and Bean

PENSACOLA RED SNAPPER

Lutjanus blackfordii Goode and Bean, Proc., U. S. National Museum, I, 1879, p. 176. Pensacola, Fla.

Formulæ: D. X, 14. A. III, 9. Scales 58–63$\frac{7}{14}$. Gill rakers 9.

Upper profile rounded, somewhat gibbous, turning gradually downward at about origin of dorsal and making a broad, somewhat convex curve to the caudal peduncle; lower profile a nearly straight oblique line to the ventrals and in a nearly horizontal line from there to the anus.

Body comparatively deep, the depth (measured at origin of ventral fins) 2.57 to 2.61 in length; least height of caudal peduncle 3.03 to 3.32 in the head; head 2.77 to 2.80 in length (measured to end of bony part of opercle); margin of preopercle finely but distinctly denticulate, the denticles at angle coarser; upper limb with a broad emargination, into which fits the feebly developed knob of the interopercle; snout medium (measured to the free margin of the eye), 2.34 to 2.40 in head and 2.85 to 2.86 as long as the eye, very slightly longer than maxillary (the snout, when measured from edge of orbit, about 2.48 to 2.54 in head); mouth medium, the maxillary 2.40 to 2.43 in head, reaching almost but not quite to vertical through anterior margin of eye; articulation of mandible on vertical through about the middle of eye; eye (measured between the free margins of the skin) 6.71 to 6.85 in head (the orbit about 5.20 to 5.25 in head).

Upper jaw with a row of small canines in front, larger anteriorly, and gradually growing smaller posteriorly; a narrow band of smaller teeth behind the canines, extending to the angle of mouth and interrupted in middle; lower jaw with a row of small, subequal canines in front and with a narrow band of smaller teeth behind, interrupted at the symphysis and extending only a short distance at the sides; teeth on the vomer comparatively strong, in a somewhat anchor-shaped patch, rounded in front, tapering to a point behind, and with a pointed projection on either side, a little back of the anterior edge; teeth on tongue comparatively well developed, divided by a straight, narrow, transverse, bare streak into two parts; the anterior part of the Key West specimen consisting of a broad patch, nearly as broad as long, rounded in front, square behind, and with nearly straight sides; the Pensacola specimen differing in having an indentation on each side of the broad patch and with smaller patches of teeth projecting into the indentations, the posterior patch only a little longer than the anterior one, tapering behind nearly to a point.

Gill rakers on lower limb of anterior arch well developed, gradually growing smaller anteriorly, 9 in number and 3 tubercles in front; upper limb with two rather long gill rakers at the angle and with five short stumpy ones above these.

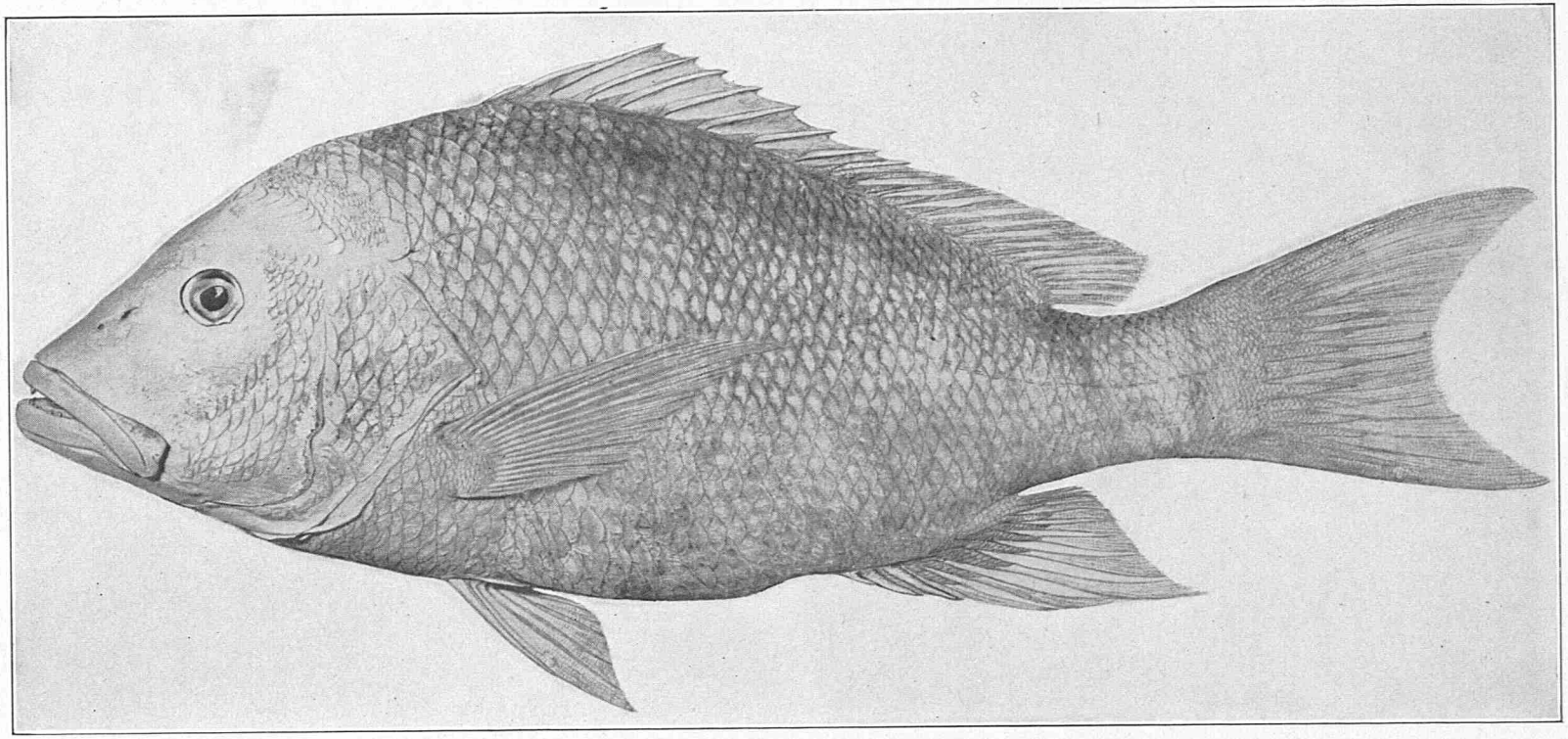

FIG. 1.—*Lutianus blackfordii*. Red snapper Photograph from a specimen 775 millimeters

The exposed portions of the scales on middle of side on anterior part of body about 1⅔ times as high as the exposed parts of the scales situated on middle of sides and over the anal fin; the number of oblique rows of scales above the lateral line, counting those running upward and backward, 58 to 63, those running downward and backward, 47 to 48; below the lateral line the rows running downward and forward number 47 to 48 and those running downward and backward number 43 to 44; scales in lateral line, 47 to 48 (all scale counts were made from the enlarged scale at the upper angle of the opercular opening to the base of the caudal); 7 scales between origin of dorsal and lateral line, counting downward and forward; 14 between origin of anal and lateral line, counting upward and backward, and oblique band of smaller scales in region of nape, running upward and forward from upper angle of gill opening to upper profile; scales of this band larger anteriorly, very small posteriorly, and followed abruptly by the ordinary large scales; opercle, subopercle, and interopercle scaly; a patch of scales directly behind the eye and a horizontal row of 4 to 6 more or less embedded, rather strongly ctenoid scales above this patch; 6 rows of scales on cheeks; snout, preorbital, and upper and lower sides of head naked; spinous dorsal bare; base of soft dorsal in a well-developed scaly sheath, rows of small scales extending for some distance on soft rays; base of anal in a scaly sheath, rows of small scales extending on soft rays; similar rows of scales on caudal rays extend to a short distance from their ends; a small patch of scales at base of pectoral fin, the rest of the fin being naked; scales on chest extending in midline a little beyond base of the ventrals; no scales on ventral fins.

The dorsal fin consisting of 10 spines and 14 soft rays, the fourth spine longest, 2.63 to 2.66 in head; the soft part somewhat angulated, the angle very little produced; distance of origin of dorsal from tip of snout 2.29 to 2.31 in length (1.21 as long as the head); origin of dorsal about an eye's diameter behind base of upper ray of pectoral; base of spinous part 1.17 to 1.18 in head; base of soft part 1.88 in head; anal fin angulated, the angle produced, longest soft ray about 1.82 in head; the first spine about one-half as long as the second, the latter 5.02 to 5.07 in head; the third spine 4.12 to 4.18 in head; origin of anal fin vertically under the base of first and second soft dorsal rays, its base 2.40 to 2.51 in head; pectorals, I, 16, falcate, rather long, 1.16 to 1.22 in head, reaching slightly past a vertical through the anal opening; distance of base of upper ray from tip of snout, 1.01 to 1.05 in head; ventrals 1.72 in head, their origin directly under that of dorsal, their tips at a distance from the vent equal to the distance of the latter from the anal fin.

Color in fresh condition (iced specimen).—Body, head, and fins scarlet red, the red color gradually becoming paler below; iris scarlet-red, with a short longitudinally elongate black spot near upper margin of eye; above the lateral line the red color of the body is suffused with a bluish green tinge; dorsal and caudal edged with a fine black streak; base of pectorals with a black, rather diffuse blotch. No distinct black lateral spot. In alcohol the red color, including that of the eyes, fades, but the short black band on the eye and the spot at the inner angle of the pectorals persist.

Localities.—Gulf of Mexico (Pensacola), specimen 775 millimeters long; Key West (Rebecca Shoals), specimen 790 millimeters long.

(Mr. Wallace states that this species was not taken in the Caribbean Sea on the expedition which he commanded.)

Lutianus campechanus (Poey)

CARIBBEAN RED SNAPPER

Mesoprion campechanus Poey, Memorias, II, 1860, p. 149. Locality not given.

Formulæ: D. X, 14. A. III, 8. Scales $70\frac{8}{5}$. Gill rakers 11.

Upper profile rounded, very slightly gibbous, line of profile turning gradually downward at about origin of dorsal and making a broad, rather convex curve to caudal peduncle; lower profile a nearly straight oblique line to about posterior edge of preopercle and a nearly horizontal line from there to origin of anal.

Body rather slender, depth (measured at origin of ventral fins) 2.82 in length; least height of caudal peduncle 2.9 in head; head rather short, 3.11 in length (measured to end of bony part of opercle); margin of preopercle finely but distinctly denticulate, the denticles at angle coarser, upper limb with a rather shallow emargination, interopercular knob obsolete; snout rather short, 2.64 in head (measured to free margin of eye), 2.03 as long as eye, shorter than maxillary (the snout when measured from edge of orbit about 2.81 in head); maxillary 2.39 in head, reaching a vertical through anterior margin of eye, articulation of mandible on a vertical through about middle of eye; eye rather large (measured between the free margins of the skin), 5.36 in head, and about as long as one-half the snout; (orbit about 4.78 in head).

Upper jaw with a row of small canines in front, larger anteriorly and gradually growing smaller posteriorly; a narrow band of smaller teeth behind the canines, interrupted in the middle and extending to angle of mouth; lower jaw with an outer row of small subequal canines, the smaller teeth behind the canines reduced to a short, elongate patch on either side of the symphysis; teeth on vomer comparatively strong, in a somewhat anchor-shaped patch, rounded in front, tapering to a point behind, and with a short, pointed projection on either side, a little back of the anterior edge, the part of the patch behind the pointed projections not much longer than the part anterior to the same; teeth on tongue comparatively well developed, divided by a straight, narrow, transverse, bare streak into two patches, the anterior patch broader than long, the posterior patch much longer than the anterior, the sides in front nearly parallel for their greater distance, abruptly turned behind and meeting in the center in gable-like manner. Gill rakers on lower limb of anterior arch well developed, gradually growing smaller anteriorly, 11 in number, and 3 tubercles in front, upper limb with 2 rather long gill rakers at the angle and 5 short, stumpy ones above.

The exposed portions of the scales on middle of sides on anterior part of body not much higher than the exposed portions of the scales situated on the middle of the sides over the anal fin; 69 oblique rows of scales above the lateral line counting those running upward and backward, 52 rows counting those running downward and backward; below the lateral line the rows running downward and forward number 53 and those running downward and backward number 48; 50 scales in lateral line; 8 scales between origin of dorsal and lateral line, counting downward and forward; 15 between origin of anal and lateral line, counting upward and backward; an oblique band of smaller scales in region of nape, running upward and forward from upper angle of gill opening to upper profile; scales of this band larger

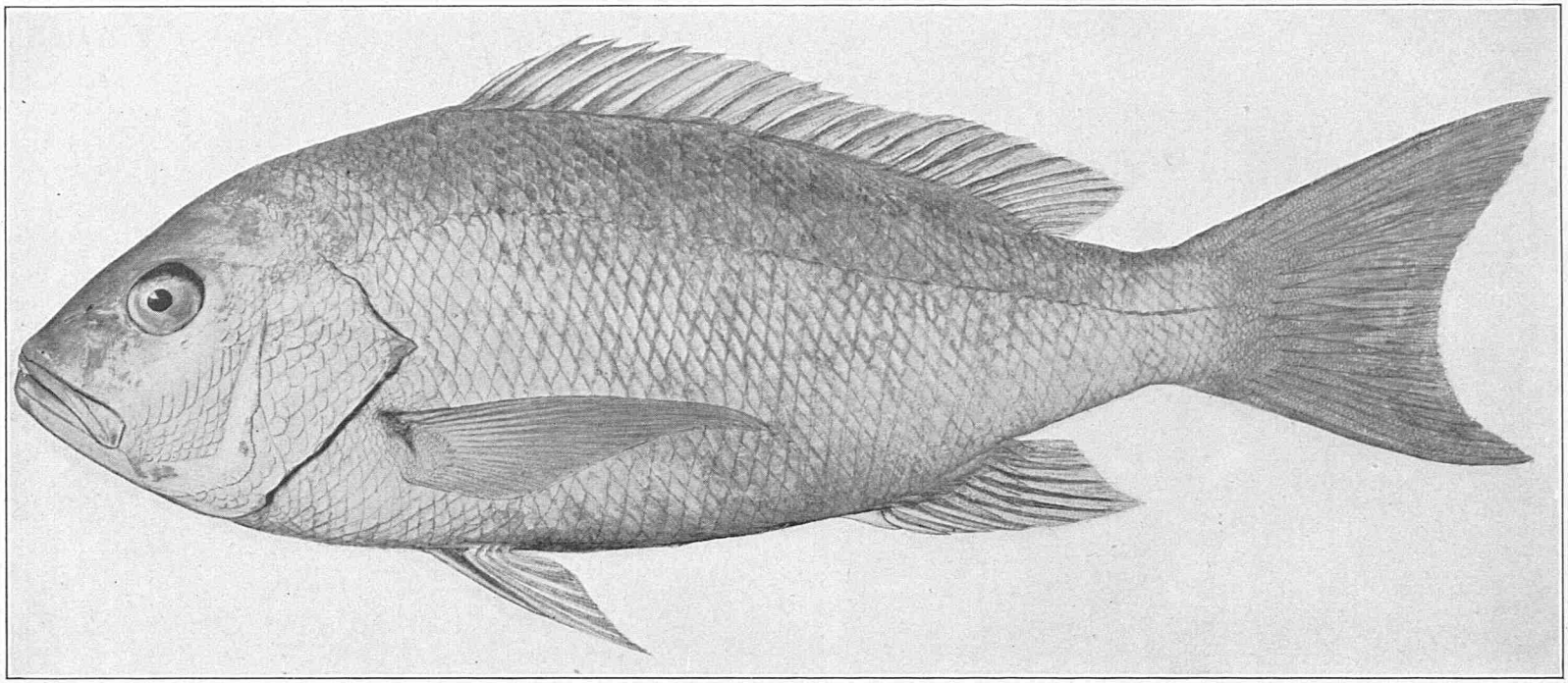

FIG. 2.—*Lutianus campechanus* Photograph from a specimen 725 millimeters

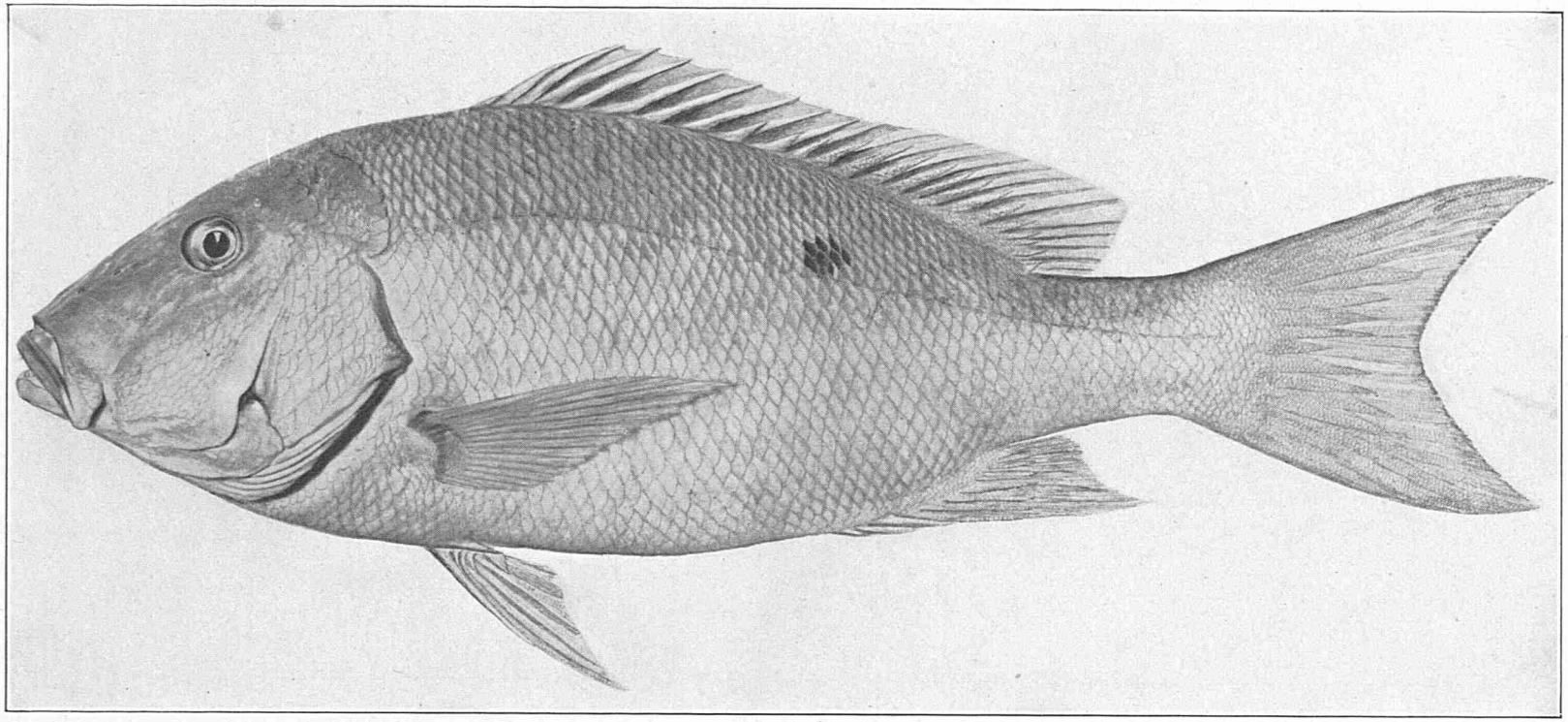

FIG. 3.—*Lutianus analis* Photograph from a specimen 650 millimeters

anteriorly, very small posteriorly, and followed abruptly by the ordinary larger scales; opercle, subopercle, and interopercle scaly, a patch of scales directly behind eye and a horizontal row of 6 more or less embedded, rather strongly ctenoid scales above this patch; 6 rows of scales on cheeks; snout, preorbital, and upper and lower sides of head naked; spinous dorsal bare, base of soft dorsal in a well-developed scaly sheath, rows of small scales extending for some distance on soft rays; base of anal in a scaly sheath, rows of small scales extending on soft rays; similar rows of scales on caudal rays nearly covering caudal fin and extending to a short distance from tips of rays; a small patch of scales at base of pectoral fin, rest of the fin naked; scales on chest extending in midline to a little beyond base of ventrals; no scales on ventral fins.

Dorsal fin consisting of 10 spines and 14 soft rays, the fourth spine longest, 2.24 in head; distance of origin of dorsal from tip of snout 2.59 in length (1.2 as long as head); base of spinous dorsal 1.07 in head, base of soft part 1.54 in head; anal fin angulated, the angle produced, longest soft rays about 1.8 in head, first spine one-half as long as second, the latter 4.43 in head, third spine 3.61 in head; origin of anal vertically under base of third soft dorsal ray, its base 2.36 in head; pectorals I, 16, falcate, 1.04 in head, reaching a vertical through anus, distance of base of upper ray from tip of snout 1.01 in head; ventrals 1.58 in head, their origin directly under that of dorsal, distance of their tips from vent a little greater than distance of latter from origin of anal.

Color in fresh condition (iced specimen).—Body, head, and fins deep red, the red color becoming fainter on lower parts; iris deep red with a longitudinally elongate black spot near upper margin of eye;[9] base of pectorals with a black blotch on inner and outer surfaces; dorsal and caudal with faint indications of a fine blackish edge; scales on upper part of body with greenish centers, giving somewhat the appearance of faint oblique streaks; no distinct black lateral spot. In alcohol the red color, including that of the eye, fades, but the short black band at the upper part of the eye and the black color at the base of the pectorals on both sides persist. After fading the body also shows a few short, faint, metallic blue crossbars.

Locality.—Caribbean Sea, off the coast of Honduras; specimen 725 millimeters long.

When two specimens, one of each species, of about the same size are placed side by side the most striking characters of the Caribbean red snapper are (1) the shorter, more compact head, (2) the shorter, blunter snout, (3) the somewhat larger eye, (4) the more slender body, and (5) the smaller scales. The difference in the size of the scales appears more striking than the actual count would indicate. This is because in the red snapper from Pensacola the scales on the anterior part of the body, especially those below the lateral line, are considerably deeper than the scales on the posterior part of the body, and this, together with their greater breadth, makes the difference in appearance quite striking. The number of rows of scales would seem to be a valuable differentiating character, and it is important to state just how the scales were counted, since the number of rows, as is shown in the foregoing descriptions, depends on the method of counting.

[9] Mr. Wallace states in his field notes that snappers taken off the coast of Honduras had a yellow ring around the eye. Such a ring was not noticed when the specimen here described was received.

In addition to the characters already mentioned, other important specific differences are set forth in the following comparative table in parallel columns. Because *Lutjanus campechanus* has nearly the same counts of scales and also fin rays as *L. analis*, the common muttonfish, and the two species are apt to be confused by a careless observer, the distinguishing characters of the last-mentioned species are included in the table. For this purpose we had a specimen 650 millimeters long, obtained in the Key West fish market. Another species which is closely related is the silk snapper, commonly called "*pago de lo alto*" in Cuba. When fresh, this last species apparently may readily be distinguished by the bright yellow color of the eye. In a comparative study of this kind it would have been advantageous, in order to understand the relationship, to have included this species. Unfortunately, however, no specimens are available for comparison.

L. BLACKFORDII	L. CAMPECHANUS	L. ANALIS
Head rather large, 2.77 to 2.80 in length.	Head rather small, 3.11 in length.	Head medium, 2.94 in length.
Snout medium, 2.34 to 2.40 in head, subequal to maxillary.	Snout short and blunt, 2.64 in the short head, 0.91 as long as maxillary.	Snout long, 1.97 in head, 1.34 as long as maxillary.
Mouth rather large.	Mouth rather large.	Mouth small.
Maxillary 2.40 to 2.43 in head, extending to a vertical slightly in front of eye.	Maxillary 2.39 in head, extending to a vertical through anterior margin of eye.	Maxillary short, 2.64 in head, extending to a vertical nearly an eye's diameter in front of anterior margin of eye.
Eye rather small, 6.71 to 6.85 in head, 2.85 to 2.86 in snout.	Eye rather large, 5.36 in head, 2.03 in snout.	Eye small, 7.0 in head, 3.56 in snout.
Interopercular knob feebly developed.	Interopercular knob obsolete.	Interopercular knob rather well developed.
Body rather deep, depth 2.57 to 2.61 in length.	Body more slender, depth 2.82 in length.	Body rather slender, depth 2.78 in length.
Teeth on vomer strong, in a comparatively large, somewhat anchor-shaped patch.	Teeth on vomer strong, in a comparatively large, somewhat anchor-shaped patch.	Teeth on vomer weaker, in a narrow, somewhat rounded band in front.
9 developed gill rakers on lower limb of anterior arch; 2 long ones on upper limb at angle.	11 developed gill rakers on lower limb of anterior arch; 2 long ones on upper limb at angle.	8 developed gill rakers on lower limb of anterior arch; only 1 long one on upper limb at angle.
Exposed portions of scales on middle of sides, in front, about 1⅔ as high as exposed parts of scales situated on middle of sides and over the anal fin.	Exposed portions of scales on middle of sides, in front, not much greater in height than exposed parts of scales situated on middle of sides and over the anal fin.	Exposed portions of scales on middle of sides, in front, not much greater in height than exposed parts of scales situated on middle of sides and over the anal fin.
58 to 63 oblique rows of scales above the 1. l. (counting the rows running upward and backward).	69 oblique rows of scales above the 1. l.	68 oblique rows of scales above the 1. l.
7 scales between origin of dorsal and 1. l., counting downward and forward.	8 scales between origin of dorsal and 1. l.	8 scales between origin of dorsal and 1. l.
14 scales between origin of anal and 1. l., counting upward and backward.	15 scales between origin of anal and 1. l.	15 scales between origin of anal and 1. l.

6 rows of scales on cheeks.	6 rows of scales on cheeks.	8 rows of scales on cheeks.
9 soft anal rays.	8 soft anal rays.	8 soft anal rays.
Anal spines comparatively long, second 5.02 to 5.07 and third 4.12 to 4.18 in head.	Anal spines comparatively long, second 4.43 and third 3.61 in head.	Anal spines rather short, second 6.44 and third 4.54 in head.
Black lateral spot disappearing in large individuals.	Black lateral spot disappearing in large specimens.	Black lateral spot persistent in large specimens, distinct.

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CRAYFISHES OF THE GENUS CAMBARUS IN NEBRASKA AND EASTERN COLORADO

By EARL THERON ENGLE

Department of Anatomy, Stanford University

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INTRODUCTION

The morphology of the crayfish has been studied in most elementary courses of zoology since the inception of the type method of study with Huxley's Anatomy of Invertebrated Animals in 1877. Previous to this (in 1878) Huxley had published a comprehensive treatise on the classification and distribution of the crayfish. Field observations in the United States began as early as 1852, when Girard investigated the habits of certain species and did some preliminary work on the geographical distribution of the family Astacidæ. This type of field observation was soon replaced by the taxonomic work of many writers, which resulted in the monographs of Hagen (1870) and Faxon (1885a) and in the numerous State surveys, of which the earliest were those of Forbes (1876) for Illinois, Bundy (1877) for Wisconsin, Herrick (1882) for Minnesota, and Hay (1896) for Indiana. With the exception of the crayfish surveys for Missouri (Steele, 1902) and Kansas (Faxon, 1885b; Harris, 1900), no work has been done up to this time within the States of the Missouri River drainage system.

In addition to the numerous studies on the taxonomy and geographical distribution of crayfishes, much work has been done in physiological experimentation with these animals. Powers (1914), Bell (1906 and 1906a), and others have used various species of crayfishes in experimental work, and others will doubtless use them for ecological investigation. They are very hardy and more easily kept in the labora-

tory than are many fishes, and they are easily obtainable in any locality. The present account gathers the literature relating to the species of crayfishes of these States, and gives a certain amount of information based on the author's studies in the field.

METHODS

The field work in this investigation extended from March 15 to October 30, 1922, and from April 15 to October 6, 1923. During that time several areas of relatively easy accessibility were studied intensively, while only a few hours or a day were devoted to others. It is felt, however, that the records furnish an accurate account of the distribution and habits of the genus Cambarus in Nebraska and eastern Colorado.

Occasionally collections were made with a net in open ponds and creeks, though, except in the evenings, this method gave only immature specimens. The most fruitful though often laborious and certainly not æsthetic method is to dig into a burrow that gives evidence of habitation, with the hands or with the aid of a small trowel, and capture the animals. Although this method is slow and difficult it yields a specimen in almost every instance, and permits a study of the nature of the soil in which the burrow is located and of the type of burrow made by each species. In addition to this, it permits the collector to work throughout the day, as the crayfishes are always to be found in their burrows save in the early morning and in the evening, when they are in the water feeding. In the case of the creek and river species (as *Cambarus propinquus*) a minnow trap was used successfully.

ACKNOWLEDGMENTS

An investigation of the crayfishes of Nebraska was first begun at the suggestion of Dr. Robert H. Wolcott, chairman of the department of zoology of the University of Nebraska, and was later extended to the crayfishes of Colorado through the encouragement of Dr. Francis Ramaley, head of the department of biology of the University of Colorado. To both of these gentlemen I am greatly indebted for their helpful suggestions and for laboratory facilities. I desire also to thank Dr. T. D. A. Cockerell, of the University of Colorado, for the loan of literature, which was not otherwise available; Dr. A. W. Meyer, of Stanford University, for reading the manuscript and for suggestions; Dr. E. B. Powers, now head of the department of zoology of the University of Tennessee, for assistance in collecting and for the loan of literature; and Gayle Pickwell, of the department of zoology of Northwestern University, for assistance in collecting.

DESCRIPTION OF SPECIES, WITH KEY TO SUBGENERA AND SPECIES

The first record of a crayfish from Nebraska is by Faxon (1885a)—"one species, *C. virilis*, from Omaha." Faxon (1898) also reports *C. virilis* and *C. immunis* as being in the collections of Seth E. Meek in the United States National Museum, bearing the locality label of "Blue River, Crete County, Nebr.," and a specimen of *C. immunis* from South Bend, Case County, Nebr.

Girard (1854) reported a new species, collected at Fort Pierre, which is in the present State of South Dakota and which he named *Cambarus nebrascensis*. Faxon regards this species as the western form of *C. diogenes*.

The previous records of the Colorado species are no more abundant. In the collections of Seth E. Meek, mentioned by Faxon (1885a and 1898), is a specimen of *C. diogenes* bearing the label "Clear Lake, Colorado." This is probably Clear Lake in Lake County, west of Denver, as the other locality by that name is in San Juan County in the more arid Southwest.

Harris (1903) reports a specimen of *C. diogenes* from the St. Vrain River near Boulder, Colo. Ortmann (1906) says "Prof. T. D. A. Cockerell has sent me for examination a young male, collected October 7, 1905, in a small stream near Boulder." This specimen was also *C. diogenes*. During 1912 and 1913 Dr. Max M. Ellis made collections at Boulder and in other parts of Colorado while working on the "Fishes of Colorado," but he did not publish his records. These records were placed at my disposal by Dr. Francis Ramaley.

While the previous records give but one species for Colorado and two valid species for Nebraska, the present investigation has given eight species for the two States, two of these being found only in Nebraska, two only in Colorado, and four being common to both States.

According to Ortmann (1906, p. 407), the genus Cambarus is divided into four subgenera. Three of these are represented in Colorado and two in Nebraska.

In the following key and description of species the male of Form I is used; that is, the condition of the adult male before the autumn molt has taken place.

KEY TO THE SPECIES

a. First pair of abdominal appendages of male short, truncate at tip, outer part ending in one to three horny teeth, inner part terminated by acute spine. Hooks present on third periopod of male..... Subgenus Cambarus (sens. strict.) Ortmann.
Represented by one species. Outer half of first pleopod of male with two terminal teeth, both alike; shoulder on anterior margin of pleopod. Rostrum without marginal teeth..... *C. (Cambarus) simulans* Faxon.

aa. First pair of abdominal appendages of male generally slender, each division of the appendage bearing a more or less elongate spine..... Subgenus Faxonius Ortmann.

b. Rostrum with median keel.

c. First abdominal appendages of male reaching to third periopod; rostral keel often indistinct..... *C. (Faxonius) propinquus* Girard.

cc. First abdominal appendages of male reaching to the first periopod. Rostrum with distinct keel; margins of rostrum subparallel..... *C. (Faxonius) neglectus* Faxon.

bb. Rostrum without median keel and without spines. Carapace with lateral spines.

d. First abdominal appendage of male long and deeply bifid, reaching to base of chela; branches slender, the outer branch long, inner branch with spoon-shaped tip..... *C. (Faxonius) virilis* Hagen.

dd. First abdominal appendage short, with sharply recurving tips. Inner face of immovable finger of chela thickly covered with hair. Tufts of hair on second periopod..... *C. (Faxonius) immunis* Hagen.

bbb. Rostrum without median keel but with marginal spines. Chela and first abdominal appendage of male as in C. immunis..... *C. (Faxonius) immunis spinirostris* Faxon.

aaa. First abdominal appendage of male short and thick, inner and outer parts each terminating in only one short and thick, strongly recurved spine, which is set at right angles to long axis of appendage..... Subgenus (Bartonius) Ortmann.

e. Inner finger of chela without excision at base; outer finger not bearded. Areola obliterated in middle..... *C. (Bartonius) diogenes* Girard.

ee. Inner finger of chela with deep excision at base; outer finger bearded. Extremity of inner tooth of first abdominal appendage of male long and slender. Areola obliterated in middle..... *C. (Bartonius) argillicola* Faxon.

CAMBARUS (CAMBARUS) SIMULANS FAXON

Cambarus simulans, Faxon, 1885, p. 112; Faxon, 1885a, p. 48.
Cambarus (*Cambarus*) *simulans*, Ortmann, 1905a, p. 105.

Male, Form I.

"Rostrum broad, deeply excavated; margins raised into sharp crests which overhang the base of the sides of the rostrum, converging, sinuated before the tip to form the short acumen; no lateral spines; the acumen is barely margined. Post-orbital ridges subacute in front, divergent and ending in slight callosities behind. Carapace ovate, narrowing in front, gastric area smooth, cardiac area lightly punctate, sides granulate; anterior border notched behind the antennæ; cervical groove sinuate, split on the sides, with a minute terminal branchiostegian spine; no lateral spine; areola more than one-half as long as the distance from the point of the rostrum to cervical groove, narrow, carinate, expanding into an anterior and a posterior triangular field; * * *. Chela long, slender, squamoso-tuberculate, internal margin long, straight, strongly dentate; fingers long, punctate, external border of movable finger tuberculate, inner border of both fingers toothed, a prominent tubercle near the base of external finger opposite a more or less clearly marked incision in the base of the thumb. * * *. Third pair of legs hooked. First pair of abdominal appendages strong, straight; internal part with a very small, straight apical spine, which does not reach the end of the external part; external part with two horny terminal teeth, one of which is flat and disk-shaped, the other slender and somewhat curved." (Faxon, 1885, p. 112.)

Colorado locality.—One collection from the north fork of the Smoky Hill River, near Oriska, Kit Carson County. I have been unable to obtain this specimen. Place records are from the records of the Museum of the University of Colorado, noting a single collection of *C. simulans*, determined by Faxon, but the specimens have been lost.

CAMBARUS (FAXONIUS) PROPINQUUS GIRARD

Cambarus propinquus, Girard, 1854, p. 88; Hagen, 1870, p. 67, Pl. I, ff. 34-38, Pl. III, f. 153; Smith, 1874, p. 638; Forbes, 1876, pp. 4 and 19; Bundy, 1877, p. 171; Bundy, 1882, p. 181; Bundy, 1882a, p. 402; Faxon, 1885, p. 147; Faxon, 1885a, p. 91; Faxon, 1885b, p. 360; Faxon, 1890, p. 628; Hay, 1896, p. 497; Faxon, 1898, p. 651; Hay, 1899, pp. 960 and 962; Ortmann, 1905, p. 400; Pears , 1910, p. 16.
Cambarus (*Faxonius*) *propinquus*, Ortmann, 1905a, pp. 112 and 132.

Male, Form I.

Body small, not pubescent, few hairs on chelæ; rostrum long, narrow, margins thin, spines on anterior end of rostrum, posterior to acumen; acumen long and triangular; rostrum carinated; post-orbital ridges short, grooved on outer surface, spines short and acute; carapace subovate, depressed or flattened dorsally; cervical groove deep, slightly sinuate, broken on sides; areola broad and smooth; chelæ short, rounded, slightly pitted on surface; third periopods hooked; first pair of abdominal appendages short and spiral shaped; the free tips long and slender, not recurved; general color dark olive green; chelæ olive yellow, mottled with olive green; finger tips orange, followed proximally by band of citron yellow. This color character is quite constant.

Nebraska locality.—Coon Creek, Milford, Seward County, several colonies.

CAMBARUS (FAXONIUS) VIRILIS HAGEN

Cambarus virilis, Hagen, 1870, p. 63; Forbes, 1876, pp. 4 and 19; Bundy, 1877, p. 171; Herrick, 1882, p. 253; Faxon, 1885, p. 147; Faxon 1885a, p. 96; Hay, 1896, p. 499; Pearse, 1910, p. 17.
Cambarus (Faxonius) virilis, Ortmann, 1905a, pp. 112–113.

Male, Form I.

Body long, not very robust; rostrum broad, long, well excavated, with raised margins, lateral teeth prominent and acute; acumen long, slender, terminal spine sharp; post-orbital ridges grooved on outer edge, slightly swollen posteriorly, having an acute spine anteriorly; carapace cylindrical, pitted dorsally, granulate laterally; lateral spine on cervical groove; cervical groove deep, broken; areola of moderate width, posterior triangle much longer than anterior; chela strong, thickly punctuate, tips of fingers equal, decurved, horny, with small tubercles on cutting edges of both fingers, immovable finger pubescent; third pair of periopods hooked; first pair of abdominal appendages very long, reaching nearly to the base of second periopods, bifid, falciform, the external branch longer, with recurved chitinous tip, inner branch recurved, flattened and spatulate at tip.

Colorado localities.—South Platte River, near Julesberg, Sedgwick County; Republican River, Wray, Yuma County; St. Charles River, tributary of the Arkansas River near Pueblo, Pueblo County.

Nebraska localities.—Blue River, Milford, Seward County; creek 6 miles south of Grand Island, Hall County; Louisville (collected by Theodore Stander).

CAMBARUS (FAXONIUS) IMMUNIS HAGEN

Cambarus immunis, Hagen, 1870, p. 71; Forbes, 1876, pp. 4 and 19; Bundy, 1877, p. 171; Pearse, 1910, p. 81.
Cambarus signifer, Herrick, 1882, p. 253.
Cambarus (Faxonius) immunis, Ortmann, 1905a, p. 113.

Form I.

Body slender; rostrum broad at base, well excavated, very slightly decurved, margins raised, converging; no marginal spines; acumen blunt, with concave sides; post-orbital ridges grooved on lateral face, without spines; carapace smooth, flattened dorsally, granulate laterally; lateral spine small, cervical groove deep, broken; areola narrow in middle, anterior triangle small and indistinct, posterior triangle larger, not distinct; chela long and tapering, internal finger deeply excised at base, immovable finger heavily bearded; second periopods with dense tufts of hair on inner side of distal segments; third periopods hooked; first pair abdominal appendages reaching nearly to the base of second periopods, falciform, bifid, external branch longer, with strongly recurved chitinous tip, inner branch recurved, flattened, and spatulate.

Colorado localities.—Denver, Denver County; Dry Creek, near Boulder, Boulder County; St. Vrains, Weld County; Greeley, Weld County; Empire Reservoir, near Deerfield, Weld County; Fort Collins, Larimer County; Louisville Junction, Boulder County; Allens Lake, Boulder County; Castle Rock, Douglas County.

Nebraska localities.—Lincoln, Lancaster County, many vicinities; Grand Island, Hall County; State fisheries, Sarpy County; Seward, Seward County; Hanlon, Lancaster County; Humboldt, Richardson County, sent by Irving Moore; Cass County; Richardson County, sent by Theodore Stander; Atkinson, Holt County; Pleasantdale, Seward County; Havelock, Lancaster County; Roca, Lancaster County.

CAMBARUS (FAXONIUS) IMMUNIS SPINIROSTRIS FAXON

Cambarus immunis var. *spinirostris*, Faxon, 1885, p. 146; Faxon, 1885a, p. 99; Hay, 1896, p. 502; Pearse, 1910, p 20.

Male, Form I.

Generally smaller than *C. immunis;* rostrum with small but acute lateral teeth; post-orbital spines well developed; lateral spines strong and acute; areola wider and slightly shorter than *C. immunis;* first abdominal appendages as in *C. immunis.*

Colorado localities.—Empire Reservoir near Deerfield, Weld County. Other specimens, labeled as *C. immunis*, in the University of Colorado collections are without definite locality records.

Nebraska localities.—Big Horseshoe pond, State fair grounds, Lincoln, Lancaster County; Stevens Creek, Havelock, Lancaster County; Louisville, Richardson County, collected by Theodore Stander.

CAMBARUS (FAXONIUS) NEGLECTUS FAXON

Cambarus neglectus, Faxon, 1914, p. 375.
Cambarus (*Faxonius*) *neglectus*, Ortmann, 1905a, p. 112.

Male, Form I.

Body small, not very robust; rostrum long, deeply excavated, margins raised, subparallel; marginal teeth small; acumen long, with horny tip, carinated; post-orbital ridges not prominent; spine blunt; cervical groove not deep, broken; areola broad, posterior triangle slightly larger than anterior; carapace subovate, depressed, punctuate; lateral spine very small; chela heavy and short, punctuate, slightly pubescent, inner finger longer, no excision at base of fingers; cutting edge of fingers with single row of small tubercles; carpus furrowed above, one large and one small spine on inner side; hooks on third periopods; first pair of abdominal appendages reaching to base of second periopods, long, slender, horny, bispinose, outer half longer, with slightly curving tip, inner half more slender, with slightly curving spatulate tip.

Colorado localities.—Republican River at Wray, Yuma County; Black Wolf Creek, tributary of Arikarre River, Yuma County; Arikarre River, Beecher's Island, Yuma County; South Platte River, Julesberg, Sedgwick County.

This species should be found in both the South Platte River drainage and in the Republican River drainage of Nebraska.

CAMBARUS (BARTONIUS) DIOGENES GIRARD

Cambarus diogenes, Girard, 1854, p. 88; Faxon, 1885, p. 144; Faxon, 1885a, p. 71; Faxon, 1885b, p. 359; Faxon, 1885a, p. 140; Faxon, 1890, p. 624; Hay, 1896, p. 489; Faxon, 1898, p. 650; Osburn and Williamson, 1898, p. 21; Williamson, 1899, pp. 20 and 48; Hay, 1899, pp. 959 and 961; Harris, 1900, p. 267; Ortmann, 1905, p. 398; Pearse, 1910, p. 20.
Cambarus obesus, Hagen, 1870, p. 81; Smith, 1874, p. 639; Forbes, 1876, pp. 5 and 19; Bundy, 1877, p. 171; Bundy, 1882, p. 183.
Cambarus dubius, Osburn and Williamson, 1898, p. 21.
Cambarus (*Bartonius*) *diogenes*, Ortmann, 1905a, pp. 120 and 135.

Male, Form I.

Body robust, smooth except for short hairs on chela and periopods; rostrum short, broad, deeply excavated, down-curved, without lateral spines; post-orbital ridges low, grooved externally and swollen posteriorly, without spines; carapace lightly granulated, with projecting angle just below the eye; no lateral spines; cervical groove deep and sinuate; areola very narrow, usually obliterated, posterior

angle larger than anterior but less well defined; abdomen shorter than cephalothorax; chela large and strong, swollen and heavily punctate, flattened dorsoventrally; inner finger slightly longer than outer; carpus short and thick, deeply furrowed above, with small blunt spine on inner surface and two smaller spines beneath; third periopods hooked; first pair of abdominal appendages of male thick and short, ending in two recurved falciform teeth, upper ones large, strong, corneous, inner ones smaller, terminating in mammary-like spine.

Nebraska localities.—Hall County, 6 miles south of Grand Island; Coon Creek, Seward County; Minichaduza Creek, Valentine, Cherry County.

Colorado localities.—Boulder, Boulder County; Fort Collins, Larimer County; Greeley, Weld County; Denver, Denver County; Louisville Junction, Boulder County; St. Vrains, Weld County; Empire Reservoir near Deerfield, Weld County; Lakeside, Boulder County.

CAMBARUS (BARTONIUS) ARGILLICOLA FAXON

Cambarus argillicola, Faxon, 1885, p. 115; Faxon, 1885a, p. 76; Pearse, 1910, p. 19; Hay, 1896, p. 492.
Cambarus (Bartonius) argillicola, Ortmann, 1906, p. 120.

Male, Form I.

Body robust; rostrum short, broad, strongly decurved, and well excavated; margins raised, slightly convergent; lateral teeth absent, acumen triangular, not sharp; post-orbital ridges prominent, without spine; carapace depressed, smooth dorsally, granulate laterally, without lateral spines; cervical groove deep, sinuate, broken; areola obliterated in middle, anterior triangular space very small, posterior larger but less distinct; chela strong and large, hand nearly smooth, inner border serrate or tuberculate, fingers thickly punctate, movable finger deeply excised at base, outer finger shorter than inner finger; third periopods hooked; first pair of abdominal appendages consisting of two falciform teeth, placed one anteriorly to the other, posterior tooth thick and strong, anterior tooth thin, spatulate, and horny, inner tooth slightly longer than outer.

Nebraska locality.—Ponds near State fair grounds, Lincoln, Lancaster County.

GEOGRAPHICAL DISTRIBUTION

IN NEBRASKA

The entire drainage of the State of Nebraska leads to the Missouri River, and is everywhere toward the east and southeast except an area north of Chadron, where the drainage is to the north. The following tabulation covers the main drainage systems within the State.

In three cases a river flowing through Nebraska has its source within another State. In each of these cases crayfishes have been reported in these streams outside of the boundaries of the State. It is reasonable to expect that the same species will continue into Nebraska, though there are yet no records of them.

Missouri River.—The banks of the Missouri River at Yankton, S. Dak., on both the Nebraska and South Dakota sides, were studied throughout the month of September, but failed to give any specimens. Investigation in midsummer on the Nebraska side of the Missouri River at Plattsmouth and for several miles north of Nebraska City failed to give the slightest indication of crayfish habitation. A

pond in Cass County, the overflow of which drained into the Missouri River, and several ponds in Richardson County that drained into the Missouri River all contributed collections of *Cambarus immunis*.

Niobrara River.—Several collections of *Cambarus diogenes* were made from Minichaduza Creek, a tributary.

Platte River.—Sarpy County, at the State fisheries, provided a collection of *C. immunis*. At Louisville, a collection of *C. immunis*, *C. immunis spinirostris*, and *C. virilis* was taken from small tributaries, and from Salt Creek and Stevens Creek collections of *C. immunis spinirostris*. From ponds within the drainage of these creeks collections of both *C. immunis* and *C. immunis spinirostris* were taken. In several small creeks in Hall County, tributary to the Platte River, collections of *C. virilis*, *C. immunis*, and *C. diogenes* were taken.

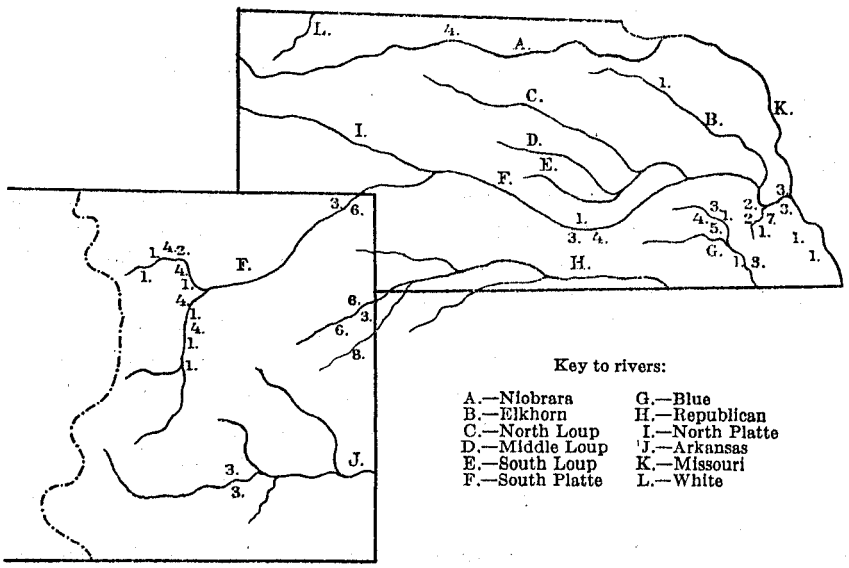

FIG. 1.—Map of rivers of Nebraska and eastern Colorado, showing distribution of crayfishes by river systems

Key to species:

1—*C. (Faxonius) immunis*
2—*C. (Faxonius) immunis spinirostris*
3—*C. (Faxonius) virilis*
4—*C. (Bartonius) diogenes*
5—*C. (Faxonius) propinquus*
6—*C. (Faxonius) neglectus*
7—*C. (Bartonius) argillicola*
8—*C. (Cambarus) simulans*

North Platte River.—From the Elkhorn River, in Holt County, a collection of *C. immunis* was taken, and from the Laramie River, Laramie, Wyo., collections of *C. virilis* and *C. immunis* were reported by Harris (1903, pp. 134 and 192).

South Platte River.—Julesburg, Colo., *C. neglectus* and *C. virilis*. From a tributary to the South Platte, in Wyoming, Harris (1903, p. 85) reported *C. diogenes*.

Republican River.—Harris (1903, p. 148) reports *C. neglectus* from near Guy, Cheyenne County, Kans., and *C. virilis* from Fort Riley, Kans.

Big Blue River.—Five species were taken from the ponds, creeks, and rivers in Seward County—viz, *C. immunis* from adjacent ponds, *C. immunis spinirostris* and *C. diogenes* from several creeks, *C. propinquus* from Coon Creek, and *C. virilis* from the Big Blue River. Faxon (1898) reports *C. immunis* and *C. virilis* from "Blue River, Crete, Nebr."

IN COLORADO

The State of Colorado is drained by three major river systems—the Rio Grande, the Colorado, and the Mississippi. The area covered by this study is that which lies east of the Continental Divide and is in the drainage system of the Mississippi River.

Arkansas River.—A collection of *C. virilis* from St. Charles River, a tributary, near Pueblo.

Smoky Hill River.—A collection of *C. simulans* near Oriska, Kit Carson County.

Arikaree River.—A collection of *C. neglectus* from Yuma County and another collection of *C. neglectus* from Black Wolf Creek, a tributary of the Arikaree River.

South Platte River.—At Julesburg, several collections of *C. neglectus* and *C. virilis*. At the Empire Reservoir, Weld County, draining from the Platte River, collections of *C. immunis*, *C. immunis spinirostris*, and *C. diogenes*. From the Poudre River, Larimer County, *C. diogenes* and *C. immunis*. From Middle Boulder Creek and South Boulder Creek, *C. diogenes* and *C. virilis*, and from adjacent ponds *C. immunis*. From creeks and ponds in Douglas County and in Denver County, *C. immunis* and *C. virilis*.

ECOLOGY AND LIFE HISTORIES

The ecology of crayfishes has been studied by Harris (1900, 1901, and 1903), who summarizes the work done by previous workers. Ortmann (1906) has studied the ecology of eastern species, but aside from the work of Harris no one has considered the special habitats of crayfishes in the Missouri River drainage. Some attention was therefore given to the ecological factors of crayfish distribution in Nebraska.

Six species of the genus Cambarus are found in Nebraska, three of which have a wide distribution; the remaining three have been found only in restricted areas.

Cambarus immunis has the widest distribution within the State, and the writer has given considerable attention to its habitats. This species was previously studied by Harris (1901) in Kansas. This is the mud crayfish. In Nebraska it is the only form that persistently inhabits the small ponds, many of which contain water only during the spring and early summer. The life of this species in periods of drought and their migration to other ponds is not known. I have found specimens in a dry pond near Lincoln in May, living in a small amount of water at a depth of 32 inches. The pond received only small amounts of water from local rains through the summer.

This species usually digs a straight burrow with a small, shapeless chimney in heavy black soil, rich in decaying vegetable material (fig. 2). Many individuals are found in temporary ponds early in the summer in small burrows several inches in depth, under small stones (fig. 3), empty cans, or decaying logs. According to W. P. Hay (see Evermann and Clark, 1920, pp. 83–86) this is a characteristic also of *C. propinquus* from Indiana.

This is the only species I have observed in the act of chimney building. The process is carried out on cloudy days or, as in the cases observed in this study, in

the evening after sunset. At Hanlon, Nebr., on June 17, I found a small pasture pond that was rapidly drying up. After 6.30 in the evening signs of activity were noticed, and many individuals were seen bringing pellets of earth in the manner described by Ortmann (1906), and depositing them on the rim of the chimney. This unusual midseason activity in burrows already over 20 inches in depth was probably due to the influence of the drying up of the pond and the necessity for the crayfish to find water at a lower level. The animals were found in burrows during the day, but in the evenings large numbers were present in the open water. I saw many specimens, also, in the streams near the pond colonies, although I did not find them in burrows on the banks of these streams. I have found several colonies of this species in Colorado living in a clay soil on a series of alkali flats. Although several similar soils are known in eastern Nebraska, not any of them were inhabited by any species of crayfish.

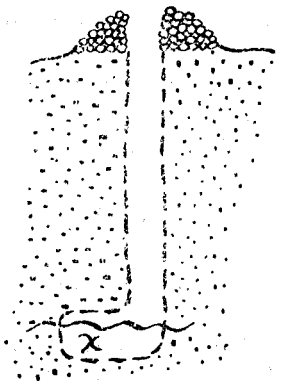

FIG. 2.—Diagram of burrow of *Cambarus immunis* in bank of permanent pond. Length of burrow, 40 centimeters. Wavy line indicates water level. X marks place where specimen was taken

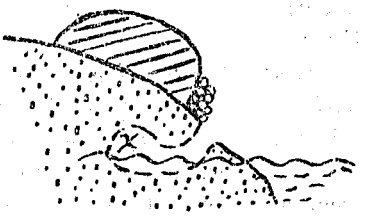

FIG. 3.—Diagram of burrow of *Cambarus immunis* beneath a stone in a temporary pond. Length of burrow, 14 centimeters. Wavy line indicates water level. X marks place where specimen was taken

Cambarus diogenes is perhaps the most interesting form of Nebraska crayfish. Although reported by writers to be an inhabitant of the ponds with *C. immunis*, several hundred collections have failed to give a single *diogenes* from any area save the clear creeks and smaller rivers. A few were taken from the Empire reservoir, a large artificial lake near Greeley, Colo. I have taken a few specimens from the creek bed in the evening, but most of my species have been obtained from the long and complex burrows which they make (fig. 4). An unusual instance of this well-digging habit is shown in Figure 5. The burrow is not deep, but had been dug through several inches of disintegrated limestone, ending on a harder terrace of the same material. The chimney was asymmetrical, with particles of stone cemented by the mud from the same excavation. In western Nebraska, at Valentine, I found large numbers of this species that had made burrows in the side of a steep bank of sandy loam, which formed the bank of Minichaduza Creek. No chimneys were present, although usually so distinctive a part of the *diogenes* well. This again is

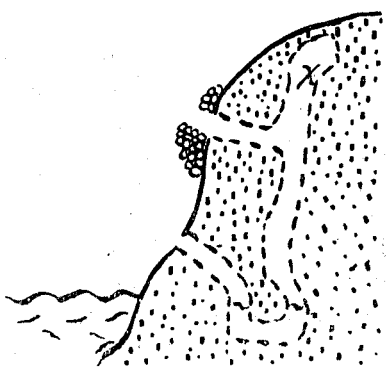

FIG. 4.—Diagram of burrow of *Cambarus diogenes* in the bank of an irrigation ditch. Total length of tunnel, 125 centimeters. Wavy line indicates water level. X marks place where specimen was taken

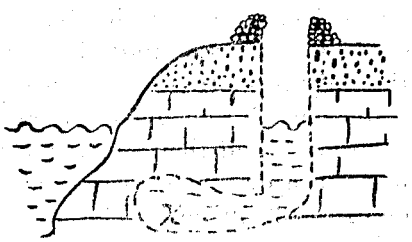

FIG. 5.—Diagram of burrow of *Cambarus diogenes* in disintegrated limestone on the bank of a creek. Depth of well, 30 centimeters. Wavy line indicates water level. X marks spot where specimen was taken

evidence, added to that of Ortmann, Harris, and others, that the chimney is no part of the economy of the crayfish burrow but is the easiest method of disposing of the material excavated. In this case the material was brought to the surface of the tunnel and thrown over the edge, to be swept away by the current. The openings of the burrows were difficult to find, as they were beneath the outthrust roots of shrubs and trees and were often 3 feet above the water level. Young of this species were found in the water throughout the period of 10 days spent in that vicinity in late August, and none in the burrows, each of which was occupied by a single adult. This species has been found in many types of soil, such as clay, sandy loam, black loam, gravel, and shaly limestone, but always on the banks of clear streams and never in ponds.

A variety of *Cambarus immunis* (*C. immunis spinirostris*) is found throughout eastern Nebraska. It is primarily an inhabitant of small, sluggish streams, making a characteristic well in the banks of the stream. In one pond, however, near such a stream, I repeatedly found mature crayfishes of this variety in the open water, and none were taken from burrows on the banks of this pond.

Cambarus virilis occurs in the swift, sandy-bottomed streams, the most constant locality known to the writer being the Blue River at Milford, Nebr. I have not failed to find a few on each trip in the swift, well-oxygenated water just below the milldam. *C. immunis* is found in great numbers in adjoining mud flats, but the two species have not been found to overlap. *C. virilis* and *C. diogenes* were both found in the same area in a creek near Grand Island, Nebr.—*C. diogenes* in one of its characteristic wells and *C. virilis* in the creek bed. *C. virili* does not dig a well.

Cambarus propinquus is an inhabitant of the more quiet places in small creeks, sometimes making a shallow excavation, more often hiding through the day in old cans or beneath rocks in the stream bed. It has been found in the same stream with *C. diogenes*, but in the more quiet, deeper sections, and it is not a chimney builder.

Cambarus argillicola has been found in Nebraska, but the data are not extensive enough to determine any specific physical character of its environment. The specimens were found at different times in a single meadow pond, within shallow excavations or beneath stones.

It would appear that in this group of crayfishes studied the reaction of the physical environment is well defined, and that the animals differ in physiological as well as taxomomic characters.

The breeding habits of the group are well summarized by Andrews (1904 and 1906), who made a careful study of the copulation, egg laying, and development of *Cambarus affinis*. The difference in times of ovulation and freedom of the young from the egg capsules is very interesting. My own observations are limited to a study of *C. immunis* and *C. diogenes*, and represent a careful investigation of their life history through two consecutive seasons.

Two "berried" females of *Cambarus immunis*, 70 and 110 millimeters long, were found in burrows in a pond near Lincoln on April 25. These were taken to the laboratory, where the young of each hatched within 10 days. Both of the adults

died and the young were not raised. It was observed that the "berried" females rarely survived laboratory conditions, whereas smaller specimens of both males and nongravid females were kept for 10 weeks.

Further records of gravid females of this species within the vicinity of Lincoln were taken on April 29 and May 13. Perhaps the most interesting record was one of two *C. immunis* 40 millimeters in length, taken at Atkinson, Nebr., on October 30. One female carried a large cluster of eggs, which were hatching, but both specimens died three days later.

Harris records March 21 as the earliest date for berried females of this species in Kansas. This is more than a month earlier than my records for the same species in an adjoining State, although I have taken specimens as early as April 1, but found no gravid females.

Herrick (1896) reports a number of females of *C. immunis* already in berry taken at Ann Arbor, Mich., on November 16, when the ice was beginning to form.

The earliest records for *C. diogenes* are May 13, taken at Seward, Nebr., and May 30, taken at Boulder, Colo. Harris (1902) reports a female with eggs taken on May 3. Pearse (1910) reports a pair copulating in White Pigeon River, Mich., on April 13. Hay reports *C. argillicola* with young on April 2. Ortmann (1906) gives April 6 as the earliest records for females of *C. diogenes* with eggs, and May 21 as the earliest date for females with young taken in Pennsylvania.

Copulation has not been observed in either Nebraska or Colorado species, though on June 17, at Hanlon, Nebr., I examined 15 burrows, in 7 of which both the male and the female of *Cambarus immunis* were found in the same burrow but not in copulatory position. This is, however, a rare condition, and according to Ortmann (1906, p. 482) it is "an absolute rule that under ordinary circumstances only one specimen occupies a hole," and that this association is found only during the mating period. That this pond was drying up, owing to an especially dry summer, may have had some influence on the time of copulation.

Ortmann states that the copulating season for *C. diogenes* falls in the autumn, having observed it on October 24 and November 5. At variance with this is the record of Hay (1896, p. 491) that *C. diogenes* was taken in Indiana on April 2 with pairs in copulation.

It is apparent that careful attention should be given to the geographical differences in the life history of a single species, studied over a series of years in localities of distinct climatic and seasonal differences.

Young of all these species leave the burrow of the mother and may be taken in schools in the open water when from 8 to 20 millimeters in length. At from 18 to 25 millimeters they begin to dig burrows for themselves, and may no longer be taken throughout the day in the open water.

PARASITES

In most of the collections of crayfishes in both Colorado and Nebraska a few specimens were found that bore the interesting annelids belonging to the Discodrilidæ. On some specimens of *C. immunis* found near Lincoln the entire carapace was covered with the cocoons of this worm, while on the ventral portion, especially around the mouth, were many of the mature animals. These annelids are rather

small, ranging from 2 to 4.5 millimeters in length. Pierantoni (1912), quoted by Hall (1915), states that this family ranges in length from 1 to 12 millimeters, with a maximum width, when in a moderate distension, not to exceed one-tenth of the body length.

The cocoons are quite conspicuous, being about 3 millimeters in length and fastened to the body of the host by a narrow stalk. It was formerly thought that these might be the eggs of Corixia, the giant water beetle, but their relationship to the parasitic worms is now known. Likewise, it was not known for a time whether they were to be considered parasites on the crayfish or messmates with it. Hall (1915) regards them as parasitic in the adult stage. "They are not parasitic when young, a study of the intestinal tract at this period showing vegetable detritus and small animals. In the adult stage the teeth are used to break the skin of the host animal in order to suck the blood. I have found several pieces of striated, voluntary muscle fiber in the intestine of the adult discodrilid described in this paper."

Ellis (1920), in a revision of the Branchiobdellidæ in the United States National Museum, records the species found on the Colorado and Nebraska crayfishes. The Nebraska species collected during this investigation have not yet been identified. *Cambarus diogenes* was found to be host to *Cambarincola macrodonta* Ellis and *C. philadelphica* Leidy, the former species only being found on *C. diogenes* from four localities in Colorado, and *C. philadelphica* being found by Ellis at Rhinelander, Wis. *Cambarus immunis* and *C. virilis* from Colorado, and *C. propinquus* from Douglas Lake, Mich., were host to *Cambarincola vitrea* Ellis. *C. propinquus* from Irondale, Ind., is host to *Xitonodrilus formosus* Ellis, and the same species from Bloomington, Ind., is host to *C. philadelphica* Leidy. *Cambarus virilis*, from Rolla, Mo., is host to *C. chirocephala* Ellis and also to *Cambarincola vitrea* Ellis and the same species from Douglas Lake, Mich., is host to *C. philadelphica* Leidy.

It is thus seen that the parasites have not developed into specific form along with the differentiation of the host species and seem to show no selection of hosts. There is no record of one specimen being host to two species of parasites, though the same species of crayfish in different localities may harbor at least three different parasites.

ECONOMIC IMPORTANCE

Although very abundant in these two States, especially in Nebraska, the crayfishes have received very little attention as regards economic importance. Personal inquiry at the office of the game and fish department of Nebraska, at Lincoln, brought the information that crayfishes were worth nothing and could not be considered among the resources of the State.

Careful investigation shows them to be of no inconsiderable value in the life balance of our streams and meadows. Shelford (1913) has shown that they play a definite part in the equilibrium of the fresh-water community, feeding upon the decaying vegetable matter, the larger aquatic insects (probably those that have died), and possibly the young of frogs and fishes. They, in turn, serve as food for the bullheads, the young and the adult black bass, and possibly also for other forms.

Pearse (1910) states that they furnish food for many turtles and snakes as well as other animals. I have examined the stomachs of a number of snakes that are frequenters of streams (*Tropidonatus sipedon fasciatus*, *Thamnopis radix*, and *T. elegans*) and have found no trace of crayfish remains. Ortmann (1906, p. 495) has seen *Natrix leberis* disgorge *C. obscurus* when captured. He also quotes Prof. H. A. Surface as the authority for the statement that *Cryptobranchus alleghensis* and Necturus feed upon crayfish. I have found the carapaces of freshly killed crayfishes (*C. immunis*) on the banks of a small stream west of Lincoln in the early morning, and many tracks of a raccoon (probably *Procyon lotor*). It is evident that this night-feeding animal feeds on the crayfishes as well as upon the mussels that are found in the same community. I have not examined the stomachs of wading birds, but undoubtedly they catch many of the young crayfishes as they swim in schools in the shallow water during the evening and morning hours.

Owing to their great numbers and the large size reached by *Cambarus immunis*, *C. diogenes*, and *C. virilis*, there is a great deal of potential food in the ponds and streams which is not utilized. I have heard of no one who has eaten them in these two States, but there is no good reason for not doing so, since they are so highly esteemed in other localities, especially in the southern United States.

The crayfishes of Wisconsin have been of some slight importance, according to R. S. Scheibel, assistant commissioner of conservation, who says:[1] "They are gathered mostly around the waters adjacent to Green Bay, and in Wisconsin were used almost entirely for free lunches in saloons. Since prohibition has been in effect the crayfish business has dropped off considerably, the last report showing that only approximately 400,000 pounds were caught and sold."

Speaking of another genus of this family—the genus Astacus—Carl D. Shoemaker, master fish warden of the State of Oregon, says:[2] "We issue in the neighborhood of three dozen crayfish licenses a year. * * * I know that in the neighborhood of 100,000 dozen are taken annually in our waters. These are sold to restaurants and hotels, and are kept in live boxes, where they are held and fed until served. The industry is not a very profitable one, as the price paid per dozen is small. Those who engage in the taking of these crayfish make a poor living and have to augment their income from other sources."

The abdomen of the crayfish is also used extensively for bait by fishermen, but the animals are usually caught alive for each trip and are of no great importance commercially.

Fisher (1912) suggests that if boiled with meal and allowed to dry, crayfish make an extremely valuable egg-producing food for poultry.

As an item of negative economic importance the crayfish has received slight attention. In some of the lower areas of the eastern part of the State the meadows along the streams and surrounding the ponds may be infested with the burrowing forms *C. diogenes* and *C. immunis*, especially the latter. A certain though negligible amount of grass may be destroyed, and the mounds may interfere with the mowing operations, but farmers who were questioned did not seem to regard them as a nuisance. In the Southern States crayfishes were at one time a very great pest,

[1] From personal letter, Aug. 20, 1923.

[2] From personal letter, Aug. 29, 1923.

and "in badly infested areas, near Muldoon, Miss., there are from 8,000 to 12,000 holes to the acre." (Fisher, 1912, p. 322.) The name of the species was not recorded, but it destroyed a great deal of the young cotton and corn crop, tearing the cotyledons and young leaves and carrying them to their burrows.

In the irrigated districts of Colorado crayfishes are very plentiful, the burrows of *C. diogenes* being seen along the banks of the ditches where they run their complex underground tunnels, often causing breaks in the bank of the ditch. A single alfalfa field inspected near Boulder has a great number of burrows of this species extending from 1 to 3 meters from the bank of the ditch, the young crop in this strip being quite destroyed.

Cambarus diogenes has become a very great nuisance on the campus of the University of Colorado at Boulder. The young entered an artificial pond by way of a small inlet stream, and the following autumn dug many burrows in the embankment on the north side of the pond. A cement wall, which was placed along this bank, extending to a depth of 2 feet below the usual water level, has eliminated the attacks of the crayfishes at this point.

The crayfish may be exterminated in a given locality, according to Fisher (1912), by using carbon bisulphide, chloride of lime, or calcium carbide. I believe that this would suffice for a single season only, and that with the migration of the following spring the population would be renewed.

SUMMARY

This study of the genus Cambarus of Nebraska and eastern Colorado summarizes the literature dealing with crayfishes of the area, paying special attention to the previous records and giving a redescription of the eight species. The geographical distribution is considered and the ecology of the species studied with evidence gathered in a field investigation for two consecutive seasons. Life history data are gathered, which demonstrate the existence of geographical differences in time of copulation and spawning, and suggestions are offered for more detailed observations regarding these differences. The literature on discodrilid parasites of the crayfish has been reviewed and the suggestion made that the generic and specific differentiation of these parasites has been independent of the evolution of the host species. Information regarding the economic value and the food relationships is presented.

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NEW GENUS OF DARTER FROM WESTERN NORTH CAROLINA[1]

By R. E. COKER, Ph. D., *University of North Carolina*

INTRODUCTION

Three specimens of darter collected in Paddys Creek, a tributary of the Catawba River in Burke County, N. C., in August, 1922, can not be referred to an established genus, at least in so far as genera are recognized and described by Jordan and Evermann in Bulletin 47 of the United States National Museum. They appear to be more nearly related to *Pœcilichthys* (*Etheostoma*) *flabellare* than to any other described species. *Flabellare* is apparently an even more variable species than others of the tribe of darters, and the writer has considered the possibility that these specimens represent an extreme variation of the *flabellare* form. This is conceivably so, but to place the Paddys Creek specimens in the genus Pœcilichthys (Etheostoma of Bulletin 47) would do violence to the principal criteria of that genus and merely cause additional confusion in the taxonomy of a group of fishes that already presents sufficient difficulty.[2] However loosely connected may be the various members of the genus Pœcilichthys as it now stands, the breaking up of the genus could not be attempted without an elaborate study in which consideration would have to be given to the validity of several other genera now standing independently. In these circumstances, the writer proposes for the new fish from Paddys Creek the genus Richia, type *Richia brevispina*.[3]

Richia brevispina differs from Pœcilichthys principally in that the parietal region of the skull is depressed and not strongly convex in section, the belly is not covered with ordinary scales, the back before the dorsal fin, as well as the entire head, is naked, and the dorsal fin has but 6 or 7 spines, as contrasted with the 9 or more characteristic of the genus Pœcilichthys. Doubtless no one of these characters is of decisive weight by itself; certainly not the last mentioned, for a very few species of the genus Pœcilichthys may have 8 spines in the dorsal, and a single species, *iowæ*, may have as few as 7 dorsal spines; but the last-mentioned species seems to have the typical squamation of belly and sides of head. No species of

[1] The specimens were collected while the author was in the service of the United States Bureau of Fisheries.

[2] Jordan, in Copeia, No. 29, April 12, 1916, suggests that several of the subgenera recognized by Jordan and Evermann in Bulletin 47 probably should stand as valid genera, in which case *flabellare* would be assigned to the genus Catonotus. If, however, the genus called Etheostoma (now Pœcilichthys) shall continue to be used in a broad sense to include *flabellare* and many other species, the name Pœcilichthys, according to Jordan, must displace Etheostoma. See also Jordan and Evermann, "The Genera of Fishes," Part I, p. 110.

[3] *Richia* in honor of Dr. Willis H. Rich, in charge of scientific inquiry, Bureau of Fisheries; *brevispina*, referring to the low dorsal spines.

those now grouped in the genus deviates so notably from the generic type in so many characters.

The Paddys Creek fish differ from species of the genera Ioa and Ammocrypta in that the body is not exceedingly elongate and the premaxillaries are not protractile. They differ from Cottogaster (*C. shumardi*) in the small number of dorsal spines, in that the first dorsal is smaller than the second, which is larger than the anal; in having dorsals not separated, the opercles and gills naked, the gill membranes well connected, and the ventral fins close together. They differ from Hadropterus in that the soft dorsal is larger than the anal, the ventral fins are well separated, the gill membranes are broadly connected, and there are hardly half as many dorsal spines as in species of Hadropterus.

The Paddys Creek specimens may be said to show affinities with *Pœcilichthys iowæ*, *Pœcilichthys* (*Catonotus*) *flabellare*, *Cottogaster shumardi*, and *Ioa vigil*, but not to fall within the presumable limits of variation of any of these species.

Richia, nov. gen.[4]

Body not particularly elongate; mouth terminal or slightly inferior; premaxillaries not protractile; skin of premaxillaries connected mesially with forehead by narrow frenum; teeth of jaws small; vomerine and palatine teeth present; parietal region of skull not strongly convex in cross section; gill membranes broadly united; body incompletely scaled, belly partly naked or covered with caduceous plates; head and region in front of dorsal naked; lateral line high anteriorly; first dorsal low with spines well separated by broad membranes, smaller than second dorsal, which is larger than anal; the first and second dorsals contiguous; anal spines 1 or 2, nearly equal; ventral fins separated by space approximately equal to one-half the base of fin.

Richia brevispina, n. sp.[5]

D. VI or VII–12; A. I or II–8; P. 12–12 or 12–11; scales 8–48 (49)–9; head 3⅓; depth 5; eye 4½–5.

Body not particularly elongate, rather compressed, tapering evenly from region of first dorsal to base of caudal. Caudle peduncle broad, depth about equaling length, or three-fourths of greatest depth of body. Back scarcely arched, dorsal profile being nearly straight from nape to caudal, but rising slightly just before origin of caudal; ventral profile somewhat round anteriorly. Parietal region of skull distinctly depressed. Cranium narrow between the eyes, the interspace less than eye. Eye small, its horizontal diameter slightly longer than vertical.

Mouth rather wide, terminal, moderately oblique, lower jaw barely shorter than upper. Maxillary reaching a little past anterior margin of pupil. Lips rather heavy, premaxillaries not protractile, skin of premaxillaries connected with forehead by very narrow frenum. Teeth small; vomerine and palatine teeth present. Gill membranes broadly united.

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[4] Type No. 87411, U. S. National Museum; two paratypes, U. S. National Museum, No. 87412.

[5] Grateful acknowledgment is due to Charles M. Breder, jr., for supervision of the drawing reproduced as Figure 1.

Area before dorsal and extending back close to base of dorsal as far as the third or fourth spine naked of scales. Belly scaled posteriorly, anterior one-half to two-thirds naked but with indications of caduceous plates. Head, cheeks, and opercles entirely naked.

Lateral line running high anteriorly, nearly complete; pores 36–38, none on last 10 or 12 scales.

Dorsal fins close together; first dorsal low, about one-half of second, its base relatively long because of wide spaces with membrane between the short stiff spines; base of first dorsal less than 5 in length of body (or about the same as with other darters having double the number of spines), corresponding to about 12 rows of scales.

Anal fin a little smaller than second dorsal. In the type there is a single relatively stout anal spine, followed by 8 rays, the first ray being simple but articulate; in the larger paratype, which is of the same size as the type, there are two spines of

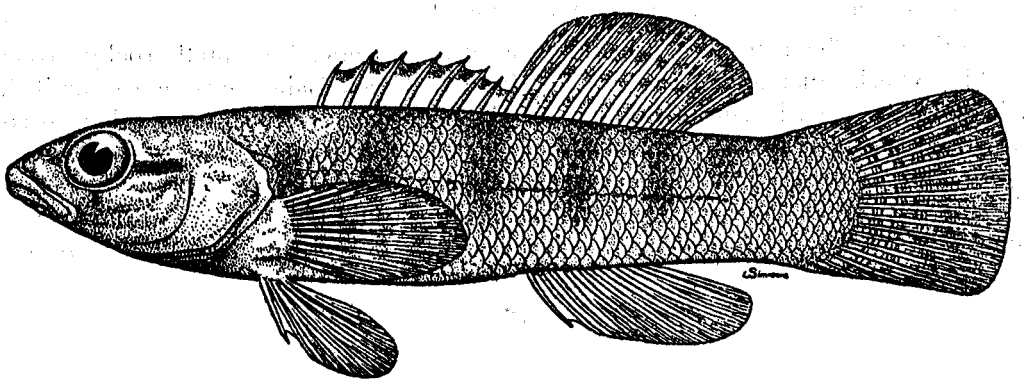

FIG. 1.—*Richia brevispina*, gen. nov., sp. nov. (From the type. Length, 46 millimeters.)

equal length, the second feebler than the first, which is less stout than the single spine of the type; the other paratype conforms with the larger paratype, the spines being feebler than in the larger fish, as would be expected; in each of the paratypes, as in the type, the spines are followed by 8 rays, of which the first is simple.

Ventral fins not widely separated, space between fins being slightly less than one-half of base of fin.

Color in alcohol.—Ground straw color, finely stippled with dark brown; sides crossed by 7 or 8 dark brown bars extending (usually) a little below the lateral line, width of bands being less than eye, and width of space between bands being about twice width of bands. Fins without conspicuous markings, distal parts of membranes between dorsal spines each with spot of dark olive. Caudal with 5 or 6 irregular reticulated vertical bars of olive green. A dark horizontal streak through eye and a similar streak extending downward vertically from eye. No pale stripes.

Measurements of type specimen

	Millimeters
Length, standard	39
Length, total	46
Length of head	12
Depth, greatest	8
Length of fourth dorsal spine	2.5
Length of fourth dorsal ray	7
Length of third anal ray	6
Length of pectoral	10.5
Length of ventral	7
Eye from snout	4
Eye	3
Snout to origin of first dorsal	14
Base of first dorsal	9
Base of second dorsal	9
Base of anal	8
Least depth of caudal peduncle	6
Distance between base of second dorsal and base of caudal	7.5

Habitat.—The fish were taken in the swift waters of a small, rocky stream (Paddys Creek) just above the head of Paddys Creek Lake, part of the artificial Lake James system in Burke County, N. C. Ten species of fish were taken in collections at the same station. Most abundant were *Campostoma anomalum, Notropis procne,* and *Hybopsis hypsinotus;* in small numbers were *Notropis skepticus, Boleosoma nigrum,* and *Schilbeodes insignis.* Species of which only one to three examples were found were *Hadropterus peltatus, Richia brevispina, Lepomis auritus,* and *Moxostoma rupiscartes.*

SALMON-TAGGING EXPERIMENTS IN ALASKA, 1924 AND 1925 [1]

By WILLIS H. RICH, Ph. D.
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INTRODUCTION

The extensive salmon-tagging experiments conducted during 1922 and 1923 [2] in the region of the Alaska Peninsula proved so productive of information, both of scientific interest and of practical application in the care of these fisheries, that it was considered desirable to undertake similar investigations in other districts. Accordingly, experiments were carried on in southeastern Alaska in 1924 and again in 1925. In 1925, also, at the request of one of the companies engaged in packing salmon in the Port Moller district, along the northern shore of the Alaska Peninsula, the work done there in 1922 was repeated. The results of these experiments form the basis for the following report.

During 1922 and 1923 operations were carried on under the direct supervision of Dr. C. H. Gilbert and the author of this paper. It was impossible to give such supervision to the work conducted in 1924 and 1925; but the field work, including the actual tagging operations and the collection of data, was efficiently carried on by various other members of the bureau's staff.

Thanks are due to Dennis Winn, agent of the Alaska service, whose helpful cooperation in planning and arranging the work assured its success; to E. M. Ball, assistant agent, who conducted the tagging and collecting of data in southeastern

[1] Contribution No. 1 from the Seattle (Wash.) biological laboratory.

[2] Experiments in Tagging Adult Red Salmon, Alaska Peninsula Fisheries Reservation, Summer of 1922, by Charles H. Gilbert. Bulletin, U. S. Bureau of Fisheries, Vol. XXXIX, 1923-24 (1924), Document No. 943, pp. 39-50. Washington. Second Experiment in Tagging Salmon in the Alaska Peninsula Fisheries Reservation, Summer of 1923, by Charles H. Gilbert and Willis H. Rich. Bulletin, U. S. Bureau of Fisheries, Vol. XLII, 1926, Document No. 991, pp. 27-75. Washington.

Alaska in 1924; to Arnie J. Suomela, warden, who handled the work in southeastern Alaska in 1925; and to L. G. Wingard, warden, who conducted the tagging operations at Port Moller in 1925. Harlan B. Holmes, junior aquatic biologist, rendered material aid in tabulating the data.

The methods employed were almost the same as those followed in the experiments conducted in the Alaska Peninsula region. These were fully described by Gilbert and Rich [3] and need not be set forth here.

Scales were taken from each fish tagged in southeastern Alaska, but it was not considered necessary to do so in the experiment at Port Moller, as none but red salmon were taken at that place, and confusion of the various species was therefore impossible. In the experiments conducted in southeastern Alaska the species of each fish tagged was recorded in the books in which the scales were preserved, and the identification of each fish returned was made by examining the scales taken at the time of tagging. A small proportion of the fish was found to have been incorrectly recorded as to species, but the number was so small that it has not seemed worth while to examine the scales of the fish that were not recaptured. The only reason for doing so would be to render more accurate the figures representing the total number of fish of each species tagged in each experiment, but we have satisfied ourselves that any error that may result from accepting the data as given by the records made at the time of tagging will in no way affect our conclusions.

The accompanying map of southeastern Alaska will serve to show the larger geographical features of that district, while the numerous minor localities from which returns were reported are included in the following list:

ALPHABETICAL LIST OF MINOR LOCALITIES FROM WHICH TAGGED FISH WERE RECORDED

Adams, Point. Northern point of entrance to Moira Sound.
Adolphus, Point. Northernmost point of Chichagof Island.
Affleck Canal. Southern end Kuiu Island.
Alava, Point. Southernmost point of Revillagigedo Island.
Alexander, Port. South end of Baranof Island, Chatham Strait.
Althorp, Port. Northwestern shore of Chichagof Island, Cross Sound.
American Bay. Eastern shore of Dall Island, Prince of Wales Archipelago.
Anan Creek. Cleveland Peninsula, across from Wrangell Island.
Arrandale, British Columbia. Portland Inlet, just west of Nass Bay.
Augusta, Point. Northeastern point of Chichagof Island.
Auke Bay. Stephens Passage, just north of Douglas Island.

Babine River, British Columbia. Tributary to the Skeena.
Baker, Point. Northwestern point of Prince of Wales Island.
Barnes Lake. Prince of Wales Island, tributary to Lake Bay, Clarence Strait.
Barnes Point. Northern point of Stevenson Island, Clarence Strait, latitude 56° 04′.
Barrie, Point. Southwestern point of Kupreanof Island, Sumner Strait.
Barrier Island. Southwestern part of Cordova Bay.
Basket Bay. Chichagof Island, Chatham Strait, latitude 57° 40′.
Bay Point. Mainland shore, Frederick Sound, latitude 57° 06′.
Bear Harbor. Affleck Canal, southern end of Kuiu Island.
Beauclerc, Port. Eastern shore of Kuiu Island, Sumner Strait.
Behm Canal. Between Revillagigedo Island and the mainland.
Bendel, Cape. Northwestern point of Kupreanof Island.

[3] See footnote 2, p. 109.

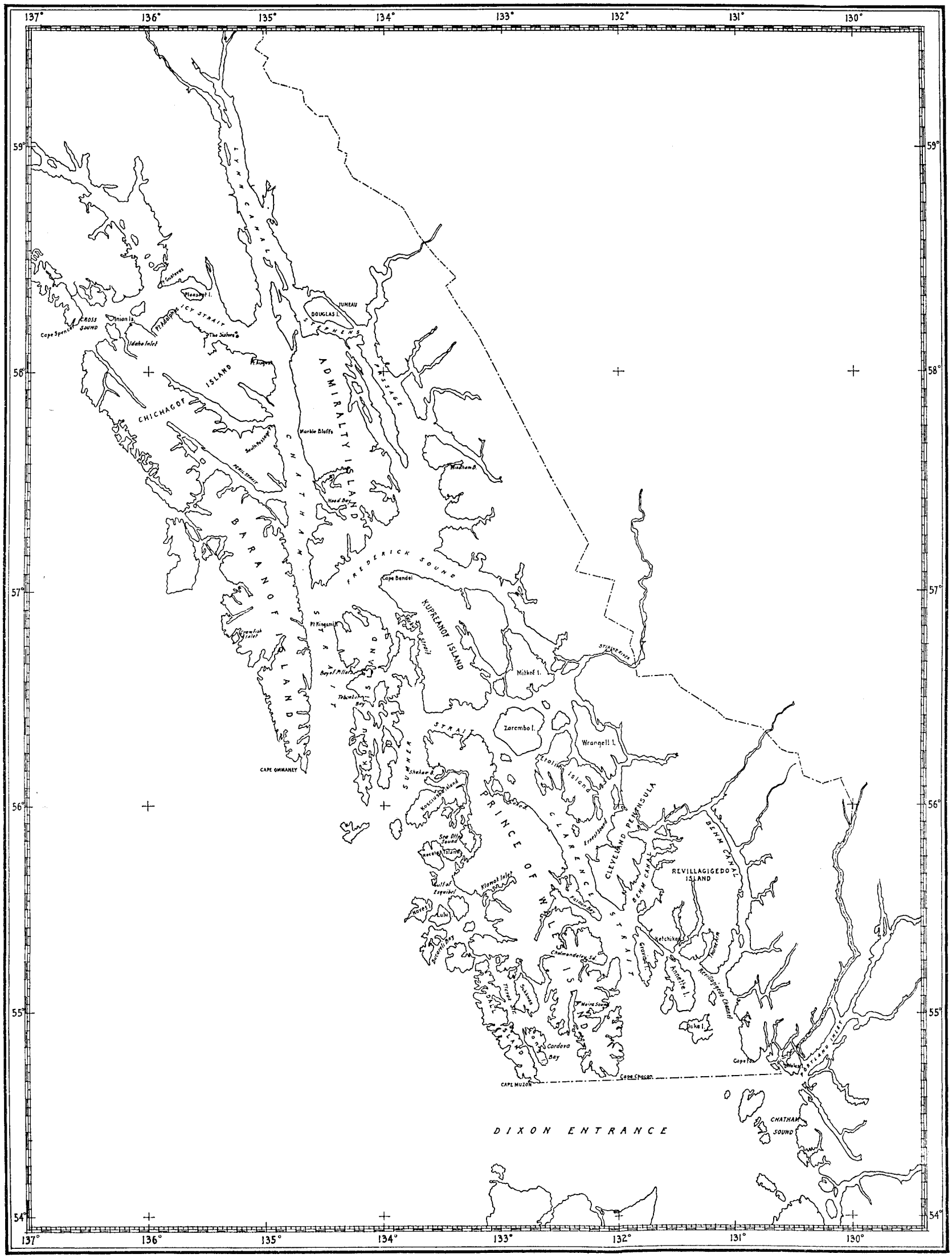

FIG. 1.

100373–26. (To face p. 110.)

Betton Island. At northern entrance to Behm Canal, Clarence Strait.
Black Island. Behm Canal, northwest of Revillagigedo Island. Another near the southern entrance to Behm Canal.
Blank Inlet. Southeastern shore of Gravina Island.
Boat Harbor. West coast of Gravina Island.
Boat Rock. At entrance to Naket Inlet, near Cape Fox, Revillagigedo Channel.
Boca de Quadra. Inlet on mainland coast opening into Revillagigedo Channel.
Bocas de Finas. Channel southwest of Heceta Island, Prince of Wales Archipelago.
Bold Island. Between Annette and Revillagigedo Islands, Revillagigedo Channel.
Bond Bay. At northern entrance to Behm Canal, east of Caamaño Point.
Bostwick Inlet and Point. Southeastern shore of Gravina Island.
Box Point. Behm Canal (exact location doubtful).
Breezy Bay. Tlevak Strait, eastern shore of Dall Island.
Brightman, Point. Southern shore of Admiralty Island, Frederick Sound; the southern point of entrance to Herring Bay.
Bronaugh Island. Just south of Gravina Island, Clarence Strait.
Bucareli Bay. West coast of Prince of Wales Archipelago, latitude 55° 20′.
Burnett Inlet. Etolin Island, Clarence Strait.

Calder Bay. Arm of Shaken Bay, Prince of Wales Island, Sumner Strait.
Camden, Port. Keku Strait, Kuiu Island, latitude 56° 40′.
Canoe Passage. Southeast of Etolin Island, Ernest Sound.
Carroll Inlet. Southern shore of Revillagigedo Island, Revillagigedo Channel.
Chacon, Cape. Southernmost point of Prince of Wales Island.
Chaik Bay. Southwestern shore of Admiralty Island, Chatham Strait, latitude 57° 20′.
Chatham Sound, British Columbia. Between Dundas Island and the mainland.
Chicagof Bay. Prince of Wales Island, Clarence Strait, just south of Moira Sound.
Chilkat River. The western one of the two great rivers entering the head of Lynn Canal.
Chilkoot River. The eastern one of the two rivers entering the head of Lynn Canal.
Cholmondeley Sound. East coast of Prince of Wales Island, Clarence Strait, latitude 55° 15′.
Cleveland Passage. Just north of Cape Fanshaw, Frederick Sound, latitude 57° 12′.
Clover Passage. Between Betton Island and Revillagigedo Island, Behm Canal.
Coco Harbor. Eastern shore of Dall Island.
Colpoys, Point. Northeastern point of Prince of Wales Island, Sumner Strait.
Copper River, British Columbia. Branch of the Skeena River.
Cordova Bay. Dixon Entrance, between Prince of Wales Island and Dall Island.
Crab Bay. Annette Island.
Craig. West coast of Prince of Wales Island, near Bucareli Bay.
Crawfish Inlet. West coast of Baranof Island, latitude 56° 45′.
Cross Sound. West of Inian Islands, Icy Strait.

Dall Head. Southern end of Gravina Island.
Dall Island. The most southwesterly one of the outer islands of the Prince of Wales Archipelago.
Davidson Point. East side of Klakas Inlet, Prince of Wales Island.
De Long Islands. Foggy Bay, Revillagigedo Channel.
Desconocida, Point. Southern point of Heceta Island.
Distant Point. Chatham Strait, southern point of entrance to Hood Bay, Admiralty Island, latitude 57° 24′.
Douglas Island. Northern end of Stephens Passage.
Driest Point. Western shore of Annette Island.
Duke Island. The most southerly of the larger islands between Clarence Strait and Revillagigedo Channel.
Duke Point. The eastern point of Duke Island.
Dunbar Inlet. Sukkwan Island, opening into Tlevak Strait.
Dundas Bay, point and shore. Northern shore of Icy Strait, near Inian Islands.
Dundas Island, British Columbia. Just south of the international boundary, longitude 130° 50′.

Eagle Creek. Northeastern shore of Prince of Wales Island, near Luck Point.
Eagle Point, Cordova Bay.
Eagle Point, Icy Strait. Northern shore of Chichagof Island, longitude 135° 38′.
Eaton Point. Cleveland Peninsula, Ernest Sound, latitude 55° 58′.
Edna Bay. Southern shore of Kosciusko Island.
El Capitan Passage. Between Prince of Wales and Kosciusko Islands.

False Point Retreat. Lynn Canal, about 2 miles south of the northern end of Admiralty Island.
Fanshaw, Cape, and Bay. Mainland, eastern shore of Frederick Sound, latitude 57° 10′.
Farragut Bay. Northern shore of Frederick Sound, longitude 133° 14′.
Fillmore Inlet. Dixon Entrance, between Cape Fox and Portland Canal.
Flaw Point. Western shore of Seymour Canal, about 10 miles from Stephens Passage.
Foggy Bay. Mainland, about 12 miles north of Cape Fox.
Foggy Point. Mainland, southern entrance to Foggy Bay.
Fox, Cape. Mainland, at Dixon Entrance.
Frederick, Point. Northeastern shore of Mitkof Island, Frederick Sound.
Funter Bay. Admiralty Island, Chatham Strait, latitude 58° 15′.

Gambier Bay. Eastern coast of Admiralty Island, Stephens Passage, latitude 57° 28′.
Gardner, Point. Southernmost point of Admiralty Island, Chatham Strait.
Gastineau Channel. Between mainland and Douglas Island, Stephens Passage.
Gedney Harbor. Western shore of Kuiu Island, Chatham Strait.
George Inlet. Southwestern shore of Revillagigedo Island.
Grant Creek. Northern end of Gravina Island.
Grant Island. About 8 miles from Clarence Strait, northern entrance to Behm Canal.
Gravina Island. Clarence Strait, latitude 55° 20′.
Gravina Point. The easternmost point of Gravina Island.
Grenville Channel, British Columbia. Between the mainland and Pitt Island.
Grindall Point. Northern point of entrance to Kasaan Bay, Clarence Strait, Prince of Wales Island.
Ground Hog Bay. Near Juneau, Gastineau Channel.
Gull Cove. Southern shore of Icy Strait, eastern point of entrance to Idaho Inlet.
Gustavus, Point. Northern shore of Icy Strait, longitude 135° 47′.

Halibut Creek. West shore of Clarence Strait, Prince of Wales Island, just south of entrance to Cholmondeley Sound.
Halibut Harbor. Southwestern shore of Kosciusko Island, Prince of Wales Archipelago.
Halibut Nose. Western coast of Prince of Wales Island, near the northern end of Dall Island.
Hamilton Bay. Western shore of Kupreanof Island, Keku Strait.
Hassler Harbor. Northeastern shore of Annette Island, Revillagigedo Channel.
Hawk Inlet. Western shore of Admiralty Island, Icy Strait.
Hayes, Point. Northern point of entrance to Peril Strait, Chatham Strait.
Haystack, British Columbia. Near Wales Island, entrance to Portland Inlet.
Heceta Island. Prince of Wales Archipelago, latitude 55° 45′.
Hessa Inlet. West coast of Prince of Wales Island, near southern end.
Higgins, Point. Westernmost point of Revillagigedo Island.
Highland, Point. Mainland, northern shore of Frederick Sound, between Cape Fanshaw and Farragut Bay.
Hobart Bay and Point. Mainland, Stephens Passage, next bay south of Windham Bay.
Hole-in-the-Wall. Northwestern coast of Prince of Wales Island, latitude 56° 15′.
Holland Rock, British Columbia. Near entrance to the Skeena River.
Hood Bay. Western shore of Admiralty Island, latitude 57° 23′.
Hoonah. Southern shore of Icy Strait, longitude 135° 25′.
Hooniah Sound. Southern shore of Chichagof Island, Peril Strait.
Houghton, Port. Mainland, Stephens Passage, near the southern end.
Hourigan Point. Near Kingsmill Point, northwestern point of Kuiu Island.
Hydaberg. Western shore of Prince of Wales Island, north of Sukkwan Island.

Idaho Inlet. Chichagof Island, Icy Strait, longitude 136° 15′.
Ildefonso Point. Western coast of Prince of Wales Island, latitude 55° 36.′
Inian Island. Near the western entrance of Icy Strait.
Island Point. There are at least six in the region covered by this report; occasionally one can be positively identified.

Kah Shakes Point and Cove. Mainland, Revillagigedo Channel, latitude 55° 04′.
Kah Sheets Bay. Southern shore of Kupreanof Island.
Kaigani Point. Southernmost point of Long Island, Cordova Bay.
Kanagunut Island. Dixon Entrance, southeast of Cape Fox.
Kasaan Bay. Eastern coast of Prince of Wales Island, latitude 55° 25′.
Kasook Inlet. Indenting the southern shore of Sukkwan Island, Cordova Bay.
Kassa Inlet. Western coast, Prince of Wales Island, latitude 54° 55′.
Keku Strait. Between Kuiu and Kupreanof Islands.
Kell Bay. In Affleck Canal, southern end of Kuiu Island.
Kendrick Bay. Eastern shore of Prince of Wales Island, Clarence Strait, about 10 miles above Cape Chacon.
Khutzeymateen Inlet, British Columbia. An arm of Portland Inlet, about 10 miles from Dixon Entrance.
Kincolith Bar, British Columbia. Near the mouth of the Nass River.
Kingsmill Point. The northwestern point of Kuiu Island.
Kirk Point. Northern point of entrance to Foggy Bay, Revillagidedo Channel.
Kitkatlah Inlet, British Columbia. Western coast of Porcher Island, off the mouth of the Skeena River.
Klakas Inlet. West coast of Prince of Wales Island, latitude 55° 00′.
Klawak Inlet. West coast of Prince of Wales Island, latitude 55° 33′.
Klukwan. Indian village on the Chilkat River.

Lake Bay. Northeastern shore of Prince of Wales Island, Clarence Strait, latitude 56° 00′.
Larch Bay. Western shore of Baranof Island, near Cape Ommaney.
Leading Point, British Columbia. Exact location doubtful.
Lemesurier Point. Cleveland Peninsula, the northern point on Clarence Strait.
Line Point. Prince of Wales Island, east of Sukkwan Island.
Limestone Inlet. Mainland, Stephens Passage, latitude 58° 02′.
Lincoln Rock. Clarence Strait, between Etolin and Prince of Wales Islands, latitude 56° 03′.
Luck Point. Eastern shore of Prince of Wales Island, latitude 55° 59′.
Lucky Cove. Revillagigedo Island, Revillagigedo Channel, just north of Point Alava.
Lyman Point. Prince of Wales Island, Clarence Strait, latitude 55° 33′.
Lynch, Cape. The western point of Heceta Island.
Lynn Canal. Extending north from Admiralty Island.

McCartney, Point. Keku Strait, northwestern point of Kupreanof Island.
McDonald, Lake. Tributary to Yes Bay, Behm Canal.
McHenry Inlet. Etolin Island, Clarence Strait, latitude 56° 00′.
McLean Point. Southern point of entrance to McLean Arm, Clarence Strait, just north of Cape Chacon.
McLeod Bay. Just north of Cape Muzon, Cordova Bay.
Mallard Bay. East coast of Prince of Wales Island, 5 miles north of Cape Chacon.
Malmesbury, Port. Western coast of Kuiu Island, latitude 56° 20′.
Marble Bluffs. Western shore of Admiralty Island, latitude 57° 43′.
Marsden, Point. Northwestern shore of Admiralty Island, just south of Hawk Inlet.
Marsh Island. Near Etolin Island, Clarence Strait, latitude 56° 06′.
Marten Arm. Branch of Boca de Quadra.
Metlakatla. Native village on west coast of Annette Island.
Meyers Island. Near Cleveland Peninsula, Clarence Strait, just south of Ernest Sound.
Moira Sound. Eastern coast of Prince of Wales Island, latitude 55° 02′.

Mountain Point. Eastern shore of Kupreanof Island, Wrangell Strait; also on Revillagigedo Island, near the upper end of Annette Island.
Muzon, Cape. Southernmost point of Dall Island.

Nakat Bay. Just east of Cape Fox, Dixon Entrance.
Naked Island. Near Funter Bay, at the southern end of Lynn Canal.
Narrow Point. East coast of Prince of Wales Island, Clarence Strait, latitude 55° 48′.
Nasoga Gulf. Portland Inlet, British Columbia.
Nass River. Entering Portland Inlet, British Columbia.
Niblack, Point. Cleveland Peninsula, Clarence Strait, latitude 55° 32′.
Nichols Bay. Southern end of Prince of Wales Island.
Nichols Passage. Between Gravina and Annette Islands.
North Passage Point. Chichagof Island, Chatham Strait, 12 miles south of Point Augusta.
Northumberland, Cape. Southern end of Duke Island.
Northwest Cove. Cleveland Peninsula, 2 miles north of Ship Island, Clarence Strait.
Noyes Island. Prince of Wales Archipelago, latitude 55° 28′, longitude 133° 45′.
Nutkwa Inlet. Western coast of Prince of Wales Island, latitude 55° 00′.

Ommaney, Cape. Southern point of Baranof Island.
Onslow Island. Clarence Strait, near entrance to Ernest Sound.

Peril Strait. Between Chichagof and Baranof Islands.
Petersburg. Town at the northern end of Mitkof Island, Frederick Sound.
Pillar Bay. Western shore of Kuiu Island, latitude 56° 40′.
Pleasant Island. Icy Strait, longitude 135° 40′.
Pole, Cape. Western point of Kosciusko Island, Prince of Wales Archipelago.
Porpoise Islands. Icy Strait, just east of Pleasant Island.
Portage Bay. Kupreanof Island, Frederick Sound, longitude 133° 20′.
Portland Canal. Boundary between Alaska and British Columbia, between latitude 54° 50′ and 56° 00′.
Portland Inlet. In British Columbia, just southeast of Portland Canal.
Prince of Wales Archipelago. The group of islands between Dixon Entrance and Sumner Strait, including Prince of Wales Island and the smaller islands to the westward.
Prolewy Point. Eastern point of Kupreanof Island, Frederick Sound.
Pybus Bay. Southeastern shore of Admiralty Island, Frederick Sound.

Quiet Harbor. Northwestern shore of Etolin Island, Stikine Strait.

Red Bay. Northern shore of Prince of Wales Island, Sumner Strait.
Reid Bay. Eastern shore of Kuiu Island, Sumner Strait, latitude 56° 22′.
Retreat, Point. Northernmost point of Admiralty Island.
Rocky Islet. At the eastern entrance to Icy Strait.
Rocky Pass. Same as Keku Strait.
Rodman Bay. Northern shore of Baranof Island, Peril Strait.
Roe Point. Mainland, Behm Canal, 10 miles from the southern entrance.
Rudyard Bay. Mainland, Behm Canal, 25 miles from the southern entrance.
Ruins Point. Western coast of Kosciusko Island, latitude 56° 04′.

Salmon Bay. Northeastern shore of Prince of Wales Island, near junction of Clarence and Sumner Straits.
Sand Point. Northern shore of Whitewater Bay, Admiralty Island, Chatham Strait, latitude 57° 10′.
Screen Islands. Clarence Strait, near Etolin Island, latitude 56° 06′.
Seal Cove. Eastern shore of Gravina Island.
Sealed Passage. Between Annette and Duke Islands.
Seclusion Harbor. Kuiu Island, near southern entrance of Keku Strait.
Security Bay. Northwestern shore of Kuiu Island, just east of Kingsmill Point.
Seymour Canal. The large inlet on the eastern side of Admiralty Island.

Shakan Bay. Northwestern shore of Prince of Wales Island, Sumner Strait.
Shawlatlans, British Columbia. Near Prince Rupert.
Ship Island. Clarence Strait, near Cleveland Peninsula, latitude 55° 35′.
Ship Islands. Cordova Bay.
Ship Islet. Tamgas Harbor.
Shipley Bay. Western shore of Kosciusko Island.
Sisters Islands, The. Icy Strait, northwest of Point Augusta.
Sitklan Island. Dixon Entrance, east of Cape Fox.
Sitkoh Bay. Chichagof Island just north of the eastern entrance to Peril Strait.
Skeena River, British Columbia. About 35 miles south of the international boundary.
Skowl Point. Southern point of entrance to Skowl Arm, Kasaan Bay.
Slate Island. Revillagigedo Channel, near entrance to Boca de Quadra.
Slocum Arm. Southwestern shore of Chichagof Island, just north of the western entrance to Peril Strait.
Smeaton Bay. Mainland, Behm Canal, latitude 55° 18′.
Smuggler Cove. Western shore of Annette Island.
Snow Passage. Clarence Strait, along western shore of Zarembo Island.
Soda Bay. West coast of Prince of Wales Island, opposite the northern end of Dall Island.
Somerville Bay. Eastern end of Somerville Island, Portland Inlet, British Columbia.
South Passage Point. Eastern shore of Chichagof Island, Chatham Strait.
Staney Creek. Southern end of El Capitan Passage.
Stanhope, Point. Clarence Strait, latitude 56° 02′.
Steamer Bay and Rocks. Western shore of Etolin Island, Clarence Strait.
Steamer Passage. Near the mouth of Portland Inlet, British Columbia.
Stephens Passage. East of Admiralty Island.
Stevenson Island. In Lake Bay, Kashevarof Passage, northeast of Prince of Wales Island.
Stikine River. Mainland, opposite Mitkof Island, latitude 56° 40′.
Stikine Strait. Between Etolin and Zarembo Islands.
Stone Rock Bay. Just north of Cape Chacon, Clarence Strait.
Strait, Cape. Northeastern point of Kupreanof Island, Frederick Sound.
Streets Island. Clarence Strait, just north of Kasaan Bay, Prince of Wales Island.
Sunset Island. Near Windham Bay, Stephens Passage.
Surge Bay. Western shore of Yakobi Island, just south of the western entrance to Cross Sound.
Suter Creek. At the southern entrance to El Capitan Passage, Prince of Wales Island.
Sykes Point. Mainland, at the junction of Behm Canal and Revillagigedo Channel.

Taku Inlet. Indenting the mainland at the northern end of Stephens Passage.
Tamgas Harbor. Indenting the southern shore of Annette Island.
Tebenkof Bay. Western shore of Kuiu Island, Chatham Strait, latitude 56° 30′.
Tee Harbor. Eastern shore of Lynn Canal, latitude 58° 25′.
Thatcher, Point. Southern point of entrance to Peril Strait, Chatham Strait.
Thorne Arm. Indenting the southwestern shore of Revillagigedo Island.
Three Mile Arm. Kuiu Island, near the southern entrance to Keku Strait.
Tlevak Strait. East of Dall Island, Prince of Wales Archipelago.
Tokeen Bay. Southern shore of Kosciusko Island.
Tombstone Bay. Western shore of Portland Canal, latitude 55° 24′.
Tongass Passage. Between Sitklan and Wales Islands, Dixon Entrance.
Totem Bay. Southern shore of Kupreanof Island, Sumner Strait.
Traitors Cove. Western shore of Revillagigedo Island, Behm Canal.
Tree Point. Mainland, Revillagigedo Channel, a few miles north of Cape Fox.
Trout Creek. Near Ruins Point.
Tucks Inlet, British Columbia. Exact location doubtful.
Tuxekan Passage. West coast of Prince of Wales Island, latitude 55° 50′.

Union Bay and Point. Just east of the western point of Cleveland Peninsula, Ernest Sound.

Vallenar Bay. North end of Gravina Island, Clarence Strait.
Vixen Inlet. Cleveland Peninsula, Ernest Sound.

Walden Point. Northwest end of Annette Island.
Wales Passage and Island, British Columbia. Lower end of Portland Inlet.
Walter, Port. Eastern shore of Baranof Island, Chatham Strait, latitude 56° 23′.
Ward Cove. Southwestern shore of Revillagigedo Island, just north of Ketchikan.
Warde, Point. Cleveland Peninsula, near the northern end of Ernest Sound, latitude 56° 10′.
Wark Channel, British Columbia. The arm of Portland Inlet nearest Dixon Entrance.
Warmchuck Inlet. Indenting southern shore of Heceta Island, Prince of Wales Archipelago.
Warren Island. Just west of Kosciusko Island, entrance to Sumner Strait.
Warren Cove. Eastern shore of Warren Island.
Warren Channel. Between Warren Island and Kosciusko Island.
Washington Bay. Western shore of Kuiu Island, about 10 miles south of Kingsmill Point.
Watkins, Point. Cleveland Peninsula, near the upper end of Ernest Sound.
Webster, Point. Prince of Wales Island, Cordova Bay, latitude 54° 58′.
Whale Bay. Southwestern shore Baranof Island, latitude 56° 40′.
Whale Passage. Between Prince of Wales and Thorne Islands, northeastern coast of Prince of Wales Island, latitude 56° 03′.
White, Point. Western end of Duke Island.
Windfall Harbor. Near the upper end of Seymour Canal, Admiralty Island.
Windham Bay. Mainland, Stephens Passage, latitude 57° 33′.
Woewoodski Harbor. Southern shore of Admiralty Island, Frederick Sound.
Wrangell Narrows or Strait. Between Mitkof and Kupreanof Islands.

Yellow Island. Tamgas Harbor, Annette Island.
Yes Bay. Cleveland Peninsula, Behm Canal, latitude 55° 55′.

In giving the localities where tagged fish were captured, local names, which we have been unable to identify, were used occasionally. As these cases were comparatively few, they have been omitted from detailed consideration and have been included among those records with which no data were submitted.

Tagging operations were conducted in localities at or near the main channels through which the fish must pass in entering southeastern Alaska from the Pacific Ocean. The primary object of the experiments was to discover the main routes of salmon migration through the maze of channels of the Alexander Archipelago and the distribution of the fish following these routes to the various spawning grounds. It was expected, also, that the experiments would yield information relative to the rate of migration of various species in various localities at various times. In so far as the routes of migration are concerned the results obtained were fairly satisfactory; but in many cases so few returns were received from any one locality that the data as to the time that elapsed between tagging and recapture are not reliable enough to warrant detailed analysis.

The time available for the preparation of this report was not sufficient to permit as complete and careful an analysis as is desirable. For various reasons, however, it seemed important to present the available facts without delay, and as the experiments will be continued in subsequent years a more detailed analysis can be deferred until more data are at hand.

EXPERIMENTS IN SOUTHEASTERN ALASKA

TAGGING RECORD

The following table gives the data for the tags attached in southeastern Alaska in 1924 and 1925. In cases where the numbers of fish tagged do not agree with the figures in the column headed "Serial numbers," the discrepancy is due to the loss or breaking of some of the tags.

TABLE 1.—*Tags attached in southeastern Alaska in 1924 and 1925*

Experiment No.	Serial Nos.	Number of fish tagged	Species	Locality	Date
1924					
1	3001–3015	3	Red	Inian Island, Cross Sound	July 7
		1	Coho		
		4	Pink		
		5	Chum		
2	2001–2150	72	Red	Ruins Point, Sumner Strait	July 12
		37	Coho		
		3	Pink		
		37	Chum		
3	3016–3218	37	Red	Inian Island, Cross Sound	July 14
		133	Pink		
		31	Chum		
4	2151–2300	18	Red	Ruins Point, Sumner Strait	July 19
		82	Coho		
		16	Pink		
		34	Chum		
5	2301–2625	27	Red	do	July 27
		90	Coho		
		193	Pink		
		15	Chum		
6	2626–2871	120	Red	do	Aug. 3
		41	Coho		
		38	Pink		
		47	Chum		
7	4001–4600	1	Red	3 miles east of Cape Bendel, Frederick Sound	Aug. 4
		3	Coho		
		573	Pink		
		20	Chum		
8	4601–5000	5	Red	4 miles south of Kingsmill Point, Chatham Strait	Aug. 7
		5	King		
		12	Coho		
		353	Pink		
		25	Chum		
9	1–25	2	Red	West end of Kanuganut Island, Nakat Bay	Do.
		22	Pink		
10	26–300	36	Red	2 miles north of Tree Point, Revillagigedo Channel	Aug. 8
		203	Pink		
		32	Chum		
11	301–600	5	Red	Duke Point, Revillagigedo Channel	Do.
		288	Pink		
		2	Chum		
12	601–800	3	Red	1 mile north of Point White (Duke Island), Clarence Strait	Aug. 9
		194	Pink		
		2	Chum		
13	2872–2970	13	Red	Ruins Point, Sumner Strait	Aug. 10
		86	Chum		
14	2971–2988	18	do	do	Aug. 17
1925					
1	1–206	161	Red	South shore of Pleasant Island, Icy Strait	June 23
		7	Coho		
		1	Pink		
		33	Chum		
2	207–400	104	Red	do	June 24
		29	Coho		
		4	Pink		
		54	Chum		
3	401–800	114	Red	Inian Island, Cross Sound	June 25
		64	Coho		
		152	Pink		
		66	Chum		
4	801–1080	58	Red	do	June 27
		22	Coho		
		153	Pink		
		45	Chum		
5	1081–1152	17	Red	Point Adolphus, Icy Strait	July 1
		1	Coho		
		35	Pink		
		19	Chum		
6	1153–1400	44	Red	Eagle Point, Icy Strait	Do.
		10	Coho		
		10	Pink		
		182	Chum		
7	1401–1881	22	Red	Hourigan Point, Frederick Sound	July 10
		41	Coho		
		152	Pink		
		264	Chum		
8	1882–2500	66	Red	5 miles south of Kingsmill Point, Chatham Strait	July 11
		111	Coho		
		245	Pink		
		195	Chum		

TABLE 1.—*Tags attached in southeastern Alaska in 1924 and 1925*—Continued

Experiment No.	Serial Nos.	Number of fish tagged	Species	Locality	Date
1925					
9	2501-2793	16	Red	5 miles south of Kingsmill Point, Chatham Strait	July 14
		28	Coho		
		96	Pink		
		153	Chum		
10	2794-3350	27	Red	3 miles south of Kingsmill Point, Chatham Strait	July 15
		98	Coho		
		46	Pink		
		384	Chum		
11	3351-3540	20	Red	Ruins Point, Sumner Strait	July 18
		46	Coho		
		54	Pink		
		69	Chum		
12	3541-4119	53	Red	do	July 20
		117	Coho		
		119	Pink		
		289	Chum		
13	4120-4600	59	Red	do	July 21
		181	Coho		
		156	Pink		
		84	Chum		
14	4601-5400	89	Red	do	July 22
		276	Coho		
		296	Pink		
		136	Chum		
15	5401-6000	37	Red	do	July 24
		159	Coho		
		373	Pink		
		30	Chum		
16	6001-6600	105	Red	do	July 25
		200	Coho		
		219	Pink		
		75	Chum		
17	6601-7200	14	Red	Foggy Point, Revillagigedo Channel	July 30
		53	Coho		
		503	Pink		
		28	Chum		
18	7201-7800	31	Red	do	July 31
		26	Coho		
		540	Pink		
		3	Chum		
19	7801-8016	34	Red	Stone Rock Bay, Clarence Strait	Aug. 8
		17	Coho		
		51	Pink		
		114	Chum		
20	8017-8700	68	Red	do	Aug. 9
		24	Coho		
		504	Pink		
		88	Chum		
21	8701-9360	4	Red	Cape Chacon, Clarence Strait	Aug. 11
		3	Coho		
		637	Pink		
		16	Chum		
22	9361-10000	9	Red	Stone Rock Bay, Clarence Strait	Aug. 12
		6	Coho		
		609	Pink		
		15	Chum		
23	10001-10560	6	Red	Cape Chacon, Clarence Strait	Aug. 13
		7	Coho		
		540	Pink		
		7	Chum		
24	10561-11160	1	Red	Cape Muzon, Cordova Bay	Aug. 15
		1	Coho		
		595	Pink		
		1	Chum		
25	11161-11760	2	Coho	Kaigani Strait, 1 mile north of Kaigani Point, Cordova Bay	Aug. 16
		594	Pink		
		3	Chum		
26	11761-12360	597	Pink	do	Aug. 17
		3	Chum		
27	12361-12530	170	Pink	do	Aug. 18
28	12531-13080	2	Red	do	Aug. 21
		1	Coho		
		546	Pink		
		1	Chum		
29	13081-13680	4	Red	Cape Muzon, Cordova Bay	Aug. 22
		12	Coho		
		547	Pink		
		37	Chum		

RETURNS FROM EXPERIMENTS IN ICY STRAIT

RED SALMON

The returns from the tagging experiments conducted in Icy Strait are presented in Table 2.

TABLE 2.—*Returns from red salmon tagged in Icy Strait*

[In this and subsequent tables the figures in the columns headed "Time" indicate, in days, the least and the greatest time that elapsed between tagging and reported recapture]

Locality of recapture	Locality and date of tagging														Total number returned
	1924: Inian Island, July 14		1925												
			Pleasant Island				Inian Island				Point Adolphus, July 1		Eagle Point, July 1		
			June 23		June 24		June 25		June 27						
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Surge Bay			1	7					1	7					2
Icy Strait:															
Dundas Point and Bay					1	3	1	4	1	2					3
Pleasant Island			2	2–5									1	5	3
Pleasant or Sisters Islands[1]			22	0–7	19	0–6	7	0–5	10	0–3	3	(2)	6	(2)	67
Sisters Islands	1	7													1
Eagle Point	[3]1	3					1	8							2
Point Gustavus			2	3	1	2									3
Near Porpoise Island					1	2							2	1–5	3
10 miles west of Point Augusta							1	42	1	40	2	8–9	1	9	5
Near Rocky Island, eastern entrance to Icy Strait					1	2	4	8–13					1	3	6
Chatham Strait:															
(No details)			1	18											1
Near Hawk Inlet									1	8			2	[3]2	3
Hawk Inlet							1	7							1
North of Passage Point							1	15							1
South of Passage Point			2	11–20	(?)	1	1	18	1	18					5
Marble Bluffs					1	42	1	18							2
Basket Bay									1	17			1	13	2
Sitkoh Bay			1	9											1
Frederick Sound									1	40			2	36–38	3
Lynn Canal:															
Lynn Canal, near Funter Bay									1	21					1
Funter Bay			1	(?)											1
Between Funter Bay and Point Retreat					1	13	1	6							2
False Point Retreat							1	15							1
Ground Hog Bay–Gastineau Channel							1	5							1
Naked Island–Lynn Canal							1	20							1
Tee Harbor							1	8							1
Chilkat River–Klukwan			1	(?)	1	(?)	1	(?)							3
Total	2		33		27		24		18		5		16		125
Percentage returned	5.4		20.5		26		21		31		29.4		36.4		23.4

[1] All the returns under this heading were obtained from one company, which, unfortunately, though perhaps unavoidably, had not kept accurate records of either the time or place of capture. All were reported as taken at either Pleasant or Sisters Islands between June 23 and 30.

[2] Taken either at Eagle Point or Gull Cove.

[3] One was recorded as taken on June 24—obviously an error.

These data indicate two main routes of migration for the fish entering southeastern Alaska through Icy Strait. Some of the fish turn southward upon reaching Chatham Strait and traverse this channel to its junction with Frederick Sound, where three of the tagged fish were taken. It is conceivable, of course, that the fish taken in Frederick Sound may have reached there by another route, passing around the north end of Admiralty Island and south through Stephens Passage, but the evidence certainly favors the other hypothesis. No doubt some of the fish taken along this route were destined to enter local spawning streams on Admiralty, Chi-Chigof, or Baranof Islands.

Other fish entering Icy Strait turn north on reaching Chatham Strait, traverse Lynn Canal, and in all probability find their spawning grounds in the Chilkat and Chilkoot Rivers at the head of the Canal. These rivers are noted for their red-salmon runs and probably are the two most important salmon streams in the northern part of southeastern Alaska. It is not surprising, therefore, that a migration to this region is indicated. Only one tagged fish was taken outside of Icy Strait or one or the other of these two main lines of migration. That was reported from Ground Hog Bay, near Juneau.

COHOES

A total of 133 cohoes was tagged in Icy Strait during 1925. Only 15 (11.3 per cent), representing only four experiments, were returned. The data are presented in Table 3.

TABLE 3.—*Returns from coho salmon tagged in Icy Strait in 1925*

Locality of recapture	Locality and date of tagging								Total number returned
	Pleasant Island				Inian Island, June 25		Eagle Point, July 1		
	June 23		June 24						
	Number	Time	Number	Time	Number	Time	Number	Time	
Icy Strait:									
Idaho Inlet			1	57					1
Pleasant or Sisters Islands [1]	2	0–7			1	0–5			3
Gull Cove					1	6			1
Point Gustavus							1	11	1
Near Rocky Islands							1	3	1
Chatham Strait:									
Near Hawk Inlet					1	4			1
Marble Bluffs			1	42	1	(?)			2
Basket Bay			1	30					1
Hood Bay			1	57					1
Crawfish Inlet					1	11			1
Sumner Strait: Point Colpoys							1	32	1
Stephens Passage: Auk Bay			1	22					1
Total	2		5		5		3		15
Percentage	28.6		17.2		7.8		30		

[1] See footnote 1 in Table 2 (p. 119).

The returns are too meager to show details of the migration from Icy Strait, but they indicate, unmistakably, that the main route is south in Chatham Strait. Only one fish went north, and it was retaken near the northern end of Stephens Passage. One returned to the open ocean and was retaken on the outside coast of Baranof Island at Crawfish Inlet, and one went to Sumner Strait.

Except for the fish recaptured in Icy Strait or the immediate vicinity, the time that elapsed between tagging and recapturing was noticeably longer than was the case with the red salmon. Most of the red salmon tagged in Icy Strait and retaken in Chatham Strait were captured less than 20 days after they were tagged, but most of the cohoes were free for a much longer time (30 to 57 days). The significance of this is not clear, but it seems probable that the cohoes were taken close to their spawning grounds, while the reds taken in Chatham Strait were destined for more distant streams. It has been shown conclusively (by the tagging experiments along the Alaska Peninsula) that salmon bound for distant streams travel at a more rapid rate than those bound for near-by spawning grounds. In this case the fact that the red salmon spawn somewhat earlier than the cohoes may also have influenced their more rapid progress.

PINK SALMON

As in the case of the reds and cohoes, the pink salmon tagged in Icy Strait showed a distinct migration southward in Chatham Strait and into the region of Frederick Sound. There can be little doubt that many of the fish were bound for local spawning grounds close to the place where they were recaptured. On the other hand, it is altogether probable that some were taken while en route to other spawning regions. It is quite impossible to determine what percentage was bound for strictly local spawning grounds and what for more distant streams. The only thing positively shown by these data is that the main migration route of the pinks found in Icy Strait during June was southward in Chatham Strait to Frederick Sound. A few individuals were taken north of the eastern entrance to Icy Strait in Chatham Strait and Lynn Canal, but it is apparent that the extent of this northerly migration was by no means as great in the case of the pinks as it was in the case of the red salmon. Two individuals passed out again into the open ocean and were taken along the western shores of Chichagof and Yakobi Islands. The data are presented in Table 4.

TABLE 4.—*Returns from pink salmon tagged in Icy Strait*

Locality of recapture	Locality and date of tagging										Total number returned
	1924: Inian Island				1925						
					Inian Island				Point Adolphus, July 1		
	July 7		July 14		June 25		June 27				
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Surge Bay					1	9					1
Icy Strait:											
Dundas Shore (Icy Strait)							1	20			1
Near Inian Island	1	5			2	11–16	1	3			4
Pleasant Island			4	1–2	1	5					5
Pleasant or Sisters Islands [1]					4		8	0–3	2	(?)	14
Eagle Point or Gull Cove			[2] 3	3	2	6–8					5
Point Gustavus					1	6					1
Near Porpoise Island							1	12			1
Point Augusta			3	7–9	1	41	1	40	1	9	6
Rocky Island							5	5–6			5
Chatham Strait:											
(No details)							1	25			1
Near Hawk Inlet					2	8–9	3	6–10			5
North of Passage Point							1	19			1
South of Passage Point									1	14	1
Marble Bluffs							1	39			1
Point Hayes							1	35			1
Distant Point							1	11	1	7	2
Frederick Sound:											
Near Point Brightman					2	22					2
Pybus Bay									1	23	1
Stephens Passage: Windham Bay							1	28			1
Lynn Canal:											
Near Funter Bay							2	5–8			2
Funter Bay							1	19			1
False Point Retreat					1	(?)					1
(No details)									1	37	1
Slocum Arm							1	11			1
Doubtful locality			1	15			4	2–10	1	9	6
Total	1		11		17		34		8		71
Percentage	25		7.9		11.2		22.2		22.8		14.5

[1] See footnote 1 to Table 2 (p. 119).
[2] Date lacking in the case of 1 fish.

CHUMS

The returns from the tagging of chum salmon in Icy Strait are given in Table 5. This species is somewhat more widely scattered than any of the others, but the essential features of the distribution are the same, the main route of the migration being south in Chatham Strait and thence to Frederick Sound. The wider distribution of this species is indicated by the records of tags taken in Rodman Bay and Hooniah Sound, Peril Strait; in Keku Strait; in Chatham Strait, south of the western entrance to Frederick Sound; in Sumner Strait; and at Cape Lynch, on Heceta Island. There is also evidence of a relatively unimportant northerly migration from Icy Strait into the region of Stephens Passage.

TABLE 5.—*Returns from chum salmon tagged in Icy Strait*

Locality of recapture	Locality and date of tagging														Total number returned
	1924, Inian Island, July 14		1925												
			Pleasant Island				Inian Island				Point Adolphus, July 1		Eagle Point, July 1		
			June 23		June 24		June 25		June 27						
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Icy Strait:															
Inian Island							1	10							1
South shore of Icy Strait (no details)	1	4													1
Pleasant or Sisters Islands[1]					1	0-6	3	3			1	(?)	4	22-29	9
Port Althorp													1	11	1
Hoonah			1	38									2	30	3
Point Adolphus													1	9	1
Eagle Point													2	2	2
Gull Cove													1	9	1
Point Gustavus													1	11	1
Near Porpoise Island					1	12									1
Point Augusta							1	42	1	37					2
Near Rocky Island					2	9-13							2	1-6	4
Chatham Strait:															
Hawk Inlet									2	13					2
(No details)					1	28	1	27							2
Near Hawk Inlet													1	3	1
Point Marsden											1	1			1
South of Passage Point													1	5	1
Marble Bluffs											1	(?)	1	35	2
Basket Bay							1	19					4	13-29	5
Near Peril Strait													2	20-30	2
Chalk Bay													1	35	1
Near Kingsmill Point							1	33							1
Tebenkof Bay													1	21	1
Peril Strait:															
Rodman Bay													1	22	1
Hoonah Sound							1	30							1
Cape Lynch													1	51	1
Frederick Sound:															
Pybus Bay													1	17	1
Frederick Sound											1	38			1
Port Houghton							1	29							1
Point Frederick			1	18											1
Keku Strait:															
Point McCartney													1	31	1
Hamilton Bay													1	32	1
Point Colpoys	1	27													1
Lynn Canal:															
Near Funter Bay					1	9	1	23							2
Tee Harbor					1	14									1
Taku Inlet							1	16							1
No locality given													2	6	2
Total	2		2		7		12		3		4		32		62
Percentage	6.4		6.1		13.0		18.2		6.6		21.0		17.6		14.4

[1] See footnote 1 to Table 2 (p. 119).

RETURNS FROM EXPERIMENTS IN FREDERICK SOUND

One red salmon, 3 cohoes, 20 chums, and 573 pink salmon were tagged at Cape Bendel, Frederick Sound, on August 4, 1924. None of the reds or cohoes were returned. Seven of the chums were recovered, five near the point of tagging. Two were taken in Hamilton Bay, Keku Strait, on August 7 and 11, and one each from near Woewoodski Harbor on August 16, the southern end of Admiralty Island on August 10, and at Kingsmill Point (date uncertain, recorded as taken July 29). One was taken on August 13 at Nakat Bay, east of Cape Fox, and one was recorded from "Kadakes" Bay, an unidentified locality, possibly Kah Shakes Cove on the mainland north of Cape Fox.

PINK SALMON

The returns of tagged pink salmon are given in Table 6. The distribution of these fish was mainly through Frederick Sound and north along Stephens Passage as far as Douglas Island. A sufficient number was taken to the westward of Cape Bendel (especially along the western shore of Kuiu Island) to indicate a definite movement in this direction. A few passed northward in Chatham Strait and were taken in Icy Strait near Point Augusta, but so few did this that it seems possible that the records are in error, especially as none were taken in Chatham Strait between Frederick Sound and Icy Strait. Others went south, either in Chatham Strait or through Kuiu Strait, and were taken in the region of Sumner Strait, along the east coast of Kuiu Island and the northern part of Prince of Wales Island.

TABLE 6.—*Returns from pink salmon tagged near Cape Bendel, August 4, 1924*

Locality of recapture	Number	Time	Locality of recapture	Number	Time
Frederick Sound:			Stephens Passage—Continued.		
Point Brightman	7	7–9	Limestone Inlet	6	[2] 2–7
2 miles northeast of Woewoodski Harbor	7	2–8	Douglas Island	5	4–27
Pybus Bay	7	[1] 0–7	Icy Strait: 4 miles west of Point Augusta	4	5
9 miles north of Cape Bendel	3	[illegible] 1	Keku Strait: Hamilton Bay	2	2–8
Cape Fanshaw	2	[illegible] 5	Chatham Strait: West shore of Kuiu Island	15	[3] 6–14
Bay Point	2	[illegible] 5	Sumner Strait:		
Portage Bay	4	[illegible]6–7	Point Colpoys	5	9–13
Between Cape Bendel and Portage Bay	1	[illegible] 3	Eagle Creek, northwest shore, Prince of Wales Island	1	8
Cape Strait	8	[illegible]7–8	Kell Bay, Affleck Canal	2	22
4 miles north of Prolewy Point	3	5	Bear Harbor, Affleck Canal	2	10
12 miles north of Petersburg	3	3–11	Kadakes Bay [4]	3	2–5
Farragut Bay	1	4	Shelter Cove [4]	5	[3] 2–7
North end of Wrangell Narrows	1	12	Scow Bay [4]	1	7
Stephens Passage:			Sukoi Island [4]	1	8
Port Houghton	16	2–7			
Hobart Bay and Point	8	2–12	Total	139	
Gambier Bay	2	[1] 4	Percentage	24.2	
Windham Bay	10	7–9			
Seymour Canal, south end	2	7			

[1] One recorded as taken before tagged.
[2] Three recorded as taken before tagged.
[3] Two recorded as taken before tagged.
[4] Unidentified localities.

RETURNS FROM EXPERIMENTS IN CHATHAM STRAIT

Five tagging experiments were conducted in Chatham Strait at or near Kingsmill Point, on the northwestern shore of Kuiu Island, one on August 7, 1924, and four between July 10 and 15, 1925. Most of the first lot of fish tagged were pinks (353 out of a total of 400). In 1925, however, more chums than pinks were tagged, and fairly good samples of both reds and cohoes were also included. As the experiments of 1925 were undertaken about three weeks earlier in the season than in 1924, it is of

interest to compare the results in the two years, although this can not be done fairly with any species except the pink salmon on account of the poor representation of the other species in the 1924 experiment.

RED SALMON

The returns for the red salmon tagged at Kingsmill Point are given in Table 7. The majority of the recaptures were made in Frederick Sound and Stephens Passage, as far north as Taku Inlet. Four fish were taken in the Stikine River; and this, together with the fact that relatively numerous returns were received from Frederick Sound, indicates that the Stikine River is the source of an important part of the red-salmon run entering southeastern Alaska through Chatham Strait and Frederick Sound. Other tagged reds were taken in the southern part of Chatham Strait along the western coast of Kuiu Island, and three were taken in the southern part of Clarence Strait near Dixon Entrance. These returns indicate a southerly migration of minor importance, possibly to the Nass and Skeena Rivers.

TABLE 7.—*Returns from red salmon tagged at Kingsmill Point*

Locality of recapture	Locality and date of tagging										Total number returned
	1924: 4 miles south of Kingsmill Point, Aug. 7		1925								
			Hourigan Point, July 10		Kingsmill Point						
					July 11		July 14		July 15		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Frederick Sound:											
Kingsmill Point					1	5			2	4	3
Hamilton Bay	2	6-9									2
Point McCartney					1	49					1
Point Brightman									1	18	1
Woewoodski Harbor			1	18							1
Fanshaw Bay									1	7	1
Stephens Passage:											
Port Houghton					1	21					1
Windham Bay					2	6-11					2
Seymour Canal					1	9					1
Taku Inlet			1	7	2	6-10					3
Stikine River					3	[1] 9-10			1	19	4
Chatham Strait:											
Washington Bay									1	10	1
Tabenkof Bay			1	22	1	11					2
Port Malmesbury					1	35					1
Southern end of Clarence Strait:											
Point Adams							1	22			1
Driest Point					1	13					1
Foggy Bay					1	27					1
Total	2		3		15		1		6		27
Percentage	40		13.6		22.7		6.2		22.2		19.8

[1] One taken at Grand Rapids on Aug. 20.

COHOES

The returns from coho salmon tagged at Kingsmill Point, as given in Table 8, indicate a migration of considerable importance through Frederick Sound and probably to the Stikine River, where 6 of the 44 returns were secured. No fish were taken north of Frederick Sound in Stephens Passage. Others, however, were taken south of Frederick Sound in Chatham Strait, Keku Strait, Sumner Strait, along

the western shores of Prince of Wales Island, and along the shores of the southern part of Clarence Strait and Dixon Entrance, both in Alaskan and British Columbian waters. The southerly movement of cohoes from Kingsmill Point is well marked, 26 of the 44 returns being from this region. Some of these fish doubtless were bound for the Nass and Skeena Rivers, but it seems probable that others were on their way to local spawning streams.

TABLE 8.—*Returns from coho salmon tagged at Kingsmill Point in 1925*

Locality of recapture	Locality and date of tagging								Total number returned
	Hourigan Point, July 10		Kingsmill Point						
			July 11		July 14		July 15		
	Number	Time	Number	Time	Number	Time	Number	Time	
Frederick Sound:									
Hourigan Point	1	8					1	15	2
Security Bay	1	33	1	22			1	20	3
Point McCartney							1	15	1
Point Brightman			1	5					1
Pybus Bay			1	6					1
Frederick Sound			2	23					2
Cape Fanshaw	1	10							1
Stikine District:									
Stikine Flats			2	46–54	1	45	1	38	4
Stikine River							2	34–35	2
Chatham Strait:									
Kingsmill Point			2	10–15			2	8–33	4
Near Washington Bay	1	6							1
Tebenkof Bay			2	4–23	1	4	1	17	4
Cape Ommaney	1	19					1	64	2
Sumner Strait:									
Keku Strait							1	16	1
Snow Passage			1	24					1
Ruins Point			2	11–20			1	12	3
Bocas de Finas					1	16	1	14	2
Clarence Strait:									
Cape Chacon			1	38	1	33			2
Betton Island			1	34					1
Kanagunut Island			1	31					1
British Columbia:									
Prince of Wales Island	1	31							1
Steamer Passage			1	26					1
Burke Channel							1	58	1
Wark Channel							1	36	1
Doubtful locality							1		1
Total	6		18		4		16		44
Percentage	14.6		16.2		14.3		16.3		15.8

PINK SALMON

In the five experiments conducted at Kingsmill Point 892 pink salmon were tagged and 185 (20.7 per cent) were recaptured. The data are given in Table 9. As has been stated, the experiment of 1924 was made about three weeks later in the season than those of 1925. In spite of this the percentage of return was almost identical, although the distribution was different. In 1924 a very great majority of the recaptures were made close to the point of tagging and in near-by localities in Frederick Sound. In 1925 a distinct migration south in Chatham Strait was shown, which was not indicated in the results for 1924, and comparatively few fish were taken close to the point of liberation. In other respects the returns for the two years were practically the same. A slight movement north in Chatham Strait from Frederick Sound occurred, but the main migration was through Frederick

Sound and north in Stephens Passage as far as Taku Inlet. South of Kingsmill Point the fish were distributed mainly along the shores of Chatham Strait and Sumner Strait, with a scattering few along the mainland in Ernest Sound, Behm Canal, and at Cape Chacon. It is interesting to note that none were taken along the western shore of Prince of Wales Island or on the smaller islands of the Prince of Wales Island or on the smaller islands of the Prince of Wales Archipelago.

TABLE 9.—*Returns from pink salmon tagged at Kingsmill Point*

Locality of recapture	Locality and date of tagging										Total number returned
	1924: Kingsmill Point, Aug. 7		1925								
			Hourigan Point, July 10		Kingsmill Point						
					July 11		July 14		July 15		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Kingsmill Point	35	[1] 0–11	1	2	3	1–7	1	5			40
North in Chatham Strait:											
Distant Point	1	2			2	10–11					3
Marble Bluffs							1	22			1
Basket Bay					1	7	1	10			2
Frederick Sound:											
Hourigan Point					1	7					1
Security Bay			4	7–25	4	6					8
Point Brightman	5	4–6			1	15	1	12	1	18	8
Woewoodski Harbor			4	9–12	3	8–17					7
Hamilton Bay	4	5–6			4	11–35					8
Point McCartney					2	14–16	2	11–13			4
Cape Bendel	6	[2] 3–4									6
Pybus Bay	1	4							1	9	2
Frederick Sound			3	12–29	1	11					4
Cape Fanshaw	1	4									1
Portage Bay	2	4–5									2
Bay Point					1	21					1
Petersburg Creek	1	34									1
Stephens Passage:											
Point Hobart	1	1	1	20	2	17–18					4
Port Houghton	4	1–4	7	10–49			1	7	1	43	13
Sunset Island			1	16	2	11–15	2	8–10			5
Windham Bay	6	5	2	12–14	2	18–20	2	11–20			12
Seymour Canal			1	6	2	9–16	1	16			4
Taku Inlet							1	7			1
Stikine District:											
Stikine Flats			1	17							1
Stikine River							1	98			1
South in Chatham Strait:											
Washington Bay							2	11–19			2
Pillar Bay			5	5–14	3	13–20	4	2–16	2	7–19	14
Tebenkof Bay			1	15			2	12	1	19	4
Port Walter					1	42					1
Sumner Strait:											
Kell Bay	1	19									1
Bear Harbor	1	7							1	22	2
Port Beauclerc			1	36			1	32			2
Ruins Point			1	21	2	11–20					3
Keku Strait	1	6					4	11–21			5
Totem Bay			1	20							1
Snow Passage									1	9	1
Cape Chacon					1	12	1	33–37			2
Anan Creek					1	21					1
Boca de Quadra									1	71	1
Sitklan Island					1	25					1
Unknown	4										4
Total	74		34		40		28		9		185
Percentage	21		22.4		16.3		29.1		19.6		20.7

[1] Four recorded as taken before date of tagging.
[2] Three recorded as taken before date of tagging.

CHUMS

As was the case with the pink salmon, a migration of minor importance was indicated north in Chatham Strait as far as Icy Strait. A much more important route of migration was through Frederick Sound and north in Stephens Passage as far as Seymour Canal; but the main distribution of chums from the region of Kingsmill Point appeared to be to the south, especially along the western shore of Kuiu Island and in Keku Strait, nearly three-fourths of the returns having been from these districts. A few returns came from Sumner Strait, the west coast of Prince of Wales Island, and two fish were recaptured at Revillagigedo Island. These fish, therefore, appear to be mainly of local origin, spawning in the numerous small streams along the intricate coast line where they were taken. The results from this experiment are shown in Table 10.

TABLE 10.—*Returns from chum salmon tagged at Kingsmill Point*

Locality of recapture	Locality and date of tagging										Total number returned
	1924: Kingsmill Point, Aug. 7		1925								
			Hourigan Point, July 10		Kingsmill Point						
					July 11		July 14		July 15		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
North in Chatham Strait:											
Point Gardner					1	5	1	7			2
Distant Point					3	3–15	1	8	2	7–11	6
Point Thatcher							1	4			1
Basket Bay			1	9							1
10 miles west of Point Augusta									2	19	2
Frederick Sound:											
Kingsmill Point	2	5–6									2
Hourigan Point			2	5–8			2	4	1	8	5
Security Bay			23	5–25	6	6–24	3	2–25	16	1–24	48
Point Brightman	1	6	1	17			1	12			3
Point McCartney					1	19	1	37	2	15–27	4
Pybus Bay			2	18	1	8	1	14			4
Near Woewoodski Harbor							2	5–14			2
Frederick Sound			1	10	1	4			1	8	3
Point Highland			1	16							1
Bay Point							1	18			1
Stephens Passage:											
Port Houghton							1	16			1
Hobart Bay					1	14					1
Near Sunset Island							1	10	2	11	3
Windham Bay					1	11	1	9	1	4	3
Seymour Canal					3	4–9					3
Keku Strait:											
Hamilton Bay			6	11–17			1	13	6	3–27	13
Port Camden					1	35					1
(No details)			10	10–28	9	7–21	5	11–19	11	6–28	35
South in Chatham Strait:											
Kingsmill Shore			16	2–13	10	4–15	7	2–7	21	2–13	54
Washington Bay			6	13–20							6
Pillar Bay			28	3–31	59	2–23	38	1–22	114	[2] 1–24	239
Tebenkof Bay			7	18–29	7	[1] 11–28	6	8–25	14	6–29	34
Gedney Harbor									1	15	1
Port Malmesbury							1	24	1	26	2
Bear Harbor			1	27			1	23	4	22	6
Sumner Strait:											
Reid Bay									1	15	1
Red Bay							1	13			1
Point Colpoys									1	8	1
El Capitan Passage									1	18	1
Shipley Bay									1	11	1
Ruins Point					1	26			1	7	2
Halibut Harbor			2	14					1	11	3
Bocas de Finas					1	20					1
Point Stanhope					1	29					1
Thorne Arm							1	18–27			1
Point Alava					1	30					1
Doubtful			1								1
Total	3		108		108		78		205		502
Percentage	12		40.9		55.3		51		53.4		50.4

[1] One with no date given.

[2] Three recorded as taken previous to tagging.

RETURNS FROM EXPERIMENTS IN SUMNER STRAIT

Twelve experiments were carried out at Ruins Point—six in 1924 and six in 1925. Fairly good series of each species were tagged, especially in 1925, and the results are of correspondingly increased value and interest. As comparatively few returns were obtained in 1924, it has not seemed worth while to show in detail the data for each experiment of that year; therefore those referring to the reds, cohoes, and pinks have been combined in the tables. There appear to be significant differences in the results obtained from the experiments with chum salmon during July as compared with those for August, 1924, and in the table (Table 14) the data for the two months have been kept separate. The returns for each experiment of 1924 were studied separately, and it is believed that no information of importance is obscured by combining the records.

One striking feature of the returns is the great number of localities from which tagged fish were recorded. This is doubtless due to the intensity of the fishing in this region as well as to the character of the gear used, a great many small purse seines having been operated in the numerous small bays as well as traps in the main channels.

RED SALMON

The data relative to the red salmon tagged at Ruins Point are given in Table 11. The main route of migration clearly is through Sumner Strait and south in Clarence Strait. Six fish were recorded as taken north of Ruins Point in the region of Chatham Strait and Frederick Sound, and 5 were taken along the west coast of Prince of Wales Island. The rest (with the exception of five doubtful records), 169 in all, were taken along this one main migration route, in the adjacent waters, and in British Columbia. Seven were taken in the Stikine River and 5 at the hatchery of the Bureau of Fisheries on Lake McDonald, tributary to Yes Bay. Two were taken in the Nass and 13 in the Skeena River. Other local streams also doubtless contributed to the run of reds in the region of Ruins Point.

TABLE 11.—*Returns from red salmon tagged at Ruins Point, Sumner Strait*

Locality of recapture	Locality and date of tagging														Total number returned
	1924: July 12 to Aug. 10		1925												
			July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Chatham Strait and Frederick Sound:															
Gedney Harbor													1	19	1
Tebenkof Bay							1	10							1
Point Brightman					1	7			1	11					2
Sand Point	1	(?)													1
Portage Bay	1	8													1
Sumner Strait:															
Ruins Point					2	6	1	9	2	1-8	1	0-3	3	0-7	9
Shipley Bay	18	[1] 0-12													18
Shakan Bay	2	[2] 24													2
Affleck Canal	1	23													1
Reid Bay			1	12											1
Red Bay							3	3-6	2	2					5
Point Colpoys	1	6	1	4	1	4			4	2-9			1	5	8

[1] Two recorded as taken previous to tagging.

[2] One with date of capture not recorded.

TABLE 11.—*Returns from red salmon tagged at Ruins Point, Sumner Strait*—Continued

Locality of recapture	Locality and date of tagging														Total number returned
	1924: July 12 to Aug. 10		1925												
			July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Stikine district:															
Stikine Flats			1	7	2	3–4	2	4							5
Stikine River	2	5–12													2
West coast Prince of Wales Island:															
Tokeen Bay							1	7							1
Suter Creek			1	4					1	2					2
Staney Creek							1	18							1
Halibut Nose	1	13													1
Clarence Strait, north of Tolstoi Point:															
Clarence Strait	2	9–10													2
Snow Passage									1	9			6	6–10	7
Salmon Bay			1	4											1
Eagle Creek	1	4					1	11			1	8	1	8	4
Whale Passage													1	4	1
Quiet Harbor									1	8			2	5	3
Steamer Bay and Rock							1	17	2	5–8			2	5–13	5
Marsh Island									1	21			2	3–6	3
Screen Islands									1	8			2	7–9	3
Lincoln Rocks	1	13									1	7	1	5	3
Point Stanhope	1	7											1	6	2
Narrow Point							1	15							1
Lemesurier Point											1	13			1
Meyers Island									1	10					1
Clarence Strait, south of Tolstoi Point:															
Northwest Cove							1	11	1	14					2
Ship Island	3	6–7			1	21	3	8–21	6	6–12	2	10–11	1	9	16
Point Niblack									1	10			2	6–7	3
Streets Island													1	25–27	1
Grindall Point							1	24	1	23					2
Island Point													1	10	1
North end of Behm Canal	1	4													1
West shore of Gravina Island	1	8			1	8									2
Dall Head	1	11	1	28	1	20			1	11					4
Halibut Creek													1	6	1
Moira Sound	2	9–12													2
Mallard Bay									1	22					1
Cape Chacon							1	26	1	25–29	1	12–27			3
Tamgas Harbor									1	16			1	13	2
Ernest Sound:															
Union Bay	1	5			2	5–31					1	6	1	17	5
Point Eaton													1	12	1
Point Watkins													1	12	1
Point Warde											1	6	1	2	2
Anan Creek											1	6			1
Yes Bay hatchery							2	50–51	2	52–58			1	55	5
Revillagigedo Channel:															
Gravina Point									1	9					1
Thorne Arm					1	12									1
Point Sykes	1	9									1	8			2
Kah Shakes Cove	1	9													1
Foggy Bay and Point											1	10			1
Nakat Bay	1	12													1
British Columbia:															
Kincolith Bar											1	13			1
Nass River							1	18							1
Holland Rock													3	2–12	3
Skeena River	9	8–16			1	27							3	(3)	13
Doubtful	3						1						[4] 1		5
Total	56		6		13		22		33		13		42		185
Percentage	22.4		30		24.5		37.2		37.1		35.1		40		30.1

[3] All recorded as taken July 4 and 5 (possibly taken Aug. 4 and 5).
[4] Shawlatlans, British Columbia.

COHOES

The distribution of the cohoes tagged at Ruins Point was very much the same as that of the reds, except that a much larger percentage was taken along the west shore of Prince of Wales Island and in the adjacent islands. Twenty-four (nearly 11 per cent) of the recaptures were reported from this locality. Eight fish were taken in Chatham Strait and one on the west coast of Baranof Island, in Whale Bay. With the exception of these two localities, all of the other returns came from Sumner and Clarence Straits and the adjacent waters, with a few from British Columbia. Table 12 shows the results of this experiment.

TABLE 12.—*Returns from coho salmon tagged at Ruins Point, Sumner Strait*

Locality of recapture	Locality and date of tagging														Total number returned
	1924: July 12 to Aug. 3		1925												
			July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Whale Bay, Baranof Island	1	37													1
North in Chatham Strait:															
Cape Ommaney											1	25			1
Baranof Island (no details)							1	30							1
Port Alexander													1	0	1
Tebenkof Bay					1	23			2	24-26					3
Security Bay					2	19-36									2
Sumner Strait:															
Ruins Point			3	4-12	4	3-17	9	1-19	11	1-16	7	0-7	11	1-15	45
Shipley Bay	2	[1] 11													2
Shakan Bay	1	24													1
Hole-in-the-Wall											1	13			1
Point Baker													1	26	1
Point Beauclerc									1	29					1
Reid Bay							1	7			2	6-13			3
Three Mile Arm	1	30													1
Point Barrie	1	6							1	13					2
Totem Bay													1	8	1
Red Bay											1	10			1
Point Colpoys	1	11	2	5-26	3	16-24	4	3-15	1	8	1	13	4	1-19	16
Mountain Point			1	68											1
Stikine District:															
Stikine Flats					1	45			1	42	2	11-42			4
Stikine River													1	31	1
West coast of Prince of Wales Island:															
Cape Pole							3	6-32	1	24	3	7-35			7
Warren Island									1	25					1
Warren Channel							3	0-18	1	13	1	11			5
Edna Bay							1	7	1	17	1	4			3
Tokeen Bay													1	60	1
El Capitan Passage									1	21					1
Bocas de Finas									2	9-31	1	8	2	2-11	5
Nichols Bay									1	8					1
Clarence Strait, north of Tolstoi Point:															
Snow Passage			2	13			1	12	2	9-10	1	14	4	6-10	10
Eagle Creek	1	10							3	10-20	2	7-11	1	7	7
Whale Passage									1	31			1	6	2
Stevenson Island	1	19													1
Point Barnes									1	13					1
Quiet Harbor							1	9							1
Steamer Bay and Rock									1	9	1	14	2	9-28	4
Marsh Island													1	8	1
Screen Islands					1	10			2	8-15	2	8-13			5
Lincoln Rocks	2	20							2	9-27					4
Narrow Point							1	32	1	25			1	12	3
Lemesurier Point	1	12													1
Meyers Island							1	28							1

[1] One recorded as taken previous to tagging.

TABLE 12.—*Returns from coho salmon tagged at Ruins Point, Sumner Strait*—Continued

Locality of recapture	Locality and date of tagging														Total number returned
	1924: July 12 to Aug. 3		1925												
			July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Clarence Strait, south of Tolstoi Point:															
Northwest Cove													1	14	1
Ship Island	2	10–18	1	19					2	13–15	2	12–13			7
Point Niblack			1	13					1	22	1	20	1	13	4
Grindall Point	1	8			1	24			1	16	1	20	1	18	5
Island Point	4	11–26							1	27					5
Skowl Point							1	27							1
Vallenar Bay (north end of Gravina Island)									1	20	1	16			1
Dall Head									2	22–24			1	21	2
Metlakatla													1	16	3
Driest Point									1	15					1
Halibut Creek	1	34													1
Chichagof Bay							1	21							1
Stone Rock Bay					1	17									1
Cape Chacon											1	26	1	22–26	2
Ernest Sound:															
Onslow Island									2	13–14					2
Union Bay	2	17–18													2
South end of Etolin Island	1	(1)													1
Vixen Inlet							1	24							1
Point Eaton									1	18					1
Behm Canal:															
Bond Bay					1	0	1	13							2
Clover Passage							1	37							1
Grant Island			1	31											1
Yes Bay hatchery									1	85					1
Revillagigedo Channel:															
Duke Island	1	71													1
De Long Island					1	28									1
Foggy Point and Bay							1	17					1	23	2
Cape Fox	1	13													1
Nakat Bay									1	22					1
British Columbia:															
Wales Island									1	56					1
Arrandale									1	33					1
Wark Channel													1	24	1
Skeena River							1	45	1	89	1	65			3
Grenville Channel	1	42													1
Leading Point (?)			1	52											1
Haystack (?)					1	30									1
Copper River (Skeena)									1	123					1
Doubtful							1		1				2		4
Total	26		12		17		34		57		34		42		222
Percentage	10.4		26.1		14.5		18.8		20.6		21.4		21		18.1

[1] August.

PINK SALMON

The importance of local spawning runs of pink salmon is well illustrated by the results of the tagging at Ruins Point, as shown in Table 13. Out of a total of 555 returns, 352 fish (63.4 per cent) were taken in Sumner Strait and adjacent waters. A great many of these, as shown in the table, were taken in the immediate vicinity of Ruins Point within a few days of the tagging. It was reported that the fish were taken chiefly in purse seines operating just below Ruins Point in Sumner Strait, and it seems probable that some, at least, were bound for the small streams along the western shore of Prince of Wales Island and the shores of the smaller islands of the Prince of Wales Archipelago. Thirty-four tagged pink salmon were actually reported from this region, and it seems probable that the number would

have been larger had it not been for the intensive fishery in Sumner Strait near the point of tagging. This region is therefore an important source of the pink salmon found in Sumner Strait.

A few of the pinks went north and were taken in Chatham Strait, at Whale Bay on the western coast of Baranof Island, in Frederick Sound, and as far north as Seymour Canal in Stephens Passage. This northerly migration is of little practical importance, however, as only 10 tagged fish were reported from these regions.

The remaining fish were taken in the waters of Clearence Strait, Ernest Sound, and Revillagigedo Channel. None was taken in British Columbia. The local nature of the pink-salmon runs is further evidenced by the fact that a large percentage of the fish taken in Clarence Strait came from the northern part above Tolstoi Point and from Ernest Sound, just 100 fish being reported from these localities. Only 40 came from the southern part of Clarence Strait and 15 from Revillagigedo Channel. In the case of the reds and cohoes, the fish were distributed about equally between the northern and the southern parts of Clarence Strait.

TABLE 13.—*Returns from pink salmon tagged at Ruins Point*

Locality of recapture	Locality and date of tagging														Total number returned
	1924: July 12 to Aug. 3		1925												
			July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Whale Bay	2	9													2
Chatham Strait, Frederick Sound, and Stephens Bay:															
Tebenkof Bay											1	6			1
Point Brightman					1	4									1
Windham Bay	1	1			1	11	1	10	1	9	1	8			5
Seymour Canal											1	13			1
West coast of Prince of Wales Island:															
Halibut Harbor											1	3			1
Warren Cove							1	18			4	15-19			5
Edna Bay	2	11							1	4					3
Tokeen Bay	1	(?)													1
El Capitan Passage					1	8			1	6			8	3	10
Suter Creek													1	1	1
Staney Creek	1	19													1
Tuxekan Passage							1	10					1	6	2
Bocas de Finas									2	2-18			1	7	3
Noyes Island	1	7													1
Halibut Nose	1	(?)													1
Kassa Inlet							1	0							1
Klakas Inlet											1	55			1
Barrier Islands	1	9													1
Kaigani Point											1	23			1
Cape Muzon													1	3	1
Sumner Strait:															
Ruins Point [1]	1	15	4	4-9	33	1-16	33	2-15	59	0-15	69	2-18	57	0-11	256
Shipley Bay	6	0-14			1	8			1	8	6	0-6	4	[2]5-17	18
Shakan Bay	3	18-26													3
Calder Bay	5	3-14													5
Hole-in-the-Wall											1	13			1
Affleck Canal	2	8-9													2
Kell Bay	1	18													1
Port Beauclerc					1	27									1
Reids Bay					2	10					1	13	1	6	4
Seclusion Harbor											1	18			1
Three Mile Arm					1	16									1
Keku Strait	1	17					1	25	1	15			2	12-16	5
Point Barrie	1	6													1
Red Bay					2	3-7	6	2-6	2	1-8	2	3-6	3	2-9	15
Point Colpoys	6	[3]5-11	1	5	3	3-10	6	2-5	15	1-9	3	2-6	4	4-6	38
Stikine Flats									1	9					1

[1] Mainly taken by purse seines just south of Ruins Point.
[2] Two recorded as taken previous to tagging.
[3] Three with date of capture not reported.

TABLE 13.—*Returns from pink salmon tagged at Ruins Point*—Continued

Locality of recapture	Locality and date of tagging														Total number returned
	1924: July 12 to Aug. 3		1925												
			July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Chatham Strait, north of Tolstoi Point:															
Eagle Creek											1	7	1	7	2
Snow Passage									2	9-10	4	7-9	2	6	8
Quiet Harbor							3	9-10			1	8	1	7	5
Steamer Bay and Rock					1	4	3	15-17	8	9-15	5	6-10	6	5-7	23
Marsh Island					1	8			3	6-15	2	4-6	1	5	7
Screen Islands			2	8			1	5	6	4-29	2	6-8	2	7-10	13
Lincoln Rock	3	6-17											2	4-8	5
Point Stanhope					1	9					1	7			2
Whale Passage											1	7			1
Lake Bay													1	(?)	1
Point Barnes											1	13			1
Narrow Point													1	6	1
Meyers Island					1	4			1	15					2
Chatham Strait, south of Tolstoi Point:															
Northwest Cove					1	10							1	6-7	2
Ship Island	1	8							1	11	2	6-14	1	9	5
Point Niblack							1	26-31			1	6	1	9	3
Lyman Point													1	24	1
Streets Island	1	13													1
Grindall Point											1	10	2	11-12	3
Island Point	3	9-10											2	3-8	5
Grant Island									1	6					1
Vallenar Bay									1	(?)					1
West shore of Gravina Island											2	8-12			2
Boat Harbor											1	9			1
Driest Point											2	7			2
Dall Head	1	6			1	15	1	28			4	8-14			7
Halibut Creek									1	18					1
Stone Rock Bay											1	20			1
Cape Chacon									1	25-29	1	23-27			2
Ernest Sound:															
Onslow Island											5	8-12	1	9	6
Union Bay					1	17									1
Point Eaton	1	5			1	7					2	13-17			4
Point Watkins											2	8-17			2
Point Warde	1	23	1	6	1	14			6	5-9	1	11	2	5-12	12
Anan Creek							1	9	3	8-10	2	8			6
Revillagigedo Channel:															
Gravina Point											1	9			1
Thorne Arm	1	8													1
Point Alava											1	24			1
Point Sykes											1	11			1
Slate Island											1	16			1
Foggy Bay	1	16									2	22			3
Tree Point					1	11									1
Cape Fox													1	6	1
Nakat Bay											1	9			1
Kanagunut Island					1	10			1	21	1	(1)			3
Portland Inlet											1	12			1
Doubtful	1								1		1				3
Total	50		8		57		60		120		148		112		555
Percentage	20		14.8		47.9		38.5		40.5		39.6		51.1		37.8

1 Recorded as taken previous to tagging.

CHUMS

The chum salmon are distributed chiefly along the western shore of Prince of Wales Island and in Sumner and Clarence Straits. Seventeen fish (8.4 per cent) were taken in Chatham Strait, Frederick Sound, and Stephens Passage as far north as Seymour Canal. None was taken far from the main line of migration or in British Columbia. While the chums tagged at Ruins Point appeared to be mainly of local origin, this was not as clearly shown as in the case of the pink salmon. The results of this experiment are set forth in Table 14.

TABLE 14.—*Returns from chum salmon tagged at Ruins Point*

Locality of recapture	Locality and date of tagging																Total number returned
	1924 [1]				1925												
	July 12–27		Aug. 3–17		July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Chatham Strait, Frederick Sound, and Stephens Passage:																	
Tebenkof Bay							2	12–24							1	7	3
Kingsmill Point	1	6	1	8			1	6	1	5	1	11					5
Rodman Bay													1	6			1
Security Bay							1	19									1
Woewoodski Harbor									1	2							1
Bay Point							1	12									1
Windham Bay			1	0			2	5–6			1	4					4
Seymour Canal											1	13					1
West coast Prince of Wales Island:																	
Warren Island											1	21					1
Warren Cove							2	19–23									2
Edna Bay			3	11–15			2	8–29									5
Tokeen Bay					2	16–18											2
El Capitan Passage									1	12	1	11					2
Suter Creek							1	4									1
Staney Creek					1	6	3	8–16									4
Tuxekan Passage							1	12									1
Point Desconocida			1	10													1
Bocas de Finas							2	4–10	1	11	1	8	1	14	1	11	6
Point Ildefonso			1	9													1
Craig									1	28							1
Point Davidson					1	14											1
Coco Bay					1	59											1
Cape Muzon			1	0 (?)													1
Sumner Strait:																	
Ruins Point			1	14	1	35	15	2–17	3	2–15	5	1–12	1	2	5	1–15	31
Shipley Bay			1	4			3	3–22							1	17	5
Shakan Bay			5	5–12													5
Calder Bay	1	8					4	13–33							1	5	6
Affleck Canal	2	11–16					2	16–22							1	11	5
Kell Bay			1	16													1
Port Beauclerc			1	17	1	21	2	16–18			2	10–17					6
Reids Bay					1	12			2	3–5	1	11					4
Seclusion Harbor							4	15–18			1	10			1	10	6
Three Mile Arm							1	29	2	13–18	1	17			1	8	5
Keku Strait	2	11–28					1	26	2	9–11			2	6–13			7
Port Camden											1	3					1
Totem Bay					1	14	1	10							1	7	3
Red Bay							1	26	1	3	1	8					3
Kah Sheets Bay							1	19									1
Point Colpoys	1	26	3	4–12			2	2–3	1	3					2	5–11	9
Chatham Strait, north of Tolstoi Point:																	
Eagle Creek			1	10													1
Snow Passage							2	4–13			1	10					3
Quiet Harbor							1	11			1	9					2
Steamer Bay											1	11					1
Screen Islands							2	10–12							1	26	3
Point Stanhope	1	7															1
Stevenson Island	2	11–15															2
Barnes Lake			1	8													1
Onslow Island							1	33									1
Union Bay							1	23									1
Narrow Point															1	11	1

[1] The returns from the experiments of 1924 were too few to warrant detailed tabulation of each experiment. As the distribution during the later experiments seems to differ from that of the earlier ones, we have arbitrarily separated the data secured from the experiments made in July and August.

TABLE 14.—*Returns from chum salmon tagged at Ruins Point*—Continued

Locality of recapture	Locality and date of tagging																Total number returned
	1924				1925												
	July 12–27		Aug. 3–17		July 18		July 20		July 21		July 22		July 24		July 25		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Chatham Strait, south of Tolstoi Point:																	
Northwest Cove											1	10					1
Ship Island											1	6			1	10	2
Point Niblack							3	14–33	1	26–31							4
Streets Island					1	32–34											1
Grindall Point							2	14–18			2	11–23			1	11	5
Kasaan Bay															1	20	1
Island Point											1	16					1
Betton Island									1	23							1
Vallenar Bay							1	22									1
Dall Head					1	22					1	27					2
Bostwick Inlet							1	18							1	18	2
Halibut Creek	1	34															1
Moira Sound									1	20							1
Chichagof Bay					1	20	1	18							1	13	3
Cape Chacon					1	29–33	1	27–31			1	25–29	1	22	1	22–26	5
Revillagigedo Channel:																	
Mountain Point							1	22									1
Bold Island							1	24									1
Point Sykes															1	11	1
Boca de Quadra							1	19									1
Tree Point													1	13			1
Cape Northumberland							1	26									1
Doubtful			1				1				1						3
Total	11		23		13		76		19		29		7		24		202
Percentage	12.8		15.2		18.8		26.3		22.6		21.3		23.3		32		21.9

RETURNS FROM EXPERIMENTS AT CAPE MUZON AND KAIGANI POINT

Six tagging experiments were conducted here from August 15 to 22, 1925, inclusive. Out of a total of 3,117 fish tagged, 3,049 were pink salmon, 7 were reds, 16 cohoes, and 45 chums. Very few returns were obtained from species other than the pink.

One red salmon, tagged on August 15 at Cape Muzon, was taken at Kasook Inlet, Sukkwan Island, on August 22. One coho, tagged on August 16 at Kaigani Point, was taken at Kassan Inlet, Cordova Bay, on August 22; and another, tagged at Cape Muzon on August 22, was taken September 18 in Coco Bay, Dall Island. Of the chum salmon, one tagged at Kaigani Point on August 17 was taken in Coco Bay on September 15. One of two fish tagged at Cape Muzon on August 22 was retaken at Hydaberg Creek on August 29 and the other in Coco Bay on September 18. The scattering returns from these three species do not indicate any extensive or definite migration.

PINK SALMON

The data relative to the recapture of pink salmon tagged at these localities are given in Table 15.

TABLE 15.—*Returns from pink salmon tagged at Cape Muzon and Kaigani Point in 1925*

Locality of recapture	Locality and date of tagging												Total number returned
	Cape Muzon, Aug. 15		Kaigani Point								Cape Muzon, Aug. 22		
			Aug. 16		Aug. 17		Aug. 18		Aug. 21				
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
West coast Prince of Wales Island:													
Cape Muzon	16	2-7	19	1-6	29	0-5	11	0-4	4	[1] 0-1	5	0-16	84
McLeod Bay	2	2	1	1	2	0-5			1	1			6
Kaigani Point	24	1-7	7	1-6	19	1-5	3	4	2	0-1	6	0	61
Cordova Bay (no details)	1	5					1	(2)			1	(2)	3
Cordova Bay—													
Eagle Point					1	3	1	2					2
Ship Island	2	3											2
Point Webster	9	6-7	19	2-6	13	1-5	5	4	5	1			51
Lime Point	8	3-7	9	5-6	8	1-5			2	0-1			27
Hessa Inlet					1	2							1
Klakas Inlet	2	5 &44	2	3	3	2-3	2	2-4					9
Kassa Inlet	9	5-7	12	3-6	16	2-5	2	4	3	1			42
Nutkwa Inlet	19	3-7	39	2-6	33	1-8	11	1-4	7	0-1	1	(3)	110
American Bay	1	3	1	6			1	0					3
Coco Bay	9	[4]31-45	3	[5]4	4	[6]0-3	1	2	2	25-35	2	24-34	21
Kasook Inlet	15	1-7	27	2-6	20	3-5	9	2-4	4	1			75
Dunbar Inlet			1	(7)			1	1			3	28	5
Breezy Bay									1	28			1
Hydaberg	3	1-5	6	0-4	5	0-5	3	[8]0-2	4	(9)	2	(3)	23
Soda Bay	2	4			1	33(?)					1	30	4
Tlevak Straits	1	7											1
Bucareli Bay	3	5-10	1	6									4
Craig	2	1-5	8	[10]4	20	[11]0-3			1	9			31
Bocas de Finas	2	5-7			1	1							3
Cape Lynch	1	6	1	5	2	4							4
Warmchuck Inlet			1	5									1
Tokeen Bay											1	39	1
Clarence Strait, south of Tolstoi Point:													
Cape Chacon	18	1-7	16	0-6	5	3-5			3	1			42
Moira Sound	2	2-5											2
Halibut Creek	1	3	1	2	2	1							4
Cholmondeley Sound									2	27			2
Dall Head	3	2-3											3
Bronaugh Islands	1	0(?)											1
Kasaan Bay	5	4-6	2	2-3					1	28	1	68	9
Clarence Strait, north of Tolstoi Point:													
Lemesurier Point	3	4-7	1	6									4
Narrow Point	1	7	1	6									2
Onslow Island					1	5							1
Luck Point	1	7			1	5							2
Revillagigedo Channel:													
Cape Northumberland	1	3											1
Crab Bay, Annette Island	1	4											1
Sea Cove, Gravina Island	2	3-5	1	4	2	3							5
Blank Inlet					1	51							1
Vallenar Bay	5	2-4	2	2-3									7
Point Alava							1	(?)					1
Wales Passage, British Columbia	1	36			1	32							2
Total	176		181		191		52		42		23		665
Percentage	29.6		30.5		32		30.6		7.7		4.2		21.8

[1] One taken Sept. 17.
[2] August.
[3] Recorded as taken previous to tagging.
[4] Except one reported as taken Aug. 20.
[5] One taken Sept. 17.
[6] One recorded taken Sept. 15.
[7] Recorded as taken Sept. 19. It seems more likely that it was taken Aug. 19.
[8] One taken Oct. 13.
[9] Two recorded as taken before Aug. 15 and 20, and two as taken Oct. 13.
[10] Two with date of capture not recorded.
[11] Four with date of capture not recorded.

From this table it is quite evident that most of these fish were bound for local spawning grounds along the western shore of Prince of Wales Island and on the islands west of Prince of Wales Island. Quite a number were taken in the salmon traps near Cape Chacon, and significant numbers were recovered along Clarence Strait between Cape Chacon and Luck Point. One fish was taken in Revillagigedo Channel

and two in Wales Bay, British Columbia. The extremely local distribution of the fish is very apparent.

It is interesting to note that most of the fish taken in other localities than those along the western side of Prince of Wales Island were of the first three experiments. Returns from the later experiments came almost exclusively from the west coast. However, the last two experiments were not nearly as successful as the earlier ones, in so far as the percentage of return is concerned. In the first four experiments a very uniform recovery was reported—approximately 30 per cent. Then, after a lapse of only two days, the recaptures dropped to less than 8 per cent, and on the next day to less than 5 per cent. This was undoubtedly the result of the closing of this area to commercial fishing (except by trolling) on August 22.

RETURNS FROM EXPERIMENTS AT CAPE CHACON

RED SALMON

Thirty-seven red salmon out of 121 tagged were recaptured, and all but four of the returns were from the southern part of Clarence Strait, a comparatively short distance from the point of tagging. Three of the fish were taken along the western coast of Prince of Wales Island between Kassa Inlet and Hydaberg, and one was recaptured in the Babine River, a tributary of the Skeena River in British Columbia. No definite conclusions can be drawn from these few data, although it appears that some of the fish are of local origin and others come from the large rivers in the northern part of British Columbia. The data relative to the returns of red salmon tagged at Cape Chacon are given in Table 16.

TABLE 16.—*Returns of red salmon tagged at Cape Chacon and Stone Rock Bay in 1925*

Locality of recapture	Locality and date of tagging										Total number returned
	Cape Chacon, Aug. 8		Stone Rock Bay, Aug. 9		Cape Chacon, Aug. 11		Stone Rock Bay, Aug. 12		Cape Chacon, Aug. 13		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Clarence Strait, south of Tolstoi Point:											
Cape Chacon	6	1–12	4	[1] 6–11			2	3–8			12
Stone Rock Bay	1	10	2	4–7					1	3	4
Mallard Bay			1	6			1	1			2
Chichagof Bay			4	2							4
Bostwick Inlet			1	7							1
Moira Sound	1	5	3	3–8					1	4	5
Kassan Bay			1	11			1	8			2
Dall Head	1	7	1	3	1	5					3
West coast Prince of Wales Island:											
Kassa Inlet							1	3			1
Nutkwa Inlet			1	8							1
Hydaberg			1	54							1
Babine River, British Columbia			1	78							1
Total	9		20		1		5		2		37
Percentage	26.4		29.4		25		55.5		33.3		30.6

[1] One with date of capture not given.

COHOES

Nine cohoes were returned of the 48 tagged at this locality. Seven were taken locally not far from Cape Chacon and 1 each in the Nass and Skeena Rivers. Although too few to be conclusive, the data point to the Nass and Skeena Rivers as the sources of an important part of the run of cohoes in this part of southeastern Alaska. The results of the experiment are given in Table 17.

TABLE 17.—*Returns from coho salmon tagged at Cape Chacon and Stone Rock Bay in 1925*

Locality of recapture	Locality and date of tagging						Total number returned
	Cape Chacon, Aug. 8		Stone Rock Bay, Aug. 9		Cape Chacon, Aug. 13		
	Number	Time	Number	Time	Number	Time	
Clarence Strait, south of Tolstoi Point:							
Cape Chacon			2	7-13	1	5	3
Kalgani Point			1	13			1
Stone Rock Bay	1	5					1
Duke Island	1	33					1
British Columbia:							
Nass River	1	1	1	42			2
Skeena River			1	36			1
Total	3		5		1		9
Percentage	17.6		20.8		14.3		18.7

PINK SALMON

Most of the salmon tagged at Cape Chacon were pinks. In five experiments conducted between August 8 and 13, 1925, inclusive, 2,341 fish of this species were tagged. Of these 983 were recovered from a great many minor localities, mainly along the shores of Clarence Strait and the west coast of Prince of Wales Island. The locality of recapture was not recorded for 11 of the returns; 87 fish (8.8 per cent of the total number returned) were taken along the west coast of Prince of Wales Island; 1 was captured on the west shore of Kuiu Island in the southern part of Chatham Strait; 71 (7.2 per cent) were from Clarence Strait above Tolstoi Point;[4] and the remaining 813 (82.7 per cent) were taken in the southern part of Clarence Strait and adjacent waters. The results of the experiment are shown in Table 18.

TABLE 18.—*Returns from pink salmon tagged at Cape Chacon and Stone Rock Bay in 1925*

Locality of recapture	Locality and date of tagging										Total number returned
	Cape Chacon, Aug. 8		Stone Rock Bay, Aug. 9		Cape Chacon, Aug. 11		Stone Rock Bay, Aug. 12		Cape Chacon, Aug. 13		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
West coast Prince of Wales Island:											
Cape Muzon			1	10	4	5-8	6	4-10	5	3-9	16
Cordova Bay			1	6							1
Ship Island			9	3-12	2	5-7	3	5-6	6	5	20
Klakas Inlet			1	39			3	8-10	2	7 & 35	6
Kassa Inlet			2	6	1	11	2	3-10	2	6-9	7
Point Webster			1	13					3	8-9	4
Kasook Inlet, Sukkwan							3	4			3
Lime Point			2	12-13					1	9	3
Nutkwa Inlet			1	8	4	6-11	3	10	1	9	9
Hydaberg			1	6-11					1	61	2
Bucarelli Bay			1	11							1
Craig					2	4-9	1	8	1	7	4
Klawak Inlet			1	11							1
Bocas de Finas					2	7-9			1	7	3
Warmchuck Inlet			1	10	3	11			3	3-9	7
Tebenkof Bay			1	4							1

[4] The part of Clarence Strait above Tolstoi Point is included by the current regulations in the Prince of Wales district, and the part below Tolstoi Point is in the southern district of southeastern Alaska.

TABLE 18.—*Returns from pink salmon tagged at Cape Chacon and Stone Rock Bay in 1925*—Contd.

Locality of recapture	Locality and date of tagging										Total number returned
	Cape Chacon Aug. 8		Stone Rock Bay, Aug. 9		Cape Chacon, Aug. 11		Stone Rock Bay, Aug. 12		Cape Chacon, Aug. 13		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Clarence Strait, south of Tolstoi Point:											
Cape Chacon	15	1–12	29	[1] 3–13	91	[1] 2–11	80	0–12	85	[2] 1–7	300
Mallard Bay			6	4–7	11	2–7	19	1–6	18	[2] 3–5	54
McLeans Point									2	1	2
Chicagof Bay	1	7	17	2–6	3	2	6	1			27
Moira Sound			6	4–11	6	[3] 6–7	4	3–6	5	4–5	21
Point Adams	1	3	5	1–9	1	3	1	1			8
Halibut Creek			4	3–9	3	3–7	6	5–6	9	4–5	22
Cholmondeley Sound			2	8					1	42	3
Bronaugh Island					2	4–7	2	3	4	2	8
Dall Head, south end of Nichols Pass	1	10	12	1–9	16	2–7	13	1–6	8	2–5	50
Driest Point			1	5			1	4			2
Seal Cove									1	4	1
Bostwick Inlet			1	3	3	5	2	4	1	3	7
Metlakatla							1	5			1
Crab Bay (Annette Island)			1	5					1	6	2
Nichols Passage, north end			1	3							1
George Inlet			2	4–5			2	[4] 2			4
Ward Cove, Tongass					1	46	1	45	2	14&44	4
West shore, Gravina Island			1	6	8	4–7	8	1–4			17
Vallenar Bay, north end of Gravina Island, Grant Creek			7	3–7	13	1–8	12	1–6	7	3–6	39
Point Higgins					1	6	1	5	1	4	3
Kassan Bay, Skowl Point, Island Point	2	5–11	23	[4] 3–10	31	[4] 4–9	14	2–8	16	[5] 3–7	86
Grindall Point					4	4–7	1	4	1	4	6
Streets Island			1	10–12	7	7–10	9	7–9	6	5–8	23
Lyman Point			1	9	1	7	1	6	2	5	5
Niblack Point	3	8–13	8	3–12	20	5–10	9	4–9	6	0–8	46
Behm Canal:											
Betton Island					1	3					1
Behm Canal (no details)							1	3			1
Bond Bay					6	5–8	1	6	1	6	8
Traitors Cove			1	9	1	7	1	6	4	5	7
Black Island			1	7							1
Ernest Sound:											
Union Bay			5	3–13	4	2–13	4	2–10	1	9	14
Vixen Inlet			1	5	2	8			1	6	4
Point Watkins					3	10	2	9–10			5
Anan Creek			1	5							1
Canoe Pass							1	8			1
Onslow Island							1	10			1
Clarence Strait, north of Tolstoi Point:											
Meyers Island			1	9	2	7	3	5–6	1	5	7
Lemesurier Point					2	9–11	3	10			5
McHenry Inlet							1	7			1
Narrow Point			1	4			1	10	1	9	3
Luck Point			2	12	1	10	3	9–10	4	8	10
Point Barnes			1	10	3	[6] 8					4
Lincoln Rocks					1	10			1	9	2
Screen Islands							1	8			1
Whale Pass					2	8			1	5	3
Steamer Bay			2	[4] 13			2	9–10	4	7–8	8
Burnet Inlet					1	10					1
Revillagigedo Channel:											
Cape Northumberland					1	4	4	6	2	5	7
Smeaton Bay	1	(?)									1
Sykes Point			1	5	2	3–6	2	6	3	1–5	8
Slate Island			1	8			1	5	1	4	3
Point Alava	1	2	1	9	5	2–7	4	[6] 2–6	2	[6] 0	13
Tree Point					3	3–5	5	0–6	1	5	9
Cape Fox			1	5	1	4			1	5	3
Nakat Bay			2	5–8			2	3–5			4
Tamaas Harbor					1	(?)					1
Kanagunut Island					2	6	1	5			3
Unknown			2		5		4		1		12
Total	25		175		289		262		232		983
Percentage	49.1		34.7		45.4		43.1		43.0		42.0

[1] Three without records as to date of recapture.
[2] Two without records as to date of recapture.
[3] One taken on Sept. 25.
[4] One recorded as taken previous to tagging.
[5] Two recorded as taken previous to tagging.
[6] One record with no date given.
[7] Recorded as taken previous to tagging.

CHUMS

Two hundred and forty chum salmon were tagged, chiefly in the experiments of August 8 and 9, and of these 54 were returned. The distribution was much the same as in the case of the pink salmon, although a somewhat greater percentage of chums went to the west coast of Prince of Wales Island. Of the 54 returns 10 (18.5 per cent) were from this region, and the remaining 44 (81.5 per cent) were taken in the general region including the southern part of Clarence Strait, Revillagigedo Channel, and adjacent water. None was taken north of Tolstoi Point in the Clarence Strait region. The data are given in Table 19.

TABLE 19.—*Returns from chum salmon tagged at Cape Chacon and Stone Rock Bay in 1925*

Locality of recapture	Locality and date of tagging										Total number returned
	Cape Chacon, Aug. 8		Stone Rock Bay, Aug. 9		Cape Chacon, Aug. 11		Stone Rock Bay, Aug. 12		Cape Chacon, Aug. 13		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
West coast Prince of Wales Island:											
Cape Muzon	1	(?)	1	11							2
McLeod Bay			1	8							1
Kaigani Point			1	13							1
Klakas Inlet									1	9	1
Kassa Inlet	1	12									1
Lime Point			1	9							1
Nutkwa Inlet			2	12–13							2
Boca de Finas	1	8									1
Clarence Strait, south of Tolstoi Point:											
Cape Chacon	9	1–12	3	6–11							12
Stone Rock Bay	2	3	1	7							3
Mallard Bay									1	3	1
Kendrick Bay			1	6							1
Chichagof Bay	2	3	3	2							5
Moira Sound	7	5–9	4	3–9							11
Point Niblack	2	8–13									2
Vallenar Bay			1	6							1
Dall Head	2	5–7	1	9							3
Cape Northumberland	1	5									1
Revillagigedo Channel:											
Bold Island	1	7									1
Thorne Arm					1	(?)					1
Sykes Point	1	7									1
Tree Point							1	5			1
Total	30		20		1		1		2		54
Percentage	26.3		22.7		6.2		6.7		28.6		22.5

RETURNS FROM EXPERIMENTS NEAR CAPE FOX AND DUKE ISLAND

RED SALMON

Comparatively few red salmon were tagged in the experiments at these points, and the returns were too few to warrant tabulation. In 1924, 2 fish were tagged at Kanagunut Island on August 7; 36 at Tree Point and 5 at Duke Point on August 8; and 3 at Point White on August 9. In 1925, 14 fish were tagged at Foggy Point on July 30, and 31 on July 31.

Twenty recaptures were made, of which 10 were along the mainland shore between Kanagunut Island and the mouth of Boca de Quadra. Three fish were taken in the Skeena River, 2 at Smeaton Bay (Behm Canal), and 1 each from the following localities: Chatham Sound (British Columbia), Nass River, Portland Canal, Hassler Harbor, and Black Island. Practically all of the returns were secured between the 1st and the 15th of August. Although inconclusive, due to inadequate data, the indications are that the Nass and the Skeena Rivers are important sources of the red salmon found in the region about Cape Fox, at least during the latter part of July and the 1st of August.

COHOES

No cohoes were tagged in this region during 1924, but 53 were tagged at Foggy Point on July 30, 1925, and 26 at the same place on July 31 of that year. Six tags from the first lot and 8 from the second were returned. Ten of these were taken along the mainland shore between Sitklan Island and the southern entrance to Behm Canal, and 1 was recaptured at each of the following places: Nutkwa Inlet, Moira Sound, Dall Head, and Wrangell Narrows. These results indicate a somewhat wider distribution of the cohoes than of the reds, but they are too meager to warrant even tentative conclusions.

PINK SALMON

Out of a total of 1,987 salmon tagged in this region, 1,750 were pinks. Six experiments in all were carried out—four in 1924 between August 7 and 9, and two in 1925 on July 30 and 31. The results in the two years were very similar, except that in 1924 no tags were reported from British Columbia, while in 1925 a little over 11 per cent of the total number of returns came from Canadian waters. The data are presented in Table 20.

TABLE 20.—*Returns from pink salmon tagged in the Cape Fox region*

Locality of recapture	Locality and date of tagging												Total number returned
	1924								1925: Foggy Point				
	Kanagunut Island, Aug. 7		Tree Point, Aug. 8		Duke Point, Aug. 8		Point White, Aug. 9		July 30		July 31		
	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	Number	Time	
Point Davidson (Klakas)											1	12	1
Clarence Strait:													
Cape Chacon			1	8			2	7			2	12	5
Duke Point			2	2-4	43	0-11	5	1-12					50
Sealed Pass					1	8							1
Tamgas Harbor			1	5			2	6					3
Dall Head							1	3	1	10	2	5	4
Bostwick Inlet and Point			1	5			1	11					2
Smugglers Cove					1	12							1
Metlakatla					1	3							1
Halibut Creek							1	3					1
West shore of Gravina Island			1	3									1
Kasaan Bay	1	4											1
Vallenar Bay			1	4							1	7	2
Point Niblack											2	5-7	2
Streets Island					1	8							1
Union Bay									1	15	4	13-14	5
Onslow Island											3	5-22	3
Behm Canal:													
(No details)							1	11			1	15	2
Traitors Cove					1	13							1
Rudyerd Bay									1	7	1	6	2
Smeaton Bay					1	6			3	6-9	8	4-17	12
Roe Point			3	5-7	2	5-7			2	6	2	5	9
Sykes Point			2	8-9	4	2-8	2	3-8	5	2-8	10	1-15	23
Revillagigedo Channel:													
Gravina Point									1	5			1
Walden Point							1	5					1
George Inlet											2	[1] 13	2
Carroll Inlet	1	8	1	4									2
Hassler Harbor					1	9							1
Thorne Arm											1	10	1
Lucky Cove			1	6	2	6-10	1	9	3	[2] 6	3	[3] 2-5	10
Point Alava											5	10-18	5
Black Island [4]					2	3-11			1	3	5	2-4	8
Slate Island									3	2-4	8	2-17	11
Boca de Quadra			1	13	1	13	1	13					3
Marten Arm											1	3	1
Kah Shakes	1	4-8	6	4-8	6	2-8	8	[3] 1-6	5	[5] 2-13	7	[5] 1-6	33
Kirk Point					1	1	1	3					2
De Long Island									2	12	2	7-11	4
Foggy Point and Bay			21	10-18	8	2-8	1	5	[6] 94	1-20	[6] 141	0-19	265
Tree Point	1	4-8			3	1-8	2	2-7					6
Dixon Entrance:													
Cape Fox			3	1-3	3	6-7	1	2					7
Boat Rock	1	4-8	1	5									2
Nakat Bay			15	4-9	16	5-9	11	4-6	6	3-7	10	2-8	58
Kanagunut Island	1	4-8					4	4-5	8	[3] 4-12	10	[7] 6-12	23
Sitklan Island									1	6	2	5	3
Fillmore Inlet	1	8	1	11	1	7							3
Portland Canal					1	5							1
Tombstone Bay									1	19	1	12	2
British Columbia:													
Portland Inlet									5	7-20			5
Wales Island									2	13	2	7-49	4
Somerville Bay											2	7	2
Steamer Passage									9	5-7	1	4-5	10
Kutzeymateen Inlet									1	11	3	5-10	4
Nasooga Gulf											1	4	1
Nass River									9	5-22	1	10	10
Wark Canal									2	[8] 19			2
Skeena River									4	[3] 4-20	1	29	5
Kitkatlah Inlet									1	40			1
Tucks Inlet (?)			1	34									1
Doubtful					4		1				2		7
Total	7		63		104		47		171		248		640
Percentage	31.8		31		36.1		24.2		34		45.9		36.6

[1] One recorded as taken in August, but no date given.
[2] Two were recorded as taken on July 24.
[3] One recorded as taken before the date of tagging.
[4] This may possibly refer to the Black Island in Behm Canal north of Revillagigedo Island, but it is believed to refer to the Black Island in Revillagigedo Channel near Point Sykes.
[5] Three were recorded as taken previous to tagging.
[6] These include all taken in the general locality of Foggy Bay, including Cape Fox. Most of the fish were taken within three days after tagging. [7] Four recorded as taken previous to tagging. [8] One taken on the spawning grounds, no date given.

As would be expected, the returns were concentrated about the localities where the tagging was done. The pink salmon taken in Alaskan waters were distributed almost exclusively through the southern part of Clarence Strait, Revillagigedo Channel, Behm Canal, and Dixon Entrance, close to the mainland. One individual only was reported from the western shore of Prince of Wales Island, and only eight were recorded from north of Tolstoi Point in Clarence Strait, which marks the southern boundary (in Clarence Strait) of the Prince of Wales district. We may safely conclude, therefore, that the pinks found in the region of Duke Island, Foggy Bay, and Cape Fox late in July and early in August are practically all of local origin, spawning in the streams within a radius of 50 miles or less of Cape Fox on both sides of the international boundary.

CHUMS

In 1924 chums were tagged as follows: Thirty-two on August 8 at Tree Point, 2 on August 8 at Duke Point, and 2 on August 9 at Point White. In 1925, at Foggy Point, 28 were tagged on July 30 and 3 on July 31. Four fish of the first experiment were recaptured, 1 each from the second and third, 5 from the fourth, and 1 from the last. Again, most of the returns were from the shores of Revillagigedo Channel and Dixon Entrance bewteen Kanagunut Island and Revillagigedo Island, 8 of the 12 recovered tags coming from this region. One each was taken at Kincolith Bay, near the mouth of the Nass River, and at Halibut Creek near the entrance to Cholmondeley Sound, and 2 were taken from Behm Canal. As usual, the chums appeared to be mainly of local origin.

VARIATIONS IN RETURNS OF TAGGED FISH

The percentages of tagged fish recaptured later vary greatly with the species and also with the locality where the tagging was done. The data are shown in Table 21.

TABLE 21.—*Percentage of tagged fish recaptured*

Locality where tagged	Red	Coho	Pink	Chum
Icy Strait	23.4	12.3	14.5	14.4
Frederick Sound			24.2	
Chatham Strait	19.8	15.8	20.7	50.4
Ruins Point	30.1	18.1	37.8	21.9
Cape Muzon			21.8	
Cape Chacon	30.6	18.7	42.0	22.5
Cape Fox			36.6	

It is not possible, from the information at present available, to determine the causes for these wide fluctuations, or even to know whether the data represent unusual or normal conditions. For instance, why were there approximately two and one-half times as many chums returned from the experiments at Kingsmill Point, in Chatham Strait, as were returned from any other experiment; and why were so many more chums than salmon of other species returned from these experiments? These are questions that can be answered only when more data are available, but it is quite apparent now that the fishing for some species and in some localities, at least, is so intensive as to require careful attention. It was pointed out in earlier tagging experiments[5] that these percentages of returns are always a minimum, and that

[5] See footnote 2, p. 109.

every factor that would modify the returns as we have them would increase the percentage of fish captured and would indicate a greater intensity of fishing than appears from the figures as given. Bearing this in mind, it is quite clear from the figures given above that the drain on some of the salmon runs in southeastern Alaska must far exceed the limits set in certain other localities. In some of the streams of Alaska, notably the Karluk and Chignik Rivers, where weirs are maintained in order that an accurate census of the spawning escapement may be taken, a 50 per cent escapement is required. Of course it is not possible to determine, in as complex a situation as that which exists in southeastern Alaska, just what the percentage of escapement to the various spawning areas is, but when 50 per cent of the released fish are again taken there can be no doubt that the actual drain on the resource is considerably greater than 50 per cent—so much greater as to menace the perpetuation of the supply.

CONCLUSIONS

It should be clearly understood that any general conclusions based on the data at present available are only tentative and must be considered as applying solely to those seasons of the year during which the tagging was done. It may very well be that the distribution at other times is quite different. Additional experiments have been planned and will be carried out in the future, which it is hoped will provide information on this subject. Based on the data presented above, the following tentative conclusions seem warranted:

1. The main route of migration of the salmon entering southeastern Alaska through Icy Strait is south in Chatham Strait and into Frederick Sound. In addition a distinct migration of red salmon of relative importance takes place northward into Lynn Canal, where important spawning areas are located in the Chilkat and Chilkoot Rivers. The experiments conducted farther south indicate that some of the red salmon there come from the rivers of northern British Columbia. There is no evidence to show that the reds of Icy Strait do so, for apparently their spawning grounds are confined to the region north of Frederick Sound.

2. Some of the fish found in Frederick Sound and Chatham Strait adjacent to Frederick Sound (Kingsmill Point) come from the north through Chatham Strait from Icy Strait, but it seems more than probable that many of them also enter through the southern entrance to Chatham Strait. These fish are distributed throughout Frederick Sound and Stephens Passage, and there is no evidence to show that the fish found in Frederick Sound and Stephens Passage enter these regions in any numbers except through Chatham Strait and the western entrance to Frederick Sound. In addition to the distribution through Frederick Sound and Stephens Passage, there is a distinct movement south through Chatham Strait and Keku Strait, especially on the part of the chum salmon. As to the other species, this southerly migration seems to be of much less importance than that to the region of Frederick Sound and Stephens Passage. The Stikine River apparently is an important spawning ground for reds and cohoes.

3. The distribution of the fish tagged near the western entrance to Sumner Strait (Ruins Point) varies with the species, but it is almost entirely to the south, either along the western shore of Prince of Wales Island or in Clarence Strait. The red salmon were taken chiefly along Clarence Strait and in streams running from the

Stikine River south into British Columbia. The cohoes were distributed over this same region and also along the western shore of Prince of Wales Island. The pinks and chums were taken chiefly along the western shore of Prince of Wales Island, in Sumner Strait and Clarence Strait. Very few were taken far from these waters, only one pink being reported from the Stikine River and none of either species from British Columbia.

4. The salmon taken at Dixon Entrance (Cape Muzon and Cape Chacon) were predominantly of local races and were distributed along the western shore of Prince of Wales Island and in Clarence Strait (mainly along the southern half), Revillagigedo Channel, and adjacent waters. Significant numbers of both reds and cohoes came from the Nass and Skeena Rivers in Northern British Columbia, but very few of any of the other species were taken in Canadian waters.

5. The fish tagged in the region of Cape Fox, Foggy Bay, and Duke Island (Dixon Entrance near the mainland) were chiefly distributed locally along the mainland shores, both in Alaska and south into British Columbia. Reds, pinks, and chums were taken in the rivers of northern British Columbia, especially in the Nass and the Skeena.

EXPERIMENTS AT PORT MOLLER, 1925

The purpose of the experiment conducted at Port Moller was to test again the theory that salmon taken off the mouths of the Bear and Sandy Rivers are of local origin and are not bound for Bristol Bay, as are many of the fish taken in the Ikatan-Shumagin Islands district. The tagging experiments of 1922 showed clearly that in that year the fish taken in Bering Sea near the Bear and Sandy Rivers were local residents. Out of 639 tagged, not a single specimen was taken in Bristol Bay.[6] However, some of the cannery men interested in the fishery at this point felt that the experiment of 1922 was not sufficiently conclusive, as it was possible that 1922 was an unusual year. At their request the experiment was repeated during the summer of 1925, and 2,000 tags were attached to salmon taken with purse seines near the beach between the Bear and Sandy Rivers.

The methods followed were practically the same as those in use since 1922. slight modification was introduced, however, and the salmon, instead of being tagged and liberated directly from the gear in which they were caught, were first placed in a live car and towed a short distance farther offshore. This was done to avoid interference with purse seines fishing close to shore, and also because it was thought that the fish might have a better chance to escape immediate recapture.

The tagging operations were planned by Dr. C. H. Gilbert, who visited Herendeen Bay late in June with the intention of immediately supervising the work. For various reasons this proved to be impossible, and the operations were actually carried out by L. G. Wingard, warden. The following numbers of the 1925 series of salmon tags were attached: 18001 to 18857 on July 1, 18858 to 19162 on July 4, and 19163 to 20000 on July 5.

The results completely confirmed those of 1922. Out of the 2,000 fish tagged, 949, or 47.5 per cent, were recaptured and the tags returned to us. Of these only 1

[6] Experiments in Tagging Adult Red Salmon, Alaska Peninsula Fisheries Reservation, Summer of 1922, by Charles H. Gilbert. Bulletin, U. S. Bureau of Fisheries, Vol. XXXIX, 1923-24 (1924), Document No. 943, pp. 39-50. Washington.

fish was taken in Bristol Bay. The others were all taken within a few days in the region where they were tagged. The following table presents the data pertaining to the fish recaptured in the Bear and Sandy Rivers regions:

TABLE 22.—*Returns from 2,000 red salmon tagged July 1, 4, and 5, 1925, near the mouths of the Bear and Sandy Rivers, Bering Sea, and recaptured near the point of liberation*

Date of recapture	Date of tagging			Date of recapture	Date of tagging		
	July 1, 857 tagged	July 4, 305 tagged	July 5, 838 tagged		July 1, 857 tagged	July 4, 305 tagged	July 5, 838 tagged
July 2	7			July 15	4	3	7
July 3	45			July 16	1	1	7
July 4	43	1		July 17 [1]	12	4	13
July 5	37			July 18			1
July 6	38	37	55	July 23	1	1	
July 7	71	54	186	No date [2]	89	29	76
July 8	2	2	7				
July 9	10	12	40	Total	367	155	427
July 10			1	Percentage returned	42.8	50.8	51
July 14	7	11	34				

[1] All but two were recorded as taken either July 16 or 17.
[2] All but four of these were received from one company, which had not submitted complete records at the time this paper was prepared.

The one fish taken in Bristol Bay was No. 19337, tagged on July 5 and recaptured at Naknek on July 13.

There is very little of interest in the results of this experiment other than the support it lends to the theory of the local origin of the fish taken in this region. The fact that a single individual was taken in Bristol Bay is entirely without practical significance. It may indicate that an occasional Bristol Bay fish is to be found among the schools of Bear and Sandy River fish, or it may mean that an occasional Bear or Sandy River fish strays into Bristol Bay. We know that the homing instinct in salmon is not absolutely unerring, although we are equally certain that an overwhelming percentage does return to the parent streams. It would not be surprising, therefore, if a few Bear or Sandy River fish did reach Bristol Bay, and the finding of one or even of several such cases would in no way affect the general conclusions. These may be summed up in the statement that in 1925, as in 1922, the fish found in Bering Sea in the vicinity of the Bear and Sandy Rivers were predominantly fish of local origin and were not natives of the important salmon streams of Bristol Bay.

DEVELOPMENT, GROWTH, AND FOOD HABITS OF THE WHITE SUCKER, CATOSTOMUS COMMERSONII LESUEUR

By NORMAN HAMILTON STEWART

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INTRODUCTION

It is the aim of the present paper to present an account of the development and biological relationships of the white sucker. Not many papers dealing with single species of our fresh-water fishes have appeared up to the present, but the complex problems of the interrelationships of aquatic organisms will be simplified only by more complete knowledge of the lives of individual species. The rôle played by any species of fish in the economy of stream life varies with its age and feeding habits; hence it is profitable to consider the part played by such a species at every stage of its life. This is attempted in the present paper by bringing together observations extending over a year, and thus including an account of the activities of the sucker during each year of its life and at each season of the year.

As this species is remarkable for its adaptability as well as for its general abundance, it becomes one of the factors that may alter the environment in which the

fish-culturist works. Only when its food is thoroughly known can we designate it as friend or enemy in our streams and lakes. While the feeding habits have been given particular attention in the following pages, an account of the embryology and postembryonic changes has been included, which may contribute to our knowledge of the structure and life history of the species.

The work was done in the region about Ithaca, N. Y., where the topography is such that it produces nearly every type of habitat in which fresh-water fishes may be found. Collections were made (especially of the fry) from every stream in Tompkins County, while the adult fish were taken in the principal streams and in Cayuga Lake.

From cold, spring-fed brooks and sphagnum bogs these streams traverse stretches of clay land, where they meander through meadow and alder swamp. Then they break in rapids, to wind through glacial drift or spread in thin, warm films over an exposed limestone floor. Leaving the upland they enter deep gorges, where they leap down in a succession of falls and pools, to emerge in the flat marshland of the Cayuga Lake Valley. By sluggish courses through the reeds they at last reach the lake, whose shores, in some parts shallow and sandy, in others abrupt and rocky, afford an additional range of fish environment. Material was collected at over 60 points in this region and should give a good index to the habits of this fish over much of its range.

For assistance in this work I am greatly indebted to Dr. G. C. Embody, who has given me every opportunity to profit by his knowledge of the region and has put equipment at my disposal for every need. I am also grateful to Dr. B. F. Kingsbury and Dr. H. D. Reed for their interest in the work and for facilities they have afforded me.

DESCRIPTION AND DISTRIBUTION OF CATOSTOMUS

The genus Catostomus, family Catostomidæ, is typified by having the body elongate, fusiform, and rounded, tapering toward each end, and with a rather pointed snout. The eye is small and placed high, the suborbitals are narrow, and a fontanelle is present above the brain. The mouth, which is so characteristic of the entire family, is inferior in position, rather large, and with protractile lips. The lateral line is nearly straight, the dorsal fin midway of the body, and the caudal with nearly equal lobes. The air bladder is double and the vertebræ number 45 to 47.

The species *Catostomus commersonii*, due to its range and abundance, has been described repeatedly and has received no less than 14 scientific names. Its present name recalls a noted Frenchman, Philebert Commerson, whose collections were examined by Lacépède in 1803. Among fishermen it is known also as "fine-scaled sucker," "pale sucker," "brook sucker," etc., though the term "white sucker" has been adopted by most authors.[1] It differs from others of the genus by the smaller size of its scales and the relatively greater girth at the shoulders. In this species the depth is contained 4 to 4⅔ in the length, the head is rather large and stout, conical and flattish but not concave above, and is contained 4 to 4½ in the body. The general color is olivaceous above, whitish below. Males, in spring, have a rosy

[1] In Pennsylvania the term "white sucker" is applied to Moxostoma, while the true white sucker is called gray or black in contrast. In Quebec, however, it is considered white, being called the "carpe blanche."

lateral band. The scale formula is 10–64 to 80–9. The length attains to 18, more rarely to 22, inches, and the weight to 5 pounds. Further details may well be left to succeeding pages.

The Catostomidæ are confined to North America and northeastern Asia. One species of this genus, *C. rostratus,* is found in Siberia. In America the species under consideration is the most common and extends from the Atlantic seaboard—that is, from Quebec—southward to Georgia and westward to Montana and Colorado, its southern limits including Missouri and its northern Lake Nipigon. It is excessively abundant throughout the middle of its range—viz, from Massachusetts to Kansas. A small race of this sucker has been found in certain cold streams of the Adirondacks, where it is dwarfed in size and more reddish in color but does not differ in essential characters. Doctor Rothrock has obtained a mountain race in the Twin Lakes of Colorado at an altitude of 9,500 feet (Bean, 1903).

Besides this extensive geographical distribution, we find that this species exhibits a wide range in its tolerance of the varied conditions of life. The experiments of Wells (1918) would point to the opposite conclusion, as he found but three species in Illinois more susceptible to chemical changes in the water. It is to be noted, however, that the white sucker is difficult to keep in aquaria and is easily affected by sudden changes. Its shy nature makes it rebel against confinement and, as Reighard says (1920), "confined with other fish in an aquarium it is among the last to become accustomed to the observer and to take food." A survey of its habits afield, however, shows that it has become adapted to practically every type of fish habitat. It associates with the brook and brown trout in our large springs; it may be found at any part of the varied course of the stream; and as the suckers dart up the rapids they may be mistaken for trout. In the warm pools of the meadow brook they are at home with the dace and shiners. They live in turbulent pools between the falls in the gorge, or hide in the very quiet ponds where goldfish are being reared. Over muddy bottoms, in the cat-tail marsh, or over rocky bottoms along the lake one meets with this same species. Forbes and Richardson (1908) concluded that it prefers bottoms of rock or sand, while in the lakes Reighard (1915) finds that it does not go below the thermocline in midsummer. Along the coast it will enter slightly brackish waters. I have failed ever to find white suckers in pools entirely isolated from any inflow, such as those left by the subsidence of a stream, though dace abound in such places.

It is of importance to the pursuit of fish culture that we know as fully as possible the food habits of any such species that may slip into a sluice or pond and make its home with cultivated species of fish.

BREEDING HABITS

We shall trace the development of the sucker by first describing the activities attendant upon spawning and later speak of the eggs and fry that result from each spawning season. So thoroughly has Professor Reighard (1920) recorded their breeding behavior that little remains to be added here beyond a comparison of his observations in Michigan with some records made in the Ithaca region.

My study of the sucker during its spawning period was made at the upper end of Beebee Lake at Ithaca, a shallow artificial lake about 6 acres in area.

From the deep, narrow gorge the inflowing creek spreads out over a delta of gravel and stones. The fish described as in deep water were in the portion of the stream at the mouth of the gorge, from which they went over the submerged delta into the shallower water of the lake to spawn. They always retreated upstream into deeper water when disturbed. As many as 40 were counted at a time, and their length ran quite constantly from 10 to 13 inches. Why smaller ones do not frequent this spawning bed remains a question, as we know the species does spawn when about 6 to 7 inches long. I am inclined to believe that this spot is chosen only by the fish that prefer the very deep water of the gorge as their home.

Professor Reighard found suckers breeding in April and early May in southern Michigan. On April 9 wire cage traps were placed in Beebee Lake and visited almost daily thereafter. The season was cooler than usual and we may conclude that spawning was retarded. The following facts encourage this view. Leaving out of consideration one warm day (April 21) the average daily atmospheric temperature was 5.6° F. below the normal from April 9 to May 18, the period during which breeding was in progress. On April 27 ripe fish of both sexes were found in traps located in about 3 feet of water between the deeper water and the spawning grounds proper. Previous catches were made only in 6 to 8 feet of water, and of these none contained ripe fish. Thereafter ripe females and males were taken at short intervals up to May 18. The observations should have been continued, but from May 9 to 18, 75 to 100 per cent of the specimens taken were partially or wholly spent. It would therefore seem that the height of the spawning season at this place was about May 5. If May 25 is taken as the approximate time when spawning ceased, the breeding period extended over 29 days.

An interesting habit, closely related to temperature, was frequently observed. Beginning April 22, whenever the water temperature reached 54° F. suckers were seen rather leisurely swimming up to the surface and breaking the water. Frequently they leaped out of the water for most of their length and then swam back to the bottom. This apparently was not a case of pursuit or of flight, and its significance is uncertain.

As Reighard found, so here on this shoal from one or two to four or five males pursue the female fish that wanders over the gravel, even where the water is but 1½ feet deep. Whenever the female stops the whole group of males stops with her. Owing to the presence of fishermen on the high rocky bank near by, I never could see the spawning act.

For several mornings areas of the bottom, from 1 to 2 feet in their greatest extent, were found to be swept clean of débris. Probably the eggs were laid here. The yellow-white stripes along the backs of the fish, peculiar to the breeding season, were very conspicuous.

Subsequent to these observations at Ithaca, the spawning of a group of white suckers was seen to great advantage in Little Buffalo Creek, Union County, Pa., on April 26, 1925. There a company of three males followed a distinctly larger female as she swam upstream into a short, stony rapid. Upon overtaking her the four stopped in swift water of but a few inches depth. So vigorously did the males contest to crowd against the female and to strike her with their heads and tails that the

surface of the water was broken by the splashing of the whole group. This lasted but a few seconds, whereupon the female retreated into deeper water downstream. In five minutes she returned, and the spawning was repeated, though this time she stopped not over 15 feet from where the observer was stationed.

That the dates given above for Beebee Lake can not be taken as applying to other habitats about Ithaca is evidenced by the fact that in streams accessible to suckers from the colder waters of Cayuga Lake breeding continues much later. Estimated dates when eggs were laid in such streams run as follows: Mouth of Taghanic Creek, May 25; mouth of Six Mile Creek, June 4; the inlet above Buttermilk Creek, June 9; mouth of Trumansburg Creek, May 25; mouth of Butternut Creek, June 25, and lower Salmon Creek, June 4. These dates were obtained by computing back from the date when fry of a determined length and age were collected. For example, if fry 18 millimeters in length were taken as late as August 10, we arrive at the spawning date by subtracting the age, in days, of such fry—viz, 45 days—from the date of capture, giving us June 26. From June 10, throughout the summer, collections were made twice or three times a week, which gave ample opportunity to learn of the average size of fry in the various streams.

This method is open to error, of course, as the basis for the computation of age was made upon eggs and fry raised under slightly unnatural conditions. However, the estimate is probably close to the truth and seems to indicate that suckers in the warmer, shallower, upland streams breed considerably earlier than those coming up out of the colder water of Cayuga Lake. Averages give us May 6 as the approximate close of spawning in the upland streams and June 5 for six streams accessible from the lake. These streams differ in temperature within the two groups here contrasted, which would alter the rate of develpment in each case, yet the difference of a month between the spawning in these two types of streams points to the coldness of the lake as the cause of the delay.

While no ripe females were taken in any habitat before April 27, it is of interest to note that ripe males were taken as early as March 23. One taken on that date, 6½ inches long, was so ripe that the milt flowed on handling the fish to remove it from the trap. A male taken February 7 was so nearly ripe that spermatozoa removed by dissection were active when placed in a drop of water.

Probably the white sucker does not breed until at least 6 inches in length. They are 4 or 5 years old at this size, and upon most sucker scales the circuli then formed show peculiarities, to be described later on, which doubtless register the physiological activities peculiar to spawning. For a clear account of the breeding behavior the reader is referred to Reighard's excellent paper (1920).

That the pearl organs of the males of this species are effective to roughen their sides and render the escape of the female difficult is witnessed by the fact that females taken from Beebee Lake after spawning showed their sides quite denuded of epidermis, the scales being bare from the caudal to the dorsal fin. Here we have one case of true effectiveness of these problematical structures, the pearl organs, though it seems doubtful that a use can be found for them as they occur on many of the Cyprinidæ.

DEVELOPMENT OF THE EGG

CONDITION AT LAYING

When expressed from the body of the ripe female the eggs are perfect spheres 2 millimeters in diameter. They are pale yellowish in color and of such translucency as to be easily overlooked in the water. When first laid they are slightly adhesive, clinging to each other and to surrounding objects, but this quality is lost as soon as they are "water hardened"; that is, rendered turgid by the absorption of water.

Like other fish eggs, those of this species are telolethical, the heavier yolk lying below the caplike disk of protoplasm, which therefore is seen plainly from above. This disk is whitish and covers about half of the surface that can be seen from the "animal" pole. (Fig. 1.) At this stage the egg membrane, or shell, everywhere rests closely upon the egg and is so thin and colorless as to escape detection easily. Its thickness is 15 microns. Of this, the inner *zona radiata* comprises 9 microns and is made up of alternate light and dark bars each 1 micron in thickness. The outer layer is very similar to the *stratum villosum* of the egg of Lepidosteus, described by Mark (1890), and is 6 microns thick. The micropyle is easily seen under the microscope. At first it is a funnel-shaped depression of the shell, which, when the egg is beginning to swell, reaches nearly to the egg proper (germinal disk). A very slight implantation cone is seen on the disk opposite it. After 20 minutes in water the space between the egg and the shell has swelled so much that the micropyle dips down but one-third of the distance. By 1½ hours it is withdrawn with the shell, now reaching but one-eighth of the intervening distance. The yolk mass consists of evenly distributed yolk globules, which, after dehydration, measure from 8 to 14 microns in diameter. There is no layering of the yolk, as in birds' eggs. No large oil drops are found in the sucker's egg, but numerous very clear droplets of minute size are seen both in the yolk about the edges of the blastodisc and contained in the cells of the latter after segmentation begins.

NUMBER OF EGGS LAID

From one 12-inch female 150 cubic centimeters of eggs, weighing 165 grams, were removed, each egg measuring 2 millimeters across before water hardening. By reference to the tables of von Bayer [2] it will be found that this volume contains 18,000 eggs of this size. Single eggs weigh between 6 and 10 milligrams. A still larger female (15 inches long) contained 31,200 eggs.

SPERMATOZOA

The sperm cells measure 24.7 microns in length, the ovoidal head or nucleus being 5.7 microns. The neck or middle piece is exceedingly small, less than 0.5 micron, and is seen with difficulty. The nucleus is sometimes blunt at the ends but is circular in cross section, resembling that of a trout. It could be seen after staining with hematoxylin. The flagellum was evident when iodine was used. The

[2] von Bayer, H.: "A method of measuring fish eggs." Paper presented before the Fourth International Fishery Congress held at Washington, September 22 to 26, 1908. Bulletin, U. S. Bureau of Fisheries, Vol. XXVIII, 1908 (1910), Part 2, pp. 1009-1014. Washington.

spermatozoa are motionless when removed by dissection from the body of the freshly killed fish and examined with the microscope, but the instant a drop of water is added they reveal an activity not exceeded in its rate and pandemic nature by the most active assemblage of protozoa or bacteria. One is reminded of chemical reactions in which every particle is thrown into violent motion.

Spermatozoa from a male trapped on February 7 and measuring 8¾ inches in length showed the following periods of such activity in various media: Tap water, 40 seconds; water from a goldfish aquarium, 45 seconds; melted snow, 45 seconds; human saliva, 5 seconds. The spermatozoa from a male that had been dead for one hour were nearly as active as this, though those from a fish four hours dead were inactive. In view of the excessive activity with which the male germ cells seek and fertilize the eggs during the minute or so of their swimming actions, it is possible to appreciate the advantage of both elements being discharged at the same time and over the same spot on the gravel.

FERTILIZATION

In nature this occurs during the moments following the discharge of eggs and sperm by the group of suckers engaged in the act of spawning. To obtain fertile eggs for study, a pair of ripe fish were taken from the traps on April 28 and removed to the Cornell University Fish-Cultural Experiment Station. Here the eggs and sperm were, by gentle pressure, expressed from the bodies of the live specimens into a small clean dish. The combined elements were stirred and allowed to stand for three minutes, after which water was added. Fertilization of well over 90 per cent of the eggs took place. That this occurred before the addition of the water, as is frequently assumed, can not be stated with certainty, as microscopic examination was not made until after the water was added. At that time the micropyle and implantation cone were clearly seen on several eggs.

WATER HARDENING

The egg when laid measures 2 millimeters in diameter. When water is added it begins to swell. The water enters through the shell or egg capsule, no doubt by way of the pores of the *zona radiata*, and lodges between the capsule and the egg. Within 30 minutes the eggs are quite turgid, have lost their partial adhesiveness, and may be handled without danger of causing injury. The capsule now stands one-half millimeter from the egg, giving a total diameter of 3 millimeters. The imbibed water probably functions to afford added protection from impact of sand, etc., prevent sudden changes of gases or liquids through the shell, and to permit movement of the embryo before hatching.

CLEAVAGE

A Meehan hatching jar was used with complete success. Such a jar provides a constant circulation of water from the lower end of an inserted glass tube upward through the eggs. The water used was from the creek, which is the source of supply for the station, so that conditions were as nearly natural as they could be made. A dozen eggs were taken daily, or oftener at first, fixed in Gilson's or Perenyi's fluid, and preserved in 70 per cent alcohol. Examination was made of them in the alcohol

for surface views, while many were embedded in paraffin, M. P. 54°, sectioned, and stained with Mayer's hematoxylin and eosin. A nonfertilized egg sections like hyaline cartilage, and fry with the yolk still unabsorbed, that were fixed in formalin, sectioned well. However, only a very small precentage of good sections of the cleavage stages were obtained. Those obtained nevertheless add much to the picture of the cleavage process.

PERIOD OF INCUBATION

The eggs in the Meehan jars hatched in 21 days. This is probably a little longer than the average time for the following reasons: About 5 per cent hatched at the end of 12 days, after which a period of cold weather delayed both eggs and fry for about a week. Then all hatched in two or three days. Cold weather is common at Ithaca even in May, so that probably 18 to 20 days is the normal period. Reighard (1915) gives 8 millimeters as the length of the newly hatched fry, but mine exceeded this by a millimeter or two, due, perhaps, to delayed hatching. The mean temperature of the water over the whole period was 50.5° F.

CLEAVAGE STAGES

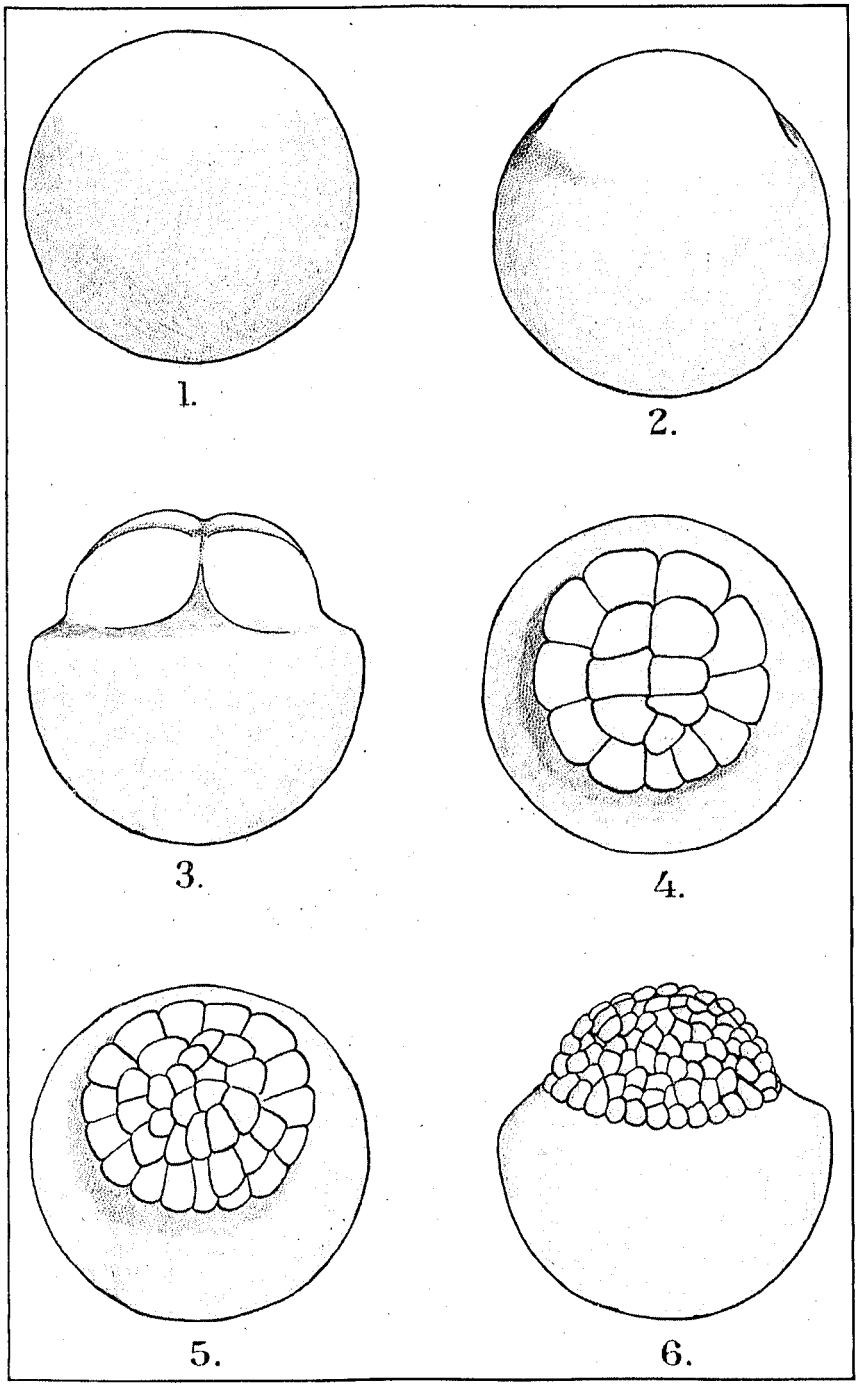
One-celled stage.—Two and one-half hours. (Figs. 1 and 2.) Samples taken two and one-half hours after fertilization are still in the one-celled stage. The shell must be removed carefully with dissecting needles. This done, the germinal disk appears white and covers about half of the top of the egg, extending down the sides about 45° from the pole. The contour of the egg is still that of a sphere, and the protoplasmic portion is but one-half millimeter thick at the pole and thins out laterally. Pseudopodialike branching processes of the disk extend down into the central region of the yolk. Clear droplets (oil?), twice the diameter of the yolk spheres, are found in the protoplasm, especially near its upper surface. Yolk spheres are sparsely but rather evenly scattered throughout the disk. These evidently are contributed from the densely packed yolk mass on which the disk rests.

Four-celled stage.—Six hours. (Fig. 3.) At the end of four hours the germinal disk contracts and arches up as a conspicuous white dome, leaving distinct shoulders to the egg when seen from the side. By six hours this dome-shaped disk is crossed by the first two cleavage furrows placed at right angles. These furrows extend one-third to one-half the distance through the disk, and sections show the continued wall below each one passing on to the yolk. The nuclei are centrally located in the cells, which are quite sharply demarked from the yolk laterally as well as below, as seen in sections. No cytoplasmic extensions of the disk were observed beyond the one-celled stage.

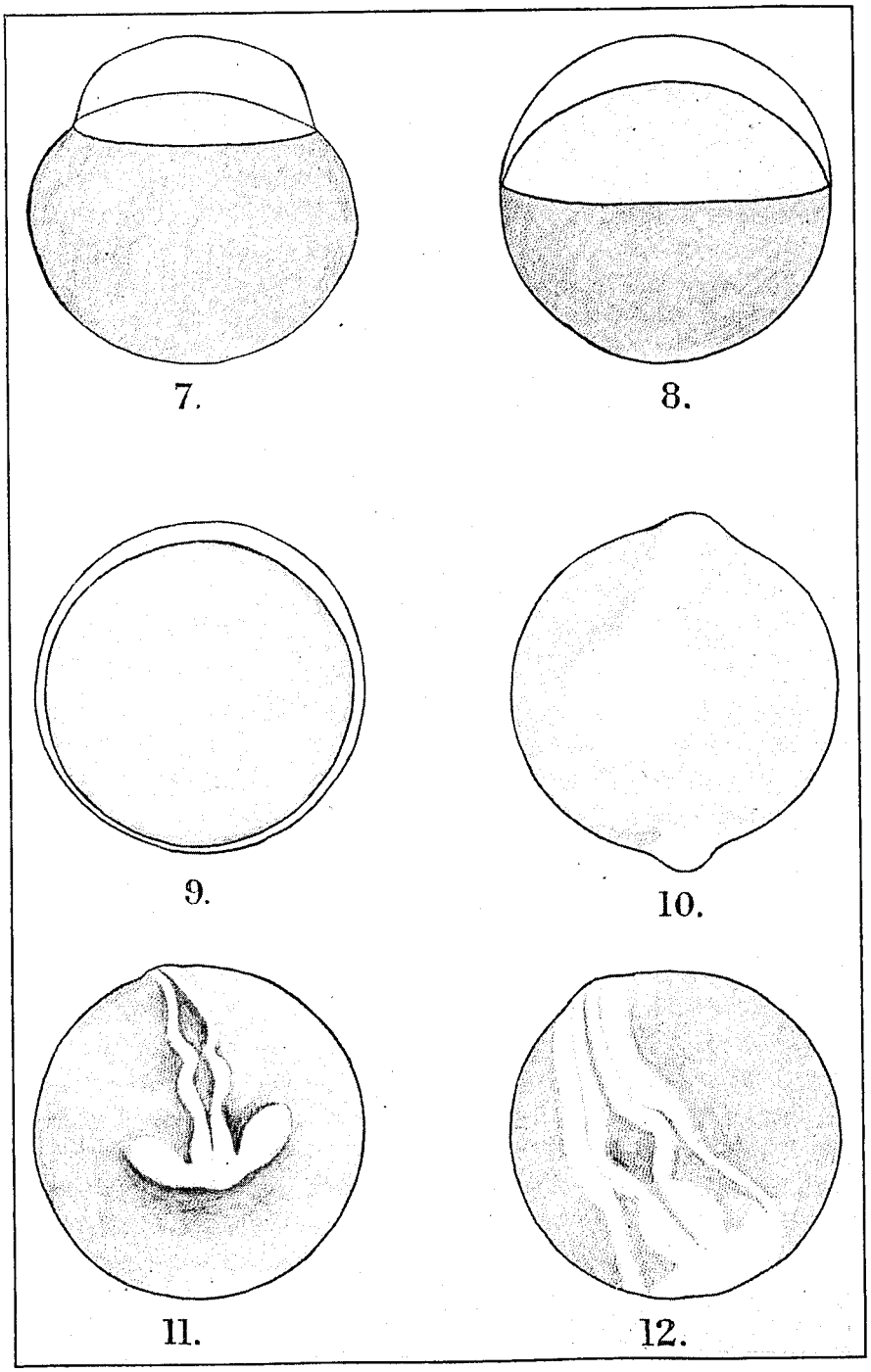
No observations were made upon the eight-celled stage.

Eighteen-celled stage.—Eight hours. (Fig. 4.) The cell cluster is sharply outlined, the cells being of nearly equal size. Cleavage planes are irregularly radial, resulting in an outer ring of about 11 cells surrounding the remainder, which are irregularly placed centrally. The outer cells are slightly larger.

Thirty-six celled stage.—Ten and one-half hours. (Fig. 5.) The centrally placed cells show by their relatively smaller size the more active cleavage. Up to this time the general contour of the egg is as in the four-celled stage—namely, a dome-shaped blastodisc surmounting the spherical yolk mass.



FIGS. 1–6.—Development of the egg of the white sucker, *Catostomus commersonii*. In each case the shell has been removed. 1. At time of laying, side view. 2. At end of 4 hours, side view. 3. Four-celled stage, 6 hours. 4. Eighteen-celled stage, 8 hours. 5. Later blastodisc at 10½ hours. 6. Condition at 21½ hours



FIGS. 7-12.—Development of the egg of the white sucker, *Catostomus commersonii*. In each case the shell has been removed. 7. At 40 hours (from egg cleared in xylol). 8. Extent of the blastoderm at 54 hours. 9. Complete investment of egg at 92 hours. 10. Dorsal ridge and head process at 149 hours. 11. Development of the brain as seen at 174 hours. 12. The same at 192 hours (8 days)

Investment of the yolk by the blastoderm up to 92 hours.—Twenty-one hours. (Fig. 6.) The blastodisc now consists of three layers of rounded cells, and its margin has begun to extend slightly farther over the yolk. In each of its 100 or more cells the cytoplasm shows a disposition to radiate from the nucleus, and yolk spherules and oil droplets are seen within the cells. The cells measure 0.1 millimeter in diameter.

Forty-four hours. (Fig. 7.) The disk of cells is becoming flat on top.

Fifty-four hours. (Fig. 8.) At this stage in development the blastoderm begins to thin out at its edge, which has reached nearly the equator of the egg. It is perhaps one-third as thick as in the four-celled stage. The whole egg is again a sphere.

Seventy hours. The yolk is now half covered. The advancing rim of the blastoderm may stand slightly above the surface level of the yolk.

Ninety-two hours. (Fig. 9.) The yolk is entirely invested. Sections show that while the blastoderm is six to eight cells thick at the animal pole, it is but one or two cells thick at the vegetative pole.

Embryo.—One hundred and twenty-six and one-half hours. Surface views give no indication of the embryonic axis.

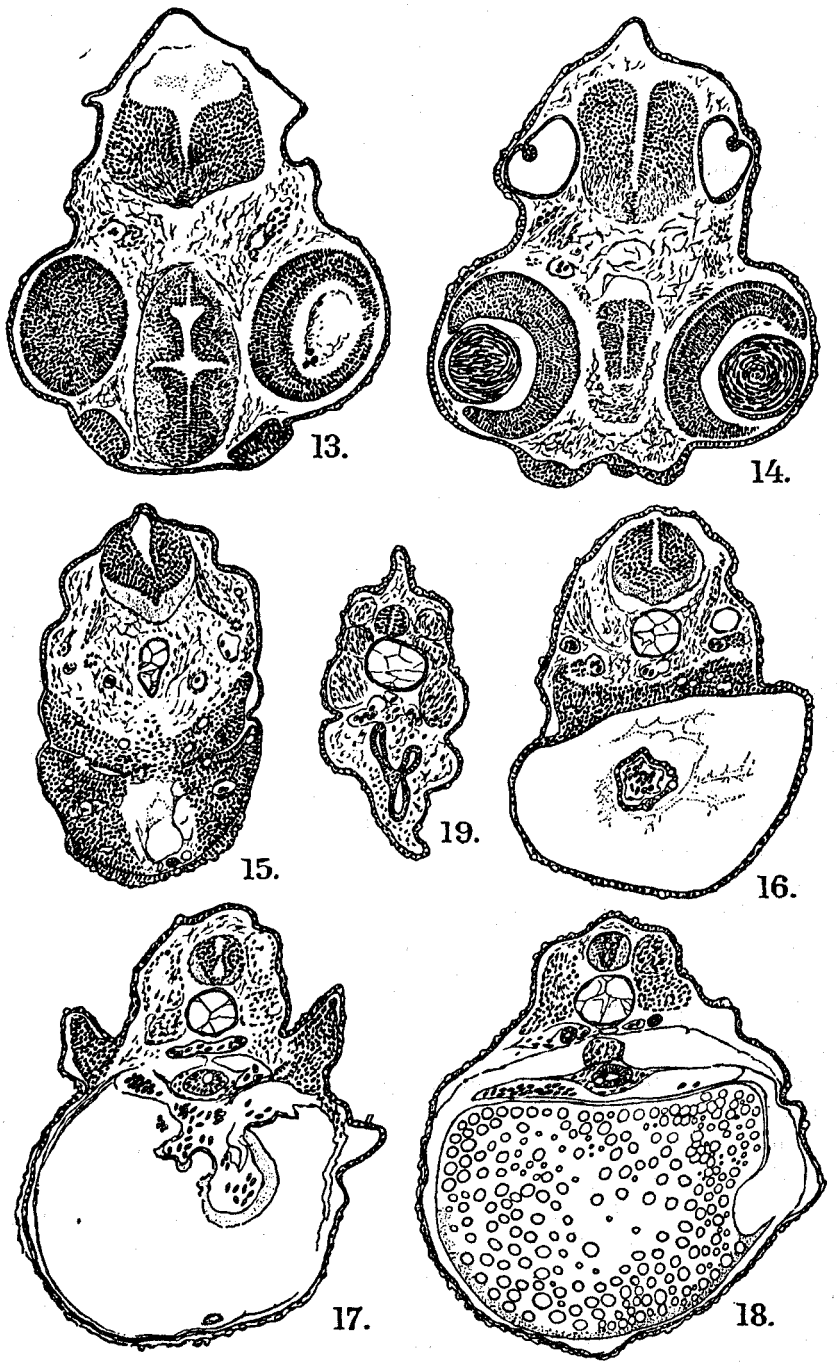
One hundred and forty-nine hours. (Fig. 10.) The body of the embryo fish is visible as a straight white ridge, narrow and rather high, nearly encircling the egg. At one end (the anterior) it terminates as a flat, rounded expansion. No open neural groove was seen, and Balfour (1881) reported the omission of that stage in the embryology of many teleosts, which has been well confirmed.

One hundred and seventy-four hours. (Fig. 11.) Marked changes, visible in surface view, have occurred in the anterior axial region. The brain is clearly seen. The optic evaginations are pear shaped and extend outward and backward from the primary cerebral vesicle. The other two cerebral vesicles are present as hollow expansions of the neural tube, the second being about as wide as long, while the third (myelencephalon) is more elongate and has a diamond-shaped ventricle. Fragmentary series of sections indicate that the neural tube is the only well-differentiated tissue present. It is almost solid, but otherwise resembles that of a chick embryo of 48 hours. The blastoderm abruptly passes from the thick ridge, which will become the body of the fish, to the portion, but one or two cells thick, that spreads out over the yolk.

One hundred and ninety-eight hours. (Fig. 12.) The lateral boundaries of the head and body are seen now. The tail process almost reaches around to the anterior limit of the head. The limits of the yolk sac are indicated caudally.

Two hundred and twenty-four hours. The yolk, which has been spherical, is now reduced to two regions. The anterior is spherical but the posterior portion, arching around the former, is cylindrical. The notochord is visible as a clear central core in the tail process, which process extends well beyond the yolk sac.

Two hundred and forty-six hours. The embryo forms more than a circle; its tail lies either to right or left of the head or is bent at a right angle across the front of the head. Pigment has appeared in the eyes. Five per cent of the eggs hatched at this time, though the majority were delayed for some days. The latter gained 1 millimeter in length over those hatching at this time, but were otherwise like them.



FIGS. 13-19.—Development of the larva of the white sucker, *Catostomus commersonii*. Cross sections through a larva of 8 millimeters. 13. Olfactory placodes. 14. Eyes and otocysts. 15. Region of the branchial clefts. 16. Ventral aorta and pericardial cavity. 17. Heart. 18. Body and yolk sac. 19. Cloaca region. The Wolffian ducts are seen joining the intestine

NEWLY HATCHED LARVA

The newly hatched fish is about 8 millimeters long but only one-sixth as deep. (Fig. 20.) The slender, whitish body extends along the cylindrical yolk sac, and the decurved head projects 0.8 millimeter in front and the tail 1.5 millimeters behind. The proportionate lengths of head, body, and tail are 1 :6 :1½, using the vent as the posterior limit of the body proper. The eyes are large and slightly elliptical, the long axis being parallel to the axis of the embryo. The otocysts are as yet simple ovoid sacs. The dome-shaped pericardial cavity containing the small S-shaped heart fits like a cap over the anterior end of the yolk sac.

The mouth is still in the oral pit stage. Myotomes are visible along the back and tail. The anus lies immediately posterior to the yolk sac. A low median fin fold arises in the mid-dorsal region and sweeps around the tail to end at the vent. In the portion that will persist as the caudal fin, delicate rays or actinotrichia are seen in some of the specimens. The pectoral fins begin at this stage as rather thick flaps of undifferentiated mesoderm overlaid with ectoderm. Pigment is present only in the retinæ.

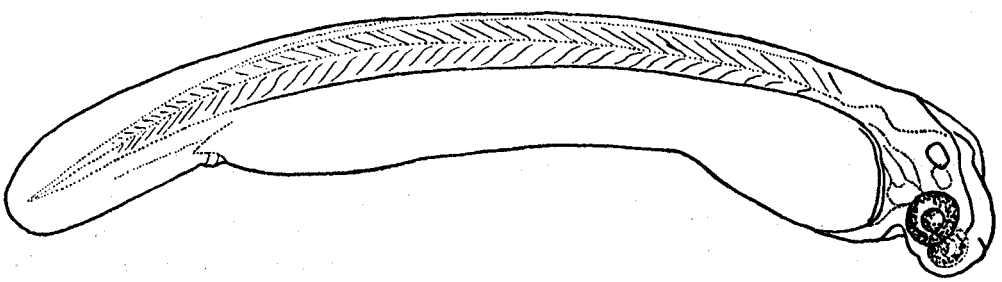


FIG. 20.—Sac fry at the time of hatching, rendered partly transparent. The oral pit is ventral, the caudal fin homocercal. 8 millimeters

Serial sections add much to our study of this stage. (See figs. 13 to 19.) The epidermis is seen to be but two cells thick. The olfactory placodes are but circular thickenings of the epidermis, five or six cells in thickness. No mesodermic coats of the eye are yet present, and the orbital musculature is barely outlined. The cornea resembles the general epidermis, while the lens itself still shows the vestige of its cavity and is relatively so large as nearly to fill the optic cup. The heart wall (myocardium) is but four or five cells thick, the heart occupying only the dorsal quarter of the pericardial cavity. The vitelline veins, the aorta and its arches, may be traced. Alongside the large notochord the slender nephric ducts maintain an even caliber as they pass back to join the digestive tube close to the vent.

The intestine itself is considerably smaller in section than the notochord, being a tube of columnar epithelium the cells of which contain very large, clear vacuoles. Just back of the heart is the junction of the anterior end of the yolk sac with the digestive tube, which is flattened. The fore-gut is mostly solid, though the branchial evaginations are well marked. The mouth as yet is not open. In this condition the larva lies on the bottom or swims upward, to sink again to the bottom of the hatching jar. Placed in an outdoor pond, they swam at the surface at the end of the second day after hatching.

DEVELOPMENT OF THE LARVA

DIGESTIVE TRACT

The yolk sac is present for but six to eight days, when the larva is 11 millimeters in length. A few complete the absorption of the yolk sac somewhat earlier. As the sac disappears the gut rapidly expands and enlarges from a size smaller than the notochord to that of the yolk sac itself. The mouth becomes open at about 9 millimeters and the branchial apparatus is completed. Food may be taken as early as the 9-millimeter stage, though this is rare. Up to 17 millimeters the gut is a straight tube from mouth to anus. The subsequent changes in the structure of the intestine will be described hereafter.

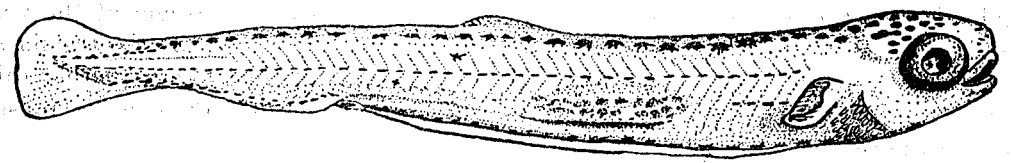


FIG. 21.—9-millimeter fry showing the terminal mouth, the exposed gills, and early condition of the fins and of the pigmentation

PIGMENTATION

After the appearance of pigment in the eyes (see p. 157), the next to form occurs as a double row of large chromatophores along the mid-dorsal region and about 30 smaller ones on the top of the head. (Fig. 21; 9 millimeters.) A row of smaller ones appears along the mid-lateral line and a double row along the mid-ventral region. By the time the embryo is 12 millimeters long (fig. 22) chromatophores appear in the caudal fin on each side of each ray. At 14 millimeters (fig. 24) the same is true of the dorsal, at 18 millimeters of the pectoral (fig. 25), and at 20 millimeters all fins contain pigment.

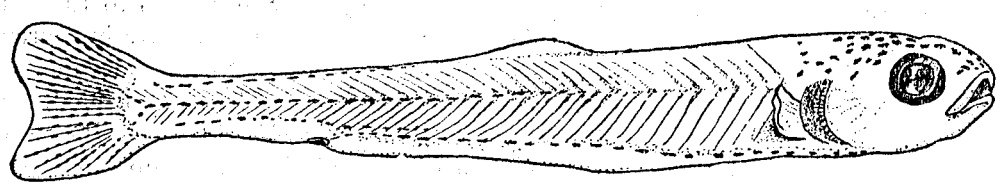


FIG. 22.—Specimen of 12 millimeters. The caudal fin is notched; the operculum covers more of the gills

At 20 millimeters scattered pigment is seen all over the body, which later (at 25 millimeters) begins to follow that of the scales by outlining the area over each scale. At this stage young white suckers begin to appear mottled, as the pigment is intensified in several laterally located spots or blotches. A yellow color appears on the sides, also, giving a distinct golden iridescence.

FINS

Upon hatching, only the homocercal caudal fin and the pectoral fins are present. The caudal is but the terminal portion of the median fin fold, which passes from the middle of the back around to the vent below. By 9 millimeters the dorsal is defined,

the remainder of the dorsal median fin fold having disappeared. (Fig 21.) The yolk sac, having rapidly reduced in size, appears as only a thin ridge along the mid-ventral line. In the same mid-ventral line the anal fin is seen back of the vent. The caudal fin begins to show its two lobes (homocercal type) at 12 millimeters. (Fig. 22.) It is not difficult to render larvæ of this length transparent and to see the upturned end of the notochord—a reminder of the heterocercal nature of this fin in

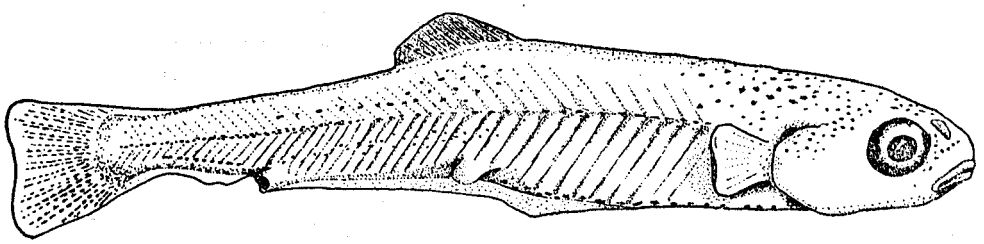


FIG. 23.—Specimen 15½ millimeters long. The gills are almost covered

the ancestor. In the adult male the lower lobe of the caudal is larger than the upper lobe. The pectoral fins are present at hatching, but are so transparent as easily to escape detection except in the examination of stained sections. They function for some time before the relatively smaller ventral fins appear at 15 millimeters. (See Figs. 23 and 24.)

PECULIAR CHANGE IN LOCATION OF MOUTH

At hatching (8 millimeters) the mouth is not yet open, the fore-gut being nearly solid. (Fig. 20.) At 9 millimeters, however, the terminal mouth, characteristic of the early top-swimming stage, is completely formed and open. (Fig. 21.) The facial expression of the larva, viewed from directly in front, is as interesting as it is grotesque. The horseshoe-shaped mouth lies in an almost vertical plane, arching up between the very large eyes so that its opening is actually as high as the center of

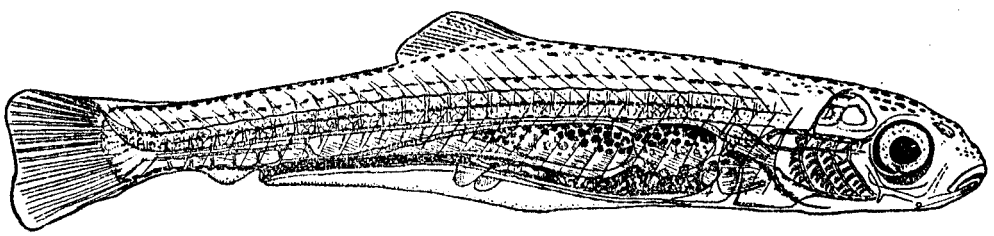


FIG. 24.—Specimen 14 millimeters in length rendered transparent. The mouth is becoming inferior, the pelvic fin buds are evident, and the upturned notochord is seen at the base of the caudal fin

the eyes themselves. The eyes, it may be recalled, are contained but three times in the length of the head at this time, whereas they are contained seven times in the head of a 10-inch adult. The nares are each a single oval depression located in the angle between the eye, laterally, and the upper lip below. From its high terminal position the mouth cavity slopes steeply downward and backward to the pharynx. Hyaline cartilage already forms the skeleton of the head.

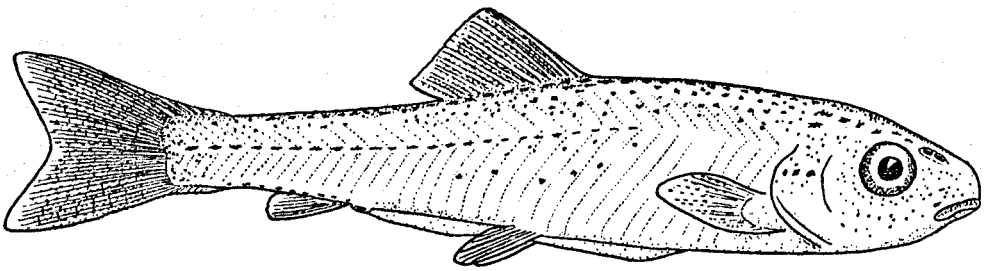


FIG. 25.—Specimen 18½ millimeters long, showing the appearance of rays in the ventral and anal fins

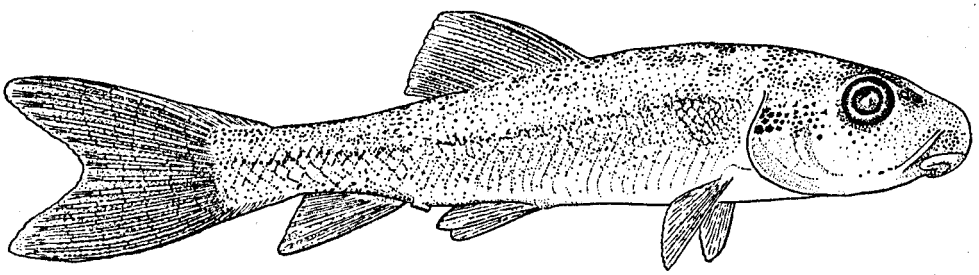


FIG. 26.—Specimen 25 millimeters long. The pigment pattern begins to follow that of the scales. The nostril is divided

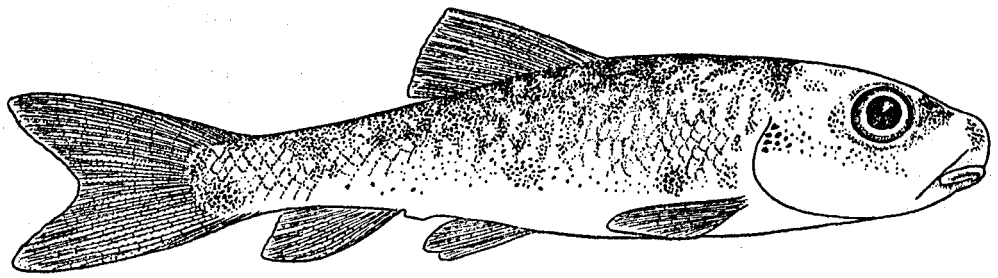


FIG. 27.—Specimen 30 millimeters long

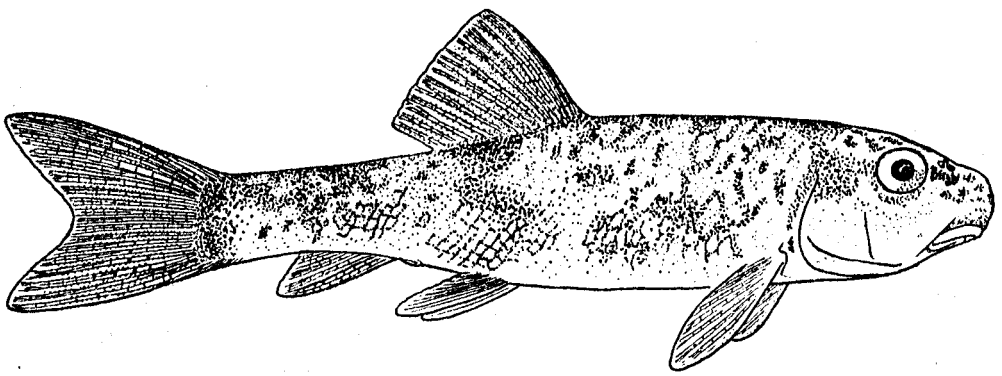


FIG. 28.—Specimen 50 millimeters long, with eye becoming relatively high, the mouth strongly inferior, and showing characteristic pigmentation

As the fish grows, the relative positions of eyes, nares, and mouth are greatly altered in a manner peculiar to this family of fishes. Probably the eyes and nares are the more fixed in position, while the mouth descends to its inferior position. At 14 millimeters the mouth opening is on a level with the lower rim of the eyes (fig. 24), and by 16 millimeters it is entirely below this level. Its position now apparently interferes with feeding on floating particles, for before attaining a length of 18 millimeters the fish adopts the habit of feeding on the bottom. This change of habit will be discussed in more detail later.

In the 43-millimeter larvæ papillæ are present on the lips, which are now thick and swollen. In fish exceeding 16 millimeters in length the mouth may be described as still a crescent but lying more and more in a plane approaching the horizontal. In an adult 12 inches in length this crescent is 20 millimeters wide and 15 millimeters from front to back, including the lips. The lips are covered with dome-shaped papillæ, five rows of them on the anterior lip and nine on the posterior. This pos-

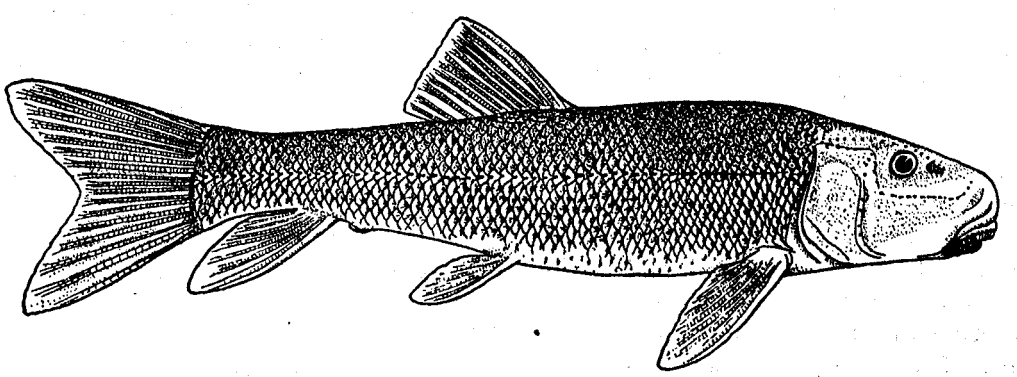


FIG. 29.—Adult sucker, showing relative size of fins and relative position of the eye, nostril, and mouth. 10 inches long

terior lip is deeply notched behind and is flattened out at its posterior margin and also laterally.

These lips are capable of much protrusion, assuming the form of a funnel, extending downward and forward. When the mouth is closed the anterior end of the head is decidedly blunted in side view. The eye in the adult is relatively quite small and high up in the head. (Fig. 29.) The nares lie just anterior to the eyes and are divided by a vertical earlike flap 2 millimeters high.

HISTOLOGY OF THE MOUTH. ORAL EPITHELIUM

At 10 millimeters the mouth and pharynx are lined with a stratified epithelium, the cells of which are rounded, some of the superficial cells being flattened. There are but two to four layers of cells in this epithelium, which is 20 microns thick. The nuclei are basal in the cells. Taste buds of striking size are found here and there throughout the mouth and pharynx. They are conical or mammiliform and extend above the surface of the epithelium for another 20 microns. (Fig. 31.)

These flasklike taste buds show, in each section, about six columnar nuclei in the basal portion and a clear upper neck, which, being finely striated, doubtless contains processes of the sensory cells. In one case seventeen of these sense papillæ

were found in the mouth of a specimen of this size. At the lips the epithelium is continued as the integumentary epidermis, which is five to six polygonal cells in thickness, the outermost, however, being a continuous layer of flatter cells. Taste buds are found here also, but are broader and do not pass beyond the surface. A small fold of the epithelium of the mouth (breathing valve) is seen just inside the upper lip. It bears no taste buds.

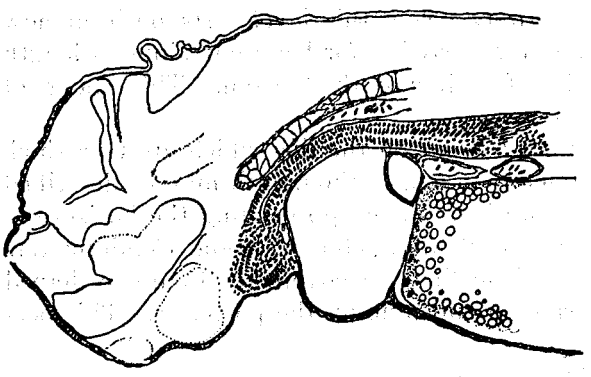


FIG. 30.—Anterior third of a longitudinal section of a specimen taken on the day it hatched. Length, 8 millimeters. The digestive tract appears as an almost solid cord of cells passing over the heart chamber and descending to the ventrally located oral depression

At 16 millimeters the oral mucosa is from 8 to 10 cells thick, but as the cells are of similar rounded form stratification is not evident. This epithelium has doubled in thickness—40 microns—the papillæ still rising 20 microns above the surface. A section 10 microns in thickness shows as many as 15 of these sense papillæ surmounting a single branchial arch (cut transversely to the arch), and as many as 40 of them per millimeter in a line along the roof of the pharynx. (Fig. 32.)

Just a little way back of the upper lip and breathing valve is another cluster of large taste buds. The epidermis of the integument has developed numerous goblet mucus cells and the mesoderm is entering into the formation of the lips. The taste buds inside the mouth all project above the surface of the epithelium, those of the lips projecting slightly as low, rounded elevations. In the skin they do not project and none occurs on the breathing valve.

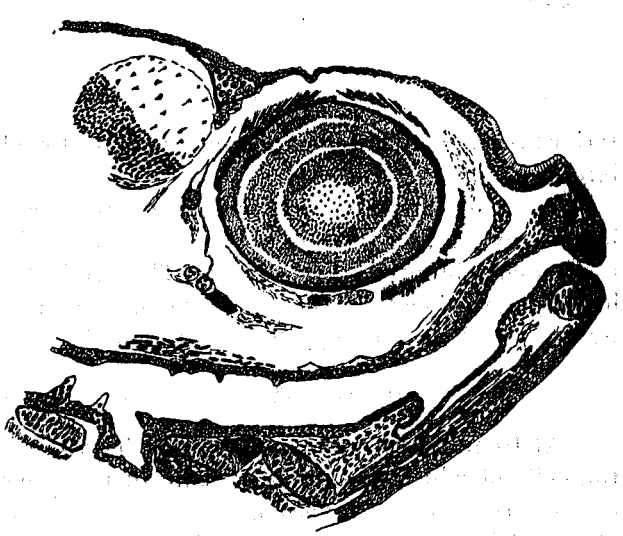


FIG. 31.—Longitudinal section of head of an 11-millimeter specimen. The early high terminal position of the mouth opening is seen clearly here

At 42 millimeters the epithelial portion of the oral mucous membrane is 80 microns in thickness; that of the skin is 100 microns. So numerous are the taste buds on the lips that, as in the pharynx, they frequently touch one another. This is the condition after the mouth has become inferior, and probably differs little from conditions later in the life of the fish. In a specimen 65 millimeters long the lips are papillose in the sense of having macroscopic elevations. Each of these, on sectioning, is found to contain a battery of the microscopic taste buds (called "sense papillæ" above).

A single section, 10 microns thick, shows as many as 18. How many occur on the lips of an adult fish is problematical, but as 576 macroscopic papillæ may be found on a 12-inch specimen, and as each of these contains at least a score of taste buds, the total number must be over 10,000. The writer is inclined to think that the eyes, due to their location, play a small part in locating the food, and that the sense of taste is very effective in locating the food.

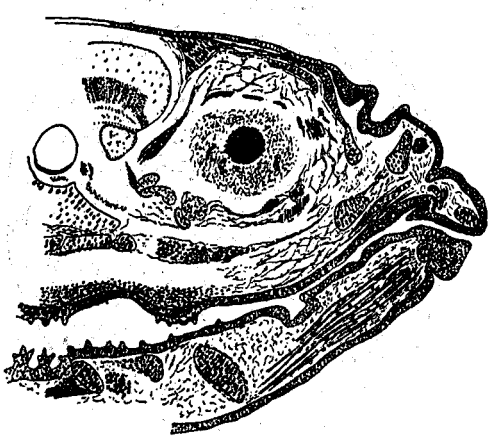


FIG. 32.—Longitudinal section of the head of a 16-millimeter specimen showing descent of the mouth, division of the nasal pit, and increase of the taste papillæ in the pharynx

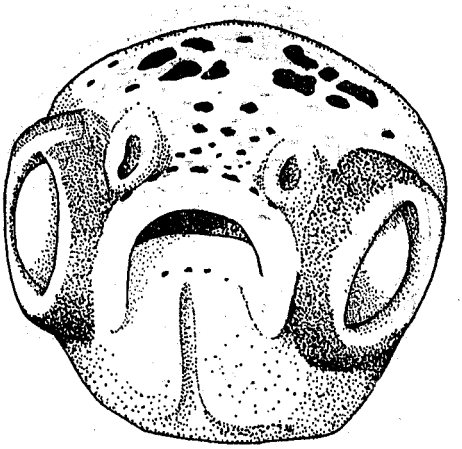


FIG. 33.—11 millimeters

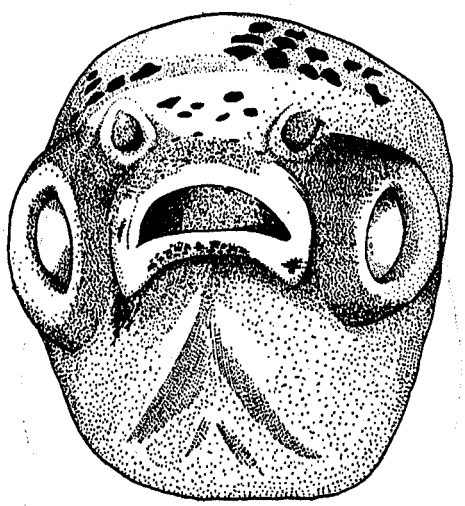


FIG. 34.—12½ millimeters

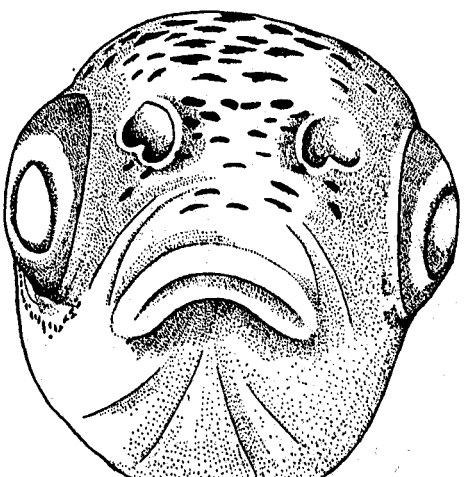


FIG. 35.—14 millimeters

Descent of the mouth, division of the nasal pits, and appearance of the labial papillæ, as seen in a series of anterior views of the developing sucker.

HISTOLOGY OF THE INTESTINE

A few words upon the development of the remainder of the digestive tract may not be out of place here. The stages preceeding and after the metamorphosis of the mouth and the sudden lengthening of the intestine are of special interest.

Conditions at hatching have been described. By the time the larva is 11 millimeters in length the yolk sac has disappeared entirely and the liver and air bladder

are well formed. While the mouth and pharynx show cubic or polygonal cells in two and three layers, this condition gives way to three layers of columnar epithelial cells in the region of the heart. Also, there is a very conspicuous sphincter of striated muscle at this level. This muscle ends abruptly as we pass backward, the gut having an exceedingly thin muscular coat.

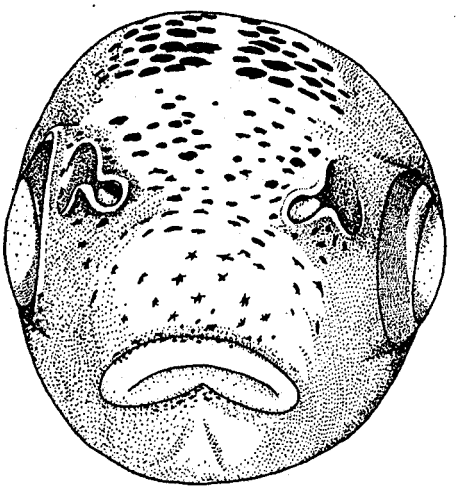


FIG. 36.—16 millimeters

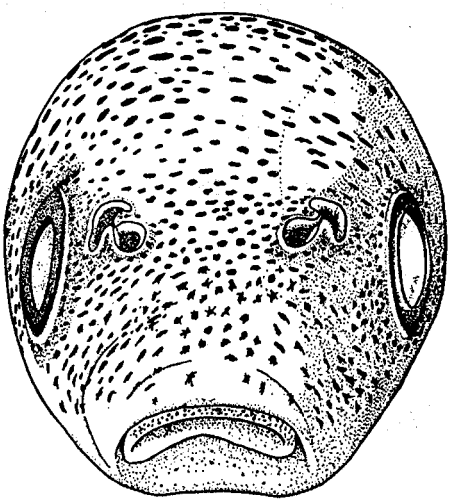


FIG. 37.—22 millimeters

FIG. 38.—42 millimeters

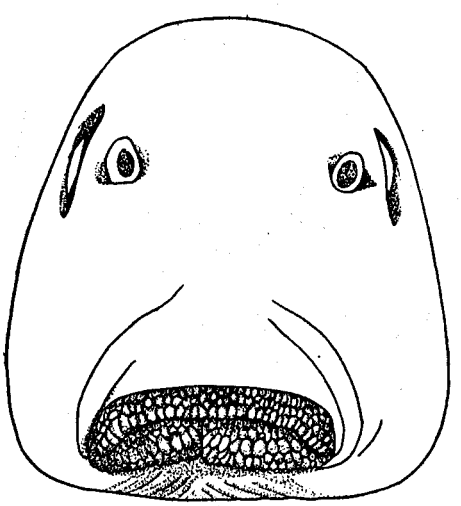


FIG. 39.—250 millimeters

Descent of the mouth, division of the nasal pits, and appearance of the labial papillæ, as seen in a series of anterior views of the developing sucker.

At the anterior region of the liver, which is located just back of the heart, the epithelium changes to the simple columnar type. The gut is a narrow tube while passing through this region, and is placed high in the body. It expands, however, before the posterior end of the liver is reached, and its lining mucous membrane is

thrown into high narrow longitudinal ridges. The duct to the air bladder leaves the gut in the mid-dorsal line, while the latter is surrounded by the liver. At the same level we see the larger duct from the liver (and pancreas?) entering in the mid-ventral region. Both are lined with columnar epithelium, the latter having the greater caliber and ending in a rounded gall bladder embedded in the liver substance. The air duct curves to the left and then returns to enter the air bladder in the median line. The bile duct curves to the opposite side and upward.

Back of the liver there are no folds in the intestinal epithelium. The diameter of the intestine rapidly increases posterior to the liver and occupies the entire body

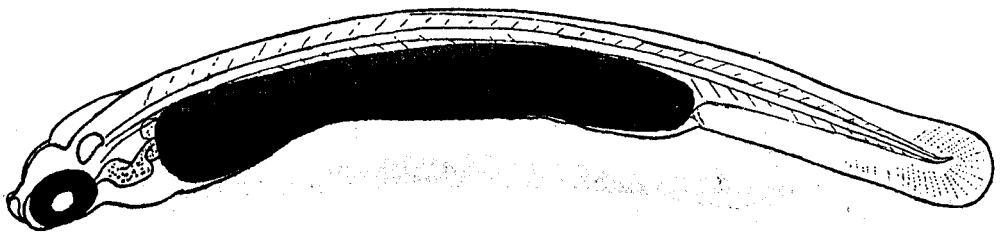


FIG. 40.—Sac fry, 8 millimeters in length, rendered transparent. The yolk sac has been drawn in solid black (camera lucida)

cavity. Its wall is of simple columnar epithelium, the cross section of the organ being an almost perfect circle.

At 14 millimeters the longitudinal folds of the epithelium are found much farther back; that is, to the posterior end of the swim bladder. The latter has grown so rapidly as to occupy twice the cross-section area occupied by the intestine and one-third the entire cross-section area of the fish. This may be a potent factor in inducing the top-swimming habit of fry under 17 millimeters. Back of the swim bladder the intestinal epithelium is not yet elevated into folds.

The intestine shows the folds, or rugæ, throughout its entire course at 17 millimeters. Also the first intestinal loop is formed and the epithelial cells of the region

FIG. 41.—Fry of 11 millimeters, showing the straight digestive tract, the development of the caudal fin, and the simple swim bladder

involved appear much more closely packed as if division were proceeding very rapidly. This, for several reasons, including the change in form of the intestine, I have called the critical period in the life history.

ADULT CONDITION

The digestive tract, as in the Cyprinidæ, has no true stomach; that is, no region containing special gastric glands. To be sure, the sucker appears to have a stomach, the first 4½ inches of the gut of a 12-inch specimen being of wider diameter and

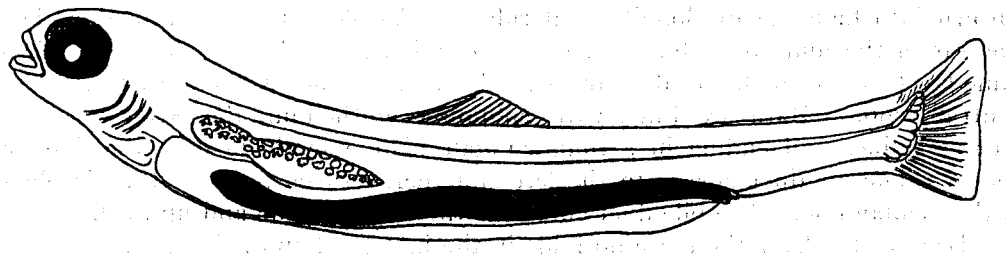


FIG. 42.—Fry of 13 millimeters. Dorsal and caudal fins show an advance, the swim bladder is becoming divided

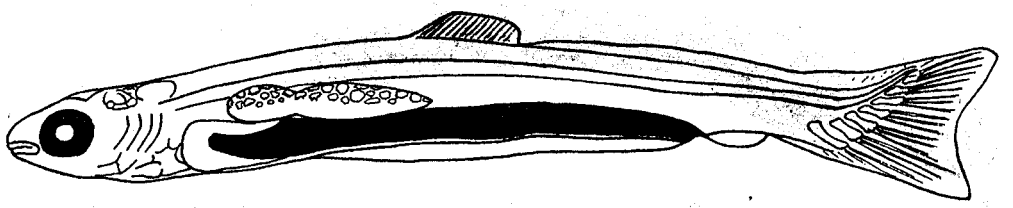


FIG. 43.—Fry of 15 millimeters. Anal fin is demarked. The gut is still straight

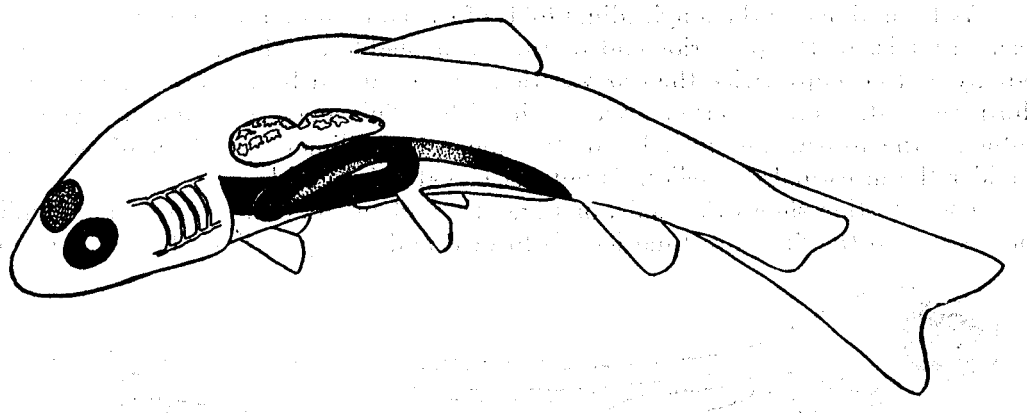


FIG. 44.—Fry of 16 millimeters, showing the first coiling of the intestine. The paired fins are also present

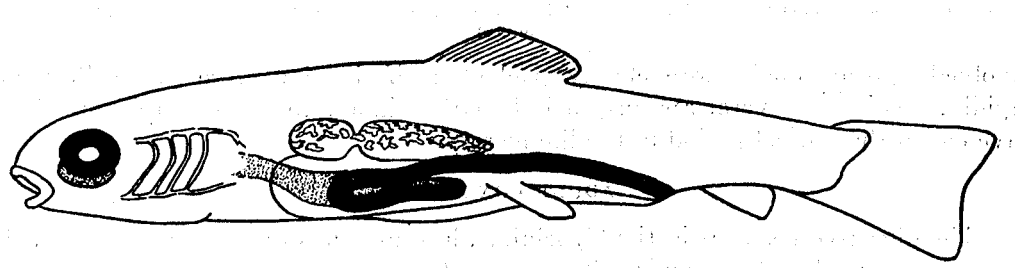


FIG. 45.—Fry of 17 millimeters, similar to that of 16 millimeters

having stronger muscular walls, but sections show that there are no glands anywhere in the digestive tract except the liver and pancreas. The entire tract is lined with a rugose mucosa consisting of simple columnar epithelium. These rugæ are coarse and high (½ millimeter) at the beginning of the tract and reduce so as to be barely visible in the rectal region. They follow a zigzag course, running about 3 millimeters in each oblique direction.

Sections at any level are similar to those of any other region except for measurements. In the straight anterior region there are about 25 rugæ, each about one-half

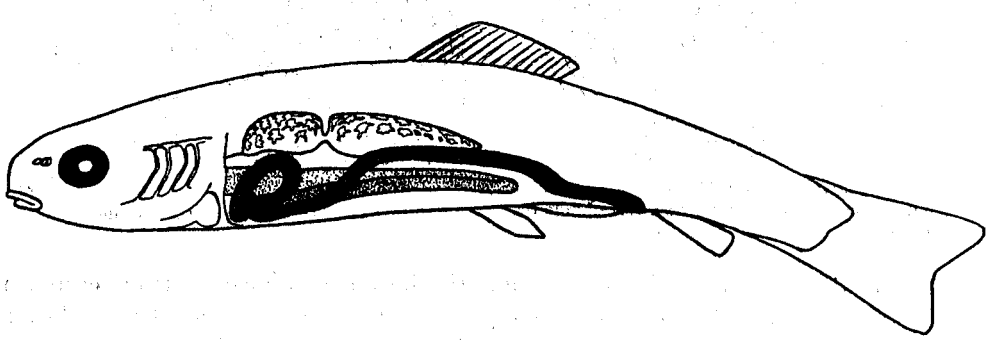


FIG. 46.—Fry of 20 millimeters, showing beginning of the laterally placed loops

a millimeter high. Below the epithelium is a densely cellular connective tissue. About one-tenth of a millimeter outward from the bottom of the rugæ lies the hyaline *stratum compactum*, 20 microns in thickness. This is a dense nonnuclear layer of connective tissue fibers peculiar to the intestine of fishes. Immediately outside of it is the circular muscle layer, one-sixth millimeter thick, and outside of this is the longitudinal muscle layer, which is only one-quarter as thick as the layer of circular fibers.

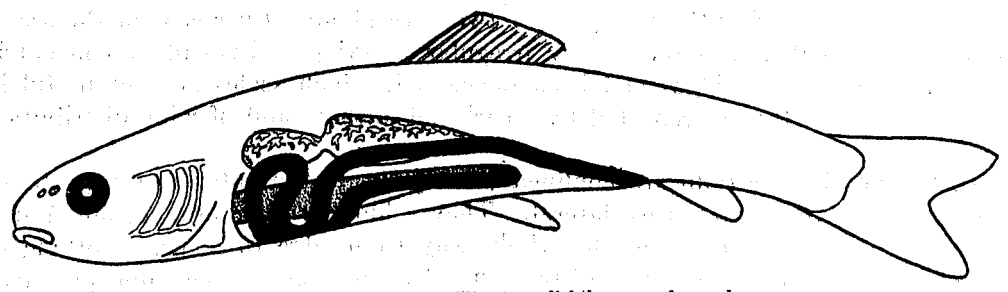


FIG. 47.—Fry of 21 millimeters, slightly more advanced

COILING

By studying a series of young fish from 9 to 25 millimeters in length, which had been rendered transparent by slow clearing in xylol, the changes in the form of the intestine could be seen with surprising clearness. (Figs. 40 to 47.) From hatching up to 17 millimeters the intestine is straight and occupies a median ventral position back of the level of the liver.

It is at the critical period (17 millimeters), when the mouth is becoming inferior and the diet is changing, that the first loop of the intestine is formed. It is located

about the middle of the body. The intestine bends so as to return forward for a distance and then curves backward to continue its course to the vent. From this time on the intestine continues to increase in length rapidly, the coils lying chiefly on the right side of the body and taking the form of a circle.

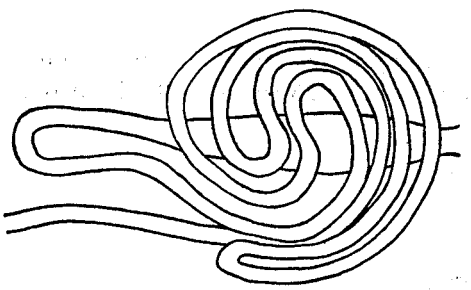


FIG. 48.—Digestive tract of a 9½-inch adult, with fat and liver removed to show its coiling, viewed from the right side

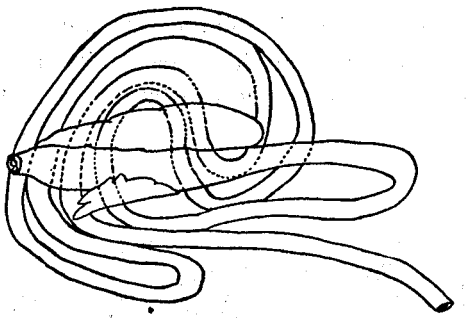


FIG. 49.—Same, from the left side

When the fish is 17 millimeters in length the entire digestive tract equals the length of the fish; at 24 millimeters it equals nearly twice its length; while adult specimens 6 to 12 inches long show that it falls little short of being as great as three times the fish's length.

DETERMINATION OF AGE

RELATION BETWEEN GROWTH OF SCALES AND SIZE OF FISH

The scale of the white sucker is of the cycloid type. While circular or elliptical the first two years, it gradually assumes a quadrilateral form, developing straight sides and a rounding base and apex. The focus is centrally located, though nearer the posterior edge during the first year or two. In about 30 per cent of the scales examined the focal area showed very irregular markings. Instead of concentric circuli, a reticulium of ridges had been developed. Such scales are not useful in age determination, though reported by nearly all authors and of wide distribution among species.

In this species the radii are confined principally to the anterior and posterior quadrants, very few being truly lateral. They seldom if ever branch, and but a small percentage fails to extend the whole way from edge to focus. Nothing of value resulted from a careful count of radii in about 200 scales taken from specimens from 28 to 250 millimeters body length. While the furrows are very shallow in young scales they are deeper and straighter in larger ones and maintain the clear appearance characteristic of the newly formed margin of the upper surface of the scale.

The circuli are fine, narrow, parallel ridges, separating relatively wider furrows. They are concentric and nearly always parallel with the true edge of the scale. If they run obliquely to the edge they always do so along the sides of the scales. Their distance from one another varies with the time of year but averages about one twenty-fifth of a millimeter.

The scales have a smooth edge except for a slight indentation of the margin at the end of each radius. I have found that this is not true of scales taken in the late winter and early spring, however, in which the edge is straight.

Attempts to photograph scales were not successful, but drawings made carefully to scale are presented in illustration of certain features of scale growth.

Scale formation begins when the fry are somewhat less than 22 millimeters in length (40 days from hatching). However, none could be removed in specimens under this length, even by scraping the surface. Those first obtained measure one-third of a millimeter in diameter, and it is probable that they represent scales from the region of the lateral line, for in fishes generally it is known that the scales first appear in this region. By the time the fry are 25 millimeters long scales seem to be everywhere present. While the first showed but three circuli, on an average four are now present. It is also noticeable that the pigment in the dermis follows the edges of the scales, forming a cross-hatched pattern. This pattern is limited at first to the sides of the fish in the first and last third of the body. When 28 millimeters long the scales show five circuli, there being a striking uniformity in this respect. The pigment pattern mentioned above now occurs over the entire scale-bearing portion of the fish.

By autumn of the first season the scales average about 10 circuli each. (Fig. 50.) This figure is important, in that we know definitely the time in which they have formed this number. One can detect, even at this time, that the circuli formed during the summer and fall are more closely crowded than those of the spring. It is in the very early spring that sucker scales show the widest spacing of circuli. In some species, such as the carp, this is said to be true of those formed in midsummer.

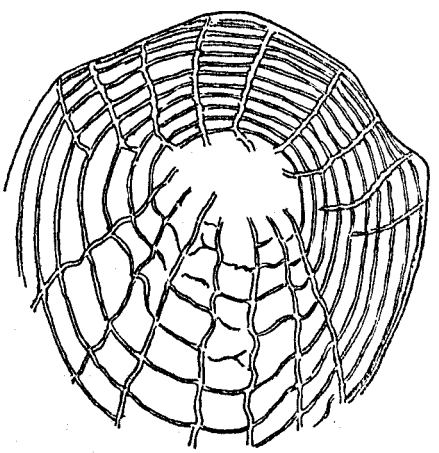


FIG. 50.—Scale of first season, taken in August from a specimen 40 millimeters in length

If we now take the scale of a larger fish, say 5 or 6 inches long, we find that it is correspondingly larger and shows many more circuli. These are seen to fall into groups or zones, each zone containing a band of widely spaced circuli followed by another band in which the circuli are more closely crowded.

In other species these zones of circuli are known to indicate the annual growth of the scale. They are spoken of as "annuli," and by counting them the age is determined. The question arises as to the evidence that they represent such annual growth in this species.

By frequent collecting throughout the summer there is left no doubt but that fingerlings 1½ inches in length are but one season old. Their scales show but one zone of circuli, widely spaced at first but becoming narrowly spaced in the fall. This is, then, a true annual zone. The fact that in later years zones of about the same width and containing about the same number of circuli are present, but in greater numbers, points to the conclusion that they are repetitions of the process

of growth of the first year. Again, the marginal circuli of specimens taken in the spring or in the fall show the spacing characteristic of the season in which the fish were taken.

While the number of circuli per zone or the total number on the scale is an unreliable basis for age determination in many species and also in old specimens of the sucker, it is a striking fact that in suckers 4 or 5 years old the number of circuli per zone is quite constant—namely, about 10.

White suckers of the same age, in terms of years, vary in length within fairly narrow limits, but they have the same number of zones of circuli. This number is a more accurate index of the age of the fish than is the length. Such are the conclusions to which the following observations appear to lead.

A series of specimens was selected, ranging from 60 to 300 millimeters in length, with an interval of 10 millimeters between specimens. Ten scales of each specimen were examined, and the annual zones and number of circuli in each zone were

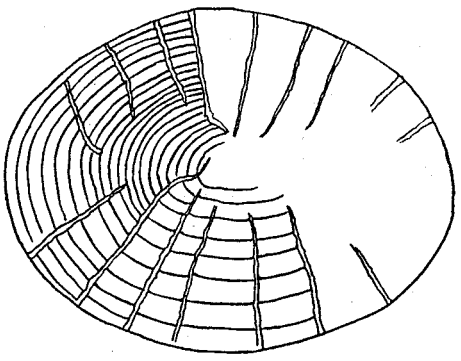


FIG. 51.—Scale of second year, taken in November from a specimen 60 millimeters in length

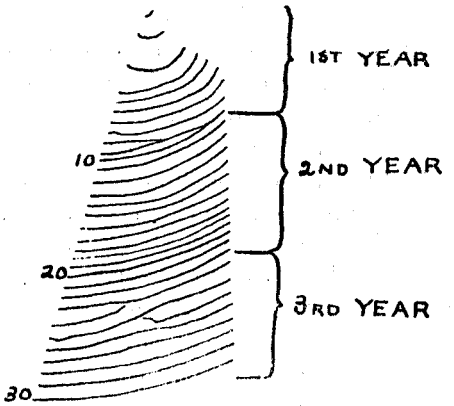


FIG. 52.—Sector of scale of the third year, from specimen 90 millimeters in length

counted. It at once became evident that the fish belonged to various groups determined by the number of annual zones, and that their age could be thus fixed.

Specimens measuring 60, 70, and 80 millimeters showed two zones (annuli) and were therefore 2-year fish. (Fig. 51). It is interesting to note that the number of circuli averaged 19 (30 scales). This is in accord with the finding that about 10 are added in each new zone. Fish of 90, 100, 110, and 120 millimeters showed three zones and belonged to the third year. (Fig. 52.) The number of circuli varied within the narrow limits of 28 to 32, or approximately three times 10. In the larger specimens similar results obtained, except that as the fish becomes older the zones tend to become narrower and contain a smaller number of circuli. (Figs. 53 and 54.)

SEASONAL IRREGULARITIES IN THE CIRCULI

Not all the circuli are even and continuous lines. Those of early spring (February and March) are quite irregular. This irregularity may consist of sinuous curvings, interruptions of the ridge, or branching. More rarely a chainlike condition is produced by junctions between two parallel ridges. These early spring circuli usually

are the most widely spaced. However, equally wide spacing may occur in those of the middle part of the annual zone, which form during the summer. As a rule they show a progressive crowding from spring to late fall, when they probably cease to form. (Fig. 55.)

Scale growth in the white sucker appears to be nearly at a standstill from November to late February. The evidence supporting this conclusion consists in finding that the number of circuli in the current annulus appears to be the same throughout this season, the full year's quota being present in the fall. Again one frequently finds scars on the scales—that is, eroded edges—which apparently have thickened during the winter while growth was at a standstill.

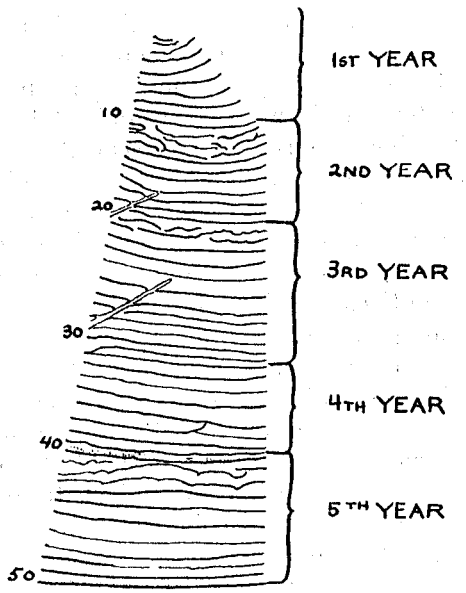


FIG. 53.—Sector of scale of the fifth year, specimen 160 millimeters

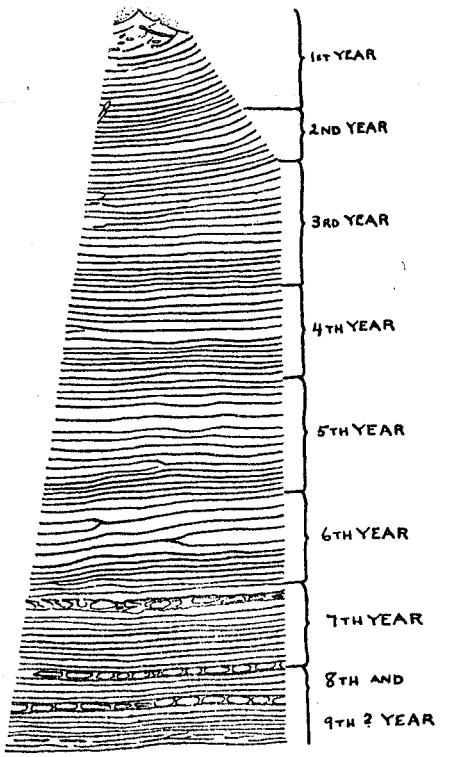


FIG. 54.—Sector of scale of the eighth or ninth year, specimen 375 millimeters

Hoffbauer believed that when a carp was poorly nourished growth proceeded more slowly, and that this was evidenced by the crowding of the circuli. Others have believed that temperature regulated the spacing phenomenon. The sucker feeds well in November and February and probably all winter, though I have not observed it. The wide circuli observed for all specimens taken in early spring, even before the ice is out of the streams, can not be assigned to temperature as stimulating growth.

The sucker spawns in April and May, and the gonads of the male are ripe as early as February. It may be that the ripening of the germ cells interferes with the nutrition of the other tissues of the body, and that this condition is responsible for the irregularity in the form of the circuli of early spring. Coupled with this is the

fact that these irregularities in form are more constantly present and more emphasized at the beginning of the fourth year than during the previous springs. This age is determined from the scale, which shows these markings at the beginning of the fourth annual zone. The fish then measures from 4½ to 6 inches. It is in specimens of this size that ripe gonads have first been found, and Reighard reports that the smallest ones seen spawning by him were about 6 inches long. However, other factors besides either the sexual cycle, food, or temperature alone must operate to cause the variations described each year. Otherwise we would have difficulty in accounting for such facts as the variation in spacing from May to October of the first and second summers.

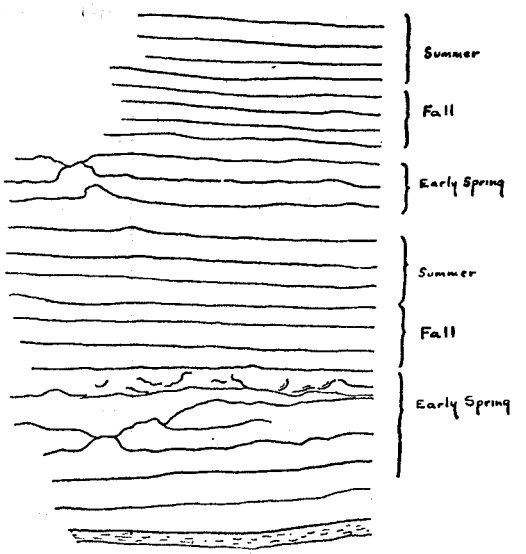


FIG. 55.—Detail of the last two annual zones on a scale of a 13-inch specimen taken in April

A very interesting local variation was observed in suckers seined in November from a large spring, where they probably lived the year round. Their scales showed virtually no seasonal variations of the sort described as usually present. Though sexually mature (6 to 10 inches), not even the markings so pronounced in the fifth and sixth springs were noticeable.[3] This fact, taken alone, would point to the direct regulative effect of an evenly cold temperature. Again, the greatest contrasts in spacing have been observed in fish from pools between falls, where they probably have remained all their lives subject to extremes of warm and cold water coming from the exposed and shallow creeks emptying into the pools.

ANNUAL GROWTH

On the basis of the annual zones on the scales we can determine the average lengths of specimens at each year of their lives. The following table is a summary of the average lengths of specimens showing from one to seven annual zones on the scales. Not over a dozen of each age were averaged, and the record is incomplete, as the white sucker is known to attain a length of 22 inches. The specimens used were taken in the late summer or fall. The first season is therefore but half a year.

	Inches
First season	1½
Second season	3
Third season	4
Fourth season	4½–6
Fifth season	6–8
Sixth season	8–13½
Seventh season	13½–15½

The rapid growth during the sixth and seventh years seems surprising and would be interesting to test upon fish confined or tagged and recovered.

[3] Scales from these and other suckers could be separated on sight, even when purposely mixed.

FOOD AND THE FEEDING HABITS OF THE WHITE SUCKER

With respect to their food, fishes may be divided into several groups. For example, we have plankton feeders, mud feeders, insectivorous species, fish eaters, mollusk eaters, and herbivorous species. Probably very few fishes confine their diet to one of these types of food, yet the classification is useful and may be applied in a broad sense. The factor that usually causes fishes to deviate from one type of food is their size. Obviously very small fishes must subsist upon still smaller organisms, so we are not surprised to learn that microorganisms form the early food of most species.

Some fishes pass through more than two stages in their feeding activities. The bass, for example, is a plankton feeder at first; later it pursues such Crustacea as the water shrimps and also insects, and as an adult it feeds largely upon smaller fishes, frogs, and crawfish.

The case of the sucker is peculiar in that a new factor—namely, the position of its mouth—enters in to alter its range of feeding. As its mouth changes from a terminal to an inferior position, the fish must alter its diet, losing those forms that swim or float and sucking in the fauna of the stream bottom. This, together with its wide range of taste, makes it almost omnivorous, and it is difficult to classify it according to the system mentioned above. While, of the various groups listed, we would be obliged to consider the sucker principally insectivorous, yet in an interesting way many insects escape it entirely. On the other hand, it does not exclude entirely any of the types of food upon which other fishes subsist.

REVIEW OF THE LITERATURE

Examination of the stomach contents of the white sucker has been made by Forbes (1890), Hankinson (1908), Reighard (1915 and 1920), Baker (1916), and Pearse (1918). Two or three facts are at once evident in reviewing this work. The number reported upon by each author ranges from 5 to 42, which seems a small number upon which to draw conclusions in the case of a fish of such varied feeding habits. Again, in most cases the size of the specimens does not cover a wide range from any one locality, which is necessary in giving a picture of the biological relationships of the organism throughout its life; and the time of year frequently is not mentioned, yet we know that age, season, and available food all influence the selection of items in the diet of fishes.

It is striking to note how much disagreement exists in the accounts referred to above. Forbes and Baker report mollusks as forming 42 per cent and 30 per cent, respectively, of the food eaten. Pearse mentions no mollusks, while Hankinson notes their presence but gives no percentages. Again, while Pearse gives chironomid larvæ as forming 40 per cent of the food, Forbes reports but 3 per cent; and while Baker (1916) found "mud and plant remains" making up 49 per cent (3 adults), Pearse finds "algæ and silt" composing but 6.6 per cent. Similar variance could be shown in the reports on Protozoa, May-fly nymphs, rotifers, etc. The observations of the authors in question probably are reliable, so we must assume that the disagreement is due to the difference in place, age, and season.

The following illustrations will make clear the fact that suckers vary in their food according to place, age, and season.

In respect to the influence of locality, which possibly is associated with variations in the distribution of food organisms, we may cite such instances as the following. Of two suckers of the same length and collected on the same date but from two different streams, one contained 100 per cent Entomostraca and the other but 5 per cent. The direct influence of the size of the fish is seen in a case where, at the same time and in the same creek, a 1-inch specimen was found to contain 90 per cent chironomids while a 4-inch fish had taken 80 per cent caddis-fly larvæ.

The effect of season is illustrated by the fact that in summer one may find suckers that are full of algæ, while in winter this item seems quite absent from their diet. Moreover, it has become increasingly apparent and equally puzzling that even small fry exhibit what we can assign at present only to individual taste. In the same small nursery pond (3 by 5 feet) the following diet was selected by fry that measured 17 to 19 millimeters in length. On June 9 one specimen contained 80 per cent sand, another 80 per cent chironomids; on June 12 one specimen contained 80 per cent Rotifera; and on June 16, one individual contained 80 per cent Difflugia, and another 70 per cent Entomostraca. It is obvious that limited observations here would lead to widely divergent conclusions. Even among 4-inch suckers taken the same day and in the same lagoon one showed 90 per cent Odonata nymphs while another showed 60 per cent chironomids and no Odonata.

While the factors here considered evidently alter the feeding habits of this species, there are probably others that likewise enter in. Of these may be suggested floods with their resulting débris, burying the bottom fauna; parasites that attack the sucker, filling its alimentary tract; and local differences in temperature of the stream or lake. Seasonal changes in the time of the appearance of its food organisms also would play a large part.

The diverging conclusions hitherto reached regarding the food of the sucker can be understood, therefore, and it is obvious that an extended survey of its feeding habits alone would afford a basis for generalizations on this point.

It is the aim of this paper to record the results of such a survey, which, while limited geographically in the wider sense, is probably more extensive in respect to numbers examined, age, and season than any previously recorded.

FOOD

It was necessary to use several methods in collecting the material utilized. For fry up to about 20 millimeters in length a dip net of very fine mesh, such as one made of cheesecloth, was necessary to prevent the escape of the tiny fish. From this size to fingerlings of 2 to 3 inches the fish were taken by means of a stout-handled dip net of coarser mesh—viz, eight meshes to the inch.

For fishes over 3 inches in length other methods had to be used. The wire-cage trap proved the best of these. These were made of both fine and coarse mesh—viz, one-third-inch square mesh and 1-inch round mesh. They had one or two funnel-shaped entrances, the passage narrowing down to about 4 inches in diameter. Such traps were baited with bread and placed in deep spots in the stream known to be frequented by suckers. A few were secured by a minnow seine 8 feet long and of

one-third-inch mesh, but only where the bottom was smooth. A seine 100 feet long and of 1-inch mesh was used in Cayuga Lake and the lagoons of Fall Creek, where specimens 10 to 15 inches in length were taken. About 40 specimens were taken by hook and line, the bait always being earthworms.

For food analysis the material from the smaller specimens was fixed in the field, while from the larger ones it was prepared immediately upon arriving at the laboratory. Either 4 per cent formalin or 70 per cent alcohol was used as a preservative. For sectioning, either Gilson's, Bouin's, or Perenyi's fixation fluid was employed with equally good results.

The region about Ithaca affords unusual opportunities to observe aquatic organisms under varied conditions, combining, as it does, cold, spring-fed brooks, gravel and bowlder-bottomed streams, areas of clay, cataracts with deep pools, sluggish waterways through cat-tail marshes, and the lake with shallow or deep waters near the shore.

The material examined was taken between June, 1922, and August, 1923. Some collections were made every week except during December and January, when the ice made collecting very difficult. All the larger streams of Tompkins County were covered in collecting the fry and fingerlings, while the traps were set and seines drawn at points nearer the Cornell Campus—Cascadilla Creek, Fall Creek, and the lagoons of the latter and Cayuga Lake.

PERIODS INTO WHICH FEEDING HABITS MAY BE DIVIDED

The life history of the white sucker shows five periods that can be distinguished on the basis of its feeding activities. This is peculiar to the sucker to the extent that its feeding is correlated with the change in its mouth from the terminal to the inferior position. Some fishes show three or four periods, due to increase in their size and the correlated need for more nourishing diet. For the sucker the following periods may be distinguished, both by the general behavior of the fish and by the actual analysis of the contents of the alimentary tract.

First or yolk-food period.—In a sense this period begins with segmentation and ends when the yolk has been entirely consumed. The fry is approximately 8 millimeters long at hatching, and the yolk is found to be its food up to a length of 12 millimeters. This may be called the "yolk-sac stage," though the sac actually is reduced, so as not to appear in surface views, before feeding through the mouth begins.

Top-feeding period.—From the time the fish begins to feed (12 millimeters), up to the change in the position of its mouth at 16 to 17 millimeters, it feeds upon organisms at or very near the surface of the water. This constitutes a very clearly-defined period in its life history, and the fry at this stage play a very different rôle in the economy of the stream life than do the older fingerlings and adults.

Critical period.—This term is used to designate the actual period during which the feeding habit changes. It extends from the time when the fish begins to go to the bottom occasionally to pick up food to the time when it ceases to feed anywhere but on the bottom. It is a brief period, only a few days in duration, when the fish is 16 to 18 millimeters long.

Fingerling period.—This period extends from the critical period (17 or 18 millimeters body length) to approximately 75 millimeters in length. The fish during this stage comes nearest to being what is suggested by the term "mud feeder." Limited by its size to small particles of food, and by the position of its mouth to the bottom as a source of nourishment, it takes a varied diet of the bottom-inhabiting organisms.

Adult period.—Fish longer than 75 millimeters may be considered adults as regards their feeding. They are no longer "mud feeders," in the sense used above, for while a fish may take mud and sand into its mouth only organisms are swallowed, and these consist principally of insect nymphs or larvæ. The almost complete elimination of microorganisms and the high percentage of macroorganisms, nymphs, mollusks, etc., distinguish this stage from all the others.

DETAILED ACCOUNT OF FEEDING HABITS AND FOOD

Yolk-food period.—The newly hatched fish has a well-filled, cylindrical yolk sac extending from the heart to the anus. The mouth is not yet open, and all nourishment is obtained from the yolk. The fish lies on the bottom but makes erratic motions that elevate it a few inches from time to time. Within two or three days the yolk sac has been reduced so that the fish apparently has no yolk left. This is so at 9 millimeters; at 11 millimeters the mouth is open; and at 12 millimeters the first food is taken.

Top-feeding period.—While fry of 12 to about 25 millimeters were collected from 62 points scattered along 10 streams in Tompkins County, it was thought wise to make daily observations of these early stages on fish confined in a pond, also. Accordingly, a pond 4 by 6 feet was dug where there was a slow seepage, both in and out, through the soil. The pond averaged 16 inches deep, with sides and bottom made of earth. Early in the spring it was fertilized by the addition of 1 quart of well-rotted manure and 1 pint of dried milk albumen. No organisms were intentionally introduced, yet the young suckers found a rich fauna and flora there in May.

To observe the earliest feeding, young fry were put into this little pond on May 22. They were but 2 and 3 days old, having been reared to this point in the Meehan hatching jar indoors.

During the first day many of them lay on the bottom, though a few maintained themselves near the surface by swimming. Soon all were swimming at the surface, and on May 27, when 9 days old (12 millimeters in length), the yolk was all gone and yet no food except a single diatom was present in the individuals examined. When 14 millimeters long or 11 days old (on May 29), samples showed food in the digestive tract. This earliest food, taken in the nursery pond, showed no important difference from that taken in the various streams of the region, and consisted of Protozoa (Euglena), Entomostraca (Cyclops adults and nauplii), chironomid larvæ, Rotifera, and diatoms. The following list gives the percentages of each organism entering into the food of fry between 12 and 16 millimeters in length, both in the nursery pond and in four of the principal streams of the county:

In the nursery pond (9 specimens): Chironomid larvæ, 15; Entomostraca, 37; diatoms, 1.3; Protozoa (Euglena), 27; Rotifera, 18.

In the streams (23 specimens): Chironomids, 62; Entomostraca, 4; diatoms, 8; Protozoa (Difflugia), 6; Rotifera, 7; fragments of arthropods, 7.

The latter is the truer picture of the diet during this second stage. The differences are due to the lack of current in the pond, increasing the proportion of Euglena and Entomostraca (Cyclops and Bosmina), which flourish in still waters. It will be shown presently that chironomid larvæ are common as floating objects in the streams.

Sucker fry can be distinguished in the field, after a little practice, by their form and actions. They are more slender than dace and shiners of the same length, and seem always to prefer a slight current, in which they maintian a rather fixed position by a very characteristic motion, which deserves a word in passing. Whereas many other fry swim by swinging the whole body, the sucker fry move only the tail. Thus they never show the jerky darting so characteristic of young minnows. Prefering a moderate current, they are not to be found in the rapids nor in still ponds, but in intermediate situations—that is, where the stream enters deep, quiet stretches. Knowing this, one can predict with some certainty what portions of a stream will harbor the young fry. Also, they swim within 6 inches of the surface. While dozens of pools entirely cut off from the streams were examined and were often found to be teeming with minnows, sucker fry under 17 millimeters never were discovered in them. They are often found associated with the plant Elodea.

During the stage from 12 to 16 millimeters, the fry, as we have said, maintains ts position in the moderate current within 4 to 6 inches of the surface and waits until food organisms float to it. Constantly they swim here and there (a matter of an inch or so), feeding on particles in suspension. On an average of once in a minute and a half they touch (taste?) or take organisms floating by. They are in small groups of 2 or 3 to 8 or 10.

Of the food eaten, it is of interest to show that it may all be obtained in the floating condition. To establish this the following tests were made:

The surface mud of the bottom taken below a school of 10 fry contained Protoza (Stylonichia), Gastrotricha, diatoms, and rotifers, but no chironomid larvæ. Evidently the latter were not obtained from the bottom. Then a handful of Elodea collected 4 inches below the surface, where 10 fry were feeding, was violently stirred in a shell vial of water, allowed to settle, and the sediment examined. This contained 20 chironomid larvæ per cubic centimeter of sediment.

To show that these larvæ do become detached and float free in the water, a Birge net was set for 24 hours a few inches below the surface. By centrifuging and examining, two larvæ were obtained in addition to Cyclops, rotifers, and desmids. The fry may pick these larvæ from the weeds, though this was not observed. It is well known that Difflugia also floats.

The sucker begins feeding when 12 millimeters long, approximately 9 days after hatching. The mouth is terminal but in process of becoming inferior. For 10 or 11 days it is a top feeder or feeds close to the surface on floating microorganisms, principally chironomid larvæ, Entomostraca, diatoms, rotifers, and Protozoa.

Critical period, 16 to 18 millimeters.—As observed in the nursery pond, this period covered nine days. On June 7 (20 days old) the fry were seen to make occasional excursions to the bottom (16 inches) and pick up mouthfuls of the sand, etc.

For a day or so preceding this they had fed farther from the surface, but not at the bottom. On June 12 (25 days old) three-fourths of the time was spent at the bottom. On June 16 (29 days old), none was feeding above the bottom. While microscopic examinations of the contents of the alimentary canal were made almost daily, the following average percentages of the more important constituents of the diet, derived from nine examinations, will suffice to show the facts: Chironomid larvæ and pupæ, 19 per cent; Entomostraca, 15 per cent; diatoms and desmids, 10 per cent; Protozoa, 2 per cent; Rotifera, 20 per cent; sand, 27 per cent; unicellular algæ, 2 per cent. Total—animals, 56 per cent; plants, 12 per cent; sand, 27 per cent.

The presence of sand is noticeable. Some of this is found in every specimen (even as much as 70 or 80 per cent of the volume in some cases), but it is also noticeable that diatoms and desmids are the only other items constantly present. These three items together form 37 per cent of the food.

With the change in feeding habit there appears also a new instinctive reaction. Whereas the early fry never enter the deeper water when alarmed, these later fry retreat to the bottom when one approaches them. Quite a few specimens of this age show that the alimentary canal is entirely empty, but when the bottom-feeding habit is established it is regularly well filled, if only by sand and diatoms.

Fingerling period.—This stage covers the time during which the young fish (25 days to 2 years old, 18 to 75 millimeters long) feeds upon bottom forms but can not separate them from the sand, which, therefore, constitutes nearly 25 per cent of its intestinal contents. It differs from the critical period in the fact that the bottom-feeding habit is firmly established. It is separated from the following or adult period by the fact that the food includes only microorganisms and no nymphs and larvæ of the larger insects.

The feeding habits are now quite different from those of the previous periods. The bottom selected for feeding is usually a stretch of uniformly fine sand or silt, covered with a thin film of such organic matter as diatoms, desmids, Protozoa, etc. The feeding grounds for fish of the first summer (up to a length of about 40 millimeters) is in water 6 to 18 inches in depth along the shores of lagoons, eddies, or ponds connected with the stream. For those 40 to 75 millimeters in length the feeding grounds are in the swifter-flowing water, as in the case of the adults, but in smaller, shallower streams.

New instincts are manifested and others are emphasized. In this stage a strong gregarious habit is apparent, especially during the first summer. The fingerlings of the first summer invariably are found in schools. These contain from a dozen or so to four or five hundred individuals. When feeding they usually spread out like sheep, advancing slowly, all facing the shore and keeping side by side. They retreat into deeper water when alarmed, but return within a few minutes to continue their almost constant plucking at the bottom ooze.

They are very protectively colored at this stage, being a mottled, sandy gray above and quite translucent. The sides are yellowish and greenish and flash when turned upward. Occasionally in very still water a large school (200 to 500) will be seen resting within an inch of the surface. They then face in all directions and are motionless. At the least cause for alarm the whole school disappears and remains in deeper water.

Feeding is most continuous on bright warm days. The fear of being exposed to view, which seems such a powerful instinct in the adults, does not prevent feeding in shallow places in the daytime during the first summer; but after the first winter suckers are inhabitants of the deeper places in the stream, except at night or during their migrations.

The food of 57 specimens of this stage was examined with the following results:

	Percentage
Chironomid larvæ and pupæ	28
Diatoms and desmids	22
Rotifers	4
Entomostraca	3
Protozoa (Difflugia)	9
Algæ	2
Fragments of arthropods	1
Sand	21
Unidentified (largely mucus)	10
Total: Animals	45
Total: Plants	24
Total: Sand	21
Total: Unidentified	10

This is virtually identical with the diet characteristic of the critical period. There is no item of food taken near the surface which is not also found at the bottom, whereas sand is taken only at the bottom.

The striking facts here are that up to 3 inches in length (2 years) the sucker continues to be limited to microscopic matter and that the indigestible sand is not eliminated from the diet. The habit of almost continuous feeding (by day at least), and the fact that the alimentary canal is seemingly never empty become intelligible when we consider how little of the matter eaten is actually available to the fish as nourishing food. The following is an attempt to estimate the nonnutritious waste matter:

	Percentage
Sand	21
Protozoa (shells of Arcella and Difflugia)	5?
Entomostraca (chitin)	2?
Rotifera (chitin)	2?
Diatoms (silicon)	10?
Chironomids (chitin)	12?
Total	52

This estimate may be far from exact, but it is not without significance.

To test whether suckers can, after the critical period (17 millimeters), catch floating organisms in sufficient quantity to maintain life, a number (12 to 15) of them, measuring 22 to 25 millimeters, were placed in a hatching tray with screen bottom and ends. This was set in one of their favorite haunts but 8 inches off the bottom. For a control, dace of equal size were placed with them. The latter survived well upon particles floating in through the screening of the ends and bottom of the tray, but the suckers all died within eight days (two in five days). Examination showed the alimentary canal to be nearly empty (a few diatoms only), and the fish were very thin.

Adult period, 75 millimeters.—Suckers of this period (3 to 15 inches in length) are shy fish, lurking among the stones on the bottom of the deeper holes along the creek, and probably in the deeper shoal waters of the lakes. While perch, bass, minnows, etc., frequently are seen leisurely feeding or resting in moderately shallow water, the white sucker is not seen unless the pool be approached cautiously, and only during the spawning season are large suckers found in shallow water in the daytime. They exhibit a shyness characteristic of trout, making off with great haste when disturbed. It is next to impossible to take them in a seine if the bottom is rough, for they escape through any gap, finding such places with great rapidity. Reighard (1915) reports seeing suckers feeding in the early morning. Suckers are taken on hook and line baited with earthworms, but mostly on cloudy days or when the water is turbid. Specimens removed from the traps in the morning regularly showed a well-filled intestine. From this and the extreme shyness of the fish it seems probable that its feeding is done in the darker hours.

While gregarious in the adult stage, one finds individuals of all sizes between 2 or 3 to 10 or 12 inches inhabiting the same pool or lagoon. In the lakes and larger streams, those of larger size—8 to 15 inches in length—appear to feed and travel in bands of a score or more. These larger ones have been seen resting quite motionless some 4 to 6 feet below the surface of the lake, and they refuse all bait.

The food of the adult is not mixed with sand to any extent. Only 0.9 per cent of the food of 52 specimens was sand, as against 21 per cent in the case of fingerlings. At the beginning of this stage (3 inches) the sucker begins to hold the food particles in its mouth and to spit out the sand. This ejecting of the sand has been reported by Reighard (1915). The diatoms doubtless are ejected in this cleaning process, as they constituted but 3.6 per cent of the intestinal contents in 52 cases. The holding of the food is possible because it now consists largely of insect larvæ and nymphs. These facts are summarized in the following percentages, based on a study of 52 specimens:

	Percentage
Chironomidæ	30
Diatoms and desmids	3.6
Rotifera	0
Arthropod fragments	5.4
Entomostraca	5
Protozoa	.1
Algæ	2.4
Sand	.9
Mollusk shells	.2
Larger insect larvæ and nymphs [4]	31
Débris (principally mucus)	22

While the most distinguishing items of diet are the immature aquatic insects of large size (31 per cent), the total of these, together with the omnipresent midge larvæ and fragments of insects, brings the total quantity of insects eaten by the adult fishes to 66.4 per cent. The adult sucker in this region must then be classed as an insectivorous species. Of the organic food but 6 per cent consists of plants, hence the fish is distinctly carnivorous in this as in the earlier stages.

Most of the insect larvæ and nymphs occur whole in the digestive tract, even larger ones, such as dragon-fly nymphs, being swallowed without fragmentation.

[4] Odonata, 9 per cent; mayflies, 9 per cent; and caddis flies, 13 per cent.

This is true of fish of every age, delicate sand shells of Difflugia, the brittle shell of Arcella, and the shells of small bivalves all passing entire into the intestine. Probably all material listed as fragments of insects was broken in the process of tearing apart the food mass with dissecting needles. This raises the question as to the function of the pharyngeal teeth, so well adapted by their shape to crushing the food. From the structure of these teeth Forbes (1890) assumed that Mollusca constituted a large portion of the diet, and Baker reports that bivalves make up 30 per cent of the food; but Baker's report (1916) is based on the examination of but three adult specimens and is therefore hardly conclusive. I have found single instances where the fish has gorged itself on one only of each of the items listed above, but these are meaningless if taken alone. Reighard (1915) reports a similar occurrence, finding the diet of five suckers (43 to 50 millimeters long) to consist "almost wholly of a cladoceran."

SUMMARY

From the point of view of the economy of the organisms that must obtain their sustenance in the same waters as the sucker, the sum of the food eaten by the latter at all ages is of importance.

For 162 fish heretofore listed by groups only, the average percentages are as follows:

	Percentage
Chironomids	32.9
Odonata	3
May fly	3.1
Caddis fly	4
Entomostraca	6
Mollusks	.1
Diatoms	11
Algæ	2.4
Protozoa	4.5
Rotifers	2.9
Sand	13.3
Other insects	3.7
Unidentified (mucus)	13.1

The variation in capacity of the fish is not taken into account here. Obviously the larger the fish the more insects necessary to make up a given percentage of the volume of its intestine. The greater numbers of smaller suckers in a stream would, however, make up in part, at least, for their smaller capacity.

Comparison of the food taken during the three principal periods

[Figures are average percentage]

Food	Top-feeding period; 12 to 16 millimeters, inclusive	Fingerling period; 17 to 75 millimeters, inclusive	Adult period; 3 to 12 inches	Food	Top-feeding period; 12 to 16 millimeters, inclusive	Fingerling period; 17 to 75 millimeters, inclusive	Adult period; 3 to 12 inches
Number examined	25	57	52	Algæ		2	2.4
Chironomids	62	28	30	Sand		21	.9
Diatoms and desmids	8	22	3.6	Odonata			9
Rotifera	7	4		May fly			9
Other arthropod fragments	7	1	5.4	Caddis-fly larvæ			13
Entomostraca	4	3	5	Mollusca			.2
Protozoa	.5	9	.1	Unidentified (mucus)	11.5	10	21.4

In the above table is presented a comparison of the constituents of the diet during the three principal periods. The figures given are percentages of the volume of the food, and it is important to bear this in mind in obtaining a picture of the rôle played by the sucker as a consumer. The number of chironomids eaten is enormous. It was estimated that one sucker, 5 inches long, contained 1,200, and in addition to this 800 caddis-fly larvæ and 60 May-fly nymphs were eaten. A daily ration of 1,200 chironomids means that 36,000 are consumed in a month, or 216,000 in six months.

It is possible to suggest some reasons that may account for the three following periods in the feeding habits—namely, the yolk-food period, the top-feeding period, and the bottom-feeding period.

The first is obviously determined by the amount of food stored in the egg when laid. Factors external to the egg, such as temperature, will determine the rate of development of the larvæ, and hence the length of time before the yolk is exhausted.

The top-feeding period presents a greater problem. The air bladder is relatively very large at this time, and up to a length of 14 millimeters it is connected to the gut. It may be that control of the gaseous content of the air bladder is not possible to the fish during this period, and that they are actually unable to submerge themselves below a depth of 6 inches.

Bottom-feeding is related to the metamorphosis of the mouth, but implies also that the content of the air bladder permits swimming at lower levels.

The separation of sand from insects, etc., and its elimination before the insects are swallowed may be merely a matter of the relative size of food and sand. As long as the food consists of microörganisms it can not, apparently, be separated from the sand; but when such insects as caddis-fly larvæ are taken they are held in the mouth while the sand is ejected. The following organisms were identified in the food of the white sucker (210 specimens):

Algae:
- Mougeotia.
- Spirogyra.

Desmids:
- Closterium.
- Cosmarium.

Diatoms:
- Gomphonema.
- Diatoma.
- Cymbella.
- Navicula
- Surirella.
- Nitzchia.
- Epithemia.
- Stephanodiscus.
- Fragilaria.

Protozoa:
- Difflugia.
- Arcella.
- Euglena.

Copepods:
- Cyclops.
- Canthocamptus.

Cladocera:
- Chydorus.
- Scapholeberis.
- Alona.
- Alonella.
- Daphnia.
- Eurycercus.

Ostracoda:
- Cypris.
- Cypridopsis.

Malacostraca:
- Gammarus.
- Cambarus (fragment only).

Rotifera: Various species.

Nematoda: Ascaris (?)

Annelida: Setæ only.

Mollusca: Sphærium (?).

Cestoda: Proteocephalus (?).

Trematoda: Crepidostomum (?).

Insecta:
- Chironomid larvæ and pupæ.
  - Chironomus.
  - Tanytarsus.

Insecta—Continued.
- Caddis-fly larvæ (Neuronia).
- May-fly nymphs:
  - Heptagenia.
  - Chirotonetes.
  - Ecdyrus.
  - Iron.
  - Blasturus.
- Dragon-fly nymphs:
  - Libellulidæ.
  - Æschnidæ.
- Orl-fly larvæ.
- Haliplid larva.
- Tipulid larva.
- Black-fly larva (Simulium).
- Chauliodus larva.
- Dytiscid larva.
- Corixa nymph.
- Stone-fly nymphs:
  - Perla.
  - Isoperla.
  - Capnia.
- Mosquito egg.
- Weevil.

Fish scale.

ECONOMIC STATUS OF THE SUCKER

The white sucker, being principally an insectivorous fish, is a rival of the trout and bass—two species of prime importance to man. While the sucker eats many May-fly nymphs and the trout may depend more largely upon the adult May flies, the rivalry is no less keen. The sucker has been reported as a "spawn eater," devouring the eggs of the log perch (Reighard, 1920). It has been reported as eating small fishes and fish eggs. In November, 1922, twenty 6 to 8-inch suckers were collected directly over the newly made nests of brook trout, where eggs were doubtless abundant in the gravel. As not a single fish egg was found in these or in over 200 other sucker stomachs examined it seems safe to assume that fish eggs are rarely taken by this species.

As a food fish the white sucker is considered of little value. In the spring its flesh is firm and of agreeable flavor, but by June it becomes soft and undesirable. When the life histories of all fish parasites are better known it may be found that this species is a carrier of infection. A single 8-inch specimen taken near the University Experiment Station contained 145 cestodes and 50 trematodes, while the intestines contained nothing else, being filled with these parasites.

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ORGANIC CONTENT OF LAKE WATER

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Wisconsin Geological and Natural History Survey

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INTRODUCTION

For many years the Wisconsin Geological and Natural History Survey has been engaged in studies on the inland lakes of the State. These have received aid from the University of Wisconsin and the United States Bureau of Fisheries, whose assistance is gratefully acknowledged.

This paper brings together the results of several investigations on the quantity and kinds of organic matter found in lake water. In these, as in earlier studies, by far the largest amount of attention has been given to Lake Mendota, on whose shore the University of Wisconsin is situated. The study has been extended to other lakes, in as great number and variety of type as practicable, in order to ascertain how far the conditions found in Mendota are present elsewhere.

The present paper reports results from 14 waters other than Lake Mendota, including 12 lakes and 2 rivers. It shows the total amount of organic matter contained in the water and gives some idea of the nature of the organic compounds. Thus it furnishes the beginnings of an inventory of the primary food supply of the inland lakes. The results from the lakes other than Mendota are such as to show that this may be regarded as a typical Wisconsin lake.

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I. DATA

The data of this paper came from five sources:

1. An elaborate study of the quantity and chemical composition of the plankton of Lake Mendota and the other Madison lakes. This was made by Birge and Juday (1922) from 1911 to 1917. The results of this work are used in this paper to furnish data regarding the average amount of plankton from Lake Mendota and also to give its composition. This paper is cited as the "plankton report."

2. A study of the quantity and the forms of nitrogen found in lake waters, made primarily by Dr. B. P. Domogalla (Domogalla, Juday, and Peterson, 1925). This study was based on the same samples as those employed in the present paper; it is the source of the nitrogen determinations of plankton and residues given in the present paper. It is cited as the "nitrogen report."

3. A more complete study of the forms of nitrogen found in a small number of these waters, made primarily by Prof. W. H. Peterson (Peterson, Fred, and Domogalla, 1925). This is used only in some of the final conclusions of the present paper.

4. A determination of the organic carbon contained in some of the residues originally prepared for the work of Doctor Domogalla. These results are published for the first time in the present paper. The determinations were made by Dr. C. R. Wise, of the department of chemistry, University of Wisconsin.

5. Determinations of the ether extract made by Doctor Domogalla on a number of the same samples. These also are reported here for the first time.

DISSOLVED ORGANIC NITROGEN AND ORGANIC CARBON

The figures for organic nitrogen in this section of the paper are taken from the nitrogen report (Domogalla, Juday, and Peterson, 1925), for which all of the samples originally were secured.

The methods of collecting and handling the samples of lake water are reported fully in this paper (p. 270); they contained from 50 liters to 525 liters of water. The plankton was extracted by a Sharples centrifuge running at a speed of 40,000 revolutions per minute, which removed the plankton, including about 70 per cent of the bacteria. The centrifuged water was evaporated in a copper vacuum pan at a temperature of about 60° C. The plankton nitrogen was determined from the dried material extracted by the centrifuge, and six forms of nitrogen were regularly determined from the dry residues resulting from evaporation. For the inorganic nitrogen these were free ammonia, nitrate, and nitrite; and for the organic nitrogen there were determined the free-amino nitrogen, peptide, and nonamino nitrogen.

All of this nitrogen from the residues is called "dissolved," and the same term is applied to the organic carbon from the same source. In the use of this word the present paper follows the terminology of the nitrogen report, which considers nitrogen under two categories—plankton nitrogen and soluble nitrogen. It is not intended that inference should be made from the use of either word as to the exact condition in which organic substances, other than plankton, exist in the water. No doubt they are present in various forms, including (*a*) that part of the plankton and the organic débris that escapes the centrifuge, (*b*) colloids of different kinds, and (*c*) true solutions. These necessarily are treated together as they are mingled in the dry resi-

dues, and at present there is no way of distinguishing them. Probably by far the greater portion of the "soluble nitrogen" or the "dissolved carbon" is dissolved only as egg albumen or starch may be said to be dissolved in water.

The organic carbon was determined by Doctor Wise, who had for his examination 31 specimens of dry residues; 14 of these were from Lake Mendota, 14 from 12 other lakes, and 3 from 2 rivers. They represented the larger samples prepared by Doctor Domogalla, the material of which had not been used up in the study of the nitrogen.

The specimens for determination of organic carbon were dried carefully to constant weight, over concentrated H_2SO_4, in a vacuum. The temperature was kept at 46 to 47° by an electrically heated nichrome wire, and a pressure of 60 to 70 millimeters of mercury was maintained. Under these conditions the organic matter should not be decomposed and the water mechanically held should be dissipated. Most of the air-dry specimens lost 4 to 5 per cent in this process.

The total carbon dioxide was determined by the ordinary methods of organic combustion. The evolved (carbonate) carbon dioxide was determined by a method almost identical with that of Hillebrand (1919). Two soda-lime tubes, however, were found to be more satisfactory than one.

All determinations were made in duplicate and checked closely. Two examples are given; these are Nos. 21 and 42, each the residue from the evaporation of 100 liters of water from Lake Mendota. No. 21 came from surface water; No. 42 was a bottom sample; both were collected on July 24, 1923.

TABLE 1.—*Determination of carbon dioxide in dry residue from water of Lake Mendota*

	No. 21		No. 42	
	A	B	A	B
	Per cent	*Per cent*	*Per cent*	*Per cent*
Total CO_2	47.75	47.77	44.45	44.89
Evolved CO_2	27.65	27.83	27.99	28.21
Difference	20.10	19.94	16.46	16.68

The results show 20.02 per cent of organic CO_2 in the surface sample and 16.57 per cent in the bottom sample, corresponding, respectively, to 5.45 and 4.53 per cent of organic carbon. The surface yielded 135 milligrams of dry residue per liter of lake water, and the bottom 129.2 milligrams. The organic carbon, therefore, was 7.36 milligrams per liter in surface water and 5.85 milligrams in water at 20 meters. Already there had been found 0.407 milligram per liter of soluble organic nitrogen in the surface sample and 0.404 milligram in the water from the bottom. These figures are reached by adding the amounts of nitrogen given (nitrogen report, p. 274) under the heads of free-amino, peptide, and nonamino nitrogen.

The following table gives the amounts of dissolved organic nitrogen and carbon found in the several waters:

TABLE 2.—*Dissolved organic nitrogen and carbon in lake water*

[In milligrams per liter of lake water]

	Depth, in meters	Date	Residue	N	C	Ratio, N : C
LAKES						
Mendota	0	Oct. 18, 1922	152.0	0.438	4.00	1: 9.1
Do	0	Dec. 5, 1922	176.2	.484	7.95	1:16.4
Do	0	Feb. 28, 1923	183.0	.554	6.31	1:11.4
Do	0	July 24, 1923	135.0	.407	7.36	1:18.1
Do	0	Sept. 21, 1923	129.1	.372	4.48	1:12.1
Do	0	Oct. 24, 1923	126.3	.289	5.96	1:20.6
Do	0	Apr. 23, 1924	119.5	.335	5.89	1:17.6
Do	0	June 18, 1924	169.0	.307	5.58	1:18.2
Do	20	July 21, 1922	136.7	.314	4.84	1:15.7
Do	20	Sept. 26, 1922	162.8	.304	4.69	1:15.4
Do	20	Feb. 28, 1923	166.5	.559	6.14	1:11.0
Do	20	July 24, 1923	129.2	.404	5.85	1:14.5
Do	20	Sept. 21, 1923	131.0	.376	5.72	1:15.2
Do	20	June 25, 1924	172.1	.357	6.37	1:17.8
Mean				.393	5.80	1:15.2
Bass	0	Dec. 20, 1923	30.8	.426	9.41	1:22.1
Devils	0	July 11, 1923	46.6	.219	3.02	1:14.0
Do	0	Oct. 27, 1923	33.3	.302	4.02	1:13.3
Geneva	0	July 16, 1923	114.0	.337	4.52	1:13.4
Green	0	July 18, 1923	143.7	.310	3.95	1:12.8
Do	0	Oct. 16, 1923	138.0	.296	6.51	1:22.0
Kegonsa	0	July 20, 1923	101.4	.730	7.33	1:10.0
Madeline	0	Dec. 12, 1923	59.5	.455	5.26	1:11.6
Michigan	0	Feb. 28, 1924	96.4	.143	3.24	1:22.7
Monona	0	June 28, 1923	141.9	.712	7.92	1:11.1
Rock	0	July 6, 1923	132.6	.550	8.20	1:14.9
Turtle	0	Jan. 18, 1924	66.3	.490	13.22	1:27.0
Waubesa	0	July 20, 1923	107.2	.744	7.11	1: 9.6
Wingra	0	June 26, 1923	199.9	.722	9.52	1:13.2
RIVERS						
Wisconsin [1]	0	July 30, 1923	82.9	.487	15.23	1:31.3
Do	0	Nov. 21, 1923	85.1	.394	9.85	1:25.0
Yahara [2]	0	July 6, 1922	684.0	.372	9.58	1:25.8

[1] At Prairie du Sac Dam.

[2] Above Lake Mendota.

Of the lakes listed in the table, Monona, Waubesa, and Kegonsa are in the same chain as Mendota. Wingra is a small and shallow lake about 1 mile south of Mendota. It is largely surrounded by marsh. Rock Lake is about 22 miles east of Madison, Green Lake is about 55 miles north, and Geneva Lake is about 57 miles southeast of Madison. All these are typical hard-water lakes of southeastern Wisconsin, ranging in depth from Wingra (3 meters) and Kegonsa (12 meters) to Mendota (24 meters), Geneva (43 meters), and Green (68 meters). Wingra is the smallest of this group (about 1 square mile); Geneva has an area of 8.8 square miles; Green has 11.5 square miles; and Mendota has 15.2. Devils Lake (360 acres) is the only soft-water lake in southeastern Wisconsin, occupying a drift basin in the gorge of the quartzites of the Baraboo Range, about 30 miles northwest of Madison. Bass, Turtle, and Madeline Lakes are small soft-water lakes or lakelets of northeastern Wisconsin. Full statistics for all of these lakes may be found in Bulletin XXVII of the Wisconsin Geological Survey (Juday, 1914). The Wisconsin River traverses the State from north to south, carrying a high-colored water with low mineral content; the Yahara is the stream connecting the Madison lakes, and its water is much like that of the

lakes. The sample was taken just above the entrance of the stream into Lake Mendota, the upper lake of the series.

The data of the table disclose no difference in the content of dissolved organic matter between hard-water lakes with large amounts of carbonates in solution and soft-water lakes with little mineral matter. Lake Wingra, with the highest dry residue, has also the second highest figure for organic carbon; while Bass Lake, whose organic carbon is nearly as great, has by far the smallest amount of dry residue. In Bass Lake the total carbon dioxide was 112.9 per cent of the weight of the dry residue, while the evolved carbon dioxide was only 2.51 per cent of the same weight. The five waters in the list (omitting Mendota) whose dry residue is smallest have an average of 6.99 milligrams per liter of organic carbon; the nine others average 6.48 milligrams.

The nature of the drainage basin of the lakes and the resulting character of the inflowing water seem also to make no noteworthy differences. Turtle Lake has the greatest amount of organic carbon and its water is very high colored, derived through streams from the drainage of marshes. On the other hand, Bass Lake, a lakelet with no affluent and with very clear water, stands very high in organic carbon. The area and volume of Lake Michigan are so enormous in relation to its margin and the small amount of water brought in by affluents that its organic carbon must come almost entirely from its inner resources. The 14 observations on Lake Mendota show no clear relation between depth or season in the amount of organic carbon.

The nitrogen-carbon ratio has a wide range in these observations. The minimum ratio is 1 to 27; the maximum 1 to 9.1; and the range is nearly as great in the series from Lake Mendota—minimum 1 to 20.6, maximum 1 to 9.1. If, however, the observations are grouped and the mean nitrogen-carbon ratio is computed the results are singularly uniform. The computation may be made in two ways—the mean of the single ratios may be found, or the quantity of carbon and nitrogen in the observations may be added and the ratio of their sums computed. The result will differ somewhat according to the method employed.

TABLE 3.—*Nitrogen-carbon ratios*

	Mean of ratios		Mean of observations	
	N	C	N	C
Mendota, surface, 8 cases	1	15.4	1	14.9
Mendota, bottom, 6 cases	1	14.9	1	14.5
Mendota, all cases	1	15.2	1	14.8
Other lakes, 14 cases	1	15.5	1	14.5
All cases, 28	1	15.4	1	14.6

The average yield from all observations, 28 in number from 13 different lakes and aggregating 3,495 liters of water, is as follows:

Organic nitrogen	0.426 milligram per liter
Organic carbon	6.230 milligrams per liter
Ratio—N:C::1:14.6	

Thus, in spite of the wide range of the single ratios and the small number of observations, there is a close correspondence of average results in five different combinations. We are warranted in believing that the average nitrogen-carbon ratio is about 1 to 15.

The organic carbon and nitrogen must be derived from (*a*) the plankton, (*b*) the higher plants growing from the bottom, (*c*) matter derived from the land and ultimately from the higher plants of dry land or marsh or from the fauna and flora of the soil. Thus the sources are similar, whether in water or on land. The proportion from each source must differ in different lakes and in the same lake at different times; but on the whole the plankton must be much the largest contributor.

Birge and Juday's plankton report (p. 215) furnishes data from which may be computed the nitrogen-carbon ratio in plankton algæ, higher water plants, and plankton. The figures used for the percentage of carbon in crude protein, fats, and carbohydrates are the same as those employed later in the present paper (p. 199). The ratio of nitrogen to carbon was determined directly in 11 samples of plankton from Lake Mendota and was found to average 1 to 6.3, a sufficiently close agreement with the ratios given in the table as the result of computation from a much larger number.

TABLE 4.—*Ratio of nitrogen to carbon in algæ, water plants, and plankton*

	N	C		N	C
Blue-green algæ (11 analyses)	1	5.5	Vallisneria (1 analysis)	1	13.5
Diatoms (1 analysis)	1	9.0	Plankton, Mendota (87 analyses)	1	7.1
Potamogeton, mature (1 analysis)	1	24.0	Plankton, Monona (21 analyses)	1	5.6
Potamogeton, green (1 analysis)	1	19.2	Plankton, Waubesa (16 analyses)	1	6.5
Myriophyllum (1 analysis)	1	11.8			

We have no knowledge of the composition of the extractives from soil or from marshes, which are always present in lakes in some quantity and which give a high color to some waters. Russell (1923, p. 172) remarks on "the slow rate of disappearance of complex nitrogenous compounds in soil as compared with the rate of oxidation of carbon." In land plants the ratio of nitrogen to carbon may be 1 to 40; in the soil it is rapidly raised to 1 to 10. But we do not know at what point in this process these substances get into the lake.

We are not able at present to show how the nitrogen-carbon ratio is established in the lakes. It is plain that the nitrogen of the dissolved matter is much smaller, relatively to the carbon, than it is in the plankton. It is plain also that the average ratio—1 to 15, in round numbers—is not far from the ratio of 1 to 17 that comes from the four analyses of higher plants, as given in Table 4. The three general there analyzed yield about 88 per cent of the crop of aquatic plants in Lake Mendota. (Rickett, 1922, p. 525.)

One might be tempted to infer that the low ratio of nitrogen to carbon is due to extractives from these plants, but such a conclusion would be wrong. The average standing crop of organic carbon in Lake Mendota is nearly 6.0 grams per cubic meter of water; the volume of the lake is 478,370,000 cubic meters. The lake, therefore, contains nearly 2,900 metric tons of organic carbon. Rickett's study of the larger aquatic plants (1922, p. 527) assigns to the annual crop for the entire lake a

dry weight of 2,100 metric tons, of which less than one-half would be organic carbon. Thus, the *annual* carbon crop of the higher plants of Lake Mendota is hardly more than one-third of the average *standing* crop of dissolved organic carbon.

The situation in Green Lake is even more unfavorable to large contributions from the higher plants. The smaller figure in Table 2 for organic carbon in this lake is 3.95 grams per cubic meter; the volume of the lake is 973,000,000 cubic meters; and on this basis the lake would contain more than 3,800 metric tons of organic carbon. Rickett (1924) found in Green Lake an annual crop of higher plants, yielding about 1,528 metric tons of dry matter; but almost exactly half of this is in the form of Chara, which contains more than 50 per cent of ash. An outside estimate of the annual crop of organic carbon from the higher plants of this lake would be 500 to 600 metric tons.

It is equally clear that inflowing water brings only relatively small quantities of organic matter into the lakes, and the plankton necessarily is left as by far the chief source of the dissolved matter. Other facts of secondary importance look the same way. If extractives from the higher plants were influential in controlling the amount of organic carbon and nitrogen, then the spread between these substances ought to be greater in late fall and winter than in spring and early summer; but this is not the case. Again, the centrifuge plankton ought to show the influence of vegetable débris at the same seasons; but this also is not the case. The small and shallow lakes should show a larger proportion of carbon than the larger and deeper bodies. This also does not appear; on the contrary, in Lake Michigan, whose water must receive only minimal supplies of organic matter from affluents and from plants of shallow water, the carbon is twenty-two and seven-tenths times the nitrogen, being exceeded in this respect by only one lake.

Much further study will be needed before the intricate story of the organic matter of lakes is finally unraveled. But at present we may conclude that the plankton is the chief source of the dissolved organic matter, and that its nitrogen compounds disappear more rapidly than its nonnitrogenous substances, thus reversing the situation as stated by Russell for the land. This conclusion might be expected in view of the rapid accumulation of carbohydrates in peat under water, as compared with the very slow growth of humus under subaerial conditions.

ETHER EXTRACT

The ether extract from several of these samples was determined by Dr. B. P. Domogalla in 1925 and 1926. Six samples of single residues were treated; of these, four were from Mendota—two surface and two bottom water—one sample was from Green Lake, and one from Lake Geneva. Ether extracts also were made from 2 large composite samples from Lake Mendota; 10 residues taken from the surface water at various dates were combined into 1 sample, and 6 residues from the bottom water made up the other. In the composite sample from surface water 2 specimens were taken in February; 2 others, April and November, during the homothermous period; the other 6 were taken during the period of summer stratification—2 in July, 2 in early October, and 1 each in August and September. The 6 bottom samples

included in the composite came 1 in February, 2 in July, 2 in September, and 1 in early October; all but the first were in the period of summer stratification of water.

TABLE 5.—*Ether extract, milligrams per liter*

Lake	Depth, meters	Date	Dry matter	Ether extract
				Single samples
Mendota	0	June 7, 1922	167.8	0.323
Do	0	Sept. 18, 1924	169.0	.380
Do	20	Sept. 26, 1922	162.8	.488
Do	20	June 25, 1924	172.1	.688
Green	0	July 18, 1923	143.7	.352
Geneva	0	July 16, 1923	114.0	.217
				Composite samples
Mendota	0	10 samples	164.3	0.482
Do	20	6 samples	149.7	.765

The range of ether extract, as shown from these specimens, is from about 0.2 milligram per liter to nearly 0.8 milligram. No doubt a larger series would show a greater range. The quantities obtained were not large enough to permit further chemical study, but under the microscope they were seen to be made up of clear droplets of oil.

This ether extract must have its main source in the plankton, just as the nitrogenous substances of the dissolved matter come from similar substances in the plankton. The ether extract has been determined for many samples of the plankton from the Madison lakes (plankton report, pp. 196, 202–209). In Lake Mendota the average amount is 0.149 milligram per liter, or 7.53 per cent of the ash-free organic matter. This may be compared with the average result of the 20 samples of residues from Lake Mendota, which yield 0.564 milligram of fat per liter, or 4.4 per cent of the total organic matter as computed.

The range of ether extract in plankton is great. It extends from 0.004 milligram per liter of lake water to 0.136 milligram in the case of the net plankton, and from 0.018 milligram to 0.356 milligram in the case of the centrifuge plankton. Thus, the fats of the dissolved organic matter found in a unit of volume of water are much greater than those in the plankton from the same amount of water. However, they constitute a smaller per cent of the dissolved matter than of the plankton.

The nitrogen and carbon were determined for the two composite samples from Lake Mendota. The results, stated in milligrams per liter, are as follows:

	Surface	Bottom
Nitrogen	0.457	0.452
Carbon	5.580	6.350
Ratio, nitrogen to carbon	1 : 13.1	1 : 14.0

PLANKTON

In the study of the forms of soluble nitrogen the plankton was extracted from the water by the centrifuge; it was dried and weighed, and the organic matter and nitrogen were determined. The quantities were too small to permit other determinations, such as ether extract. The amounts of nitrogen from these samples already have been published (nitrogen report, pp. 273, 282), but the other data appear here for the first time. The "ash" of these specimens ought rather to be called "total inorganic matter," for it is composed in large part of minute particles of silt that remain suspended in the water and are removed by the centrifuge. This subject is discussed in the plankton report, page 80.

TABLE 6.—*Plankton, milligrams per liter*

	Date	Depth, meters	Total plankton	Ash	Total organic	Nitrogen
LAKES						
Mendota	Oct. 18, 1922	0	3.23	1.98	1.25	0.105
Do	Dec. 5, 1922	0	3.20	1.47	1.73	.144
Do	Feb. 28, 1923	0	1.62	.74	.88	.052
Do	July 24, 1923	0	4.60	1.23	3.37	.113
Do	Sept. 21, 1923	0	4.06	2.00	2.06	.091
Do	Oct. 24, 1923	0	3.90	2.08	1.82	.045
Do	Apr. 23, 1924	0	1.96	1.01	.95	.080
Do	June 18, 1924	0	2.12	.80	1.32	.092
Do	July 21, 1922	20	2.12	1.43	.69	.050
Do	Sept. 26, 1922	20	3.60	2.75	.85	.047
Do	Feb. 28, 1923	20	2.45	1.68	.78	.057
Do	July 24, 1923	20	3.42	1.93	1.49	.058
Do	Sept. 21, 1923	20	4.62	2.34	2.28	.098
Do	June 25, 1924	20	1.84	1.00	.84	.045
Mean			3.05	1.60	1.45	.077
Bass	Dec. 20, 1923	0	1.08	.51	.57	.034
Devils	July 11, 1923	0	1.30	.88	.42	.015
Do	Oct. 27, 1922	0	.86	.47	.39	.038
Geneva	July 16, 1923	0	2.18	.93	1.25	.051
Green	July 18, 1923	0	2.18	1.25	.93	.042
Do	Oct. 16, 1923	0	2.05	1.16	.89	.049
Kegonsa	July 20, 1923	0	22.30	3.02	19.28	.697
Madeline	Dec. 12, 1923	0	2.26	.52	1.74	.096
Michigan	Feb. 28, 1923	0	4.38	2.76	1.62	.020
Monona	June 28, 1923	0	7.20	2.00	5.20	.389
Rock	July 6, 1923	0	1.66	.64	1.02	.073
Turtle	Jan. 18, 1924	0	1.40	.66	.74	.030
Waubesa	July 20, 1923	0	10.12	1.97	8.15	.299
Wingra	June 26, 1923	0	25.72	8.51	17.21	.882
RIVERS						
Wisconsin	July 30, 1923	0	7.95	5.38	2.57	.161
Do	Nov. 21, 1923	0	2.26	1.25	1.01	.053
Yahara	July 6, 1922	0	20.12	(1)	(1)	.609

[1] Not determined.

The average amount of organic matter in the specimens from Lake Mendota is small, as is also the percentage of nitrogen in it. In 87 large samples that were analyzed during the years 1915–1917 for the plankton report, the organic matter averaged 1.974 milligrams per liter and the nitrogen was 0.140 milligram. The specimens in the plankton report were taken, meter by meter, through the whole depth of the lake and therefore represent average conditions; also, they were far larger than those employed for evaporation, each sample analyzed representing about 2,000 liters of water, as compared with 50 to 100 liters, the ordinary sample for evaporation.

In the case of the other lakes there is no such opportunity for comparison, as the analyses are not so numerous. In general, the cases reported are fairly representative. The total plankton reported from Lakes Kegonsa and Wingra is very large, aggregating more than 60 per cent of the total organic matter from the 14 specimens. Large amounts, but less noticeable, also are found in Lake Monona and Lake Waubesa. In the first two cases the water was collected close to the surface at the time of great growths of blue-green algæ, and the collection was made at this time in order to note the effect of these growths on the dissolved organic matter. The samples from the other two lakes also were taken at a time of maximum abundance of plankton. It will be noted that the "ash" is relatively low in these specimens, especially in the first two cases. The ash of the blue-green algæ is low; in 11 analyses (plankton report, p. 215) it ranged from 4.3 per cent to 7.8 per cent, and the presence of many milligrams per liter of this material greatly reduces the percentage of total inorganic matter.

The ratio of the nitrogen to the total organic matter of the plankton in Lake Mendota is 1 to 20.1, a ratio that is much lower than the average for the catches analyzed in the plankton report. In these the ratio was 1 to 14.1. The ratio of the average from the other lakes, as given in Table 6, is 1 to 21.8, or 1 to 20.2 if Lakes Kengosa and Waubesa are omitted as being exceptional cases.

II. DISCUSSION OF THE DATA

ORGANIC NITROGEN AND ORGANIC CARBON

Table 2 states the amount of organic nitrogen and organic carbon found in the residues from the water of the several lakes. They represent what is usually called "dissolved" or "soluble" carbon or nitrogen, as the water has been passed through a supercentrifuge to remove the plankton.

It should be noted that the lake water received a different treatment from that given to sea water by Raben (1910) and by Moore (Moore, et al., 1912); for example, in determining the dissolved carbon. In their experiments a small amount of water was employed, which had been passed through a Berkefeld filter. In studies on lake water the plankton was extracted from large quantities of water—50 to 575 liters—by means of the centrifuge. It is not probable that the two methods yield identical results. Both leave the water far from optically pure, and both undoubtedly remove substances that are neither living cells nor organic débris that exists in a particulate form—to employ Moore's useful word. In either case the weight of the matter left in particulate form probably is very small.

Two classes of experiments were made in the course of our studies that give some idea of the percentage of the particulate organic matter that was removed by the centrifuge. The first gave an indirect answer, based on the percentage of bacteria removed from the water by the centrifuge.

It is difficult to imagine that particles of organic débris suspended in water should be free from bacteria, and if they have bacteria adherent to them or colonized in them, a rough measure of the efficiency of any process in removing these particles of débris may be found in its efficiency in removing bacteria.

We found that the De Laval centrifuge, employed in the extraction of the plankton for the plankton report, removed 35 to 50 per cent of the bacteria. The Sharples supercentrifuge, used by Domogalla, Juday, and Peterson, removed about 70 per cent of the bacteria (p. 270). It is a fair conclusion that about the same percentage of the particles of débris also was removed, at least down to the size of the bacteria.

It is a fair conclusion also that the weight of the very numerous particles left in the water by the centrifuge is only a small fraction of the amount extracted by the centrifuge. In the plankton report (p. 89) there was computed the weight of the bacteria of Lake Mendota. At the summer maximum of 30,000 per cubic centimeter there were about 20,000 rods averaging 2.5μ long and 0.9μ in diameter, and about 10,000 cocci averaging 0.44μ in diameter. Such a crop would yield 0.0048 milligram of dry organic matter per liter, which would represent about one-half that weight of organic carbon. Such an amount is almost infinitesimal when compared with the average of nearly 6.0 milligrams per liter of dissolved organic carbon found in the water of Lake Mendota.

We may conclude, therefore, that only a small part of the organic material found in the evaporated residues is in the particles left behind by the centrifuge. The nitrogen and carbon of Table 2 may be called "dissolved" in any sense of that word in which it is properly applicable to colloids.

The same conclusion was reached directly by filtration experiments. In two cases 100 liters of water from Lake Mendota were divided into two parts after centrifuging. One-half was evaporated at once and the other was passed through a Berkefeld filter before evaporation. In both cases the nitrogen was determined both as to amount and kinds. The filtered water yielded slightly less organic nitrogen than did the unfiltered.

TABLE 7.—*Organic nitrogen in filtered and unfiltered water, milligrams per liter*

Date	Filtered	Unfiltered
Dec. 16, 1924	0.306	0.319
Feb. 19, 1925	.341	.351

These specimens were used in the study of the nitrogenous compounds, which agreed in detail as closely as in the total.

As some part of any colloids in the water would adhere to the filter and thus reduce the total nitrogen, it does not seem probable that any considerable part of the weight of the organic substances left in the water by the centrifuge exists in the form of particles. It is certain that very little is left that is removed by a Berkefeld filter.

Those who have studied the organic content of sea water (Henze, 1908; Raben, 1910; Moore et al., 1912) have left the subject with the statement of the amount of organic nitrogen and carbon. Table 2, therefore, gives a basis of direct comparison between the conditions existing in fresh and in salt water. If comparisons regarding nonorganic nitrogen are desired also, the data may be found in the paper on the forms of nitrogen (p. 273).

Thus the facts presented in Table 2 complete the proof, if such were needed that the fresh-water lake offers an unrivaled opportunity for the study of plankton in its relations to the fundamental food supply of water animals. The lake contains not only a complex association of living organisms, each group existing in numerous representatives and forms and in quantities great enough for study, but it contains also a great amount of organic material not removable by centrifuge and apparently not existing in particulate form. In this matter of quantity the fresh water has a great advantage over the sea. Studies on the water of the Mediterranean (Henze, 1908), the Baltic (Raben, 1910), and the Irish Sea (Moore et al., 1912) agree in finding that the total amount of organic carbon in the water of the open sea is so small that it lies "at the limits of detectability by the best known methods" (Moore et al., p. 269). The difficulty of studying this minute amount is increased further by the great quantity of salts dissolved in the water.

The water of lakes, on the other hand, contains organic matter, extractable by the centrifuge, in quantities ordinarily present to the amount of 1 milligram per liter; often as great as 5 to 7 milligrams per liter; and sometimes much greater. It contains, also, organic matter not thus extractable, whose quantity is ordinarily five to ten times as great. The dissolved salts of fresh water are small in amount, and there are many lakes whose dissolved organic content is larger than that of the dissolved salts. Thus, the fresh water far exceeds the salt in its opportunities for the study of the numerous and complex problems offered by its organic content.

As yet the science of limnology hardly has begun to deal with these problems. For years there has been an active discussion of the question whether the organized plankton is distributed to the two classes of eaters and eaten so as to make them into a self-sustaining community. But as yet there is no agreement on the quantity of organic matter contained in either group, on the rate of its renewal, or on the amount, kinds, and availability of organic matter in the water but outside of organized beings.

TOTAL ORGANIC CONTENT

In this section the organic content of lake water is discussed without taking into account the ether extract. The amount of this and the effect on the statement of total content are discussed in the next section.

The data for the plankton content of the water are given in Table 6, which gives total content and nitrogen. The "crude protein," the nitrogenous part of the plankton, may be computed from the nitrogen by employing the standard factor—6.25. The nonnitrogenous part is the remainder of the organic matter after the crude protein has been subtracted. The samples of plankton were too small to permit the determination of the ether extract, and therefore the nonnitrogenous substance can not be subdivided further into fats and carbohydrates. The plankton of the Madison lakes has been so analyzed in the tables of the plankton report.

In the study of the dissolved organic matter it is not possible to separate this from the relatively large quantities of inorganic salts that make up the bulk of the residues from evaporated lake water. Recourse must be had to indirect methods, based on the data of Table 2, which states the nitrogen and the organic carbon.

The nitrogenous part of the dissolved matter—the crude protein—is computed as in the case of the plankton by multiplying the amount of nitrogen by 6.25. The

proteins contain 50 to 55 per cent of carbon, and an average amount of 53 per cent may be assigned to them. Thus, the organic carbon may be divided at once into two parts, one belonging to the nitrogenous substances and the other to nonnitrogenous compounds. The first part equals 53 per cent of the weight of the crude protein and the remainder goes to nonnitrogenous substances. If the ether extract has not been determined (and this is true for most of the residues here considered), the nonnitrogenous substance must be computed as carbohydrate. This method involves an overestimate of the total amount of organic matter, proportional to the quantity of fat that is present; in the present cases the excess is about 3 per cent.

The carbohydrates contain only a negligible amount of sugars, as is the case also with the water plants and plankton. They may be computed as starch or cellulose, containing an average of about 45 per cent of carbon. The "crude fiber," so far as it contributes to the dissolved matter, comes either from plankton or higher water plants, and this also would have about the same composition.

If, then, the organic carbon is distributed to proteins on the basis that 53 per cent of these consists of carbon, and to nonnitrogenous organic substances on the basis of 45 per cent of carbon, the following table will result:

TABLE 8.—*Total organic matter, milligrams per liter*

[D.=depth. N.=nitrogen×6.25, or crude protein. Nonn.=nonnitrogenous matter computed as carbohydrate. Pkn.=plankton. Dis.=dissolved organic matter.]

	Date	Plankton				Dissolved			Total organic			Per cent	
		D.	N.	Nonn.	Total	N.	Nonn.	Total	N.	Nonn.	Total	Pkn.	Dis.
LAKES													
Mendota	Oct. 18, 1922	0	0.66	0.59	1.25	2.74	5.67	8.41	3.40	6.26	9.66	12.9	87.1
Do	Dec. 5, 1922	0	.90	.83	1.73	3.02	14.10	17.12	3.92	14.93	18.85	9.2	90.8
Do	Feb. 28, 1923	0	.32	.56	.88	3.46	9.95	13.41	3.78	10.51	14.29	6.2	93.8
Do	July 24, 1923	0	.70	2.67	3.37	2.44	13.48	15.92	3.14	16.15	19.29	17.5	82.5
Do	Sept. 21, 1923	0	.57	1.49	2.06	2.32	7.22	9.54	2.89	8.71	11.60	17.8	82.2
Do	Oct. 24, 1923	0	.28	1.54	1.82	1.81	11.10	12.91	2.09	12.64	14.73	12.4	87.6
Do	Apr. 23, 1924	0	.50	.45	.95	2.10	10.61	12.71	2.60	11.06	13.66	7.0	93.0
Do	June 18, 1924	0	.58	.74	1.32	1.92	10.12	12.04	2.50	10.84	13.34	9.7	90.3
Do	July 21, 1922	20	.31	.38	.69	1.96	8.44	10.40	2.27	8.82	11.09	6.3	93.7
Do	Sept. 26, 1922	20	.30	.55	.85	1.90	8.17	10.07	2.20	8.72	10.92	8.7	91.3
Do	Feb. 28, 1923	20	.36	.42	.78	3.50	9.50	13.00	3.86	9.92	13.78	5.7	94.3
Do	July 24, 1923	20	.36	1.13	1.49	2.52	10.01	12.53	2.88	11.14	14.02	7.8	92.2
Do	Sept. 21, 1923	20	.62	1.66	2.28	2.35	9.92	12.27	2.97	11.58	14.55	15.7	84.3
Do	June 25, 1924	20	.28	.56	.84	2.23	12.65	14.88	2.51	13.21	15.72	6.0	94.0
Mean			.48	.97	1.45	2.45	10.07	12.52	2.93	11.03	13.96	10.2	89.8
Bass	Dec. 20, 1923	0	.21	.36	.57	2.66	17.76	20.42	2.87	18.12	20.99	2.7	97.3
Devils	July 11, 1923	0	.24	.18	.42	1.37	5.08	6.45	1.61	5.26	6.87	6.1	93.9
Do	Oct. 27, 1923	0	.19	.20	.39	1.89	6.70	8.59	2.08	6.90	8.98	4.3	95.7
Geneva	July 16, 1923	0	.32	.93	1.25	2.11	7.55	9.66	2.43	8.48	10.91	11.5	88.5
Green	July 18, 1923	0	.26	.67	.93	1.94	6.48	8.42	2.20	7.15	9.35	10.0	90.0
Do	Oct. 16, 1923	0	.30	.59	.89	1.85	12.28	14.13	2.15	12.87	15.02	5.9	94.1
Kegonsa	July 20, 1923	0	8.62	10.66	19.28	4.56	10.90	15.46	13.18	21.56	34.74	55.5	44.5
Madeline	Dec. 12, 1923	0	.60	1.14	1.74	2.84	8.35	11.19	3.44	9.49	12.93	14.6	85.4
Michigan	Feb. 28, 1924	0	.14	1.48	1.62	.89	6.15	7.04	1.03	7.63	8.66	18.7	81.3
Monona	June 28, 1923	0	2.43	2.77	5.20	4.45	12.34	16.79	6.88	15.11	21.99	23.7	76.3
Rock	July 6, 1923	0	.46	.56	1.02	3.44	14.14	17.58	3.90	14.70	18.60	5.5	94.5
Turtle	Jan. 18, 1924	0	.19	.55	.74	3.06	25.75	28.81	3.25	26.30	29.55	2.5	97.5
Waubesa	July 20, 1923	0	3.74	4.41	8.15	4.65	10.32	14.97	8.39	14.73	23.12	35.2	64.8
Wingra	June 26, 1923	0	5.51	11.70	17.21	4.51	15.83	20.34	10.02	27.53	37.55	45.8	54.2
RIVERS													
Wisconsin	July 30, 1923	0	1.01	1.56	2.57	3.04	30.24	33.28	4.05	31.80	35.85	7.2	92.8
Do	Nov. 21, 1923	0	.34	.67	1.01	2.46	18.98	21.44	2.80	19.65	22.45	4.5	95.5
Yahara	July 6, 1922	0	1.19	(1)	(1)	2.32	18.54	20.86					

[1] Not determined.

So far as the dissolved organic matter is concerned, much the same comment may be made on Table 8 as on Table 2, from which it is derived. The total quantity of dissolved organic matter varies greatly in different lakes and in the same lake at different times. It may be less than 7 milligrams per liter (Devils Lake), or it may be more than 28 milligrams (Turtle Lake)—a fourfold range. The second observation on Green Lake was nearly 70 per cent larger than the first; and in the 14 observations on Lake Mendota the smallest quantity is less than one-half of the largest. These results are entirely in accord with those on the plankton, though the range of variation is much smaller.

There is much difference in the relation of nitrogenous to nonnitrogenous matter, just as there is in the nitrogen-carbon ratio of Table 2; and, as in that case, the average relation is much the same in the various groups. In the 14 cases from Lake Mendota the crude protein ranges from 12.6 to 36.9 per cent, a nearly threefold range; in the 14 cases from other lakes the minimum percentage is 10.6 per cent in Turtle Lake and the maximum is 29.5 per cent in Lake Kegonsa. The average per cent for Lake Mendota is 19.6; for the other lakes it is 20.1. This average is lower than it is in the plankton. Table 8 shows that in Lake Mendota the crude protein is 33.1 per cent of the total organic matter of the plankton; in the other lakes it is 31.1 per cent. The plankton report (p. 196) gives 44.5 per cent as the average for Lake Mendota during the years when that study was made.

The total organic matter of the water is obtained by adding the plankton and the dissolved matter, as is done in Table 8. In interpreting these figures the statement that was made earlier in this paper should be remembered. Not everything included under the first head is properly plankton, and the amount of nonplankton organic matter there included will increase with the efficiency of the centrifuging process. It is true, also, that not all of the "dissolved" matter really is dissolved. These divisions of the organic content of the lake water overlap to some extent, the degree of overlapping being dependent on the efficiency of the processes of separation. But, on the whole, the two categories fairly represent the facts.

The quantitative relation between plankton and dissolved organic matter is very variable. In the case of Lake Mendota the plankton may constitute nearly one-fifth of the total organic matter, or it may be less than one-sixteenth; in the other lakes the range is much greater. The plankton is more than one-half the total organic matter in Lake Kegonsa; nearly one-half in Wingra; and it is as little as one-fortieth of the total in Turtle Lake.

The mean of the 14 specimens from Lake Mendota shows that the crude protein of the plankton constitutes about one-sixth of the total protein, and the nonnitrogenous part of the plankton is little more than one-twelfth of the corresponding total. The range of variation in other lakes is so great in comparison to the number of observations that an average result has not much value.

TOTAL ORGANIC MATTER, INCLUDING FATS

In this discussion the ether extract is regarded as fat. The quantities obtained were too small for further chemical treatment, but under the microscope they appeared as transparent droplets of fat.

Table 9 brings together the facts for those residues for which the fats have been determined as ether extract. The table relates chiefly to Lake Mendota, there being samples from only two other lakes for comparison.

The table gives the data and the results computed from them; the data include organic nitrogen, organic carbon, and ether extract; the computed results are crude protein, fats, and carbohydrates. To the fats is assigned a carbon content of 75 per cent; the other substances are computed as in Table 8. Thus, in Table 9 the organic carbon is distributed to three classes of compounds.

TABLE 9.—*Total organic matter, ether extract included, milligrams per liter*

Lake	Depth	Date	Total dry	N	C	Ether extract	Crude protein	Fats	Carbohydrates	Total
Mendota	0	June 7, 1922	167.8	0.567	(1)	0.323	3.54	0.32	(1)	
Do	0	June 18, 1924	169.0	.307	5.58	.380	1.92	.38	9.44	11.74
Do	20	Sept. 26, 1922	162.8	.304	4.69	.488	1.90	.49	7.38	9.77
Do	20	June 25, 1924	172.1	.357	6.88	.688	2.23	.69	11.51	14.43
Do	0	10 samples	164.3	.457	5.98	.482	2.86	.48	9.09	12.43
Do	20	6 samples	149.7	.452	6.35	.765	2.83	.76	9.50	13.09
Mean of 20				.441	6.06	.504	2.76	.56	9.27	12.59
Geneva	0	July 16, 1923	114.0	.337	4.52	.217	2.11	.34	7.00	9.45
Green	0	July 18, 1923	143.7	.310	3.95	.352	1.94	.31	5.98	8.23

[1] Not determined.

TABLE 10.—*Percentile distribution of dissolved organic matter*

Lake	Protein	Fat	Carbohydrates
Mendota:			
Surface (10 samples)	23.0	3.9	73.1
Bottom (6 samples)	21.7	5.8	72.5
Mean (20 samples)	21.9	4.4	73.7
Green (1 sample)	22.3	3.6	74.1
Geneva (1 sample)	23.6	3.8	72.6

The data from Lake Mendota comprise 20 samples and are numerous enough to warrant computing an average result. The results from Green Lake and Geneva show that the variation in the fats of different lakes is entirely similar to that in proteins and carbohydrates. The data from Lake Mendota, both in the single and the composite samples, show that there is a larger amount of fat in the water at the bottom than at the surface. It should be noticed that all of the single observations were made under summer conditions. The specimens that made up the composite surface sample were fairly distributed through the year; but all except one of the specimens from the bottom were taken during the period of the summer stratification of the water, when there would naturally be a maximum difference between surface and bottom.

There is a very close correspondence between the average results of the 20 specimens from Lake Mendota reported in Table 9 and the mean of the 14 specimens reported in Table 8. If the organic matter for Table 9 is computed on the same basis as in Table 8, the result will be as follows: Nitrogenous, 2.76 milligrams per liter; nonnitrogenous, 10.21 milligrams; total, 12.97 milligrams. The total exceeds that of Table 9 by 0.38 milligram. The per cent of protein, when computed from

these data on the basis of Table 8, is 21.3, which is to be compared with 19.6 per cent in Table 8, derived from other data, and with 21.9 per cent in Table 10, resulting from a computation that includes the fats. The differences are plainly very small.

Table 10 shows the percentile composition of the organic matter in the more important items of Table 9. The figures for Lake Mendota may be compared with those for the plankton of that lake, as reported in the plankton report on page 196. There the average of 87 specimens gave protein, 44.5 per cent; fat, 7.5 per cent; carbohydrate, 48 per cent. These figures show clearly the relative decrease in the proteins and fats of the dissolved matter as compared with those of the plankton, and the corresponding relative increase of the carbohydrates.

If the total organic matter is computed from the data in Table 9 on the basis employed in Table 8, the excess due to computing all nonnitrogenous matter as carbohydrate ranges from 0.19 milligram in the case of Green Lake to 0.55 milligram in the bottom water of Mendota on June 25, 1924. The per cent of excess ranges from 2.2 to 3.9; the average excess in the 8 cases is 0.35 milligram per liter, and the average per cent is 3.0. This correction might be applied to the figures of Table 8, if desired, but the error due to method of computation doubtless is much smaller than those inherent in the variations due to sampling.

Table 11 exhibits the general results for Lake Mendota. The data for the plankton are the mean of 87 analyses of plankton taken from April 1, 1915, to June, 1917; the data for dissolved matter are from 20 residues, taken from 1922 to 1924. So far as the total amounts are concerned, the result would have been virtually the same if the figures from Table 8 had been used instead of those from Table 9. Further study certainly will make changes in the figures here reported but is not likely to alter the general situation shown by them.

TABLE 11.—*Lake Mendota. General result*

	Plankton		Dissolved		Total	
	Milligrams per liter	Per cent	Milligrams per liter	Per cent	Milligrams per liter	Per cent
Crude protein	0.88	44.5	2.76	21.9	3.64	25.0
Fat	.15	7.5	.56	4.4	.71	4.8
Carbohydrate	.95	48.0	9.27	73.7	10.22	70.2
Total	1.98	100.0	12.59	100.0	14.57	100.0

Thus, the water of Lake Mendota contains an average of nearly 15 milligrams of organic matter per liter; less than one-seventh of this is contained in the plankton that may be collected with the net or extracted with the centrifuge. The maximum amount of organic matter yielded by the plankton when it was a special study was 3.33 milligrams per liter on April 15, 1916; this is less than 40 per cent of the minimum amount of dissolved matter reported in Table 8. The minimum amount of plankton was taken on March 9, 1917, and yielded 0.91 milligram per liter. This is larger than several of the plankton catches reported in Table 8, but these were taken at one level only while the plankton catches for the plankton report represent all depths of the lake taken meter by meter. The water from which the dry residues came also

was taken at one level; but while the amount of dissolved matter varies, it shows no such differences with depth as does the plankton.

NATURE OF THE DISSOLVED ORGANIC MATTER

No special study has been made of the ether extract from the residues, but its appearance under the microscope shows that probably it is composed of normal fats. The exact nature and the nutritive value of the carbohydrate material have not been studied, either in the plankton or the dissolved matter. Something more definite may be said regarding the crude proteins.

The nitrogenous compounds of the plankton of Lake Mendota have been compared with those from the dissolved matter. Two composite samples of plankton were made up, one from the net plankton and the other from the nannoplankton. Each was made up from 10 catches, representing all seasons from April, 1915, to June, 1917. The organic nitrogen was determined by the methods used in the study of the residues, and it was separated into the three forms that were standard for the residues—free-amino nitrogen, peptide nitrogen, and nonamino nitrogen. The result is given in Table 12, where the analyses of the plankton are compared with the average results from the residues, as given by Domogalla, Juday, and Peterson (1925, pp. 273, 274). The residues include 29 samples of water from the surface and 21 from the bottom.

TABLE 12.—*Percentile distribution of organic nitrogen from Lake Mendota*

Nitrogen	Plankton			Residues		
	Net	Nanno	Total	Surface	Bottom	Total
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Free amino	20.5	16.3	17.0	20.0	20.4	20.3
Peptide	50.5	39.5	41.4	39.8	38.9	39.3
Nonamino	29.0	44.2	41.6	40.2	40.7	40.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

The net plankton contains nearly all of the animal matter that comes from Crustacea and rotifers; in computing the total results it has been given a weight of 17.4 per cent, corresponding to the average relation existing between net plankton and nannoplankton.

It appears, therefore, that the main classes of nitrogenous compounds exist in the residues in almost exactly the same proportions as in the plankton; there is much less difference between the means, as given in the table, than exists between the observations that go to make up the several means. In 15 samples from other lakes (nitrogen report, p. 282) the forms of soluble nitrogen showed much the same kind of variation as in Lake Mendota; the average of the 15 cases was as follows: Free-amino nitrogen, 17.2 per cent; peptide nitrogen, 38.7 per cent; nonamino nitrogen, 44.1 per cent.

The forms of nitrogen in the residues have been analyzed still further by Peterson, Fred, and Domogalla (1925, p. 293). It appears that such indispensable amino acids as tryptophane, cystine, tyrosine, histidine, and arginine are present in the

residues from Lake Mendota and other lakes. Therefore, there is every reason to believe that the nitrogen compounds of the residues from evaporated lake water are suited for animal nutrition.

Lake water contains organic matter in quantities very large in comparison to those found in the water of the open sea. The question of the possible use of this material as food, therefore, presents a different aspect.

Only a small fraction of this organic matter can be removed by net, by centrifuge, or by Berkefeld filter, and the relatively large amounts left behind by the centrifuge may be called "dissolved," as contrasted with the particles that make up the plankton. They certainly contain crude proteins of the same kinds and in much the same proportions as are found in the plankton; the small amount of fat apparently is of the same kind, and there is no reason to believe that there is any essential difference between plankton and residues in the miscellaneous assortment of substances grouped under the name of "nitrogen-free extract."

In the study of the plankton of Lake Mendota an attempt was made to estimate the proportion of eaters and food (plankton report, p. 155). Numerous counts were made, which gave the number of Crustacea and rotifers, and the average dry weight of their organic matter also was determined. The result showed that the dry organic matter of the two main groups of eaters constitutes about one-third of the organic matter of the net plankton, in which are found virtually all rotifers and Crustacea, including Nauplii. The average net plankton is a little more than one-sixth (17.4 per cent) of the total plankton; in the particulate matter removable by the centrifuge, therefore, there is from 15 to 20 times as much organic matter as exists in Crustacea and rotifers. This would seem to be in itself a sufficient quantity of food, but not all of it is practically available for all of the eaters. Many of the plankton algæ are too large to serve as food for most rotifers, and some algæ, like the larger forms of Lyngbya, probably are too large to be eaten by any of the plankton animals. Gloiotrichia is perhaps in the same situation, and though Cyclops sometimes browses on the ends of its filaments it probably contributes much more to the weight of organic matter than to available food.

By far the larger part of the organic matter of the plankton is found in Naumann's groups (1918, p. 44) of the smaller organisms and the "larger particles of peritripton." This material should be available as food for all of the larger eaters in the plankton, and its weight is so many times that of Crustacea and rotifers that there would seem to be in the lake a sufficient supply of particulate food, so far as organic substance is concerned.

How far these algæ, even though of moderate size, can be utilized as food by plankton animals is another question. Naumann (1921) has shown that food remains in the intestine of most of the limnetic Cladocera only for a very short time (15 to 30 minutes), and that almost all of the algæ pass through the intestine without being affected by the digestive process. These Crustacea seem to get their nourishment from the minuter organisms and from similar particles of débris. Copepods and rotifers (Naumann, 1923) seem able to make a more complete use of the food material ingested.

The facts presented in the present paper offer a new basis for the investigation of the nutrition of plankton animals. Looking at the proteins alone, there is dissolved

in the water three times as much as exists in the plankton, perhaps four times as much as the plankton offers as available food for Crustacea and rotifers. These soluble proteins are as nutritious, so far as their chemistry gives evidence, as are those of the plankton. The question of their use, therefore, is a question of fact to be settled by study, just as the question of the utilization of algæ as food by Daphnia must be settled.

The same statements may be made regarding the nonnitrogenous dissolved matters, with a confidence proportional to our knowledge or ignorance of the relation of these substances to the corresponding elements of the plankton. Outside of the centrifugible plankton there is four times as much ether extract as within it; the organic carbon assignable to carbohydrates is ten times as great outside of the plankton as within it.

It is evident that many questions are raised here, both of fact and theory, to which there are no answers at present. The story of the organisms and the organic substances of the lake water is comparable in its difficulties and complexities to the story of the cells and the organic matters in the human blood. It will take time to work out the story of the lake, and it may be long before we know the nature, the origin, the renewal, and the fate of the substances that we have here called dissolved.

It may be even harder to read the story of the possible or actual utilization of these substances as food. We may fairly assume that they have the potentialities of food; but dissolved matter in proportions of 6 to 30 in a million parts of water makes a very dilute nutriment, unless for creatures that have some special apparatus for selecting just these materials out of the water.

The carbon dioxide of the atmosphere, from which the land plants derive their carbon, constitutes 1 part in 2,500 by volume and more than this by weight; and of this, the carbon is more than one-fourth. In the water of Lake Mendota the organic matter of the dissolved protein constitutes only 1 part by weight in about 400,000 of water; the average total organic carbon, instead of being more than 1 part in 10,000, is less than 1 part in 150,000; and this great dilution is in a fluid far less mobile than air and one in which there is only a small relative movement between organisms and surrounding medium.

SUMMARY

1. The water of Lake Mendota contains in its plankton an average of about 0.140 milligram per liter of nitrogen and about 0.990 milligram of organic carbon.[1]

[1] A very large series of determinations of the amount of organic carbon and nitrogen in fresh water is to be found in the sixth report of the English commission on pollution of rivers, presented to Parliament in 1874 (House of Commons Documents, 1874, vol. 33). This report contains many hundreds of determinations of organic carbon and nitrogen from potable waters, made by Frankland and Armstrong. Twenty-three lake waters were examined, chiefly from soft-water lakes. The mean amount of organic carbon found in these waters is 2.30 milligrams per liter; the organic nitrogen is 0.314 milligram per liter; the nitrogen-carbon ratio is N : C :: 1 : 7.2. If the organic matter is computed on the same basis as in the present paper the result is nitrogenous, 1.96 milligrams per liter; nonnitrogenous, 2.80 milligrams per liter; total organic matter, 4.76 milligrams per liter.

This report has received little notice from limnologists. The methods of analysis were slow and complicated and did not come into general use. In some cases they might lead to inaccurate results. Our attention was called to the report by a reference in a paper by W. H. Pearsall, entitled "Phytoplankton and environment in the English lake district" (Revue Algologique, March, 1924). He evidently accepts the data of the report for the lakes to which he refers; and, in general, the report shows conditions quite similar to those found by us in soft-water lakes of northeastern Wisconsin during the field seasons of 1925 and 1926. Pearsall's paper was received after the present paper had gone to press

The residues from large samples of evaporated water, from which the plankton has been extracted, yield an average of about 0.393 milligram per liter of organic nitrogen and about 5.80 milligrams of organic carbon. The nitrogen and carbon from the residues are called "dissolved." (See Table 2.)

2. The residues from the water of Lake Mendota yield ether extract to an average amount of more than one-half milligram per liter of water (0.564 milligram, Table 5). Green Lake and Lake Geneva yield comparable though smaller quantities.

3. Part of the organic matter in the residues is, no doubt, particulate, but most of it seems to be dissolved. The quantitative relation of these two classes needs further investigation.

4. The crude protein of the residues may be computed from the nitrogen (factor 6.25), and the organic carbon may be distributed to proteins (assigning them 53 per cent C) and to nonnitrogenous matter (computed as 45 per cent C); if the ether extract has been determined the nonnitrogenous matter may be divided into fats (75 per cent C) and carbohydrates (45 per cent C). The average difference between these two methods of computation is about 3 per cent of the total organic matter. (See Tables 8 and 9.)

5. On the first basis of computation the water of Lake Mendota contains an average of nearly 14 milligrams per liter of organic matter, of which about one-tenth is in the plankton. On the second basis, and employing for the plankton the larger average results of the plankton report, the total is nearly 15 milligrams per liter of water, of which less than 2 milligrams are in the plankton. (Tables 8 and 11.)

6. The average nitrogen-carbon ratio in the plankton is about 1 to 6; in the dissolved matter it is about 1 to 14 or 15. In both cases the figures are subject to much variation.

7. The average dissolved protein is from three to six times as great as that of the plankton; the dissolved nonnitrogenous material is about 10 times as great. (See Tables 8 and 11.)

8. Studies of residues from 12 other lakes and 2 rivers show conditions essentially similar to those of Mendota, both in regard to plankton and dissolved organic matter. (See the several tables.)

9. The question of the fundamental food supply of the lake must be reexamined in view of the presence of these relatively large amounts of dissolved organic matter.

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DESCRIPTIONS OF TWO NEW SPECIES OF FISHES FROM KEY WEST, FLA., WITH NOTES ON NINE OTHER SPECIES COLLECTED IN THE SAME LOCALITY

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Contribution from the United States Fisheries Biological Station, Key West, Fla.

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INTRODUCTION

At various times the authors (Hildebrand, 1919–20, and Ginsburg, 1922–24) were stationed at the United States Bureau of Fisheries Biological Station at Key West, Fla., where they gave attention to the collection and study of fishes. The present short paper sets forth the data obtained from some of the collections.

Myrophis punctatus Lütken

Lütken, Vidensk. Meddel., Nat. Foren. Kjøbenhavn, 1851, 1.

One specimen, 150 millimeters long, was taken in a muddy pond. This appears to be the first record of this species for Key West.

Fundulus ocellaris Jordan and Gilbert

Jordan and Gilbert, Proc., U. S. Nat. Mus. 1882, 255.

This fish was quite abundant on April 11, 1919, in a brackish swamp, nearly dry, in which many fish were dying. The ocellus is lacking on the dorsal fin of one female. Three specimens were measured with the following results: D. 11 to 12; A. 9 to 10; scales 34 to 35; depth 4.35 to 4.5; head 3.1 to 3.35; eye 3.3 to 3.4; snout 3.3 to 3.5; maxillary 3.4 to 4.4; pectorals 1.80 to 1.97. This species apparently has not previously been recorded from Key West.

Menidia conchorum n. sp.

Diagnosis.—Anal soft rays 11 to 14, the modal frequency being 12; 33 to 35 vertical rows of scales; origin of spinous dorsal nearer to base of caudal than tip of snout; eye larger than length of snout; base of anal distinctly shorter than head; size small, the smallest known Menidia.

Description of type.—Dorsal profile gradually ascending to spinous dorsal, slightly curved behind head; ventral profile nearly horizontal from articulation of mandible to origin of anal; body not slender, depth at origin of ventrals 4.61 in length; head 3.39; eye large, 2.65 in head; snout shorter than eye, 3.35 in head, upper profile nearly straight, the lower one very oblique; jaws subequal; distal tip of maxillary distinctly projecting beyond the broad premaxillary; distance from tip of upper jaw to tip of maxillary 2.85 in head; interorbital flat, 4.56 in head; caudal peduncle not slender, its depth 2.85 and length 1.37 in head; spinous dorsal with 5 flexible, approximate spines, last spine slightly more separated from the preceding, origin of fin nearer to the base of caudal than tip of snout, the predorsal distance being 0.56 of the length; soft dorsal I, 8, its origin over base of fifth soft anal ray, insertion of last ray over base of eleventh anal ray, length of its base 2.43 in head, last ray made up of two separate rays united at base; anal I, 12, first ray simple, last divided to base, distance of its origin from tip of snout 0.62 of length; ventral 1.97 in head, its tip terminating at a distance from origin of anal about equal to interorbital, not quite reaching vent; pectoral extending beyond origin of ventral, 1.44 in head; scales entire, not laciniate, 35 oblique rows over the silvery band, between upper angle of gill opening and base of caudal; 8 scales in a row, counting obliquely downward and backward from origin of soft dorsal to base of anal; 13 scales on mid line of back in front of spinous dorsal (not including enlarged scales on top of head); row of scales at base of anal partly extending on fin; fins otherwise scaleless; teeth small, in narrow bands in jaws, some of outer series slightly enlarged, none on vomer and palatines; width of silvery band 8.75 in head.

Color in alcohol.—Walnut brown; belly and underside of head lighter; some metallic silvery reflections, especially on cheeks and opercles; pupil white; iris silvery with a golden wash; upper part of head and body and underside of snout rather diffusely peppered with bluish silvery and minute dark dots.

Variability.—The specimens at hand, when like sizes are compared, show a rather high degree of uniformity of the various proportional measurements. The following table gives the individual variations of this species as to measurements and scale and fin ray counts. The depth was measured at the base of the ventrals, the head to the posterior margin of the bony part of opercle, and both are compared with the standard length, while the other measurements are compared with the head. The predorsal distance is expressed as a percentage of the length. The first seven specimens given in the table include the type and six paratypes, all obtained on the same date.

Standard length	Depth	Head	Eye	Snout	Maxillary	Interorbital	Pectoral	Ventral	Base of anal	Predorsal distance, per cent	Dorsal	Anal	Scales	Scales before dorsal
38.7	4.61	3.39	2.65	3.35	2.85	4.56	1.44	1.97	1.37	56	V-I, 8	I, 12	35	13
39.1	4.54	3.40	2.56	3.29	2.88	4.26	1.44	2.09	1.44	55	V-I, 8	I, 14	35	13
38	4.58	3.42	2.71	3.17	3.00	4.63	1.35	1.98	1.48	57	V-I, 8	I, 12	35	13½
35.6	4.45	3.36	2.52	3.66	2.94	4.61	1.38	2.00	1.35	53	V-I, 8	I, 13	35	12½
35.6	4.51	3.30	2.57	3.60	3.09	4.70	1.35	1.96	1.61	55	IV-I, 7	I, 12	34	13
33.1	4.14	3.31	2.50	3.13	2.78	4.17	1.20	1.87	1.47	58	V-I, 8	I, 14	35	12
35.2	4.40	3.42	2.58	3.68	3.12	4.48	1.29	1.91	1.43	56	V-I, 7	I, 13	35	14
31.9	5.23	3.36	2.57	3.65	3.28	4.75	1.36	2.07	1.58	57	IV-I, 7	I, 13	33	12
19.8	5.21	3.25	2.54	3.05	3.81	5.08	1.53	2.10	1.65	53	V-I, 7	I, 13	-------	-------
20.1	4.69	3.38	2.61	3.31	3.19	4.30	1.34	1.91	1.69	57	V-I, 7	I, 12	36	-------
26.1	4.58	3.22	2.45	3.52	-------	4.26	1.39	1.98	1.62	55	IV-I, 7	I, 12	34	12

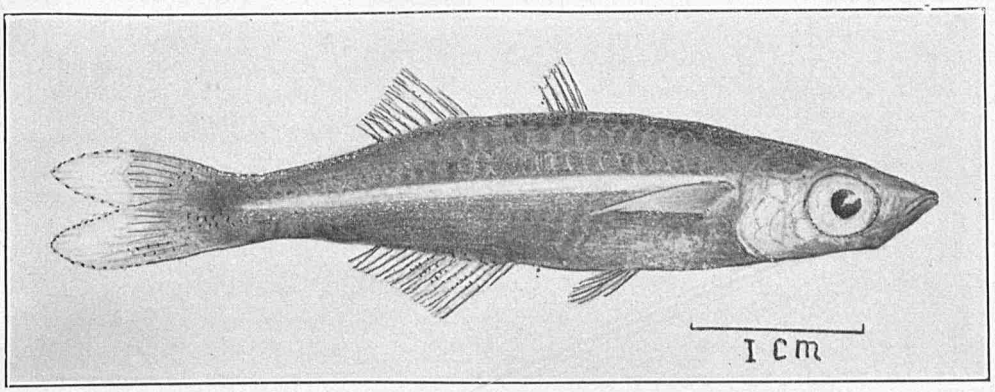

FIG. 1.—*Menidia conchorum*. (Enlarged 2⅓ times)

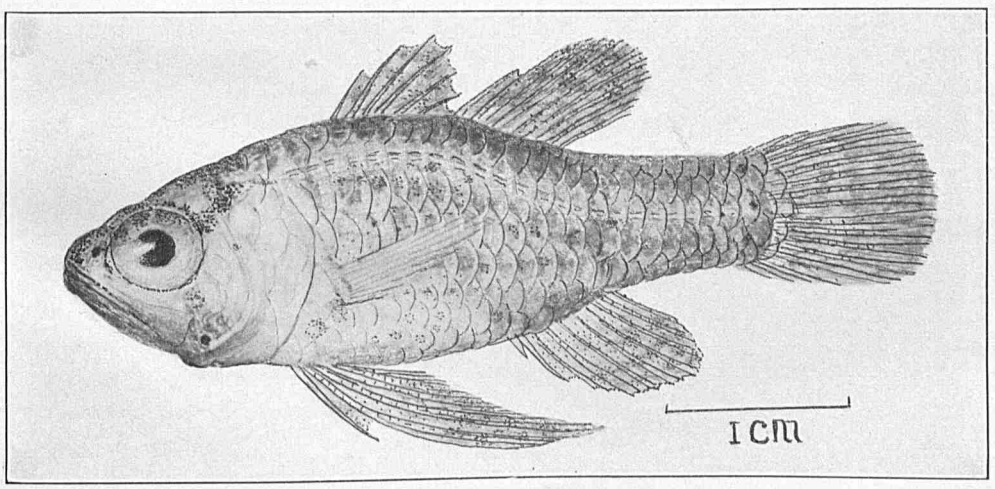

FIG. 2.—*Apogonichthys stellatus*. (Enlarged 2⅓ times)

In 51 specimens, including those given in the preceding table, the following number of soft anal rays were counted:

Number of soft anal rays	11	12	13	14
Number of specimens examined	3	25	17	6

The last ray usually is made up of two rays connected at the base; sometimes it is a single ray like the preceding one. In either case it was counted as one ray.

Holotype.—No. 87535, United States National Museum, 48 millimeters long.

Type locality.—Key West (Boca Chica), May 16, 1919.

Paratypes.—All from Key West; 6 specimens, 43 to 48 millimeters, obtained with the type; 12 specimens, November 13, 1922, 14 to 37 millimeters; 1 specimen, November 25, 1922, 26 millimeters; 22 specimens, December 7, 1922, 19 to 40 millimeters; 9 specimens, February 8, 1919, 26 to 37 millimeters.

Etymology.—Conchorum, of the conchs, referring to the local name by which the natives of Key West are known.

This species is well distinguished from all other species of Menidia known to the writers by the small number of anal rays. It probably does not grow to a large size, as no specimens larger than the type were observed. It is not uncommon in shallow water around Key West, and most probably forms a part of the diet of shore-feeding fishes, such as the gray snapper, which is quite an important food fish at Key West.

Hynnis cubensis Poey

Poey, Memorias, II, 1860, 235.

A specimen of this rather uncommon species was obtained in the Key West fish market, weight 11 pounds, total length 875 millimeters, standard length 737, head 200, depth 275, maxillary 80, eye 43, pectoral 202, depth of caudal peduncle 22.5, longest dorsal ray 100, longest anal ray 110, D. 18, A. 16; gill rakers rather short, coarse, 12 and 1 rudiment; pseudobranchiæ small; pharyngeal teeth in moderate patches, partly blunt or paved and partly villiform.

This fish is considered more or less of a curiosity by the fishermen of Key West, who say that it is seen only occasionally. The species originally was described from Cuba, and it has only comparatively recently been recorded from the coast of Florida.

Apogonichthys stellatus Cope

Apogonichthys stellatus Cope; Trans., Amer. Philos. Soc., 1869 (n. ser.), vol. 13, p. 400.
Apogonichthys stellatus Fowler; Proc., Ac. Nat. Sci., Philadelphia, 1907 (1906), vol. 58, p. 527, fig. 10.
Apogonichthys strombi Plate; Zool. Anz., 1908, bd. 33, p. 393.

Seven specimens of this fish, 36 to 50 millimeters in total length, were measured and studied, the measurements varying as follows: Depth, 2.76 to 2.93; head, 2.49 to 2.59; predorsal distance, 2.18 to 2.36; ventrals, 2.38 to 2.71 in standard length; eye, 2.57 to 2.78; snout, 2.83 to 4.57; maxillary, 1.7 to 1.8; interorbital, 4.45 to 5.4; pectorals, 1.53 to 1.84 in head. The dorsal spines are constantly 6. One specimen has 8 soft rays in the dorsal and 7 in the anal; all the others have 9 and 8 soft rays in addition to 1 and 2 spines, in the second dorsal and anal, respectively. The tip of the ventral reaches backward to the base of the third to the seventh anal rays. Scales in lateral line, 22 to 24 to base of caudal and one or two more on caudal fin. The color is light brown, somewhat coppery (in life the fish is of a bright, shining, copper color). The lower half of the postorbital part of head, the chest, and the region around the base of the pectorals is usually lighter, more or less silvery. The

head and body with brown, somewhat stellate spots, many of which have silvery centers. The distribution of the stellate spots varies; they may be confined to the head and anterior part of the body or they may be uniformly scattered over the head and entire body. The body is sometimes diffusely peppered with minute bluish silvery dots (some of which may have been stellate in life). One specimen is quite dark, the head and body being suffused with black, and the fins, except the pectorals, are jet black.

In two very small specimens, 16 and 17 millimeters long, the appearance, form, and coloration are very similiar to those of larger examples. The tip of the ventral does not reach beyond the base of the first soft ray of anal. The specimens, however, are not in very good condition and the tips of the fins may have been frayed. The counts of the dorsal and anal are the same as in the majority of larger specimens.

Four specimens were obtained in the shells of living conchs as follows: Forty-three millimeters long, December 8, 1922; 50 millimeters, January 1, 1923; 43 millimeters, February 1, 1923; 42 millimeters, April 27, 1923. Three were found in sponges, as follows: Two specimens, 37 and 40 millimeters, June 7, 1918; 36 millimeters, August 29, 1919. The two young specimens of 16 and 17 millimeters were obtained by means of a seine on the beach of Boca Chica, November 4, 1922.

On account of Cope's erroneous description, we were at first inclined to regard this as an undescribed species. The *Apogonichthys strombi* described by Plate seems to be the same species, this author apparently also having been misled by Cope's description of his *A. stellatus*. Fowler, in figuring this species, has corrected the statement in the original description as to the number of spines in the first dorsal. Another character by which Plate separates *strombi* from *stellatus* is the lack of small silvery spots on the center of the scales of the former. The specimens at hand show that this is a variable character. The small silvery spots, when present, usually form the center of small brown stellate spots. Three individuals show the silvery spots very distinctly when examined with the naked eye. One specimen in particular appears to the naked eye almost a replica of Fowler's figure. When examined with a lens it becomes evident that two or more silvery spots of various sizes may be present on a scale. One specimen does not show any silvery spots when examined with the naked eye, but such small spots may be seen under a lens. Two specimens that were originally preserved in formalin do not show any traces of silvery spots when examined with a lens, showing that the presence of such spots on preserved specimens depends also on the preservative used.

The posterior margin of the caudal is shown by Fowler as well as by Plate to be slightly emarginate. In our specimens it seems to be convex, but the caudal fins of all our specimens are shrunken, which makes it hard to determine this character with certainty.

This fish is very interesting biologically on account of its curious association with the conch. The conch is quite common around Key West. It is in good demand as an article of food and is also frequently used for bait in line fishing. The exact relationship between the conch and little fish remains to be learned. Plate found the stomachs of his specimens to be filled with Crustacea of various kinds. Some of our specimens were collected also in sponges. This would seem to indicate that the fish is a sort of facultative inquiline. What benefit, if any, the conch derives from this association is not clear. The two very young specimens that were obtained by means of a drag seine along the shore are of interest in connection with the question of the spawning habit of this fish.

Eleotris pisonis (Gmelin)

Gobius pisonis, Gmelin; Syst. Nat., 1788, 1206.

The color of live specimens are as follows: Body dark, dirty brown, stippled with lighter dots; back and head lighter than rest of body, the lighter portion of the back being abruptly and rather sharply separated from the darker sides; a dark horizontal streak from snout to eye, continued back of eye to gill opening; two shorter somewhat diffuse streaks radiating backward from eye and situated below the larger streak; belly washed with golden shades and stippled with dark dots; dorsal and anal light with dark streaks; pectoral light, stippled with dark dots and with a black blotch at its base; caudal dark with lighter streaks.

The foregoing color notes were taken from two specimens 83 and 85 millimeters long. The soft dorsal and anal each had nine rays in both fish. The smaller specimen had 55 rows of scales, counting from the base of the pectoral to the base of the anal while the larger had 49 rows on one side and 54 on the other. Four more specimens from Key West have 53 to 62 rows of scales.

Erotelis smaragdus (Cuvier and Valenciennes)

Eleotris smaragdus, Cuvier and Valenciennes; Hist. Nat. Poiss., XII, 1837, 231.

This species has the peculiar habit of burrowing in the bottom mud, where it may be taken. It is quite probable that this fish is more common than it is generally supposed to be, but is not taken more often because of its unusual habitat. Our material from Key West include the following: Two specimens, 46 and 59 millimeters, February 7, 1919; 2 specimens, 45 and 63 millimeters, February 15, 1919; 1 specimen, 60 millimeters, June 4, 1919; and 1, 85 millimeters, August 7, 1919. The first five were taken in mud, while the last was taken in a muddy pond. Color greenish above, pale below, and everywhere with dusky punctulations; caudal bluish; dorsal and anal with dark spots; other fins pale.

Brannerella ocellata (Steindachner)

Clinus ocellatus, Steindachner; Ichth. Beit., V, 1876, 182, Pl. 12, fig. 5. D. XXI, 8-9; A. I-I, 10; lateral line 37-38.

Upper profile strongly ascending to origin of dorsal, thence descending gradually to base of tail; lower profile much less curved than upper, nearly straight from articulation of mandible to anal fin, thence making a gradual curve to tail; body robust, not very slender, greatest depth a little behind insertion of pectoral, 4.29 to 4.71; head (measured to margin of bony part of opercle) 3.23 to 3.29; mouth terminal, rather large, oblique, lower jaw slightly protruding; maxillary 2.04 to 2.1, reaching a vertical through posterior margin of eye; snout rather blunt, 4.37 to 5.1; eye large, 3.32 to 3.57; interorbital quite narrow, 10.4 to 10.7; anterior nostril with a short, slender, simple tentacle; a similar but longer tentacle on eye; a single slender nuchal tentacle placed near mid line of back, about an eye's diameter in front of dorsal; origin of dorsal over insertion of ventrals, slightly behind posterior margin of preopercle; predorsal distance 3.5 to 3.69 in length; spinous dorsal with a deep emargination posteriorly, first spine 4.28 to 4.36 in head, spines gradually increasing in length from first to tenth (second spine sometimes slightly shorter than first), tenth spines 2.43 to 2.59 in head, tenth to sixteenth spines subequal, then rapidly decreasing in length to nineteenth, latter slightly shorter than first spine, twentieth slightly longer than eighteenth, last subequal to longest spines; soft part of dorsal rounded, higher than spinous part, third or fourth ray longest, 1.57 to 1.68 in head; membrane

from last ray not quite reaching caudal; origin of anal under eighth or ninth dorsal spine; first spine entirely separated, enveloped in thick skin that projects beyond its tip, its length about 3 in head; second spine normally pungent and connected with the following rays; pectorals with 13 to 14 rays, 1.32 in head, the tip reaching slightly behind a vertical through origin of anal; insertion of ventrals very slightly behind margin of preopercle, fin 1.4 in head, not reaching origin of anal; scales of medium size, cycloid, entirely covering body; head, nape to origin of dorsal, base of pectoral, chest, and part of abdomen (about two-thirds of distance from insertion of ventrals to origin of anal) naked; 17 scales in arched portion of lateral line, 20 to 21 in posterior straight part to base of caudal, 1 or 2 more rather large imperforate scales on caudal, 2 rows between highest part of arch and spinous dorsal, 7 between origin of anal and straight part of lateral line; teeth in jaws consisting of an outer enlarged series and an inner band of villiform teeth; a series of rather large teeth on vomer continued posteriorly on palatines; head and nape with large pores.

Color in alcohol.—Body light brown, marbled with lighter and darker shades, darker marblings forming three indistinct longitudinal rows of blotches, reticulate lines sometimes setting off a few of the blotches somewhat more distinctly; fins rather light, somewhat clouded with darker, a row of light spots at base of dorsal separating off darker areas; a rather diffuse dark spot on membrane between first two dorsal spines; head brownish, a diffuse dark blotch behind eye, some dark irregular lines on cheek; cheek, opercle and base of pectoral with very small brownish rings against a lighter background, the rings being formed by a strong concentration of pigment about the margins of rounded pigmentless areas. Color of a freshly preserved specimen has been described as follows: Grayish olivaceous, paler below; a row of 10 large dark spots on back, extending on dorsal fin; another row below this and a third indistinct row below lateral line; about 12 small yellow spots arranged in a semicircle extending halfway around and underneath orbit; about 10 small yellow spots, surrounded by dark, on cheek; 2 similar spots on opercle and 2 on base of pectoral; top of head marbled with dark and light; ventrals pale, pectoral, anal and caudal marked with dark.

Three specimens of this species are at hand. All are from Key West and all were collected in sponges on the following dates: Thirty-four millimeters, August 27, 1919; 42 millimeters, August 29, 1919; and 38 millimeters, September 4, 1919.

These specimens, in the main, agree well with Steindachner's description and figure and seem to belong to that species. The dark rings on the side of the head seem to be a good color mark, which, apparently, does not disappear in alcohol. The centers of these rings, however, in our specimens are not blue, as stated in the original description of the species, but are yellowish, pigmentless areas. The counts of scales and fin rays and the proportional measurements agree closely with the original description. Steindachner does not state in his description the peculiar structure of the first anal spine, the main character on which the genus Brannerella was based, but his figure plainly shows that character. Also, no mention is made of the presence of a nuchal tentacle, which was probably overlooked by the author inasmuch as all our specimens have a single, slender tentacle in front of the dorsal. The arrangement of the teeth in our specimens also does not agree with the original description. The specimens at hand have a narrow band of minute villiform teeth behind the outer enlarged row, and the row of rather enlarged teeth on the vomer is continued backward on the palatines.

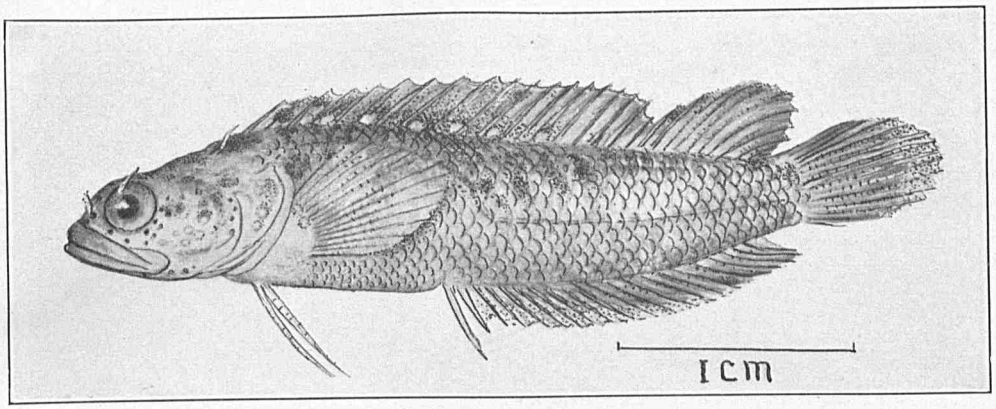

FIG. 3.—*Brannerella ocellata*. (Enlarged 3 times)

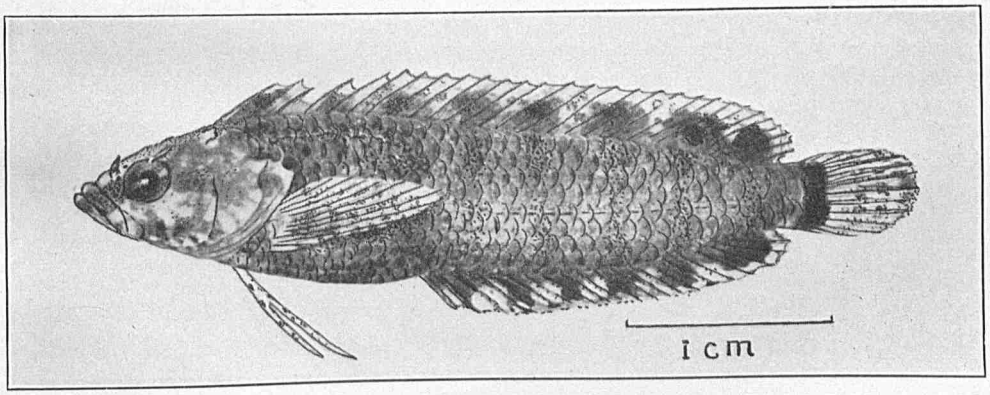

FIG. 4.—*Paraclinus fasciatus*. (Enlarged $2\frac{2}{3}$ times)

Paraclinus fasciatus (Steindachner)

Cremnobates fasciatus Steindachner; Ichth. Beit., V, 1876, 176.

Seven specimens are provisionally referred to this species. In six of these the dorsal has a well-developed emargination in front, the third and fourth spines being subequal and shorter than the preceding and following spines. The membrane from the third spine is inserted at about the middle of the fourth or nearer to the base of the latter, and the membrane from the fourth spine is inserted at about the middle of the fifth. The dorsal has 29 spines in 5 specimens and in 1 it has 30, the last ray always being spinous and pungent, not articulate. Three specimens have 18 soft rays in the anal and 3 have 19. The lateral line has 33 to 35 scales. The orbital tentacle is branched; the nuchal tentacle is in the form of an elongate flap with exceedingly short and fine fimbriæ at the top. Four specimens have more or less diffuse crossbars on the body, while two specimens are quite dark to nearly black, and the bars are not evident. The dorsal and anal have a series of dark blotches, which are quite indistinct in some of the lighter-colored examples and more or less confluent in the darker ones. The dorsal has a blue ocellated spot on the penultimate blotch.

In the seventh specimen the anterior emargination of the dorsal is very shallow, the third spine being shorter than the preceding and following spines, but the interspinous membrane reaches to the tip of the spine in all cases. This specimen also has 28 spines in the dorsal. However, it does not seem to differ in other essential characters from the rest. So far as may be judged from a single specimen, it seems to be nothing more than an individual variation.

These specimens are referred to Steindachner's *C. fasciatus* because they seem to agree with the description of that species. The species apparently is common in the regions of the Straits of Florida. However, we do not feel absolutely certain about this identification. A review of current descriptions shows that this group needs a comparative study and critical revision, with a reexamination of the types, and until such a study is made our identifications must be tentative.

The genus Paraclinus is separated from Auchenopterus, by some authors, on the basis of the emargination of the dorsal. No sharp line, however, may be drawn with respect to that character, because it varies gradually among the species, and it seems probable that it is not more than an individual variation in some species. On the other hand, the presence or absence of an articulated ray in the dorsal is constant within the species, so far as known, and the two genera may conveniently be separated by that character.

Gobiesox (Rimicola) beryllinus n. sp.

Diagnosis.—Body elongate, slender; ventral disk short; dorsal and anal fins subequal and short, each with six rays; outer teeth of lower jaw with entire edges, inner smaller teeth present; color in life light green with small white spots.

Description of type.—Body elongate, slender; depth 8.0 in length; head oblong, angular, its sides being in nearly vertical planes, the top being in a nearly horizontal plane, its width 1.66 in its length, the latter 3.3 in body; eyes small, oblong, placed partly on lateral and partly on superior aspect of head, longest diameter 4.5 in head; interopercular spine well developed; snout broad, rounded in front, 2.8 in head,

interorbital 2.8; pectoral 2.3; dorsal and anal each with 6 rays; distance of origin of dorsal from tip of snout 1.33 in length; origin of anal a little behind that of dorsal; ventral disk small, its length 5 and its width 6.2 in length, distance from posterior margin of disk to anal 2.4 in length; outer teeth of lower jaw horizontal, broad incisors with entire edges, smaller teeth behind outer row present; upper jaw with an outer series of rather long, narrow, subequal, pointed teeth, with smaller teeth behind.

Color in life.—Bright emerald green, covered with white spots and dots; one longitudinal row of rather large white spots on mid line of back, a similar row along middle of side, smaller white dots scattered between the rows of larger spots; white spots on head and underside of body being of intermediate size and irregularly scattered; a longitudinal, somewhat oblique, dark line in front of eye, faintly continued for some distance back of eye.

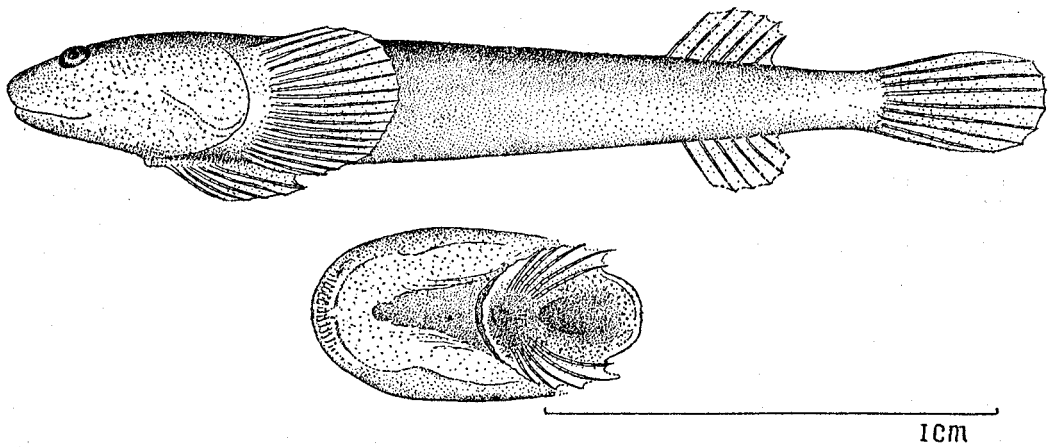

FIG. 5.—Gobiesox beryllinus. (Enlarged 6¾ times.) The lower figure represents a ventral view of the head and disk

The foregoing color description was drawn from the specimen while it was being kept alive in a pan of water in the laboratory. After being kept for a few days in alcohol the green color entirely disappeared and red tints became evident. A red streak was present behind the eye; the iris was red and the body was sprinkled with minute reddish dots. The red tints also disappeared after the specimen had been in alcohol over two years. This may have been due in part to the strong light in which it was constantly kept. The body and head then became plain olivaceous, without distinct markings, and the eyes were dark.

Holotype.—No. 87533, United States National Museum, 20 millimeters long.

Type locality.—Key West (Boca Chica), Fla., November 2, 1922; obtained with a drag seine along the shore.

A single specimen of this species has been studied. Its nearest relatives in the West Indian fauna appear to be *Sicyases rubiginosus* Poey (Synopsis, 1868, p. 391) and *Sicyases carneus*, Poey (loc. cit., p. 292). From the former it differs strikingly by its color pattern, and from the latter it appears to differ by its color and smaller eyes. When a direct comparison of material is made, other structural differences most probably will be found.

Canthidermis sobaco (Poey)

Balistes sobaco, Poey; Memorias, II, 1861, 324.

One small specimen, 49 millimeters long, was taken on April 16, 1919, D. III, 27; A. 24; depth 1.6; head 2.4; eye 3.25; mouth 1.8; pectoral 2.2. This small fish appears to be a new representative of the genus and species of the Key West fauna. It agrees essentially with Cope's *C. asperrimus* (Trans., Amer. Philos. Soc., 1871, p. 478), held to be a synonym of *C. sobaco*, but the color is somewhat different. Our specimen is very dark brown, with elongate black spots arranged indefinitely in longitudinal series.

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THE SMELTS

By WILLIAM CONVERSE KENDALL

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INTRODUCTION

From early youth the writer has been familiar with the smelt, and to him the little fish always has been of intense interest. Some years ago he became imbued with ambition to write a monograph on the smelts and smeltlike fishes of the world. Every opportunity was grasped for making collections and studying the habits of the fish and for compiling all available published information concerning them; but during the fleeting years there were so many more or less prolonged interruptions by other work in which smelts had no part that it became necessary to restrain the comprehensive ambition and restrict the proposition to a treatise concerning the smelts of the Atlantic only, and particularly to those of the eastern United States.

In the course of the studies it was somewhat surprising to find that almost nothing was known, or if known had not been published, concerning the habits and life history of the smelt. Extensive collections of smelts of the Atlantic coast and inland waters of the Eastern States were made, and hundreds of specimens were studied in detail in an effort to solve certain problems of relationship and the life history of the fish in the interest of the fisheries and fish culture. It is now believed that sufficient data are at hand to contribute substantially to the desired solution and knowledge. A report upon these phases of the subject is in preparation, but as that report will be somewhat technical in nature, and in view of the facts that so little is generally known concerning the smelt and such information as has been published is so scattered, often in brief notes, through many publications, it has been thought desirable to bring together in one publication available published and unpublished matter of more general interest. This the writer has attempted to do in the present paper.

As much as possible pertaining to the natural history of the smelt, based upon the scattered literature and occasional observations by the present writer, has been embodied in the discussions. A brief history of the smelt fishery has been included, but it may be regarded as almost "ancient history," for the reason that there are scarcely any data pertaining to the smelt fisheries in the last 10 years excepting in Canada. Fish-cultural propagation, depletion, and conservation also are subjects that receive some attention.

A list of publications consulted and quoted is appended In the text both direct and indirect quotations are credited to the author, when known, or to the publication in which the article quoted appears. Such credit references are indicated by the authority and the year of publication in parenthesis, which signifies that the full literary reference is to be found in the bibliography. If more than one publication by the same author appears in the same year, the second, third, or fourth are respectively indicated by *a*, *b*, *c*, etc., both in parenthesis and in the list of references.

While it is recognized that the discussions embodied in this document are incomplete and otherwise defective, it is hoped that those facts will stimulate effort directed toward the attainment of greatly needed further knowledge, and more intensive and intelligent measures and action toward the conservation of the fishery.

THE SMELT FAMILY

"Second cousin to the grayling and trout, and one of the neatest, most graceful, and delicate of all our food fishes, is that universal favorite, the smelt." Samuels (1904)

The smelts, with closely related forms, compose a group of fishes of wide geographical distribution in nothern latitudes. Their recorded distribution shows them inhabiting both coasts of the North Atlantic, both North Pacific and both Arctic coasts, or their coastal fresh waters, thus forming an irregular, interrupted, distributional belt that encircles the Northern Hemisphere.

Concerning most of these forms very little is known; and it was not until in comparatively recent years that any of them received any scientific attention beyond that of description of species and attempts at classification, which for the most part were based upon small numbers of museum specimens preserved in alcohol.

The full significance of these little fishes in the "scheme of nature" has not been recognized, although some of them for a long time have been locally of considerable commercial importance both directly and indirectly—directly as food for man and indirectly as natural food supply for fishes of greater commercial importance. In fact, in some localities the success of the cod fishery depends upon the seasonal presence of one of these forms—the capelin. While this is known to be true in connection with this particular species, it is not known how much the fishery for some other fishes of great commercial value may depend upon one or another of these little fishes.

For a time these fishes were regarded as members of the same family that included the salmon, trout, grayling, and whitefishes, but recently it has been shown that by virtue of certain distinctive structural characters they constitute a family group by themselves. While smelts are denominated as salmonoid (salmon like), structurally they are somewhat remote in relationship to the salmon or other members of the salmon family.

Wherever any species of these fishes occur they abound, or once abounded. E. A. Samuels once wrote (1904):

> Some idea of their abundance at this period [spawing time] may be had when I state that they are or were netted by the hundreds of barrels full and used by the farmers on the bay shore for manure; this was the case a number of years ago, but I believe the practice of using them in this manner has been abandoned for the more profitable one of packing them in cases and shipping them to the great markets of the country. This business has become a large, important and lucrative one; many packing stations having sprung up on the coast of Maine and the Maritime Provinces.

All or nearly all are essentially shore fishes, at least in their breeding seasons. None of them, so far as known, spawns in deep water. Some spawn in the surf along the shore, some among the seaweed in quiet water, others in brackish water, and still others, like all members of the salmon family, ascend fresh-water streams for breeding. It is during the breeding season only that some of them are caught; and in the instance previously mentioned of the dependence of the cod fishery upon one of the species, it is when the little fish are approaching the shore to spawn.

The genera comprised in the smelt family (Osmeridæ), according to Jordan's latest "Classification of Fishes" (1923), are principally the smelts (Osmerus), several species; capelin (Mallotus), 1 species; the eulachon (Thaleichthys), 1 species; and the surf smelts (Hypomesus), 2 or more species. The latter two genera are peculiar to the Pacific. The others are common (generically) to the Pacific, Arctic, and Atlantic. This paper is concerned only with the genus Osmerus, principally with the smelts of the Atlantic, and more particularly with those of the Atlantic coast of North America.

Opinions vary concerning the number of species of smelts comprised in the genus Osmerus. Whatever the number of species, they are all very closely related and not easily distinguished at a glance. Mary Fisk (1913) recognizes three species on the California coast—*Osmerus thaleichthys*, *O. attenuatus*, and *O. starksi*. The most northern of the Pacific smelts and the one most closely related to the Atlantic forms is technically known as *Osmerus dentex*. Besides these is the little known *O. albatrossis*, Jordan and Gilbert, for which Jordan (1919) made the new genus Eperlanoi. Smelts that have been identified as this species have been caught at Point Barrow, Alaska, at the mouth of the Mackenzie River, and on the northern coast of Siberia. A later classification (Hubbs, 1925) causes the genus Spirinchus (Jordan and Evermann, 1896, p. 522) to comprise *O. thaleichthys* and *O. starksi*, and he makes a new genus, Allosmerus, for *O. attenuatus*. This arrangement leaves *O. dentex* as the only species of Osmerus on the Pacific coast.

There are, or have been, ichthyologists who regard the smelt of both sides of the Atlantic as specifically identical and identical with the above-mentioned *O. dentex*. Futhermore, both in northern Europe and eastern North America there are smelts permanently resident in fresh-water lakes. As a rule, these also have been considered as specifically indistinguishable from the marine smelt. Thus Smitt (1895) does not distinguish between the smelts of certain lakes of Sweden and smelts of the Baltic, although he recognizes and shows that the Arctic-European smelt (Murman and White Seas) noticeably differs from the common smelt of Sweden.

In this country smelts from two lakes in Maine were long ago described and named as specifically different from the marine smelt and also from a fresh-water smelt from another Maine lake. Years ago Foster and Atkins (1868) suggested that there might be many distinct species in the fresh-water lakes of Maine. Aiming at a solution of this question, hundreds of smelts have been studied by the present writer, and a great many data remain to be analyzed. This is reserved for a future paper. Herein the marine and fresh-water smelts are discussed separately but in a very general way.

ATLANTIC MARINE SMELTS

RANGE

Smelt of one species or another occur on both Atlantic coasts. In Europe they range from England and France northward to the White Sea; in North America they are recorded from the Delaware River to the Gulf of St. Lawrence. Bloch (1796) wrote that the salt-water smelt lives in the depths of the North and the Baltic Seas, whence it leaves and appears upon the coasts in November, December, and January. Pennant (1776) said that it inhabits the seas of Europe, but he believed it never was found as far south as the Mediterranean. The Seine is mentioned as one of the French rivers inhabited by it, but he could not authoritatively say that it occurs south of that stream. He said that it inhabits the littoral waters of the British Isles throughout the year, never going very far from the shores except when it ascends the rivers. Reuter (1883) says that it is met with in the White Sea but not on the coast of the Arctic Ocean; at Hogland and around Kokar it is rarely met with, but it is to be found in Sweden, southern Norway, Denmark, and northern Germany, and along the coasts of the North Sea. He said it is found very seldom

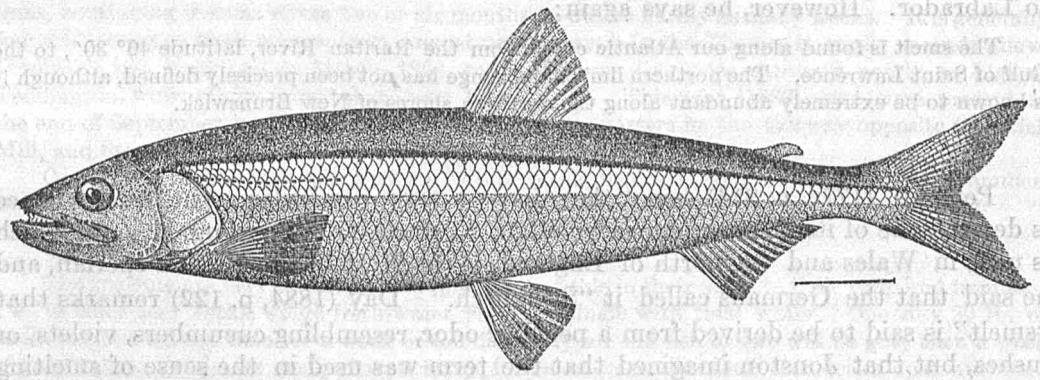

FIG. 1.—Eastern smelt, *Osmerus mordax* (Mitch.) Gill.

on the west coast of Sweden and not at all on that of Norway. Smitt (1895, p. 872) states that generally speaking the smelt is confined to a zone comprised between the fortieth and sixtieth degrees of latitude. He mentions, however, that in the Baltic it is found up to the head of the Gulf of Bothnia. He wrote:

> South of France it is unknown, and it is not common south of the northwest of that country; but from this region, including the British Isles and the Continent, up to the southeast of Norway, throughout the greater part of Sweden, in Finland, and in Russia, it occurs, and in suitable localities is common, within the basins of the North Sea and the Baltic.

Goode (1884) says that it is found in southern Sweden as far north as the Christiania Fjord district, latitude 62°, and south as far as the entrance to the Loire, latitude 47°, ascending the Seine as far as Rouen; also that it is found in the Baltic, and entering the Gulf of Finland becomes a member of the fauna of Russia.

Cunningham (1896) states that it is found in the Thames and Medway but not on the southern coast—for example Plymouth—where a fish belonging to a different family is called a smelt. He says that it is found in the Firth and the Tay, the rivers entering the Solway, the Dee, and the Mersey, but that it is not known to

occur in the rivers of Ireland. Regan (1911) gives its range as southward on the British coasts as far as Hampshire and North Wales, and says that it probably occurs also on the northern coasts of Ireland. Meek (1916) regards the Baltic as evidently a self-contained area, as no smelt are obtained in the sound, and says that like the grayling the smelt is absent from Ireland.

According to Gaimard (1851) the smelt occurs on the coasts of Iceland, but Faber (1829) does not mention it and Sæmundsson (1908) says that its occurrence in Iceland is very doubtful.

On the Atlantic coast of North America the range of the common smelt has been said to extend as far south as Virginia (Goode, 1884). Norris (1862) records it from below Fairmount Dam in the Schuylkill, and in 1868 from the Brandywine below the dam at the head of tidewater as well as at the foot of rapid water at Trenton in March, "appearing for a short time before spawning and apparently only for that purpose"; but it is not now known south of New Jersey. From there it becomes progressively more common as far north as the Gulf of St. Lawrence, but there appears to be no definite record of it from Labrador and northward, although Goode (1884, p. 543) gives the general distribution of the American form as from Virginia to Labrador. However, he says again:

> The smelt is found along our Atlantic coast from the Raritan River, latitude 40° 30′, to the Gulf of Saint Lawrence. The northern limit of its range has not been precisely defined, although it is known to be extremely abundant along the northern shores of New Brunswick.

VERNACULAR NAMES

Pennant (1776, p. 314) says "they have a very particular scent, from whence is derived one of its English names 'smelt,' i. e., smell it." Sparling, he says, which is used in Wales and the north of England, is taken from the French éperlan, and he said that the Germans called it "Stinkfisch." Day (1884, p. 122) remarks that "smelt" is said to be derived from a peculiar odor, resembling cucumbers, violets, or rushes, but that Jonston imagined that the term was used in the sense of smelting metals and was derived from the transparent appearance of the fish, as if it were going to melt away. However, according to Regan (1911), it has been wrongly said to take its name from its odor, which is commonly stated to resemble that of cucumbers and is sometimes quite strong, but there can be little doubt that the word "smelt" is from the Anglo-Saxon "smeolt," signifying smooth and shining. Regan also says that the name "sparling" is the equivalent of the German "Spierling" and the French "éperlan," the old French being "esperlan."

On our Atlantic coast the fish is known everywhere as smelt. There are other fishes, however, not at all closely related, that are known locally as smelts. Thus, a minnow in the Potomac is called smelt. Usually, however, there is some prefix or nominal attribute to distinguish such fishes from the true smelt. For instance, the common silverside (Menidia) is sometimes called "sand smelt." The name "frostfish" has been applied to it locally, and the smelt of Lake Champlain is referred to commonly as "icefish."

In Europe each country, naturally, has its peculiar names for the fish. In "Fauna Svecica," Linnæus (1746) stated that there were two varieties, the larger being known as "slom," which has no bad odor, and the smaller, of bad smell, being called

"Nors." Bloch (1796) wrote that it is called "Stint," "Seestint," and "grosser Stint" in Germany.

Goode (1884) says that the smelt is the Stint or Sparling of Germany, the smelt or sparling of England, and the spiering or spearling of Holland. Hoek (1904) lists the names used in Europe as follows: Smælt (Denmark), Norssi and knore (Finland), spiering (Holland), éperlan (France), Nors (Sweden and Norway), and korjuschka (Russia).

HABITAT

The marine smelt of the western Atlantic, and probably of Europe also, is of far greater commerical importance than the fresh-water smelt. It is essentially a shore fish that apparently varies its habitat to only a limited degree, and that variation is largely in accordance with the variation in habits of the various ages of the fish, which itself is detemined largely by the different requirements pertaining to food, food supply, and other conditions of self-preservation. Day (1884, p. 122) says of it:

> A gregarious and voracious species, remaining with us throughout the year, and passing a portion of each season in fresh, and the remainder, as a rule, in salt water, but irregular in its migrations, continuing in some rivers five or six months, in others hardly as many weeks. It is generally found in rivers or fresh waters, from August until May. In the Thames it rarely ascends above Woolwich, but Buckland in March, 1868, received three live ones captured nearly as high as Teddington, while others were taken near Kew Bridge. This year [1882] some were present at the end of September, and had selected their spawning quarters in the tideway opposite Chiswick Mill, and Strand-on-the-Green.
>
> One fully 9 inches long was captured while bleak fishing at Wooden-bridge-creek, Hammersmith. It drives the dace before it, these latter fish ascending to Richmond, Isleworth, etc.

In another place (p. 123) he wrote:

> The sparling are very uncertain and apparently fickle in their visits to their supposed haunts—i. e., in holes near rocks, where fresh-water streams mingle with tidal water. One day 20 lb. or 30 lb. may be taken; then for a week or ten days only an odd fish or two will be got; then a week of good takes. They are easily driven away, for on one occasion some men left a boat anchored in a hole to reserve the right of first draw. Whilst that boat remained there no sparling rested in the hole, but when it was removed they returned to their haunt.

Smitt (1895, p. 873) says:

> As the spawning-season approaches, it assembles in large and dense shoals; but at other times it leads a more solitary life, being frequently taken in the herring-nets used in the Baltic, but not in any great number.

This may be true of the European smelt, but it is well known that in this country smelts occur in large schools in the fall of the year during the fishing season. Young smelts appear always to be in schools. However, if opinion were based upon the number of smelts taken in the herring weirs in the sardine fishery of Maine perhaps the same conclusion would be reached as in the case of the Swedish smelt. Perhaps if they were fished for in the Baltic as in Maine, for instance, they would be taken in greater numbers.

Nordqvist (1910) states that in the Gulfs of Finland and Bothnia the smelt lives all winter in brackish water, chiefly at depths of 15 to 16 fathoms, but that near Helsingfors the large smelts occur at depths of 17 to 18 fathoms, and the smaller fish at depths of 8 to 9 fathoms.

While other factors are concerned, temperature of the water appears to influence the local distribution and movements of the smelt to some extent, as well as do the tides and character of the shores. The exact extent of these influences is not known. It is known that certain localities are frequented by smelts throughout the year, while other localities are devoid of them at all times. These facts appear to be determined by natural conditions.

In some localities the presence of smelt is a seasonal phenomenon—that is, adult smelts are apparently absent during the summer but appear in the fall and remain until spring. In this connection the following quotation from the Fishing Gazette for February 1, 1925 (p. 3) is of interest.

> The size of smelt that have been frequenting the waters of the Ipswich River for a number of days past has not only been unusally large, but the fish run quite uniform in size, and as is to be expected at this season of the year, many of the female species are filled with spawn. It is probably in this latter phase of the situation that the answer may be found as to the reason why the fish are now in the river, and such being the case, when the fish disappear they may make their exit over night. Some of the experienced fishermen at the "shore" part of the town, hold to the theory that the recent dredging of the river has provided deeper water way for the fish to follow on a journey to the upper waters of the Ipswich River.

SIZE

The American smelt is known sometimes to attain a length of 13 or 14 inches, although such sizes are not common, and smelts from 10 to 12 inches long are regarded as exceptionally large fish. The average length of smelts selected for their large size probably would not exceed 9 or 10 inches. The general average of the most common smelt may be inferred from the following: Fish obtained in the Washington market in December and said to have come from Portland, Me., averaged six to the pound, ranged from 7.5 to 8.75 inches in length, and averaged 8.1 inches. A lot from New Brunswick average eight to the pound and ranged in length from 6 to 8 inches, averaging about 7.14 inches.

Storer (1858) states that the largest individuals he had ever seen in Massachusetts were taken in Milton River in the latter part of December, 1837. Four specimens taken without regard to size weighed 1½ pounds. According to the Maine Sportsman for January, 1896 (p. 19), "Peaks Island fisherman caught a remarkably large smelt the other day in Casco Bay (Maine). The average weight of these little fish is less than two ounces, and this one weighed but half an ounce less than half a pound."

According to Atkins's notes (made in 1871), two spent smelts obtained at Verona Island, about 9 and 9.35 inches long, respectively, weighed 3.4 and 4.3 ounces.

At Eastport, Me., 18 smelts seined on a sand beach on July 31, 1893, ranged in total length from 7 to 10.5 inches. On August 23, 1893, at Harbour de Lute, Campobello Island, New Brunswick, 14 smelts seined on a gravel beach ranged from 7 to 9 inches in total length.

The following figures represent the sizes of smelts as obtained from commercial fishermen of Maine in various years. They are arranged in sequence of months, however, rather than of years. Those from Casco Bay were obtained from weir fishermen, probably after the larger or marketable sizes had been removed from the catch.

Those from Dennysville and Millbridge were just as they came from the weirs. The sexes are shown separately but many of those designated as males were immature and perhaps uncertain.

Locality	Date	Sex	Number of individuals	Range in size, inches	Approximate average
Casco Bay, Me.	Sept. 9, 1915	Male	26	4 - 5.2	4.7
		Female	6	4.5 - 5	4.8
Do	Oct. 2, 1908	Male	15	4.16- 5.5	4.8
		Female	12	5 - 6	5.37
Do	Oct. 31, 1907	Male	97	3.7 - 6.2	5
		do	59	4.75- 7.7	6
		Female	81	5 - 7.16	6.1
		do	4	5.3 - 5.8	5.4
Do	Nov., 1907	Male	50	4.5 - 6	5.12
		do	11	4.8 - 5.75	5.3
		Female	14	5 - 5.75	5.38
		do	4	5.3 - 6	5.75
Dennysville, Me.	Nov. 6, 1915	Male[1]		4.8 - 6.75	5.7
		Female	30	5.2 - 8	6
Millbridge, Me.	Dec., 1915	Male	128	3.8 - 7	5.6
		Female	38	4.6 - 6.5	5.6

[1] Immature specimens thought to be males.

Smelts bought in the market at Freeport, Me., on October 24, 1903, averaged 14 to the pound. Among them was one of 10 inches total length, not counted in the average.

For comparison with the foregoing sizes, the total lengths of breeding fish taken in a brook flowing into an arm of Casco Bay (at Freeport, Me.) are given as follows:

Date	Sex	Number of individuals	Range in size, inches	Approximate average	Date	Sex	Number of individuals	Range in size, inches	Approximate average
Apr. 20, 1903	Male	6	6 - 6.5	6.2	Apr. 9, 1925	Male	30	5.9 - 6.9	6.68
	Female	6	5.7 - 7.7	6.7		Female	10	6.2 - 9.2	8
Apr. 12, 1924	Male	101	6 - 8	7.12	Apr. 10, 1925	Male	43	5.7 - 7.1	6.5
	Female	4	7.2 - 7.8	7.5		Female	32	6.3 -10.4	8
Apr. 13, 1924	Male	249	5.75- 8.87	6.66	Apr. 16, 1925	Male	122	5.5 - 7.5	6.25
	Female	17	6.4 - 7.8	7.33		Female	55	5.9 -10.25	7.14
Apr. 28, 1924	Male	23	6.4 - 8	7	Apr. 21, 1925	Male	23	5.65- 8	6.4
	Female	14	7.38-10	7.7		Female	10	6.3 -10	7.4
Apr. 29, 1924	Male	8	6.3 - 7.33	6.9	Apr. 22, 1925	Male	74	5.85- 8.35	6.5
	Female	6	6.66- 8.75	7.25		Female	45	5.9 - 8.75	6.75
Apr. 30, 1924	Male	10	6 - 6.5	6.33	Apr. 23, 1925	Male	45	5.8 - 8.1	6.4
	Female	26	6.2 -10	8.5		Female	30	5.95- 9.2	6.9
May 5, 1924[1]	Male	80	6.3 - 7.8	6.8	Apr. 29, 1925	Male	15	6 - 8	6.7
Apr. 1, 1925	Do	13	6.2 - 8.7	7+		Female	10	6.25- 9	7.1
	Female	1	10.4		May 1, 1925	Male	16	5.9 - 6.9	6.3
Apr. 2, 1925	Male	45	6.2 - 8.15	7.18		Female	15	6 -10.15	7.4
	Female	21	5.15- 9.3	7	May 2, 1925	Male	25	5.5 - 7	6.3
						Female	35	5.5 -10	6.9

[1] Among 105 smelts taken only 1 female was found. Its total length was 7.2 inches.

FOOD

Writing of the Swedish smelt, Smitt (1895, p. 872) said:

It is a voracious fish of prey—which which may easily be seen by its teeth—and its form of body indicates no lack of agility. * * *. It feeds principally on fish, small or large—at least up to half its own size—and especially on herring fry and the young of its own species. Other kinds of food, however, such as crustaceans (shrimps and Gammaroids), worms, and larvæ, do not come amiss.

In the Gulf of Finland, according to Nordqvist (1910), adult smelts subsist largely upon mysids (*Mysis relicta, M. mixta,* and *Neomysis vulgaris*), but that they also eat little pelagic crustaceans, especially *Euytemora herundoides,* which form the principal food of young smelts. Although bottom crustaceans, such as *Pontoporeia affinis,* and other gammarids are stated to be only rarely found in the stomachs of smelts, *Idotea entemon* is mentioned as smelt food.

Day (1884) says that it appears to be particularly partial to small fish and shrimp, and cites an instance of a "sparling" having been opened as soon as it was taken out of the net which was found to contain herring fry. Cunningham (1896) says that the English smelt feeds on small fish and Crustacea. Regan (1911) regards it as a "greedy fish of prey, feeding on small fishes, shrimps, worms, etc."

At a meeting of the Academy of Natural Sciences of Philadelphia Norris (1868) presented a vial containing the stomach contents of a smelt, comprising three shrimp, one small fry of some fish, and a half dozen fish ova "not quite as large as those of our brook trout." He said that the ova had made no progress in the process of incubation, from which he inferred that they had been seized by the smelt as soon as or not long after they were deposited by the parent fish.

As indicated by our own observations, the larger individuals subsist largely upon crustaceans such as various shrimp and shrimplike forms, amphipods, etc., as well as small fishes such as young killifishes, sand eels, etc., much depending upon what the other conditions that affect their habits render available.

Numerous smelts seined at Saltworks Beach, Eastport, Me., on July 27, 1893, had their stomachs distended with crustaceans locally known as shrimp (Thysanopoda). Again, on July 31 and August 1, 91 specimens seined in the same place as the above, measuring in length from 6 to 10 inches, with one specimen 13 inches long, were found to contain mostly the previously mentioned shrimplike crustaceans (Thysanopoda) and scuds (amphipods—Gammarus). One individual had in its stomach one young stickleback (Gasterosteus) and some phosphorescent material.

In the same year (1893) smelts collected at Freeport, Me., gave the following data: On November 8 nine smelts 6 to 7.5 inches long had their stomachs distended with young killifishes (*Fundulus heteroclitus*) and a few shrimp (*Crangon vulgaris*). On November 9 seventeen specimens 5.5 to 7 inches long contained killifishes and shrimp. On November 10 seven smelts had their stomachs distended with killifishes and a few shrimp (Crangon) and scuds (Gammarus). On November 13 seven smelts contained killifishes, shrimp, and scuds. On October 24, 1903, nine female smelts taken in Casco Bay were mostly empty, but a few contained shrimp (Crangon).

Smelts taken at Dennysville, Me., on November 5, 1915, had their stomachs full of Thysanopoda. One was distended with scuds (Gammarus) and one contained a young alewife a little over 2 inches long.

The food of the very young smelt is composed of minute organisms technically called "plankton," consisting mainly of small crustaceans usually referred to as Entomostraca. In the first feeding stages the food necessarily is microscopic in size, but the fish rapidly attains a size that permits it to feed upon larger entomostracan forms.

The following notes were made by Prof. A. A. Doolittle, of the Central High School, Washington, D. C., in an unpublished report to the Bureau of Fisheries:

Four lots of smelts from 2.6 to about 4.7 inches in length were taken from the salt water of Harraseeket River, Freeport, Me., in the years 1900, 1907, and 1908. The fish taken in August, 1900, had no food in the alimentary tract. Those taken in October had two small shrimp, two fish, and large fish eggs. The collections of 1907 and 1908 were made in late October and early November, and the 12 specimens examined all had fed upon Entomostraca and 4 species of Copepoda, averaging 150 Entomostraca each. A few small shrimps (averaging two-thirds of a shrimp each) supplemented the diet.

A collection of smelts made in the "eel pond" at Woods Hole, Mass., in mid-July showed that three out of five smelts of from 4.9 to a little over 8 inches in length had food in their stomachs. They had eaten in all 46 Entomostraca, amphipods, annelids, and gastropods.

In salt water smelts feed upon Entomostraca to an extent sufficient to state that they are staple, but they are frequently supplemented by considerable miscellaneous food, such as small decapods, amphipods, gastropods, annelids, fish, and fish eggs. Only those taken after the 15th of October showed any considerable amount of food, which was then entomostracan.

Stomach contents of smelts taken from the salt water of the Harraseeket River, Freeport, Me., and the eel pond at Woods Hole, Mass.

Locality	Date	Length		Number of fish examined	Number of fish eating Entomostraca	Number of Entomostraca eaten	Miscellaneous food eaten
		Millimeters	Inches				
Harraseeket River, Freeport, Me.	Aug. 11, 1900	120	4.7	1	0	0	
	Oct. 6, 1900	122–250	4.8 –9.8	5	0	0	2 shrimp, 2 fish, fish eggs.
	Nov. 4, 1907	68–90	2.7 –3.5	6	6	1,030	
	Oct. 27, 1908	70–90	2.75–3.5	6	6	775	8 shrimp.
Woods Hole, Mass., eel pond.	July 19, 1912	133–160	5.2 –6.3	5	3	46	Crab larvæ, amphipods, gastropods, annelids.

Of 127 smelts caught in Harraseeket River, Freeport, Me., between October 2 and November 20, 1925, 34 had no food in their stomachs, but there was more or less dark-colored unidentifiable material in some of the intestines. All but the 35 specimens of November 12 were taken at night. This lot was seined in the afternoon at first of flood tide. The organisms eaten consisted of a species of isopod crustacean related to the common sow bug (*Idotea irrorata*); a species of mysis or a small shrimplike crustacean (*Mysis stenolepsis*); the common shrimp (*Crangon vulgaris*); small amphipods locally called "sea fleas" and sand hoppers (*Orchestia agilis* and Gammarus sp.); an annelid commonly called clam worm (*Nereis virens*); a mummichog commonly called minnow (*Fundulus heteroclitus*); and a silverside, in this region incorrectly called capelin (*Menidia notata*). One smelt about 7⅔ inches long contained a somewhat folded piece of eelgrass (Zostera), which when extended measured about $3\frac{3}{16}$ inches in length. Another smelt 8⅞ inches long contained 20 isopods of various sizes, besides two shrimp.

Of 127 smelts caught in the same place as shown in the preceding table, between October 6 and November 21, 1926, 21 had no food in their stomachs; but the intestines of most of them contained remains of crustaceans and unidentifiable refuse. The fish were seined at night. The species represented are the same as those of 1925,

excepting possibly some of the amphipods. The crustaceans of November 20 were mostly young.

The following table shows the foregoing in detail:

Stomach contents of smelts taken from salt water of Harraseeket River, Freeport, Me.

Date	Number of smelts examined	Length in inches	Stomach contents														
			Number of smelts containing—								Number of each organism contained—						
			Nothing	Isopods	Mysis	Shrimp	Amphipods	Worms	Minnow	Silversides	Isopods	Mysis	Shrimp	Amphipods	Worms	Minnow	Silversides
1925																	
Oct. 2-3	22	6.18- 9.0	11	6	1	4	2	1	0	0	10	1	4	3	1	0	0
Oct. 22-23	21	6.4 -10.4	2	11	5	7	0	0	2	3	32	11	11	0	0	2	3
Oct. 29-30	28	5.35- 8.5	6	3	16	12	0	0	0	1	23	16	16	0	0	0	3
Nov. 12	35	5.47- 8.7	15	9	6	4	0	0	0	2	55	4	4	0	0	0	0
Nov. 19-20	21	7.0 - 8.4	0	14	14	10	0	0	0	0	29	10	10	0	0	0	0
1926																	
Oct. 7	16	5.8 -10.0	9	7	0	4	0	0	0	0	7	0	4	0	0	0	0
Oct. 11	15	7.12- 8.5	2	16	3	10	1	0	0	0	17	3	10	1	0	0	0
Oct. 22	47	5.9 - 9.25	2	8	11	29	2	0	0	8	16	18	62	30	0	0	10
Nov. 2	21	5.9 - 8.66	8	6	1	9	0	0	0	1	33	(?)	12	0	0	0	1
Nov. 20	28	5.8 -10.4	0	9	23	20	25	0	0	0	16	120	72	234	0	0	0

BREEDING HABITS

Season.—Concerning the spawning season of the European smelt, Bloch (1796) states that it occurs in March, when they arrive in great numbers and deposit their eggs upon the bare rocks. Pennant (1776) says that they appear long before they spawn and are taken in great abundance in November, December, and January in the Thames and Dee, but in other rivers not until February, and in March and April they spawn; after which they all return to salt water and are not seen in the rivers until the next season. In a footnote he indicated that in the rivers Conway and Mersey the smelts never continue spawning more than 3 or 4 weeks. It was observed that they never entered the Mersey as long as there was any snow water in the river.

According to Yarrell (1836) the British smelt repairs to fresh or brackish water and remains there from August to May. Day (1884) stated that Lubbock observed migrations of roach and dace in the Thames, fleeing from smelts that regularly ascend the river in spring to spawn and only stop their upward course at some insurmountable barrier.

Cunningham (1896) says the smelt spawns in March, April, and May, ascending to near the limit of the rise of the tide, where the water is fresh or nearly so. In the Forth it spawns annually just below Stirling, where Cunningham said he had taken the eggs and fertilized them artificially.

Boulenger (1904) states that the smelt breeds in salt water, and although it often enters rivers it does not ascend beyond tidal influences.

Regan (1911) says that in the early spring the smelt assemble in shoals and ascend the rivers to spawn, in some localities not going farther than tidal waters for this purpose, but in others pushing up well beyond. He also states that spawning

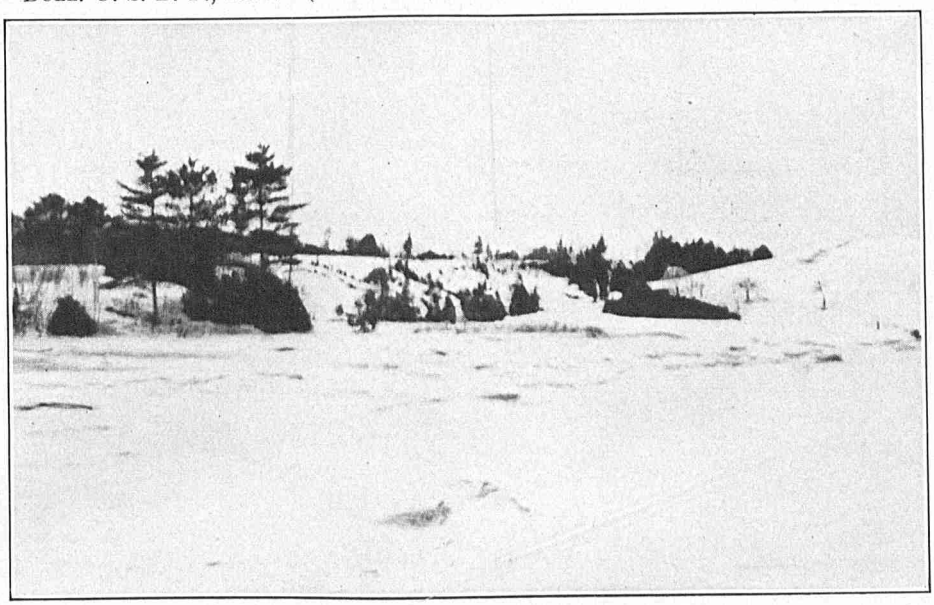

FIG. 2.—Upper portion of tidal creek (Porters Landing, Freeport, Me., smelt brook), looking upstream from near Porters Landing bridge, in early spring just before (about two weeks) breaking up of the ice

FIG. 3.—Porters Landing smelt brook (Freeport, Me.), a short distance below mean high tide limit, in spring just before (about two weeks) breaking up of the ice

FIG. 4.—Porters Landing smelt brook (Freeport, Me.) just below mean high tide limit. W. O. Kendall taking temperature on the "rips," where during the smelt run many smelts are picked up by hand

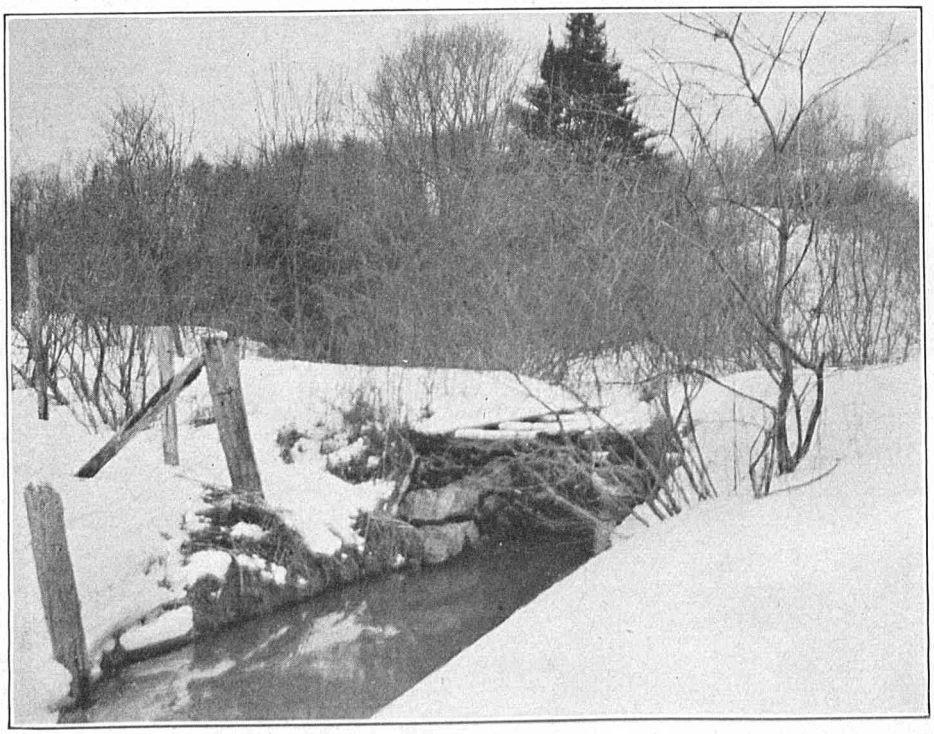

FIG. 5.—Porters Landing smelt brook just below the remains of the bridge shown in Figure 4. Extremely high tides reach this point. Taken in the early spring about 2½ weeks before breaking up of ice

usually takes place from March to May, "when the fish crowd together in dense array and the eggs are shed."

Meek (1916, p. 140) writes that the smelt migrates into estuaries in the early winter, the young shoals appearing first. The mature fish ascend the estuaries in the spring as far as fresh water to spawn. Meek cites Masterman's statement that the breeding season for the smelt in the Wash district in England is end of February to the beginning of April. The spawning time in the River Ouse (in England), according to Charles W. Harding (1882, p. 428) in a letter to Prof. Spencer F. Baird, extends from April to the beginning of June.

Smitt (1895, p. 873) says: "It is a migratory fish like the salmons, though not in so high a degree, roving at the spawning-season from salt water to fresh, or, in the lakes, from deep water to the shallows." He mentions that in the Norrstrom off Stockholm, Sweden, a female 196 millimeters long (7.7 inches) and a male 188 millimeters long (7.4 inches), both quite ready to spawn, were taken on the 4th of November, 1892; but as a rule "the smelt does not muster in Sweden for its breeding expeditions until the end of March or even later." He says that Ekström wrote: "In March or April, according to the earlier or later breaking up of the ice, the smelt ascends to rivers, straits, or shores where there is some current."

Johansen and Løfting (1919, p. 134) say that the smelt spawns in the main stream of the lower Gudenaa between Frisenvold and Langaa in March and April, and that in these months large shoals of ripe smelts coming from the Randers Fjord enter the Gudenaa, and they seem to return shortly after spawning, always choosing water of some depth with clear, sandy bottom. It generally rises toward evening and continues its journey the whole night, but at daybreak again retires for the most part to deep water. A remarkable circumstance is that whereas all other fishes prefer to spawn in fine weather the smelt is just the reverse. In squally and snowy weather it is most eager in its ascent, the violent gusts of wind and snow that occur then being known as *nors-il* (smelt squalls). Males and females swim in company during the spawning and are so densely massed that they seem merely to rub their bodies together in order to rid themselves of the roe, which is deposited on the bottom beneath. Smitt says that the young start first, but do not ascend so far up the rivers as the older fish, and often spawn in the lakes [1] on shallow shores. Ekström's account (1895) is the most complete of any known to us concerning the spawning migrations of the European smelt.

There is not much more published concerning the breeding habits of the American marine smelt. Norris (1868, p. 94), referring to the smelt that he had announced as a new species under the name of *Osmerus sergeanti* and the northern smelt, said:

> In observing the habits of both species above referred to I have found them to go to the head of tide, but no further, for the purpose of spawning. This occurs as soon as the rivers are free from ice in the Spring.

Goode (1884, p. 543) says:

> The smelt enters our rivers and brackish bays during the winter months for the purpose of spawning, and at this period is caught in immense quantities in nets and by hook and line.

[1] Both Smitt and Ekström appear not to distiguish between the marine and the fresh-water smelt.

Goode apparently had no definite information concerning the actual spawning season, for he further remarks:

> It is to be regretted that no one has made careful observations upon the beginning and close of the breeding season of this species at different points along the coast, but the spawn appears to be deposited, generally, late in the winter and early in the spring.

In general it may be said that for breeding purposes our smelt ascends freshwater streams variably from late in March until early in May, and farther north the season may extend into June. The streams ascended may be of any size, from the smallest rivulet to a great river, although in the latter it is probable that they divert themselves into smaller tributaries for spawning. This is known to be the case in a few instances at least.

Samuels (1904) says:

> Along the Massachusetts coast and thence north and east the fish enter the brooks and small streams in immense numbers. The spawning season varies with the degree of latitude, beginning almost with the breaking up of the ice in very early spring in Massachusetts, and becoming later in Maine and Nova Scotia, the fish entering the streams that empty into Margarets Bay, N. S., early in May, while in the rivers which flow into the Bay Chaleur quite late in that month, incredible numbers ascend the Jacquet and other rivers as late as May 20 or 25.

It is probable that all along the coast the first runs of smelts follow the clearing of the streams of ice and abatement of freshets—in other words, as soon as the streams become suitable—the successively late appearance of smelts being correlated with the successively later breaking up of the ice northward. The streams are not ascended until clear of ice and turbid or snow water, but the fish appear to congregate near the outlet of the streams in salt water or tidal creeks.

The local seasonal variations that affect the time of their ascent may differ in different years. Meek (1916, p. 140) said of the European smelt: "It has been observed that the migration takes place at night at the surface, the shoal retiring from the surface during the day."

In the case of the American smelt there appear to be no published observations on this fact. It is known that the smelt runs take place at night and always during ebb tide, according to the present writer's observations. Ehrenbaum (1894) says that the smelt of the Elbe presents itself in tne spring in very large numbers in the brackish and salt water to spawn in fresh water. If the British smelt spawns in salt or brackish water, it is contary to all known habits of the fish on this side of the ocean; and it would seem that the smelt of northern Europe spawns in fresh water.

Atkins stated in his notes that on May 25, 1877, he collected 53 eggs that he found attached to stones, sticks, and weeds, of which 22 were imuregnated and 12 were white. He said that most of these were attached to green seaweed, and none of them were found above high-water mark, where the water must have been pretty salt when the tide was in, yet the eggs developed. He also observed that those low down among the seaweed were twice as large as those taken near high-water mark. He stated that the eggs were in various stages of growth, from early appearance of trunk of the embryo to black eyes. Where the eggs were found were sundry marine organisms, such as amphipods, isopods, etc.

In Brunswick, Me., a brook flows into "Maquoit Bay," an estuary of Casco Bay. This brook flows over a ledge at high-water limit, making a waterfall that smelts can not surmount. Below the fall, at low water, is a long channel of virtually fresh water that the smelt ascend at the spawning time as far as the falls. It is probable that they spawn at the foot of the falls, notwithstanding the fact that on flood tide and during high water the water must be fairly salt. However, the smelts undoubtedly spawn in fresh water, and as there is a longer period of fresh and slightly brackish water than of the salt water it may be that the salt water has no deleterious effect upon the eggs. As a rule, however, as previously stated, the smelts ascend to fresh water to spawn, and it is more than probable that the eggs would not develop in salt water or even strongly brackish water if at first subjected to such conditions.

It is not impossible that smelts sometimes spawn in the tidal portions of creeks where conditions of bottom are suitable. As the smelt run up the brooks on ebb tide, the tide having left the creek with a stream of fresh water in the channel, the smelts coming in on the late ebb may deposit their spawn in that section, particularly if shoals or other obstructions, impassable by smelts, are left by the receding water. The upper tidal portions of such creeks are subjected to salt water for a brief period at high tide.

Thomas (1876) says that in the creeks of Long Island smelts were found "in perfect condition" from Febuary 20 to March 20.

In 1878 the Massachuetts law provided a closed season for smelts from the 15th of March to the 1st of June. In that year a correspondent of Forest and Stream ("Memoir" 1878), writing from Medford under date of March 23, said:

> Smelts have returned to their spawning beds at an earlier date and in larger numbers than heretofore. * * * During the unusually warm weather of the first of the month they made their appearance in large and goodly numbers.

The most definite records of smelt runs in Massachusetts appear in the later reports of the commissioners of fish and game of that State. The report for 1918 (p. 141), referring to Weir River near Hingham, says:

> By March 18 the ice was gone from the salt water, but still thick in the pond. From the 19th to 26th the air temperature rose steadily, and on March 29 (eight days later than the previous year), at 12:50 A. M., twenty minutes after high tide, the first smelt of the season came up Weir River and remained until 2:15 A. M., thus opening the season.

Concerning a run in the same river, the report for 1919 (p. 97) says:

> The salt-water smelt season of 1919 was an unusual one. With an open winter the fish came to tidewater in the rivers in January and lay there until March 1, when the run was on, earlier than is usually the case. * * *
>
> On March 6 there was a large run of fish at Weir River and Fresh River, and they were in perfect condition for spawn-taking. On March 10 the first spawn, about 35 quarts, was taken. Cold weather and low water temperature followed immediately and lasted until March 23, when eggs were again taken. Unfavorable conditions continued, and on April 14 part of the crew was sent home as the run was over, and what fish came were very few and small. * * * On April 22 there was a good run of fish * * * .
>
> The first few nights of the run, it has been noticed, are the best for taking eggs, as the fish are full, having shot none of the spawn. After ten days a great difference can be noticed in the fish. They soon begin to harden, and the quanity of spawn is less. On moonlight nights the run

is not so heavy and the fish are very wild, whereas on dark nights they lie very still and have no fear of a noise.

Temperature records of the water were kept from March 6 to April 13, both inclusive, both at noon and midnight, as follows:

Date	Noon, ° F.	Midnight, ° F.	Date	Noon, ° F.	Midnight, ° F.
Mar. 6	37	35	Mar. 25	43	42
Mar. 7	38	36	Mar. 26	46	44
Mar. 8	40	38	Mar. 27	47	44
Mar. 9	39	37	Mar. 28	43	37
Mar. 10	40	37	Mar. 29	30	(2)
Mar. 11	38	36	Mar. 30	31	(2)
Mar. 12	40	37	Apr. 4		39
Mar. 13	37	31	Apr. 5	39	39
Mar. 14	38	30	Apr. 6	38	38
Mar. 15	30	29	Apr. 7	41	44
Mar. 16	30	30	Apr. 8	48	49
Mar. 17	29	(1)	Apr. 9	48	46
Mar. 21	40	40	Apr. 10	42	44
Mar. 22	40	39	Apr. 11	48	48
Mar. 23	37		Apr. 12	50	50
Mar. 24	47	42	Apr. 13	51	50

[1] Ice on ponds and rivers. [2] Ice on falls.

The report for 1920 (p. 71) says:

Mild weather prevailed the third week of March, and on the 25th the fish made their first appearence at the falls in the Weir River, Hingham. * * * . Heavy rains began to fall and the water in the river rose to the freshet mark. The deep, swift-flowing current of water was more than the spawn-loaded fish could navigate, and they appeared content to remain far below the falls, where they deposited their spawn upon the river bottom. * * * .

As soon as the water receded to its normal flow, making it possible for the fish to reach the falls with ease, the weather broke, and cold and stormy weather prevailed. The mild weather of April was of brief duration and the water temperatures fluctuated greatly. The spawn in the fish develops only in warm water, and the sudden changes in water temperatures retarded this develop. ment to such an extent that the depositing of spawn was not completed until the middle of May, making the season one of the longest on record.

The report for 1921 (p. 75) says:

Following a generally open winter, spring came early, and the spawn-loaded fish made their first appearance at the Weir River, Hingham, on the night of March 8, nearly three weeks ahead of the normal year. Both water and weather offered the most favorable conditions possible, and by March 10 an abundance of smelt was to be found in all the streams. A very large run was observed in all the South Shore streams for two weeks, until about March 22, when the numbers began to fall off, notwithstanding favorable conditions, indicating the first run had completed spawning. The new run, from April 13 to the freshet of April 29 to May 1, was reasonably steady. To the best of our observations the 1921 run of smelt was the greatest in a number of years, being about 25 per cent greater than that of 1918, which was a record year. With the water at normal height throughout the season of 1921 there was no such destruction of spawn as occurs when, during a freshet, it is deposited on the high shoals, only to be left high and dry with the recession of the waters. The natural hatch was unusually heavy. * * * .

It appears that a temperature of at least 45° F. is necessary for the opening of the spawning season.

The report contains a chart showing the comparative run of smelt in the Weir River, Hingham, during 1918, 1920, and 1921, as well as the temperature of the water in 1921. Concerning this chart the report says that the intimate connection

between the temperature of the water and the run of smelt is shown, the fluctuations depending upon the sudden changes in the temperature and the heavy rainfall. The chart shows that in 1918 the first aspearance of smelt was on March 28, and the height of the first run from April 1 to 3, with a falling off to none at all on April 10. There were no more fish until April 15, when a small run reached its maximum on April 17 and declined again to April 20, there being no more fish until April 22. This intermission was followed by a comparatively large run on April 23, which gradually increased to the 27th, which height was maintained until May 1, and after that date declined to May 8. A few continued until May 13, followed by their disappearance May 15.

The first run of 1920 began March 24, increased in numbers until March 30, and again declined irregularly to April 6, followed by an intermission of 3 days. Then there was a large run on April 12, followed by a falling off to April 15, at which point it remained until April 17, when it again increased to a point equal to that of March 30. Then followed a decline to April 22 and an entire absence of fish until April 26. The intermission was followed by a small run, which attained its maximum on April 27 and declined again to April 29. It fluctuated to May 5, and then a large run equal to that of April 27 occurred. Finally a fluctuating decline terminated on May 15.

The comparison of runs and temperature in 1921 perhaps may be better shown by the following table:

Notes	Date	Temperature, °F.	Notes	Date	Temperature, °F.
Run began about	Mar. 8	40	Numbers maintained	Apr. 11–Apr. 12	45–50
Small increase	Mar. 10	40–50	Considerable increase to numbers equal to those of Mar. 20 and 21	Apr. 14–Apr. 15	60–50
Decline to	Mar. 12	50	Numbers maintained	Apr. 16	60
Rapid increase to	Mar. 16	53	Decline to	Apr. 18	52.5
Numbers maintained to	Mar. 18	46	Numbers maintained (heavy rainfall)	Apr. 19	52.5
Some decrease	Mar. 19	43	Increase to numbers of Apr. 15 to 17	Apr. 20	58
Small increase	Mar. 20	53	Numbers maintained	Apr. 21–Apr. 29	61–54
Increase maintained	Mar 21	51	Decreases to no fish (heavy rainfall caused a freshet)	May 1	52
Decided decrease to	Mar. 24	50	Freshet carried the fish out of the river from May 1 to May 3	May 3	54.5
Constant low run	Mar. 25–Apr. 4	44–55	Later a small run to	May 5	57
Small increase	Apr. 5	55	Decrease	May 6	60
Decrease	Apr. 6	55	Small numbers to	May 10	(?)
Number maintained	Apr. 7	50	Decrease to no fish	May 12	(?)
Some increase	Apr. 8	50			
Numbers maintained	Apr. 9	58			
Decrease to same level as from Mar. 24 to Apr. 4	Apr. 10	47.5			

The director's report for 1922 states:

As a whole the spring run in 1922 was much greater than the previous one. The smelt appeared in the falls on March 14 and the first run began the 23d, but was broken by a heavy snowstorm on the 30th just as it began to be heavy. The second run from April 10 to May 1 surpassed all records, with the day run nearly equaling the night run, and smelt were found in practically all the streams.

About the only observations made upon the breeding habits of the smelts of Casco Bay, Me., were by the present writer from time to time in previous years.

In a gully a short distance back of the writer's boyhood home is a small brook that was then called the "Smelt Brook," as it was frequented by smelts in the spawning season. The fresh-water portion of the brook is not over a mile in total length. It is fed by springs and three small spring rivulets some half mile, more or less, in

length. Except in occasional pools the brook is nowhere over 3 feet wide in ordinary height of water, until within two or three hundred yards of extreme high-tide mark. At this distance above high-tide mark there is an old stone bridge, through which the water flows over large rocks, making a cascade beyond which smelts could not pass. The brook then becomes considerably wider, with a few pools and intervening shallow ripples over gravelly and rocky bottom. Below high-tide mark the stream becomes a tidal creek, with sandy bottom in the channel or continuation of the brook, and with mud flats and marsh on either side, which are covered by salt water at high tide. This condition extends for about a quarter of a mile, when it broadens out into the head of Harraseeket River, a tidal arm of Casco Bay, at "Porters Landing," Freeport, Me. At the lower end of this brook proper there is a short extent that salt water covers only during high runs of tide. At other times the water is unaffected by the tide. The immediate banks of this portion of the stream are without bushes or trees, but above, as far as the stone bridge, it is mostly thickly overhung by alders.

Just below the lower end of the creek another much smaller and shorter tidal creek comes in on the right. Its channel is very shallow and muddy below the fresh-water brooklet that supplies the fresh water. The brook is a mere spring-fed, woodland rivulet, which in narrow portions is not over a foot wide but in places is relatively deep, especially in the marsh near high-tide mark. To distinguish it from the previously mentioned brook, the boys used to designate it as the "Little Brook." Smelt ascended Little Brook also, but according to the present writer's recollections not as early as in the large brook. Why smelts should divert themselves into this little creek and brook when their course was practically straight away up the larger stream is hard to explain.

As soon as the ice was out of the creek and the water of the brook fairly clear the smelts would appear. The time of the first appearance varied more or less, according to the season, from the latter part of March to some time in the first week of April.

There are other brooks in the region in which usually smelts did not run quite as early, being considerably larger streams and requiring a longer time to become clear of ice and turbidity.

The first smelts to appear were comparatively small, dark-hued males, their bodies rough with tubercles, which, when a fish was taken in the hand, made it feel as though covered with sand. Later the smelts would run in gradually increasing numbers, comprising both sexes, until in the latter part of the season it would hardly be exaggeration to say that the brook was full of them. It is literally true that on some mornings after a big run the pools would be black with smelts, as, looked at from above, the fish appear black or very dark.

The runs are known to extend well into May, but gradually decrease in number near the last of the season. No intermittent runs, as mentioned of the smelts in Massachusetts, were noticed, although fish would appear more abundant at certain times than at others. Of course, there might be times of heavy rains and freshets that prevented runs of smelts, or at least they could not be seen if present.

Smelts never were known to run in these brooks in the daytime, or, so far as any authentic information goes, in any other brook in this vicinity, and at no time did

they appear until after the tide had begun to ebb. The numbers would increase with the lowering of the waters. Smelt fishing at these times too frequently interrupted or annihilated the runs.

Standing by the brook on a dark night, one could very accurately judge whether smelts were numerous or scarce by the sound made by the fish as they ascended the riffles. If numerous, there was an almost continuous sound caused by the flipping of the tails of hundreds of fish as they darted up the shallow water. Anyone with a lantern could stand in the brook and watch the fish as they passed, paying no attention to the person or the light, unless now and then a brief pause in the ascent of some individual was thus attributable; but it is more than likely that any such pause was to gather momentum against the current or to determine direction amongst the stones before attempting to go on, for if one waded in the brook above them and tried to drive them downstream the fish would endeavor to pass by. Many succeeded in doing so, too, even against violent agitation of the water by the feet and alder brushes that the fishermen used in making a " drive "—that is, driving the fish into the nets set below.

There appears to be no evidence that the smelts that ascend during the night return to salt water the same night; in fact, in the one particular brook above mentioned it would have been impossible for them to have done so, as at low water some distance down the tidal creek, just below the junction of Little Brook Creek with this creek of the "Smelt Brook," the passage was obstructed by the site of a one-time gate of a tide mill. Although sometimes the smelt fishers would follow the creek down to this point, in the daytime or even at night, no smelt was ever observed there. If smelt returned to salt water after spawning they would need to wait until the next tide. Furthermore, if by good fortune smelts were undisturbed the night before, there were always many in the pools of the brook the day following the run.

For a number of years no smelts were known to ascend these brooks except on occasion, when a few would put in appearance; but in the last few years the runs appear to have increased gradually, although by no means have they become as large as they used to be. In the last three years (1924, 1925, and 1926) it was the writer's good fortune to have an opportunity to make some observations upon the smelt runs in these same streams, but unfortunately certain unavoidable interruptions broke the continuity of the observations.

In 1924 smelts began to ascend the larger brook a few days (or nights, rather) prior to April 1, and they continued until about May 15. On that date only four smelts were found in the brook, and they were males. As usual, the runs occurred at night. If, as was observed, high tide occurred before dark, as soon as it was dark smelts were seen in the lower part of the brook. As the season progressed the smelts increased in quantity, but usually impatient smelters, who would not wait long enough to permit many fish to ascend, effectually checked the run by a violent and abusive method of fishing. This method is described hereafter.

In 1925 the first smelts were found in the brook on the morning of April 1, doubtless having ascended the previous night or early in the morning, when it was high tide at about 5 o'clock. The water in the brook was still somewhat turbid and

rather high. The temperature of the water was 42° F. and the air 50° F. at noon; at 8 p. m. the water was 40° F. and the air 32°. The smelts continued to run until May 6. The last seen were only two inividuals on the morning of May 7. On May 6, at midnight, the temperature of the water was 42° and that of the air 40°. Probably very few smelts escaped capture, for almost every night the brooks were frequented by boys and men who fished in the usual abusive way.

In 1926 the season was very backward. No smelts were seen until April 17, when three or four were observed below extreme high-tide mark. The fish must have come up during the preceding night, when high tide occurred at 3.05 a. m. At 10 a. m. the temperature of the air was 40° F. and that of the brook 36° F.

The first visit to the brook was on April 11, when the stream was high and muddy and the weather very cold. Cold weather continued, with the exception of April 14 (which was mild), until the 17th, when three or four smelts were seen. On that date it is possible that other smelts than those seen were present, but the water was turbid.

On the 18th the brook was still turbid but had subsided considerably. One male smelt, nearly 7 inches long, but not quite ripe, was caught. No other fish were seen. At 9 a. m. the temperature of the air was 34° F. and the water 36° F.

On the night of the 20th 10 smelts were caught and a few others were seen. At 10 p. m. the temperature of the air was 32° and that of the brook 34°. High tide occurred at 5 to 5.20 a. m. The smelts were all taken below high-tide mark.

From that date the smelts gradually increased in number, with some fluctuations, until April 30, when they began to fall off. The last (about a dozen) were taken on May 16. This season the fish were not nearly as numerous as they were the preceding year, and there were so many fishermen it is probable that the fish were nearly all caught.

The following notes represent some of the observations made in previous years in the aforementioned brook in Freeport, Me., and in another tributary of Casco Bay at Brunswick, Me.:

Freeport, Me., April 18, 1903.—The ice went out during a warm spell in the last of March. Smelts were caught for some time prior to this date. On the night of the 18th a few hundred were caught. It was high tide at Portland at 4 p. m. The smelts did not appear in the brook until after dark, but were running on ebb tide for some time after the tidal water had left the brook. About 9.30 p. m. one young man had taken about 200 smelts and ceased fishing. He estimated that about 400 in all had been taken.

Freeport, Me., April 18, 1903.—A good many smelts were caught by six boys and young men. Most of the fish were taken below high-tide mark, even several hundred yards below; probably between one-half and one bushel of smelts were caught. Notwithstanding the intensive fishing evidently some escaped, for a number were seen some distance up the brook. Fishing had been begun too early to permit of a good "run." The fish were easily caught by hand. So intent were they on ascending the brook that it was with difficulty that they could be driven down into the nets set in the brook. Milt did not run freely from the males, but eggs were easily expressed from the females.

Freeport, Me., April 23, 1903.—Considerably many smelts were taken in the previous two nights. One boy got 11 dozen on the night of the 22d. Only two boys were on the brook this night, and they got four dozen smelts each.

Freeport, Me., April 24, 1903.—Some smelts were taken this night.

Freeport, Me., April 27, 1903.—The previous night the boys got a few smelts by "dipping" above the high tide. There were a few along the brook in the morning. Small schools were observed here and there along the stream for about 300 yards, or nearly as far as it was possible for them to ascend. Two spent males were caught.

Freeport, Me., April 30, 1903.—No smelts were seen in either the fresh-water or tidal sections of the brook. However, for two days previous the water had been roily, although the bottom could be seen in most places. At 2 p. m. the temperature of the air was 59° F. and of the water 51° F. At 10 p. m. the temperature of the air, as indicated by the thermometer, was 44° F., but the stiffening of the nets when removed from the water suggested a lower temperature. The temperature of the water was 46° F.

Brunswick, Me., April 26, 1903.—During the day smelts were observed in a small brook flowing into Casco Bay. When disturbed the tendency of the fish was to conceal themselves. They rushed *en masse* to one or the other end of the pool, and if sufficently frightened would run farther upstream, but seldom downstream. If they did run down at any time it was only a short distance; then they would run up again. Occasionally one or more sought concealment under the bank. Most of these smelts were in pools below high-tide limit, but some were found here and there for a mile or more up in the fresh-water section of the stream. Two fish were caught, one a spent male 5¾ inches long and the other a spent female 10 inches long.

A man familiar with this brook and well informed concerning smelts said that some smelts remain in the brooks very late in the season, even to the last of May or first of June, and that they "waste away to water" and become sick and are attacked by "worms" especially under their gills or throat. He said that he had picked them up in dying condition and almost dead, not from injury but apparently from inanition, which suggested to him a general mortality among smelts after spawning. The temperature of the brook at 12.30 p. m. was 51° F.; that of the air was 59° F.

Some little plausibility is lent to the idea that there is considerable mortality amongst breeding smelts by the statement of Smitt (1895, p. 873), who says that after the spawning the shore and the bottom are strewn with numbers of dead smelts that have struggled in vain to disburden themselves of the roe. Furthermore, it is a well-known fact that many dead and dying fresh-water smelts often are observed during the spawning season. This phenomenon is discussed in connection with the part of this paper concerned with fresh-water smelts.

Brunswick, Me., May 7, 1903.—On this day no smelts were seen until about one-half mile up the brook, where eight were caught. In a pool not far from the salt-water limit four specimens were taken out of a school of about a dozen. A man met on the brook, who was trout fishing, said that farther up were quite a number of smelts. The smelts caught were all spent males, from which only a very little milt could be expressed. At 5 p. m. the temperature of the air in the shade was 50° F.; temperature of the water, 52° F.

Freeport, Me., April 6, 1904.—Smelts first appeared in this season in the particular brook previously discussed, but none had been found in other brooks, as they were not yet free of ice. On the night of April 8 some were caught in other brooks, and smelts were still running on April 17.

The breeding season in a given locality of average abundance may last from four to six weeks for the species (not individuals), yet individuals may remain in the stream for a long time after they have spawned. (As far as observed all individuals that seemed so reluctant to leave proved to be spent males.)

The statement has been made, and it is a prevalent belief, that smelts run up a stream, spawn, and return to salt water on the same night. Apparently this is the case when the run on ebb tide takes place early in the evening and the subsequent high tide occurs early in the morning before daylight. However, the aggregation composing one night's run, if undisturbed, may remain in the stream for several days. Especially is this so in case of the later season.

Concerning the Scandinavian smelt, Smitt (1895, p. 873) says:

> Each shoal completes its spawning operations in a few days; but one shoal follows in the wake of another, and thus the spawning continues as a rule from the latter part of March to the first weeks of May.

The only information concerning breeding smelts east of Casco Bay available to the present writer is contained in the previously mentioned notes of Charles G. Atkins. In his notes of 1878 he definitely mentions the following streams, flowing into Penobscot Bay, as frequented by smelts in the breeding season: A brook entering Surry Harbor from the west; Browns Brook, in the vicinity of Surry; Lawrence Brook and another above it, about 2 miles upriver from Bucksport; Sweetsers Brook near Bucksport; and three brooks on Verona Island.

In 1878 he says that on April 21 what were supposed to be smelt eggs were seen on the rocks below the dam at Orland. Some smelts were being taken there then, but on May 1 none was to be found. John Whitmore, of Verona Island, a weir fisherman, knew of two brooks on the island in which smelts abounded about "high tide" of May; and George Small thought that smelts abounded in a brook near his weir in June. On May 1 Atkins got two smelts from the island, but they were completely spent. On May 20, according to a Mr. Tower, smelts were running in Lawrence Brook. On May 23 only three smelts were caught in Sweetsers Brook. On May 25 Atkins received some freshly caught smelts from the same brook. On May 28 no smelts were found in this brook, and very little spawn, whereas on the 25th of May, 1877, one got a bushel. Up to May 27 hardly any smelts had been seen in the brook at the head of Surry Harbor or in Browns Brook.

Writing of the smelt of New Brunswick, A. Leith Adams (1873, p. 244) said:

> As soon as the ice breaks up and drifts seaward, sculls upon sculls of this savoury fish push their ways up the rivers, where they bite bait readily, and are captured by nets.

Farther north our available data are still meager. On May 26, 1895, the present writer observed smelts ascending creeks at Owls Head Bay, Nova Scotia.

Concerning smelts in the St. Lawrence region, Chambers (1903a) wrote that there had been very little observation of the habits of the smelt in the St. Lawrence.

FIG. 6.—Porters Landing brook at the old bridge shown in Figure 10. The ice is all gone and snow melted except in sheltered places. Taken in April, 1924. The brook is now muddy and no smelts have yet been seen

FIG. 7.—Porters Landing smelt brook (Freeport, Me.) just above mean high tide limit. Extremely high tides reach the bridge. Typical of the smaller smelt brooks

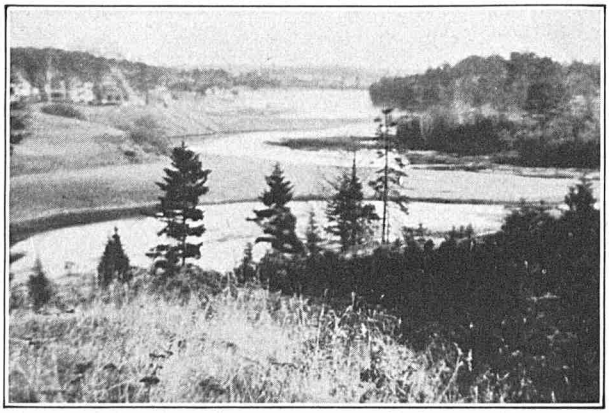

FIG. 8.—Section of tidal creek at Porters Landing, Freeport, Me., May, 1924

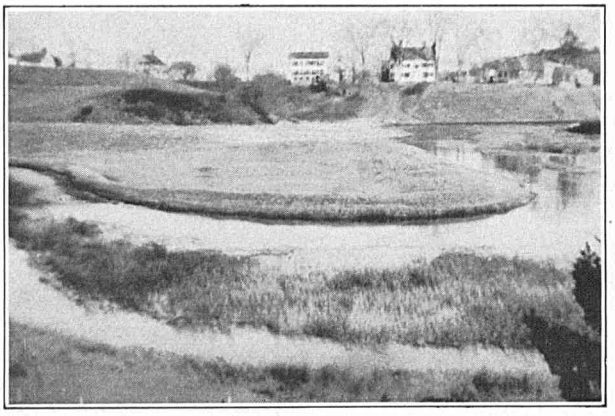

FIG. 9.—"Close up" of tidal creek at Porters Landing. Another view of the low point shown on the other side of the creek opposite the trees in Figure 12. May, 1924

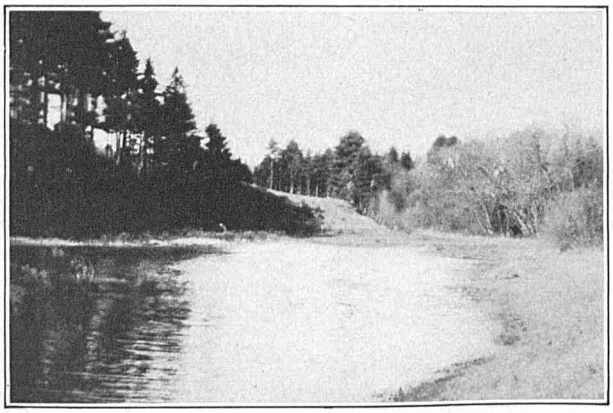

FIG. 10.—Upper section of Porters Landing smelt brook (Freeport, Me.) at extreme high tide. Section of the brook is the same as shown in Figures 10, 11, and 12. The tide at this time reached nearly to the old bridge. May, 1924

He said that it was presumed that they spawn there in the spring, as they do elsewhere, but he considered it as rather remarkable that they ran up the river both at the commencement and at the end of winter, and that many of them were found to contain spawn in the autumn as well as in the spring.

Concerning the same condition, Cheney (1894a, p. 162) wrote that he had a query from a correspondent in Canada who said:

> "We catch smelts here in the St. Lawrence twice a year, in April or May, and again in October or November. At both seasons they are full of spawn. How is this to be accounted for? Do they spawn twice a year, or are they not the same individuals that run up spring and fall?"

Concerning this point it may be said that in the fall the ovaries and eggs have begun to develop and the little eggs are plainly visible, being clear yellow in color, but they do not completely fill the fish then as they do in the spring near the breeding season. The bright yellow color of the eggs makes them so conspicuous, however, that those who have observed them often have been misled and regarded them as fully developed.

Smitt (1895) says of the Swedish smelt that the greater part of the breeding shoal is composed of females. This is contrary to the present writer's observations. It has long been observed that the initial runs consist almost wholly of males, and that as the season progresses the proportion of females increases until they are approximately in equal numbers. In 1924 such regularity in increase of females was not observed, although they did increase in number. Males greatly predominated at first, and of 113 fish caught on April 12 only 4 were females. Perhaps if observations could have been continuous and unhindered by fishing operations they would have shown a different tendency.

On April 13, of 266 smelts taken, 17 were females. Of 37 smelts taken on April 28, 23 were males and 14 females. On April 29 so many persons were fishing that the writer secured only 14 smelts; 8 of these were males and 6 were females. On April 30 again observations were hindered by fishermen and only 33 smelts were secured, of which 10 were males and 23 females. On May 6, 105 smelts included but 1 female; and finally on May 15 there were only 5 smelts to be seen in the brook, the 3 caught being males.

The interruption in the runs of smelts was not caused wholly by fishing, but also may be attributed to heavy rains and freshets. In fact, the latter may have been the principal cause. So far as the principal brook under observation is concerned, the smelts appear to have ceased to run by May 15, as subsequently none was seen there. The night of the 16th was beautiful and there was a high run of tide, high water occurring at 9.42 p. m. The brook was explored but no smelts were found.

In the spring of 1925, in the same brook, the proportion of females to the total number caught on consecutive dates from April 1 to May 2 was as follows: On April 1 only 14 fish were taken. Of these only one was a female. On April 2, 66 fish were caught, of which 22 were females. On the 8th only 11 fish were caught, 7 of which were females. On the 9th 45 fish comprised 11 females. The 10th yielded 75 fish, of which 32 were females. On the 16th 177 fish comprised 55 females, and

on the 21st 10 of 33 fish were females. On the 22nd 119 fish comprised 45 females; on the 23rd 75 fish, with 30 females, were caught, which proportion is very close to that of April 10. On the 29th, of 29 fish 13 were females. On May 1 of 31 fish 15 were females, and the last catch of the season, on May 2, consisting of 60 fish, contained 35 females. For the whole season 735 fish comprised 276 females and 459 males.

In 1926 the spawning run of smelts in this brook was considerably smaller than in the preceding year. The season was backward and the run did not begin as early as in 1925. The first catch, on April 20, consisted of only 10 fish, and these were apparently nearly all that there were in the brook. Of these 5 were females. The proportions for subsequent dates up to May 10 were as follows:

April 21, 18 fish, comprising only 4 females; April 23, 25 fish, comprising only 3 females. Thirty-seven fish taken on April 27 comprised 14 females, and 29 fish taken on April 29 comprised 16 females. This is a curious coincidence, in that the same number of smelts were taken on the same date in 1925. On May 6, of 103 fish 61 were females; on the 9th, of 14 fish 6 were females; and on the 10th, of 18 fish 7 were females.

Of the total catch of 259 smelts, 116 were females and 143 were males.

The choice places of spawning, when possible, are gravelly ripples, which may contain aquatic moss, water cress, or other plants, or sticks, leaves, and other adventitious material. The fish sometimes spawn in pools or along the stream margin, but always normally where there is some current. Bloch (1796), writing of the European smelt, said that they deposit their eggs upon the bare rocks.

Regan (1911) says that the fish crowd together in dense array and the eggs, when shed, attach themselves wherever they happen to fall. Regan repeats the much quoted reference to the spawning of the smelts in the Forth, saying that when "the smelts spawn in March, about two miles above Stirling Bridge, every stone, plank, and post has been described as covered with their yellow eggs." This reference is to the statement of Richard Parnell in 1839, who said the smelts ascend the Forth in numerous bands in the month of March for spawning. It occurs, then, in great quantities 2 miles below Stirling Bridge (not above, as stated by Regan) and soon each pier is covered with their eggs, which have a "yellowish color."

From the foregoing it would appear that the English smelt spawns in streams large enough to be called rivers. If this is so of the smelt in this country, it has not been discovered, although the general impression is that it sometimes does. Beyond doubt it does ascend rivers; but it seems probable, judging from analogy, that the smelt diverts itself from the rivers into tributary brooks; at least most references pertain to moderate streams, such as are called brooks. Samuels (1904) says they appear to have favorite localities for spawning and visit the same brooks and streams year after year.

A run may be observed in a small brook about high tide, or soon thereafter a few smelts may be seen straggling upstream and ere long they come faster and thicker. When a light is cast upon them they may pause or even settle back a little, but they soon shoot ahead. So intent are they in ascending the stream that

it is with difficulty that they can be driven downstream, even when violent beating and thrashing[2] of the brook with alder tops or wading in the stream are resorted to. If the fish are particularly numerous those near the net (set crosswise in the brook) may be driven in, but the net must be lifted quickly or many of the smelt will run out. The fish do not rush upstream but move with moderate speed until they come to a place where the water is swift, when they shoot ahead; and if the water of such places is shallow, the flipping of the tails of the fish indicates how numerous they may be.

Writing of the Swedish smelt, Smitt (1895, p. 872) says:

> "The smelt is of a stupid and sluggish temperament," wrote Ekström, and this opinion has afterwards been reiterated by other writers—"silly as a smelt" is a common Swedish saying. But why it is thus stigmatized more than other fishes, we cannot say. Gathered in shoals during the spawning, when it is ruled by sexual instincts alone, it is easy to catch like many other fishes; and this is probably the origin of its reputed stupidity.

On the day following a run of smelts the eggs may be seen attached to grass, stones, leaves, sticks, twigs, or anything in the water with which they come in contact. A great many of the eggs are observed to be white. In fact, it is the white eggs that usually attract attention, as the natural amber-hued eggs are difficult to see in the water. Sometimes the eggs are deposited in tidal water—that is to say, where the fresh water has been backed up—so that after ebb tide there are may eggs left high and dry. Usually, too, during the first of the season the brooks are much higher than later, so that after subsidence eggs are left dry. Thousands of eggs are destroyed in this way. Atkins was inclined to believe that the unfertilized eggs that he found on May 28 in Lawrence Brook were attributable to the pursuit of the fish with dip nets, which he felt sure must break up spawning operations. This quite probably was the cause of some of the white or unfertilized eggs observed by the present writer.

The report of the commissioners of fisheries and game of Massachusetts for 1917, referring to the great waste of naturally deposited smelt spawn, said (p. 76):

> At Weir River, Hingham, in 1917, the smelts were depositing spawn on the river bottom at the rate of a quarter of an inch each night when there was a good run. Eggs would be found in layers from 1 to 2 inches in depth, and in eddies, even from 4 to 6 inches. Under such circumstances the top layer only is exposed to the running water and properly fertilized, the remainder being wasted.

In his annual report for 1922, the director of the division of fisheries and game of Massachusetts (1922, p. 21), referring to the interrupted runs of smelts in Weir River, stated that the deposit of spawn by the first run was very good, and as it was not overabundant the eggs had a better chance to hatch. The water was not excessively high, so there was no great waste of spawn on the ground above normal water mark, and probably all had hatched before the second run began. The deposit from the second run was so heavy, in many places 3 or 4 inches deep, that doubtless nearly all went to waste.

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[2] There is no word that adequately describes the process of d riving with these alders. A word in common local use among the smelt fishermen is "raunching." If one has witnessed the procedure one will appreciate the aptness of the word "raunch," which appears to have been adopted on account of the sound made by the quickly successive, violent thrusts of the alder into the water, rather than on account of the original meaning of the word.

ENEMIES

Very little has been published concerning the so-called enemies of the salt-water smelt, although doubtless it has many. Bloch (1796) mentioned at some length a parasite infesting almost all of the fish he had examined. He said that ordinarily they were on the upper part of the back; sometimes in the muscles, where they were occasionally completely buried. One was on the head near the eye. It was only necessary to hold the fish to the light to perceive the parasite, as the smelt was transparent and the parasite opaque; and he stated that the "worm" would live on dead fish for many days, as he had observed it on those sent from Hamburg.

Day (1884, p. 124) says that the picked dogfish (*Acanthias vulgaris*) destroy large numbers of them. Smitt (1895, p. 874) said "Man is not the only enemy which the smelt has to fear; it often falls victim to predatory fishes and waterfowl."

Under date of April 17, 1878, in his notes, Atkins indicated that on good authority a salmon brought from St. John in July had been opened and found to contain six smelts, and that Commissioner Stilwell said that at Bickford's (a fish dealer in Bangor), the preceding summer, a salmon was found to have smelt in it.

Venning (1902, p. 493) wrote that in his boyhood the trout from the rivers (New Brunswick) came down in the spring in large numbers to meet the smelts coming in to spawn.

Chambers (1902) stated that the arrival of the autumnal run of smelts in the St. Lawrence River, in the vicinity of Quebec early in December, 1902, was quickly followed by that of a number of porpoises that remained for some days disporting themselves in front of the city. He said that these unusual visitors apparently were in pursuit of the toothsome little smelt, and the latter apparently were aware of the fact, for during the time that their monster enemies remained in the neighborhood the smelt were conspicuous by their absence, and the smelt fisher fished in vain. After the porpoises left the smelt resumed biting.

On April 26, 1903, in a brook flowing into Casco Bay, Brunswick, Me., the present writer caught 11 brook trout from 5.75 to 7 inches long, averaging nearly 6.4 inches, all of which, among such things as caddis-fly larva cases and sand, contained many smelt eggs. The sand probably was ingested with the smelt eggs.

On May 13, 1903, 13 specimens of sticklebacks (*Gasterosteus aculeatus*), all females, ranging from 2.36 to 3 inches in length, were caught in the tidal portion of a creek flowing into Casco Bay at Freeport, Me. One individual 2.67 inches long had its stomach distended with recently hatched smelt fry.

Twelve specimens of another species (*Gasterosteus bispinosus*), ranging from 1.6 to 1.87 inches in length, were taken. All were distended with smelt fry with the exception of one, which contained only a few fry and a lot of some unidentified material.

One of six specimens of the four-spined stickleback (*Apeltes quadracus*), 1.8 to 2 inches long, was also found to be distended with smelt fry. The others contained other material or were empty. All but one of the eight specimens of the nine-spined stickleback (*Pungitius pungitius*), 2.16 to 2.63 inches long, contained more or less smelt fry.

SMELT FISHERY

EUROPE

According to Bloch (1796), at spawning time the smelts were taken in large quantities, especially in Prussia, where they were air-dried, placed in casks, and shipped to Pologna. Great quantities were found in the Elbe, also. He stated that as the fisheries of Hamburg could not sell all they caught, they salted and dried them and shipped them to neighboring Provinces. Quoting Pennant, he said that in London they were eaten at breakfast with a glass of wine.

Day (1884, p. 123) stated that in Norfolk, England, the fishery for smelts commences in March and continues until the middle of April, during which period the fish are full of roe. He credited Lubbock with the following description of one of the methods employed.

> Hour after hour does the smelter persevere, moored exactly in the same spot with a torch attached to the side of his broad flat-bottomed boat (for this is a nocturnal occupation) in flinging his immense casting net, dropping the near side of it at each throw, within three inches of the torch. One fortunate cast, if smelts sell well, may recompense him for hours of fatigue, wet, and cold: and he waits like the losing gambler for the lucky throw which is to brighten his fortune. The smelts captured are kept alive in a tank.

Day went on to say that they were also taken in the estuary of the Ouse and in Breydon by means of the stake nets. He wrote that smelts could be caught with a "paternoster" line and No. 8 or 9 hooks, with or without floats, using bait of shrimps (either fresh or boiled), gentles, redworm, or pieces of fish. Early mornings and late evenings were considered the best times for this fishing, and bread crumbs were recommended as ground bait. Day said that in the Solway Firth the best fishing season in September, but that the fish disappear the next month until March and April, when they ascend to spawn.

According to Nordqvist (1910), near Helsingfors smelts are caught as long as the sea is frozen—from December or January to April. In the northern sections of the Gulf of Bothnia, where many large rivers enter, many smelts are caught in winter with drag nets.

The well-know smelt fishery in the Norrstrom off Stockholm, according to Smitt (1895, p. 874) is carried on with large hoop nets, such as are in general use at many places among the island belt of Stockholm to secure all kind of small fishes for bait. These hoop nets, usually 3 to 3.5 meters in diameter, are let down and hoisted up from a boat with the aid of a long pole erected obliquely upwards in the stern, and a hand net is employed to scoop the fish out of the large net. The smelt is also caught on the hook with a bait of shrimps, sand hoppers (gammaroids), worms, or bits of fish, but this method is successful only when used for the large smelts—the *slom* or *norskung*, as they are called in some parts of Sweden when they occur as solitary specimens among the smaller smelts.

Quoting Ekström, Smitt says that it is during the spawning season that the smelt is taken in any quantity, the fishery being commonly conducted in the following manner: Across the straits or the rivers to which the smelt ascends in order to

spawn fences are built of green spruce branches arranged so as to leave gaps at the deepest parts of the channel. At these gaps the fisherman stations himself with a scoop net large enough to fill the opening and having meshes so fine that the smelts can not slip through. This net, which is distended on staves, he lets down into the opening and takes up after a longer or shorter interval, according to the numbers of fish that come up, the take being turned out of the net into a "catte" held in readiness.

When the smelt spawns on shores or off headlands, it is taken in dragnets, which differ from the ordinary seine only in the comparative fineness of the meshes. This fishery is pursued only at night, bonfires not infrequently being lighted on shore by the fishermen in the belief that the fish, enticed by the glare, come nearer land.

ATLANTIC COAST OF NORTH AMERICA

In former years of abundance the smelt generally was regarded as of minor importance as a food fish, and except in a few localities no use was made of it except as fertilizer, a limited amount only being used for home consumption. However, the aborigines evidently used them as food, for Capt. John Smith, in 1622, records that "of Smelts there is such abundance, that the Salvages doe take them up the rivers with baskets, like sives." In more recent times the fishery gradually assumed importance. Forty years ago Goode (1884, p. 543) wrote: "The smelt fishery is increasing yearly in importance, owing to the greater facilities for the transportation of fish in ice." Nine years before this Scott (1875, p. 340) wrote: "Trade in smelts is confined to six months, or to the inclement season of the year, for which time the sales in Fulton Market averaged 1,352,000 [pounds ?] at 16 cents—$216,320.00."

In former years it appears that the smelt fisheries of New Jersey and Long Island were of the greatest importance, few if any smelt being caught south of those localities. However, over 60 years ago Norris (1862, p. 59) called attention to smelts in the Delaware River. He said:

> I have been told that these fish can be taken occasionally in February along the wharves and in the docks of the Delaware with a cast net. They are taken with case and scoop nets at Fairmount dam. They are common and abundant at New Brunswick, New Jersey, on the Raritan, and it is said also in the Passaic, though during some winters they even there are comparatively scarce.

John A. Thomas, of Reading, Pa., under date of March 7, 1876, contributed a short article to Forest and Stream concerning New Jersey and Long Island smelts, from which the following is an extract:

> In the creeks of Long Island, they are found in perfect condition from February 20th to March 20th. In the Jersey river, for a long period in the early spring and fall, they are not taken with the hook, I believe, but [are dipped] up in quite large quantities by those who know their value. I remember once buying in Jersey nearly one half bushel for seventy-five cents, which was more than the boys asked for them, fresh, not an hour from the water. These fishes might be cultivated wherever they can reach the salt water. It is supposed that they love to keep near the shores on sandy bottoms. I have seen them at least twelve inches long, playing in the bays of New England and in the harbor of New York, about Communipaw.

As this fishery, like other fisheries, depends upon an adequate supply of fish, those more southern localities once noted for abundance of smelts, such as the Raritan

and Passaic Rivers in New Jersey, Long Island, and southern New England, are no longer any considerable factor in smelt production.

In statistics of the Bureau of Fisheries for 1888 no smelts were recorded for New Jersey or New York, and in the United States Census Report for 1908 a catch of 7,500 pounds, valued at $1,500 taken by seines, was credited to New Jersey. The record for Connecticut showed increases from 9,600 pounds, valued at $770, in 1888, to 10,000 pounds, valued at $7,200, in 1908. In Rhode Island, for the same period, there was a falling off from 61,500 pounds, valued at $3,135, to 1,200 pounds, valued at $100.

At the present time probably the largest proportion of Atlantic smelts appearing in the markets of this country come from New Brunswick, although at times some have been received from Nova Scotia, Prince Edward Island, and Newfoundland. Thus it is seen that the commercial smelt fishery has receded gradually northward. However, it is locally of considerable importance in Maine. Probably one of the most potent factors operative in the depletion of smelt waters has been net fishing during the spawning season of this fish. This sort of fishing had such marked effect upon the smelt supply of Massachusetts that long ago legislation tended toward the reduction of net fishing and the encouragement of the hook-and-line method.

Massachusetts.—As early as 1868 or 1869 taking smelts by any other method than by hook and line was prohibited excepting in a few specified instances, when they were permitted to be taken by seines when fishing for "perch," etc. With little modification the law still stands. Prior to the passage of the act referred to, smelts were caught chiefly by seines and dip nets near and in the streams to which the smelts resorted for spawning. The report of the commissioners of fisheries of Massachusetts for 1869 (p. 15) states that the seine used might be 360 feet long and 20 feet deep, with a 1½-inch mesh. The report cited one haul of such a seine in which 6,700 pounds of smelts were taken, and said "as twelve usually go to a pound in the 'school' fish, this would make 80,400." The report further stated that smelts were taken in great quantities with dip nets on the spawning beds. A table was given, which showed the number of dozens of smelts taken by two dip nets during 13 seasons at the backwater dam at Milton on the Neponset River, as follows:

1855	300	1862	417
1856	100	1863 (3 nets)	2,275
1857	21	1864	850
1858	1,113	1865	1,715
1859	507	1866	714
1860	927	1867	1,154
1861	725		

The foregoing figures represent approximately as many or perhaps twice as many pounds, according to size of fish. The report for 1870 (p. 23) notes an increased catch of smelts by hook and line in the autumn of 1869 in Back Bay, "quite out to Brookline. The mill-dam was lined with patient anglers; and distinguished merchants, of lower Beacon Street, might be seen, at early hours, eagerly catching their breakfast from their back doors."

The report for 1871 (p. 11) remarks:

The present season has proved even better than the last, and the hook-and-line men everywhere report a good catch, and often an increase of large specimens.

The report for 1874 (p. 18) indicates that a law was passed prohibiting the catching of smelts by any other method than by hook and line in all State waters except Taunton Great River, Dukes County, Yarmouth, Dennis, Bass River or its tributaries, North, and Westport Rivers. The statement continued:

Twenty-five years ago the lower waters of the Mystic River were, in winter, crowded with little tents for the protection of persons engaged in fishing. Many, out of employment at that season, made two to three dollars per day catching smelts, with hook and line, for the market, at six or seven cents per pound. The seining in the river and netting them on their spawning beds soon destroyed all fishing with hook and line, and, in a few years more, seines and nets were abandoned because they did not pay. So completely was the the river depleted that the fish committee of the town of Winchester spent several nights in catching fifty-two smelts for the purpose of stocking the river above Mystic dam. For the past five years these fish have been carefully protected in this river and its tributaries; so rapidly have they increased that in the spring the small streams are alive with them crowding up to spawn, and last winter the little tents began to appear on the river below, many persons catching from twelve to fourteen dozen, each, a day.

The report went on to say that seven-eighths of the constant and steady supply of smelts for the Boston market came from Green Bay, near Portsmouth, and were caught with hook and line, the fishermen making from three to five dollars per day.

The report for 1875 said that smelts had been very plentiful that fall, as high as 80 dozen having been taken with a single rod in one day. According to Forest and Stream, this year smelts were abundant and retailed at from 25 to 30 cents per pound.

Ordway (1875), writing from Boston on December 12, 1874, to the commissioners of inland fisheries of Massachusetts, said:

In reply to your inquiries as regards the practical working of the smelt-law, passed by our last legislature, and the effect of the close time, allow me to say that it has exceeded the most sanguine expectations of the friends of this beautiful fish. Smelt of enormous size have been caught, whilst thousands of small smelt have shown the beneficial result of allowing the females to throw their spawn last spring, instead of being stolen by a few seines. Besides this, hundreds and tens of hundreds of poor mechanics have had a chance to catch a good mess for their families after their day's work was over. In addition to this, the dealers have reaped a good harvest, from the fact that they have had a better class of smelts, and received better prices. But perhaps I cannot do better than to give you a few extracts from letters sent me by gentlemen who take an interest in smelts. These are but a few of the many which have been sent, all expressing similar views. A gentleman, writing from Salem, says, "You have done a great and good work in increasing the smelts in this vicinity. It seems like old times to see the boys with their baskets well filled." Dr. E. J. Thompson, writing from Lynn, says, "It would do your soul good to come to Lynn and visit the wharves at the present time [October 12], and see the smelt-fishers at it, —old and young, rich and poor, split-bamboo and beanpoles, all together, and such smelt-fishing as they have not seen for years. Every one thought that smelt-fishing was played out; but now some of the best fishermen have caught as high as twenty and thirty dozen in one day."

Benj. P. Ware, Esq., writing from Marblehead, after speaking of the wholesale and wasteful methods of slaughtering fish with seines and trawls, especially in the spawing season, says: "Smelts, which were becoming quite scarce, have this fall been very abundant. In Swampscott, where smelts in previous years have been almost unknown, they have been taken in great numbers, many of them weighing half a pound each. This change is doubtless due to the close time and legislative Acts passed in relation to the catching of smelts."

In this connection, I would say that many persons have, to my knowledge, made from ten to twenty dollars a day catching, legally, with hook and line, so plenty have smelt become; and I have no doubt that this winter, as the result of the law, hundreds of persons who perhaps could not get work, will be enabled to make excellent wages by catching through the ice. I have no hesitation in saying that the law has worked splendidly, and that another close time, next spring will produce excellent results; viz., still larger smelts and in greater numbers.

Forest and Stream (1874, p. 188) attributed the marked increase of smelts to a law passed by the Massachusetts Legislature in the preceding winter, making it unlawful to seine or net smelts at any season; and four years later the same journal contained an article by some one signing himself "Memoir," dated at Medford, March 23, 1878, which said:

Smelts have returned to their spawning beds at an earlier date and in larger numbers than heretofore. The law provides for their safety (or rather the watchman's pocket) from the 15th of March to the 1st of June, but during the unusually warm weather of the first of the month they made their appearance in large and goodly numbers, which necessitated the employment of a watchman to protect hasty *eperlanus* from the frying pan of the immediate neighborhood.

No further reference was made to smelts in any of the reports of the Massachusetts fish commissioners until 1880, when the following catch for 1879 was given in a statistical table of seines: Westport, 5,598 pounds; Tisbury, 44,250 pounds; and Edgartown, 3,000 pounds. The report for the year ending September 30, 1880, gave 28,184 pounds for Westport and 53,850 pounds for Edgartown, while that for the year ending September 30, 1881, showed that 2,414 pounds were taken at Westport and 32,800 at Tisbury.

The returns for the year ending December 31, 1882, were as follows: Tisbury, 28,050 pounds, and Edgartown, 6,500 pounds. In the fall of 1885, according to John Cutter, of Charleston, smelts were selling for 20 cents per pound and the following numbers were taken: At Tisbury Great Pond, 126,000; at Job and Great Neck Pond, Edgartown, 25,955; and at Oyster Pond, Edgartown, 65,728. No further reference was made to smelts, except in citing amendments or revisions of laws, until 1916.

In 1891 exceptions to prohibition of seines and nets were made in favor of Bristol, Barnestable, Nantucket, or Dukes Counties "during the time and in the manner in which fishing is allowed for perch, herring, or alewives."

In 1894 the following localities were restricted to hook and line: Boston Harbor, Hingham Harbor, Weir River, Weymouth Fore River, Weymouth Back River, Neponset River, Charles River, Mystic River, or any cove, bay, inlet, or tributary of same.

Statistics later than the foregoing are found in the reports of the United States Commissioner of Fish and Fisheries for 1900 and 1905, and the report of the United States Bureau of the Census for 1908. According to these statistics the total catch in 1900 was 7,079 pounds, valued at $515, taken as follows: Dukes County, by seines, 2,479 pounds; Bristol County, by seines, 4,200 pounds; and Barnstable County, by pounds and traps, 400 pounds. In 1905 the total catch was 7,375 pounds, valued at $866, taken as follows: Dukes County, by seines, 2,000 pounds; Bristol County, 3,150 pounds, 3,100 of which were taken with seines; Barnstable County, 325 pounds in pound nets and traps; and Essex County, by hook and line, 1,900 pounds.

"Grif" (1900) wrote:

The Massachusetts law allows the smelt to be caught with only hook and line, and no seining is permitted. It also makes a close season during the spawning time, and on account of this law, the fish have increased in number and in size.

The Fishing Gazette (New York) for March 16, 1907 (p. 259) contained the following:

It is safe to say that the ice smelt fishery in Essex River, which was closed down Thursday last until June 1st, will be an established pursuit at Essex next winter, says a Gloucester exchange. The strike of Warden Nixon, of the Massachusetts Fish and Game Commission, has fairly set the fishermen of the town into a state of excitement. Ever since the day when the warden located the fish, the river in the locality of the strike has been fairly alive with men and boys, all fishing Some of them fished all day and many fished well into the night, by lantern light. The smelt were an extra big run and fully half of them are by far the largest ever taken in this vicinity, easily running from 10 to 13 inches in length.

In 1908 the total catch was 16,200 pounds, valued at $2,500, principally in Essex and Suffolk Counties, of which 3,200 pounds were taken by seines and 13,000 by lines. The following is quoted from the report of the commissioners on fisheries and game of Massachusetts for 1916:

The smelt fishery in Massachusetts is in a depleted condition, and strenuous and radical measures will be required to save this species from extinction. The only available natural breeding grounds of importance are the Weymouth Back and Fore rivers, particularly the former. To this locality each year thousands of smelt resort for spawning. Unless steps are soon taken to prevent it, even this last breeding ground will soon be past history because of the depredations of man.

Plans are now under consideration toward protecting this locality as a reservation where a station can be established for obtaining the smelt eggs, the majority of which would otherwise perish, and from which the collected eggs could be distributed for restocking other coastal streams, possessing suitable spawning grounds. Only by this means can the smelt fisheries of our coast be maintained and replenished.

The report of these commissioners for 1917 (p. 76) says:

The smelt fishery of Massachusetts, while never achieving a commercial importance like that of the New Brunswick fishery (an important winter fishery, carried on through the ice, and the product shipped frozen to market), is now of value to the recreational fishermen, and does represent a substantial food supply. The commercial possibilities should be the primary reason for its development, for conditions can be made favorable to restoring the once abundant supply.

The reappearance of smelts in localities that they had not frequented for years was attributed to previous stocking. The annual report of the Massachusetts commissioners for 1918 (p. 148) said:

It was reported to one of our men on January 29 of this year that large quantities of smelt were being taken from Bournes Wharf River, in the Duxbury Marshes, in the part called Captain Simmons Turn. Fifty pounds were taken in one day by one man. This, our deputy reports, is an unusual circumstance, since in forty years of acquaintance with the river he never knew smelt to be so plentiful or present at that season. This is doubtless attributable to the informal stocking a few years ago by deputies of the department, who, in passing to their work, were in the habit of filling baskets with eyed spawn at the Weir or Weymouth Rivers, and depositing it in the rivers where smelts were formerly found, but which had since become depleted.

Results have also been apparent in the Jones River, Kingston, where the fishery was badly depleted. In 1916–17 the fishermen took large quantities of smelt through the ice, weighing frequently two to the pound. One of our deputies was eye-witness to a catch of 139 pounds by one man, all large-sized smelt. In the same river, in the winter of 1917–18, some good catches were

made, but the ice was very thick, and on extremely cold days the fish did not bite. There was an average of from 12 to 40 pounds. The prices received were from 21 to 35 cents. The average smelt this year ran four or five to the pound.

Some years ago eggs were planted in Poor Farm Brook in Saugus where smelt had been extinct for some years, and three years from the next fall there was good fishing.

An analysis of the foregoing indicates that many years ago smelts were abundant. The catches of the eighties also indicate that they were still plentiful. Records of anglers fishing in the vicinity of Boston and along the north shore in that period support the evidence, but in the nineties there is evidence of decline. This may be illustrated by taking Dukes County alone, where the seine fishing in the Great Ponds was practically monopolized by two or three individuals. In 1880 this county had a catch of approximately 3,687 pounds, which constitute about 97.9 per cent of the total catch of Massachusetts, as shown by available statistics. In 1882 the catch of the same county constituted 100 per cent of the total State catch, and in that year exceeded the total catch of Massachusetts by some 2,000 pounds; but in 1908 no smelts were reported from Dukes County, although the county may have been included in the category "all other counties," which showed some 500 pounds. In 1900 other counties were represented in the statistics—that is, Bristol and Barnstable—with something over 59 per cent of the total catch, Dukes County having a little over 35 per cent. In 1905 the total catch of the State somewhat exceeded that of 1900, the increase being attributable to the hook-and-line fishing of Essex County, which was first recorded in this year. Dukes, Bristol, and Barnstable Counties each fell off, Bristol, however, leading. In 1908 Essex County reported 62.5 per cent of the total State catch, of which 81.25 per cent was by hook and line.

It is quite evident that for some years the smelt fishery of Massachusetts has been declining, notwithstanding the prohibition of dip nets and seines, which was intended to protect them. But other things were not equal; while there is no definite information at hand, everything being taken into consideration, it seems evident that the depletion is not wholly attributable to excessive and untimely fishing, except possibly in the case of Dukes County, but to the fact that streams formerly resorted to for spawning had become unsuitable or inaccessible.

Maine.—In Maine, fishing for smelts through the ice seems to have been one of the most primitive methods, for in 1677 Josselyn thus described the Indian way:

> The *Frostfish* (*O. mordax*) is little bigger than a *Gudgeon*, and are taken in fresh brooks; when the waters are frozen they make a hole in the ice, about half a yard or yard wide, to which the fish repair in great numbers, where, with small nets bound to a hoop about the bigness of a firkin-hoop, with a staff fastened to it, they take them out of the hole.

It is not known whether present-day ice fishermen use dip nets, but hook-and-line fishing through the ice was the practice long before any sort of net was used, except dip nets in the brooks during the spawning runs.

Of smelt angling for sport alone their appear to be no records in this State, but there are accounts of winter fishing with hook and line for profit. Many hook-and-line fishermen combine business with pleasure, disposing of their catches by sale. The principal hook-and-line fishery was, and still is, largely a commercial proposition in certain localities along the coast. According to Hallock (1893) Portsmouth, N. H., near the Maine border, was a favorite winter resort for smelt fishermen, but now

most of the hook-and-line ice fishing is carried on farther east. A very good description of the winter hook-and-line smelt fishery in Maine, entitled "Taking smelts through the ice," was printed by the Belfast (Me.) Journal in 1884. An extract from this article follows:

On Monday afternoon a Journal representive took a tramp up the river among the smelt fishers. There are twenty-three cosy tents on the ice, fifteen of which are in a cluster, or rather in a row, close together off Kaler's Mill. Four tents are off Beaver's Tail and the others are scattered along the western shore. The fishermen all said " This is the best season for fish we ever knew, or at least for many years." As soon as the ice was of sufficient strength the fishermen placed their tents thereon. The smelts were there in plenty and took the hook readily. In fact, before the river was frozen Mr. Fred Cottrell caught large quantities from the shore with a line attached to a pole. Entering the tent of Mr. Joseph H. Trussell, one of the successful fishermen, he politely gave up his chair, and with a board across the head of a small keg he improvised a seat for himself. His tent is a frame about five feet square and six feet high at the ridge pole, covered with drilling. The covering is painted to better protect the fishermen from the wind. A small coal stove is at one side, the pipe leading out through the roof. The fire not only keeps the tent warm but heats the fisherman's dinner. The floor is boarded, with the exception of a square space with a corresponding hole in the ice. Through this opening, and made fast to a rack above, four lines are suspended, each having a single hook. The lines are kept down by a lead sinker, to the lower end of which the snell and hook are attached. The hooks are baited with clam worms dug from the flats. Seated on a chair the fisherman thumbs his line with as much comfort as though by the fireside in his own house.

Some of the tents are double and contain two fishermen with a double set of gear. The single ones are considered the best, as two persons will make more or less noise. The fish bite better on the ebb tide when they are moving down the river. This can not always be relied upon, however, for some days they take the hook readily, at other times sparingly. It has been observed that the smelts bite better on cold stormy days. Last Saturday as many as sixty pounds per man were caught. At such times the fisherman has brisk work with his four lines. Mr. Trussell thinks there are two different varieties of smelts—one he classes as the school smelt and the other as the permanent smelt—those that are always to be found in the river. The school smelt, he thinks, moves about from place to place and takes the hooks most readily. This smelt has a very light colored back. The fishermen all thought that smelts would be more plentiful in our waters if the mill dams were provided with fishways. Goose River, the Wilson stream and Gurney's are dammed so that the fish are unable to ascend to deposit their spawn, and are obliged to spawn along the rocks, where they are mostly destroyed. * * *.

The fish are mostly sold to Sleeper and Field of this city, who ship them frozen to the Boston, New York and Philadelphia markets. The fish are nicely packed in a box back down, and will keep for a long time.

A still more interesting account of ice fishing appeared in the American Angler (Vol. V, Feb. 2, 1884, pp. 72–73). As a matter of history and of early customs it seems worth reprinting in full. Its title was simply "Fishing for smelts."

"If any one likes fishing through the ice with the thermometer ten degrees below zero and the wind blowing sometimes at the rate of twenty-five miles an hour, he can find his ideal sport just now on any of the rivers and inlets along the coast of Maine," said "Mort" Scott, well known in angling circles in this city, who returned on Saturday from a week's fishing for smelt on the Maine coast. "Smelt fishing is now at its best up there, but the weather is about at its worst. At least in the estimation of the visiting sportsman it is; but those native and to the manner born think it couldn't be better. They don't seem to mind a little matter such as the mercury registering fifteen degrees below, and to see their tents lifted from the ice by the wind and carried upward like a balloon is regarded by them as only an episode that adds zest and humor to their enjoyment. When I left there last Thursday it was so cold that the holes in the ice froze over nearly as fast as they were cut, even with fires in the tents, and to keep them open required a little more labor than

FIG. 11.—Smelt house and fisherman, Damariscotta River, Me., winter of 1925–26. Fisherman holding up two smelts caught at the same time

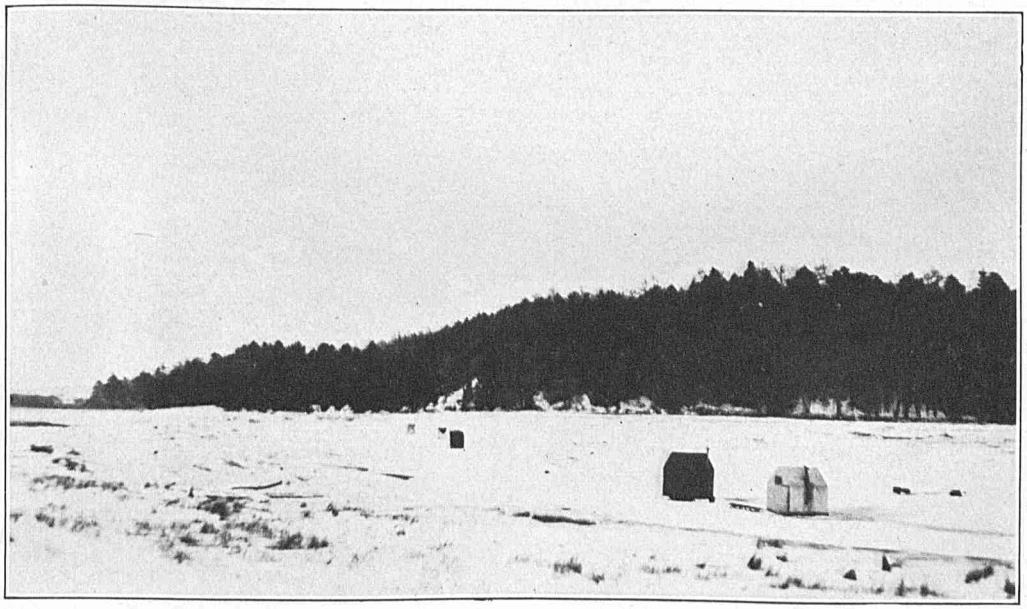

FIG. 12.—Smelt houses on Damariscotta River, Me., winter of 1925–26

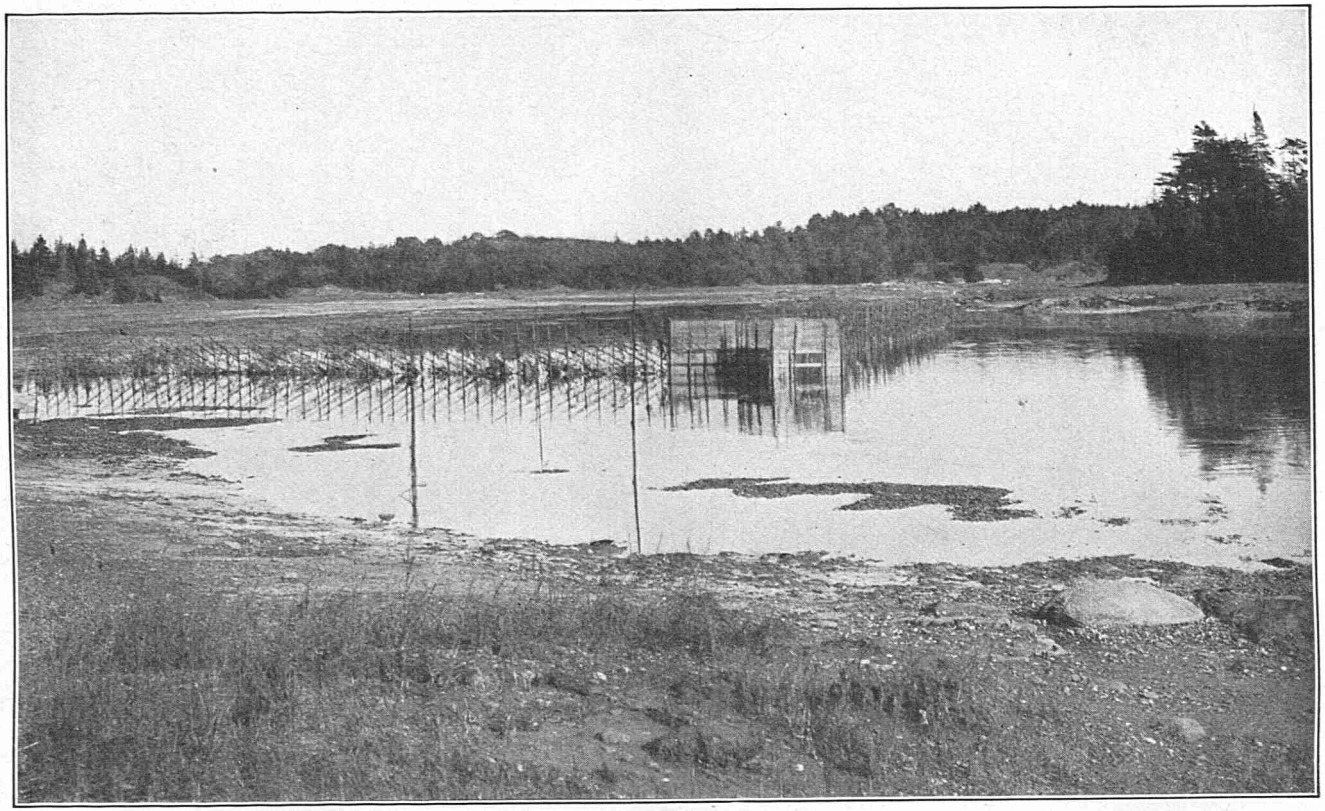

FIG. 13.—Brush weir for smelts in a tidal creek at Freeport, Me. There are now no weirs in this creek, nor in the neighborhood anywhere

even my enthusiasm in the sport could well overbalance. But there were scores of fishermen on the ice when I left, for the smelt seems to bite better the colder it is, and after this month the fishing gets poorer, and the fish move gradually to other quarters.

"Smelt fishing through the ice," continued the speaker, "does not differ much from the same mode of angling for pickerel, but the element of uncertainty is unknown in the former sport. You may fish all day sometimes for pickerel, then be obliged to buy enough to save yourself from going home 'skunked,' but when you cut your holes in the ice and put in your line for smelt, you are just as certain of being kept busy pulling out fish as you bait your hook. A smelt isn't as big as a pickeral, but he's a game fighter, and there is an excitement about 'tending' the lines that pickerel fishing does not create. The people up in Maine look upon smelt fishing as the sport of the year, and they come from miles about the country to enjoy it. Even the Indians from the far back country tramp in to the coast during the season to excerise their skill in luring smelt. The tackle for smelt fishing is very simple. The line is an ordinary stout linen cord, about four feet long. To one end of this is attached a piece of lead about three inches long and the size and shape of a three cornered file. This is called a file-sinker. To a swivel in the other end of the sinker is tied a pink-colored snell, made of common fish line, to which is attached a hook such as is used in fishing for catfish. The snell is two feet long. The water acting on the triangular sinker hung on swivels, keeps it constantly twirling about, and the bait, which is an ugly looking insect called the clay worm, always in motion. Each fisherman will have out an average of four lines, in as many different holes, if he seeks the enjoyment of the sport under the protection and shelter of a tent, or 'house,' as the natives call them. If he, like many of the local anglers, is braving the elements with the sole intention of extracting profit from the catch, and dances and trots about on the ice regardless of extraneous aids to combat the wind and storm, he is likely to have or a dozen lines to care for, spread over an area a hundred feet around; and if the fish are biting good he will have but little time to think of the cold, as he will be kept busy hauling up his lines and keeping the holes open.

"It has only been within a few years that such a thing as smelt fishing under shelter was known. The fishermen had either to stand out unprotected against the gales and storms that seem to be kept 'on tap' along the coast for use at any moment, or pull their lines and go home. To be sure, they would pile up walls of ice and patch them with pine boughs, but as it frequently is necessary for the fisherman to change his location and the ice barricade could not well be taken along, the building of them was generally time and labor thrown away. By the way, that is a peculiarity of smelt fishing. The fish may be biting so that you will be kept constantly hopping from one hole to another to stand your catch. Suddenly your 'tipups' will cease to tip. The smelt have taken it into their heads that the locality is not safe for them and have moved. Well, in a case of this kind, as I said, the angler would find his ice and pine boughs useless, and he would have to desert them to hunt up the spot where the fish had changed their base. But one season a man named Job Secor went up from Boston to try smelt-fishing. He tried it for a day and froze one foot and both ears, and then went away. But he didn't go home. He went to Belfast, and had a heavy wooden frame ten feet square made by a carpenter. He procured some sail canvas and covered the frame with it, leaving an opening for a door. The frame was on runners. When the house was finished he had it drawn upon the ice and placed over the holes he intended to fish through. Then it occurred to him that he might add still further to his comfort, and he bought a small box stove, ran a pipe from out of one side of the house, started a roaring pine wood fire in it, and, seated on a bench, fished as comfortably as if he were in his room at the hotel watching a stove pipe hole in the floor. The house was secured to the ice by grappling irons. If smelt ceased biting in one spot, he simply loosened his grapples, shoved his house along on the runners, and 'squatted' in more favorable quarters. No one who fishes for smelt simply for the sport there is in it has gone on the ice since then without one of the houses. Many who make a business of smelt fishing have adopted the plan, and now, in the height of the season a stranger going, for the first time to any of the rivers or inlets along the coast, would imagine that a small army was in camp there.

"On a good day for smelts the average catch per line will be at least 100, or say, 30 pounds. The fish net the business angler about five cents a pound, and have a ready sale in the local markets. On Wednesday of last week I was having a busy time in my house. I had only two holes in use, for the fish were biting so lively that I couldn't take care of any more. It was snowing

hard and blowing harder, but my fire was roaring inside, and I was tolerably comfortable. Suddenly, along came one of those zephyrs that love to play up and down the Maine coast. It seemed to think that I was cutting things a little too fast around there, and it stopped at my hut, got a leverage on my grapples, and the next instant hut, fisherman and stove were moving off at a lively speed. The front part of the stove—which was not much more than a toy stove, being only two and-a-half feet long—dropped into one of the holes in the ice, and the whole business went down among the smelt. We were scudded along for a hundred yards, when my house came in contact with another fisherman's house. This called a sudden halt, and I took advantage of it to crawl hastily out. The collision loosened the grapples on the other house, and in a moment both were flying along over the ice in all parts of the inlet. The gale lasted for not more than ten minutes, but the whole smelt-fishing village had been moved about a mile from its site when it ended. That little episode convinced me that it would be more pleasant for me to leave smelt-fishing until next May or June, and then resume it on a convenient stream; so I struck my tent and cut sticks for Belfast.

"I believe smelt-fishing is becoming more popular every year, and even the ladies are manifesting a willingness to brave its risks and, sometimes, its hardships. There was a party of three ladies and gentlemen from Boston camped on the ice when I came away."

Later that season George W. Singer (1884) wrote:

I read in your issue of Feb. 20 [Forest and Stream] an account of smelt fishing in Saco, and I think an account of the same in another town in Maine may be of interest. I left Waldorough [*sic.*, meaning Waldoborough], Me., seven weeks ago. There were then about sixty shanties on the river. They are neat little houses of ¾-inch stuff, and vary from 4 x 6 feet to 6 x 10. A cousin and myself fished in a shanty 6 x 10, and we used twelve lines. From Dec. 26 to Jan. 20 we took from fifteen to forty pounds every day, usually averaging in size about nine to the pound. We fished about four hours each day, just before and after low water. I left for home Jan. 22, but I have learned that there has been not more than a week since when the smelts did not bite. We use a great variety of bait, but nothing attracts them like marine worms or clam worms.

In his report on the sea and shore fisheries of Maine for 1886, Commissioner Counce stated that during the winter months the shipping of smelts had become quite an important business in Maine, many thousand pounds of this little fish being sent out of the State during the winter and spring. Two years later the American Angler, for February 25, 1888 (p. 126), contained the following notice:

Tons of smelts are being sent daily from Bath, Me., to the New York and Boston markets. The fishermen have erected a village of shanties on the ice in Back River, Arrowsic. The ice serves as flooring for the shanties, which are large enough to contain two men and a stove. A small hole is cut through the ice and fisherman plies his vocation indoors. Some of the smelters who fish in the open air are protected from the chilling blasts by screens of cotton cloth stretched between two posts. When the weather is cold they build bonfires on the ice to keep them warm. Most any afternoon from 75 to 200 men and boys make up the army of smelters and they are a jovial set. They get from four to five cents a pound for what they catch, and they earn from $1 to $4 a day each during the smelting season, which lasts during the winter months.

The report on the sea and shore fisheries of Maine for the same year (Counce, 1888) stated that "this little fish is caught in weirs and in large quantities in this State, and shipped to Boston, New York and Philadelphia, at a profit in the fall and winter." Two years later (April 10, 1890), Forest and Stream, quoting from an exchange (Gloucester Daily Times), said:

Old fishermen say that smelts have not been so abundant in the Kennebec River for twenty-five years as they have been this winter.

The account stated that "Winterport, on the Penobscot, is said to be the greatest smelt-fishing town in Maine. The fishing is done with bag nets, which are set at the beginning of the flood tide, and drawn at high water. The best catches are made at night. Eighty pounds is considered a fair catch, but this amount is generally exceeded."

According to the Maine Sportsman for April, 1894, the eastern smelt fisheries continued good as to quantity of fish caught, although it appears that in this instance the account pertained to smelts caught near the breeding season, if not in it. The account said:

Smelt fishing in the river at West Pembroke came to a close early last week. The catch during the last day was a remarkable one, the quantities landed by the nets being so great that it required several teams to transport them to Eastport and Calais, it being necessary to send half a ton or more to the latter place to go by rail, as the smelt season in Massachusetts closed the 15th instant, and they had to be rushed into market before that date. The season has been very fair as to catch, but prices have been rather low. For the first time in the prosecution of the business in that river the purse net was used this season and to good advantage. The smelt industry has reached large proportions in Maine and is worthy of some special attention from the bureau of statistics.

In March, 1897, the same journal announced that 15 tons of smelts were caught on Damariscotta Bay by hook and line during the months of December, 1896, and January and February, 1897. "They netted 7 cents a pound." This would make the total value of the smelt fishery at this place for the three-month period $2,100.

Nickerson (1898) reported as follows:

The catch of smelts for 1898 in which every county on the coast is represented, was 1,156,684 pounds, which returned to the fishermen eighty thousand, three hundred and fourteen dollars. As compared with the previous year there were 35,579 pounds more caught in 1898 than in 1897. Ten hundred and ninety-five persons were engaged in the taking of the above fish with weirs and seines, and by hook and line. There is usually a quick market for smelts, and recent prices, though fluctuating have ruled high. Large shipments are made to the Boston and New York markets, and December consignments have returned to the fishermen fifteen cents clear of expense to the pound.

Over 40 years ago, at Surry, on May 27, Atkins noted that according to N. Hinckley, Esq., House of Representatives, smelts were formerly of considerable importance. They were taken mostly through the ice with hook. In the spring they were said to run up the stream that enters the head of the harbor west, but this year (1878) hardly any had come up into the stream. It was suggested that the failure was attributable to too much dipping of them early in the season when the tide was out and the fish collected in bodies in tide pools. On May 28 of the same year Atkins indicated a scarcity of smelts in Lawrence Brook, whereas the year before an individual got a bushel at one catch.

It would seem, however, that at Surry, some 22 years later, the fishery had not declined greatly. The following excerpt from the Bangor Commercial of January 23, 1900, indicates that the Surry hook-and-line fishing was still yielding satisfactory returns:

Nearly 100 men and boys together are engaged in the winter's fishing at Surry, and in 35 years more than $40,000 worth of smelts have been taken.

The smelts are all caught with hook and line. Taking them otherwise, such as by seine, would be regarded by the fishermen here as a great wrong. The fishing is all done in tents, the

tents being about six feet long, five feet wide, and high enough for a man to stand up in them. These tents are covered with cloth, heated by a stove, and lighted usually by a lantern. I have known the temperature of my tent to vary, however, 60 degrees within 10 minutes during a cold day.

A hole about six feet long and eight inches wide is cut in the ice, and the tent set lengthwise of this. Six lines attached to a pole fastened to the plates of the tent hang into the water nearly eight inches apart. These lines, during fishing hours, are always kept in motion.

The way the fishermen handle these lines, how they can bait the hooks and slat smelts, when, as they say, they are "taking holt," is certainly wonderful. I have known one man to catch 100 pounds in less than one hour. This means at least 1,000 fish, or about 17 a minute. One smelter has been known to catch 500 pounds during one tide's fishing. Some have made $25 to $30 a day, and others $200 in a few weeks. But these big catches are only made by those expert in fishing. The chances are that a green hand would starve the first winter if dependent wholly on what fish he caught.

During the fishing season politics, religion, war and all other subjects generally discussed in the stores are dead issues. Nothing but smelts is talked about; nothing but fish discussed by the fishermen. The usual salutation when meeting another is: "How many?"

It is a beautiful sight some still, cold, morning to watch the streams of white smoke belching out of a hundred stove pipes and slowly ascend almost perpendicular 100 feet in the air. From a distance these little houses huddled together remind one of some miniature city. Sometimes when the Bay first freezes these villages come into existence with as little notice as that of a mining settlement.

The smelts are all shipped to Boston and New York markets.

For about the same period (1899–1900) the report of the commissioner of sea and shore fisheries of Maine (Nickerson, 1901) indicates a continued prosperous smelt fishery in that State. It says that from this business (considered small and practically of no account by those who do not know about it) in the year 1900 the State derived a revenue to its fishermen of $77,074, the yield being 1,017,434 pounds. The total investment in boats and gear, weirs and camps used in this business in 1900 was $25,398, or about $26 to each person engaged in the fishery, which numbered 977 persons, men and boys. All the counties on the coast excepting Knox, Cumberland, and York prosecuted the fishing largely through ice from camps, while the Waldo County catch was taken without the use of either weirs or camps, and that of York County entirely with hook and line. Most of the fishermen carry on the fishing but a few weeks and in some sections but a few days, still the men engaged average about $80 each. As compared with the previous year (1899) the catch and money return increased somewhat over the latter year, and the men fishing increased from 830 to 977. Large shipments continued to be made to Boston and New York markets.

The commissioner's report for 1903 and 1904 (Nickerson, 1905), states that the aggregate yield for the term of the report was greater than shown in any previous report; the catch of 1903 was very large compared with previous years, being an increase of 343,000 pounds over 1901. The average price in 1903 was 11 cents per pound, a higher average than in previous years, which showed a good demand in the markets of New York and Boston, where the fish are principally shipped by the fishermen direct. The report says:

While the winter fishing is much pursued as a sport these fishermen receive very good wages while thus engaged fishing through the ice.

The commissioner's report for 1905–6 (Nickerson, 1907) stated that it was obliged to report a largely reduced catch as compared with the last previous report.

The catch of 770,391 pounds for 1905 was a falling off as compared with the previous year of more than a quarter million pounds, and for the two years here reported the production is 319,128 pounds less than for 1903 and 1904.

This condition may be accounted for in measure by the fact that the number of men engaged in the fishery has been very materially decreased. In 1903 there were 824 men thus engaged, while in 1906 the number has fallen to 654.

The average price received by the fishermen was almost 12 cents a pound, a little better showing than two years ago.

The ice fishing has been classed in some localities as a "sport," but the catches have been so large, and returns so satisfactory, that it has become a business proposition, a hundred or more dollars being easily and quickly gathered in, while for a few days the local "sport" has engaged in this "pastime"—a pastime so profitable is likely to be popular.

As has appeared in the foregoing, other methods of fishing than by hook and line were sooner or later adopted. These methods were by some sort of nets, such as seines, weirs, traps and pounds, bag nets, dip nets, gill nets, and fykes. As this net fishery expanded the catch of smelts increased for some time, but the inevitable decline was shown later.

The statistics of the New England States for 1905[3] indicate that in that year in Maine, there were 5,986 shore fishermen, of which the Maine sea and shore fisheries commissioner's report shows 776 were smelt fishermen. The quantity of smelts taken in that year amounted to 587,985 pounds, valued at $64,000. The following table shows the take of smelts, by countries:

County	Pounds	Value	County	Pounds	Value
Cumberland	95,135	$9,008	Penobscot	8,000	$640
Hancock	220,100	18,875	Sagadahoc	34,500	3,325
Knox	52,500	6,150	Washington	121,900	18,516
Lincoln	54,700	7,283	York	1,150	207

The report says:

Since 1902 there has been a decrease of 47 per cent in the catch of smelts and 34 per cent in its value. There is always a demand during the fall and winter, however, and the fishermen seldom realize less than 10 cents a pound, the average being considerable more.

In 1905 the hand-line fishery was paramount and was restricted to Hancock, Lincoln, and Sagadahoc Counties, according to the statistical report. Hancock County led Sagadahoc and Lincoln Counties by 115,000 pounds, as follows:

County	Pounds	Value
Hancock	156,500	$12,520
Lincoln	25,600	4,293
Sagadahoc	15,500	1,550

Pound nets, trap nets, and weirs being so nearly alike in principle, the catches are combined. These were employed in Cumberland, Hancock, Sagadahoc, Washington, and York Counties. The catch of Washington County exceeded the combined catches of the other four counties by 29,450 pounds.

[3] Report, U. S. Commissioner of Fisheries, 1906, Bureau of Fisheries Document No. 620, 93 pp. Washington.

County	Pounds	Value	County	Pounds	Value
Cumberland	2,500	$300	Washington	51,900	$7,851
Hancock	14,300	1,585	York	1,150	207
Sagadahoc	4,500	325			

Seines were fished in Cumberland, Hancock, Knox, and Lincoln Counties, with the following results:

Counties	Pounds	Value	Counties	Pounds	Value
Cumberland	92,635	$8,708	Knox	52,500	$6,150
Hancock	16,000	1,600	Lincoln	25,100	2,590

Gill nets appear to have been used only in Washington County, where they took 17,500 pounds, valued at $2,035. Dip nets and bag nets were employed in Hancock, Penobscot, Sagadahoc, and Washington Counties. The largest catch was in Washington County, which fell behind the combined catches of the other counties by 1,800 pounds.

County	Pounds	Value	County	Pounds	Value
Hancock	33,300	$3,170	Sagadahoc	13,000	$1,300
Penobscot	8,000	640	Washington	52,500	8,630

Fyke nets were used only in Lincoln and Sagadahoc Counties. The combined catch of the two counties was only 5,500 pounds, valued at $550, of which Lincoln had 4,000 pounds, valued at $400. The following table shows the quantities of smelts taken by the various methods from 1887 to 1908, as revealed by the only available statistics:

Methods of capture	1887	1888	1898	1905	1908
Hand lines	589,105	601,812	577,133	197,600	89,000
Seines	142,300	179,600	590,703	186,235	222,000
Weirs, traps, and pounds	79,650	93,600	6,196	74,350	113,000
Bag nets and dip nets	388,145	397,538	266,272	106,800	29,000
Gill nets			12,000	17,500	34,000
Fykes	3,600	2,000	4,237	5,500	107,000
Total	1,205,150	1,279,550	1,608,045	587,985	654,000

On December 10, 1906, smelt fishing in Maine had begun, according to advice from Bangor Fishing Gazette, New York, 1906).

At the mouth of Union River the ice is safe and enough smelts are being taken to encourage the fishermen to continue, but there have been no big hauls. At Surry, the most important smelt-fishing town in Maine, 10 or 15 tents have been erected by fishermen. Within a week or two, if the weather continues cold, half of the population of the town will have moved out on the ice, and there will be fully 100 tents and shacks. The Penobscot River smelt fisherman have not been able to begin the season because the ice has not formed solidly below Hampden.

The following table shows the amount of smelts, in pounds, caught in each county for certain years from 1897 to 1924, derived from reports of the commissioner of sea and shore fisheries of Maine and reports of the United States Bureau of Fisheries:

Year	Counties								
	Washington	Hancock	Penobscot	Waldo	Knox	Lincoln	Sagadahoc	Cumberland	York
1897	41,360	240,114	----------	65,450	1,638	207,237	180,692	376,714	7,900
1898	117,875	150,852	----------	68,790	16,200	339,200	92,576	368,000	3,191
1899	115,110	193,134	----------	81,860	24,078	272,335	4,200	187,236	2,147
1900	199,960	219,658	----------	70,850	37,700	193,731	78,935	212,600	4,000
1901	149,267	102,523	----------	45,540	24,042	214,085	79,056	71,815	----------
1902	249,088	187,034	----------	28,425	52,900	297,320	67,940	119,055	----------
1903	255,065	315,364	----------	30,142	29,276	204,024	55,729	139,900	400
1904	276,872	280,393	----------	56,835	17,000	203,385	17,010	127,345	2,300
1905	176,800	151,166	----------	29,160	84,000	214,700	11,945	101,420	1,200
1906	245,818	235,508	----------	33,300	49,500	176,887	15,535	164,765	208
1907	238,635	180,249	----------	46,700	25,375	117,648	11,900	169,030	497
1908	263,780	149,228	2,000	----------	68,875	210,500	3,440	227,545	1,350
1909	306,601	217,738	7,500	----------	25,195	137,600	31,190	228,130	----------
1910	207,170	292,109	12,000	45,000	57,100	176,000	34,255	264,820	----------
1911	292,790	334,257	16,000	----------	96,750	125,200	60,310	242,785	----------
1912	317,675	131,700	15,700	----------	61,500	185,000	66,635	211,935	----------
1916	52,433	176,200	25,500	200	61,000	3,000	24,040	195,500	----------
1919	36,300	95,435	1,900	23,450	93,600	53,500	74,230	136,202	8,000
1924	92,315	105,115	24,140	52,000	58,289	106,760	99,005	86,583	3,500

The following table shows the available statistics of the total catch, in pounds, value of the catch to the fishermen, number of fishermen and average catch of each, average value received by each, and the average price per pound received by the fishermen in certain years from 1897 to 1924, inclusive, as derived from the reports of the commissioners of sea and shore fisheries of Maine and the United States Bureau of Fisheries:

Year	Pounds	Value	Number of men	Approximate quantity per man	Average value per man	Average price per pound
1897	1,121,105	$67,960	1,121	1,000+	$60.62+	$0.060
1898	1,156,684	80,314	1,095	1,058+	73.34+	.069
1899	880,106	66,682	830	1,060+	80.33+	.076
1900	1,017,434	77,074	977	1,040+	78.80+	.076
1901	686,328	56,930	859	798+	66.27+	.083
1902	1,001,762	95,833	753	1,330+	127.26+	.096
1903	1,029,900	101,720	824	1,249+	123.44+	.099
1904	981,140	97,769	765	1,282+	127.79+	.099
1905	770,391	86,588	776	993+	111.58+	.112
1906	921,521	107,206	654	1,409+	163.92+	.116
1907	790,034	86,437	----------	----------	----------	.109
1908	926,718	110,186	----------	----------	----------	.119
1909	953,954	110,004	----------	----------	----------	.115
1910	1,088,454	115,107	----------	----------	----------	.106
1911	1,168,092	125,011	----------	----------	----------	.107
1912	990,145	106,351	----------	----------	----------	.107
1916	537,633	63,679	----------	----------	----------	.118
1919	523,967	94,496	----------	----------	----------	.180
1924	627,707	137,430	----------	----------	----------	.219

Basing computations upon the figures shown in the foregoing tables, there apparently was a considerable decline in the smelt fishery up to 1916. In the decade from 1887 to 1897 a falling off of 84,045 pounds is found, which might, perhaps, represent only a fluctuation due to one cause or another; but in the 20-year period from 1888 to 1908 there is a greater loss of 625,550 pounds, and in the 30-year period from 1887 to 1916 a still greater falling off of 667,277 pounds is seen. Again, taking a 20-year period, from 1897 to 1916, as shown in the last table, while a drop

of 583,472 pounds is shown in the period from 1897 to 1911, an increase over 1897 of 46,987 pounds is indicated, and the quantity taken in 1911 was larger than that of any year represented in the tables since 1888, but there is a pronounced falling off in quantity in subsequent years.

From 1897 to 1906 there was a fluctuation in the number of fishermen, which would account for some fluctuation in the quantity caught, indicated also in the average quantity taken per man. The average value of the fishery per man shows a fluctuating but progressive increase, as does the average price per pound of fish. Whether the increase in value and average price per pound are attributable to increased demand or to a relative decrease of the smelt, and whether the apparent comparative steadiness of the supply may be attributed to more intensive fishery methods, can not be determined from present data. It is unfortunate that there are not more complete data extending up to the present time, whereby some light might be thrown upon these points. The figures for 1919 show a marked falling off in quantity from those of 1911 and a considerable decrease from 1912, but there is a marked increase in value per pound.

During the fall of 1924 there was a general complaint of scarcity of smelts, although now and then a fair catch would be made by one or another fisherman. Such complaints have arisen from time to time in the last few years. Statistics for that year indicate an increased catch over that for 1919, as well as increased value.

The gradual increase in price per pound up to 1916 without fluctuations corresponding to fluctuations in the quantity of fish taken, with an increase in the number of fishermen, would strongly suggest a relatively diminished fishery. In this connection an item that appeared in the Fishing Gazette (New York) for February 1, 1925, entitled "Maine smelt fishing pays well this season," may be regarded as highly significant. It said:

> Years ago the winter smelt fishermen in the vicinity of Bath used to get six or seven cents a pound for smelts. When they went to 10 or 12 cents they considered themselves fortunate. Today they are receiving as high as 40 and 45 cents a pound for the maximum quotation and 30 for the minimum. At Arrowisic, where most of the fishing is done from little smelt-houses placed on the ice, there are an unusually large number of fishermen this winter. In former years there have been as many as 200 of these little smelt shanties on the Arrowsic ice.

Comparison of the quantity, value, and average price per pound of smelts taken in the coastal fisheries of New England in 1888, 1908, 1919, and 1924

State	1888			1908		
	Pounds	Value	Average price per pound	Pounds	Value	Average price per pound
Maine	1,279,550	$94,927	$0.074	654,000	$65,000	$0.099
New Hampshire	36,000	3,600	.100	2,600	300	.115
Massachusetts	10,800	1,152	.106	16,000	2,500	.156
Rhode Island	61,500	3,135	.050	1,200	100	.083
Connecticut	9,600	770	.080	10,100	1,200	.120

State	1919			1924		
	Pounds	Value	Average price per pound	Pounds	Value	Average price per pound
Maine	523,967	$94,496	$0.180	627,707	$137,430	$0.219
New Hampshire				3,835	1,630	.425
Massachusetts	39,150	10,690	.273	37,698	9,823	.260
Rhode Island				7,860	1,592	.202
Connecticut	25,217	4,466	.177	11,300	2,410	.213

Apparatus employed in the smelt fishery of coastal waters of the New England States, except Maine, in 1888 and 1908

Year and apparatus	New Hampshire		Massachusetts		Rhode Island		Connecticut	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1888								
Hand lines			8,000	$897			2,200	$150
Seines					19,300	$982	7,400	620
Weirs, pound nets and trap nets	36,000	$3,600	2,800	255	42,200	2,153		
1908								
Hand lines			13,000	2,200				
Seines			3,200	300			8,000	1,100
Weirs, pound nets and trap nets	2,600	300			1,200	100	1,500	100

Canada.—The smelt fishery of Canada has attained considerable magnitude. During the period from 1912 to 1923, both inclusive, the largest catch for the Dominion was taken in 1914, when 9,038,900 pounds valued at $713,501, were recorded. The smallest catch was in 1923, when 5,811,800 pounds were taken, but the value was considerably greater, being $789,361, representing a gain of $75,860.

The Canadian Provinces that support any smelt fishery are New Brunswick, Nova Scotia, Prince Edward Island, and Quebec in the east, and British Columbia on the west coast. In the east, also, Newfoundland appears to have entered the list of northern smelt-producing localities. The smelt of British Columbia is a different species from that of the east. The largest quantities are taken during months when there is little or no smelt fishing in the east, and compared with eastern fisheries it is of far less commercial importance.

The smelt fishery of Canada first became of note in New Brunswick, and that Province is still paramount in the fishery. The profits realized by New Brunswick in this fishery could but impress other localities where smelts were obtainable, so later other Provinces became interested in the industry.

The history of the development of the smelt fishery of eastern Canada is very interesting, but whatever has been published pertains largely to New Brunswick. Very little has been written concerning the other Provinces, and most of the data pertaining to them consist of statistics.

In 1849 Perley (1850, p. 135) said:

> The smelt (*osmerus eperlanus* of Cuvier, and *osmerus viridescens* of Agassiz), is found in excessive abundance in all the Rivers and Streams flowing into the Gulf. In the latter part of winter, when in the best condition, they are taken through holes in the ice, and at that season are a very great delicacy; they are then frequently called "frost-fish." Immediately after the ice disappears,

they rush in almost solid columns up the brooks and rivulets to spawn, and are then taken by cart-loads. This Fishery, under proper management, might be made one of considerable profit as the smelt is really delicious, and always highly esteemed.

In the same report specific mention is made of the River Miramichi. Perley said that the smelt ascended this river and its tributaries very early every year, in almost miraculous quantities; and in Buctouche River he stated that there was a great abundance of smelt every spring, and that parties of French settlers went up the brooks in log canoes and each party frequently got 50 to 60 barrels of smelts, which were used to manure the land.

In 1871 W. H. Venning, then fisheries inspector of New Brunswick, stated that large quantities of smelt were sent in a frozen state from Northumberland County to the United States, where they brought good prices. In 1872 the same inspector stated that from Westmorland County smelts were taken in large quantities and shipped fresh to the Boston market. In Kent County, in the same year, smelts were said to have been abundant in the rivers and a valuable resource for the fishermen during the winter season.

In 1873 Venning reported that smelts were being taken in larger quantities than ever before in Kent County, and that preparations were being made for extensively shipping them to the United States, where they commanded a ready sale and good prices. In his report for 1876 Venning (1877) said:

> Hitherto smelts have been very numerous because the fishery has not been followed to any great extent, but the facilities now offered for transportation are so great that a large business in this fish is growing up all along the Nothern Shore of New Brunswick, including the counties of Kent, Northumberland, and Gloucester. They are sent to the United States, where they find a ready sale at profitable prices.

Adams (1873), writing of New Brunswick, said:

> Enormous numbers of smelt are caught on the seaboard in midwinter, mostly to feed pigs, the flesh of which becomes tainted by the cucumber flavour of this fish.

Whiteaves (1874), in a report for 1873, said that the smelt was or might be taken abundantly throughout the Gulf of St. Lawrence all the year round, and that in New Brunswick and Nova Scotia smelts were exported to New York and Boston.

A note in Forest and Stream for October 12, 1876, stated that a large number of men were employed daily near Barthurst, New Brunswick, in fishing for smelts for American markets, principally New York and Boston. "During the past two weeks [first half of October] about forty tons have been forwarded by rail."

Venning (1877) indicated that the closed time for smelts in New Brunswick from April 15 to May 15, did not cover the spawning season of the "summer smelt" nor sufficiently protect the breeding fish. He said that large numbers were taken after the 15th of May (before they were done spawning) and used as manure. He stated that to be effectual the close time should be extended to the 1st of July, not only to prevent destruction of the spawning fish but also to prevent their being used as manure, adding that if they were caught all winter to the extent that then prevailed, and then destroyed wholesale during the spawning time, a very few years would effect their exhaustion.

Available statistics for a period of some 50 years ago, more or less, when W. H. Venning was inspector of fisheries of New Brunswick, indicate that the smelt fishery

of Canada was restricted to New Brunswick and Nova Scotia, at least so far as export to the United States was concerned. The reports for the years 1871 to 1878, both inclusive, show a constantly rapid increase in quantity of smelts and a corresponding enhanced gross value. The increase appears to have been attributable to more intensive fishing operations. The price per pound remained almost constant from 1873 to 1877, but in 1878 a 50 per cent drop in the price received by the shippers occurred, and Venning states that only 1 cent a pound was paid to the fishermen. This situation was due to an oversupply.

Year	All Canada		New Brunswick		
	Pounds	Value	Pounds	Value	Price per pound
1871	520,146		485,100		
1872	584,160		495,500	$10,527.00	
1873	810,499	$48,623.94	697,520	41,851.20	$0.06
1874	1,156,440	69,391.00	915,600	54,936.00	.06
1875	1,451,580	87,094.80	1,086,280	65,176.00	.06
1876	1,990,825	98,228.40	1,559,200	93,552.00	.06
1877	2,264,002	13,584.12	1,950,700	117,042.00	.06
1878	2,715,107	90,007.86	2,426,952	72,808.56	.03

Twenty-five years later the same inspector, then retired (Venning, 1902), after referring to former abundance and their use as fertilizer, said that since the I. C. R. had furnished a means of reaching Provincial and United States markets, frozen smelts had formed a large export from all the northern countries, and in 1901 the aggregated shipment from New Brunswick amounted to 7,863,000 pounds. Samuels (1904) wrote:

I have before me a clipping from a St. John paper, which contains a communication from Richibucto, N. B., that shows how important the smelt packing industry has become in that place, which is one of many that are scattered along the shores of the bay. It reads as follows:

"The smelt fishing season, which opened yesterday, is the biggest thing in this part of the country. Although it is carried on but a little over two months in every twelve, it does more real good in that time than all the other industries put together can do in a whole year. The secret of its beneficial effect is found in the system by which the business is conducted. Other kinds of fishing, lumbering and such things are nearly all done by due method, but the man who attempts to take a hand in buying smelts without cash on the spot, 'is not in it.' * * * .

"Following the catching of the fish comes the preparation of them for market. It is nothing unusual for small boys to earn from a dollar to a dollar and a half a day packing the smelts in boxes. No matter in what way you are connected with the work it is cash. Forty or fifty thousand dollars emptied out within a radius of ten miles in a few months, means something, and the man or woman who cannot talk about smelts from now to the middle of February, is of no use in the vicinity."

Samuels stated that the net used in seining smelts is pretty close-meshed, and large enough to inclose several thousand pounds at a haul. He said:

The struggles of the fishes as folds of the net encompass them more and more closely, together with the weight of the captives as they become compact, forces the spawn from them, and that to such an extent, that I have seen the beach where the seining was done covered with the eggs in winrows looking like so much saw dust.

An article in the Fishing Gazette (New York) for November 24, 1906, asks the question:

Did you happen to know that the smelt output of the Dominion is now upward of 5,000 tons annually; that the monetary value is a half million dollars, and that only a few years ago the fish were taken for fertilizing uses?

On January 5, 1907, the same publication, quoting the P. E. I. Agriculturist, said:

As many as thirty fine boxes [of smelts] were taken in one "draw" quite recently. At this rate there is a little fortune in the business and if there be no extended break in the winter communications many of our fishermen will make more during the winter months than any of us. A few of the fisherman have, we are told, discarded the purse net and take smelts, as they catch herring, in old-fashioned gill nets which lets the little ones through. This is the only method by which the smelt fishing will be preserved and which ought to be adopted by all fishermen.

Again, the Halifax correspondent of the same journal, on March 9, 1907, says:

Apropos of dainty food fish, Capt. Sol Jacobs, the noted mackerel king, recently sent the first shipment of Newfoundland smelts to Boston across to Sydney and then by rail. These smelts averaged four to the pound and proved excellent in flavor. Should the supply be sufficient a large demand will doubtless spring up.

In 1912, five years later, Henry S. Culver, the consul at St. John, New Brunswick, stated that smelt fishing in New Brunswick, which he said commenced the 1st of December, was an important industry, the catch of 1911 having amounted to 726,661 pounds.

In 1913, Theodosius Batkin, the consul at Campbellton, New Brunswick, wrote:

Smelt, which only a few years ago were caught solely for fertilizing purposes by the farmers, are now an ever increasing source of revenue. In 1911 over 691,000 pounds, valued at $46,553, were exported by carload lots to American markets. In 1912 more than 1,120,000 pounds, valued f. o. b. at $63,595, were sent to American centers. These figures do not include the numerous exports by express and otherwise where the value of the shipment fell below $100. Most of the smelts are taken at the mouths of the Restigouche and other streams near by.

On December 1, 1916, E. Verne Richardson, the consul at Moncton, New Brunswick, reported: "Opening of the smelt season in the Province of New Brunswick, begins to-day." He stated that consular invoices certified at the Moncton consulate during the calender year showed shipments of smelts to the United States totaling 880,176 pounds, valued at $56,395, or a little over 12 cents per pound average selling price.

Quantity, in hundredweights, and value of the smelt fishery of all Canada, eastern Canada, and New Brunswick from 1913 to 1924, and average price per pound in New Brunswick

Year	All Canada		Eastern Canada		New Brunswick		
	Hundredweight	Value	Hundredweight	Value	Hundredweight	Value	Price per pound
1913	73,937	$689,959	73,937	$689,959	60,117	$601,170	$0.100
1914	90,389	713,501	90,389	713,501	65,189	651,890	.100
1915	62,143	562,064	62,143	562,064	52,961	529,610	.100
1916	66,109	825,115	66,109	825,115	55,025	715,112	.129
1917	69,780	994,545	69,780	994,545	55,703	834,415	.149
1918	82,638	925,625	82,638	925,625	69,937	801,244	.114
1919	75,271	835,195	74,023	820,513	54,963	611,839	.111
1920	68,118	789,361	56,749	773,425	40,041	565,279	.141
1921	84,597	835,393	82,780	815,963	62,042	589,804	.095
1922	83,268	934,608	82,868	930,194	62,680	731,151	.116
1923	65,254	868,629	64,218	858,920	43,210	475,523	.110
1924	90,066	1,146,673	88,926	1,134,500	63,975	844,730	.132

In comparing this table with that on page 261 it is interesting to note that in the 45 years from 1878 to 1923 the quantity of smelts caught increased by about 1,894,000 pounds, and increased in price received per pound from 3 cents (or possibly it should be normally 6 cents) to 11 cents per pound.

As previously indicated, the smelt season in New Brunswick is chiefly in the winter and lasts for about three months—December, January, and February. The foregoing table shows the annual quantity of smelts and their value for the year, but it does not show the extent of the fishery in any one season. The following table gives the quantity and value for each month of the season, from September to March, a period of seven months, during the seasons of 1911–12 to 1916–17, and quantities and values in quarterly periods from 1917–18 to 1920–21, inclusive:

Month	1911–12		1912–13		1913–14	
	Hundredweight	Value	Hundredweight	Value	Hundredweight	Value
September	22	$132	78	$412		
October	1,177	3,743	894	3,292	260	$1,040
November	3,045	11,363	1,115	3,603	384	1,434
December	18,829	80,401	25,664	102,206	18,859	76,236
January	22,368	88,704	28,616	127,468	21,791	102,010
February	12,616	49,639	15,563	67,785	1,284	64,135
March	152	608	100	500		
Total	58,209	234,590	72,030	305,266	42,578	244,855

Month	1914–15		1915–16		1916–17	
	Hundredweight	Value	Hundredweight	Value	Hundredweight	Value
September	73	$365	50	$150		
October	297	1,037	324	1,114	566	$2,499
November	948	3,604	782	2,662	1,911	9,670
December	19,908	102,586	12,188	58,260	12,403	91,523
January	22,479	102,395	20,468	118,668	25,807	210,690
Feburary	20,025	77,037	18,690	98,231	18,906	173,562
March						
Total	63,730	287,624	52,502	279,085	59,593	487,944

Month	1917–19[1]		1919–20		1920–21	
	Hundredweight	Value	Hundredweight	Value	Hundredweight	Value
September						
October			22,898	$164,323	10,550	$94,751
November						
December						
January						
February	[2]61,598	[3]561,475	31,430	214,882	38,532	353,973
March						
Total	61,598	561,475	54,328	379,105	49,082	448,724

[1] Includes the seasons of 1917–18 and 1918–19.
[2] Of this amount 30,834 hundredweight are for 1917–18 and the balance is for 1918–19.
[3] Of this amount $353,177 are for 1917–18, and the balance is for 1918–19.

Secretary Dimick of the Boston Fish Bureau, under date of December 30, 1924, is the authority for the following statements concerning shipments of smelts from Canada, Newfoundland, and Maine:

Canada.—The Canadian smelts are exported largely to the Boston and New York markets. The catch for the nine months ended September 30, 1924, amounted to 60,783 hundredweights valued at $563,299, compared with 32,450 hundredweights, valued at $377,573, in the same period in 1923. The total catch in Canada for 1923 amounted to 62,254 hundredweights, value $868,629, compared with 83,268 hundredweights, value $934,608, in 1922.

Newfoundland.—During the winter of 1923–24 there were exported from Newfoundland 99,825 pounds of smelts, valued at $10,460, compared with 116,832 pounds in the previous winter, valued at $12,189.

Maine.—It is estimated that 10,000 boxes of smelts, or about 300,000 pounds, are received at Boston in a season from Maine, valued at $66,000. The total production in Maine probably would amount to 700,000 or 800,000 pounds, as a good many are sent from there to New York.

As about all of the Canadian and Newfoundland smelts are sent to the Boston and New York markets, the above figures will give you some idea of the receipts of smelts.

According to the Canadian Fisherman for June, 1924 (p. 169), the smelt-fishing season in the Miramichi fishery of New Brunswick extends from the 1st of December until the 15th of February, leaving an open season of only about two and one-half months. Most of the fishing is done at night at the "turn of the tide," and the catch per net in one night's fishing has ranged from 100 pounds to 2 tons, for which the fishermen got from 8 to 14 cents a pound, the average for the season being around 10 cents. The account went on to say:

The Miramichi smelt fisherman makes his home on the ice near his nets during the fishing season. Small tar papered shacks are hauled to the most convenient places and here the fishermen make their home. "Smelt Shanties" as they are called, have room for only two and despite the coldest weather are always warm and comfortable and once inside the shanty, though the wind may blow its hardest the hardy fisher folk live in peace and comfort.

Bag nets and box nets are both used but the bag net seems to hold the favor. It has a mouth about twenty feet square with a trailer of about forty feet, at the end of which is located a trap in which the smelts are taken. To empty the net one closes the mouth, fishes up the trap, unties the end and empties his catch on the ice. Here they are sorted, for in addition to smelts, the fisherman is always assured of a generous catch of tom cod and flounders—their value is very low, ranging from $1.25 to $2.00 per barrel—and these are generally marketed in Upper Canada.

The smelt, however, finds its favor with our neighbors to the south, and so highly is it prized, that it, almost alone, is exempt from the Fordney Tariff of 1 c. to 2 c. per lb. as is imposed on other fish. During the season just closed there were shipped to the United States from the Miramichi district alone a total of over 4,347,000 lbs. of smelts, with a total declared value of approximately $711,052 in United States currency.

Let us place the Canadian consumption at one-tenth of that shipped to the United States—a prominent fishermen places this as a very conservative estimate—and we can easily put the catch for the season of 1923–24 at 4,782,000 lbs. and the value at $782,157.00. To this add the exchange at the current rate for the United States shipments and we find that during the past winter the smelt fishing industry was worth upwards of $800,000 to the Miramichi, or over $10,000 for every day of the fishing season. Sunday included.

To sum up the matter—the smelt fishing industry is one of the biggest industries in the province to-day and one of the least heard of. Unlike the lumber industry, it is growing enormously, and with proper regulations is practically inexhaustible. It deserves more sympathy and support than it now receives from the residents of the Miramichi and the province of New Brunswick in general.

ANGLING FOR MARINE SMELT

Probably the oldest printed account of smelt fishing for sport is a short sketch entitled "Smelt Fishing—As practiced in Boston," which appeared in the American Turf Register and Sporting Magazine for October, 1832 (Vol. IV, No. 2, p. 85). The author, who signed himself "Walton, Jr.," after a preliminary reference to the novice's fly fishing and a highly laudatory description of the smelt as a pan fish, went on to say:

> This amiable fish frequents our shores during the fall and winter months. In the latter season he runs up rivers to spawn, but he affords sport to the angler, from September to December. At this time, our wharves and docks are crowded with anglers of all sorts, sizes, and colors, and in no kind of fishing is the effect of skill and good tackle more evident * * *. I have known twelve dozen killed in one tide by one sportsman, but he was a right good one. I, myself, with one other killed seven dozen in two hours one cold morning in November.
>
> A light fly rod is the best for this sport, your line of silk or grass. Running tackle is not essential, but every true angler will use it, on account of its superior neatness and convenience. The main thing is the disposition of the hooks, which should be from four to ten in number, each hook whipped on a strong bristle, and attached to the snood (which is of gimp) by a little swivel of bone or ivory, so that it may turn freely in any direction, observing that the hook stands at right angles with the snood—this is to prevent so many hooks from entangling. A large cork float, well painted, is to be used—the best bait is the minnow—though the angle worm is used, or better still, a smelt's throat. You will have a small tin kettle, with the cover pierced with holes, for your baits, and a creel strapped to your back for your fish.
>
> Being thus appointed, you arrive on the ground at young flood, if a frosty morning so much the better; bait each of your hooks with a minnow, passing it carefully under the back fin, so as to allow him to play freely—graduate your float so as to fish at mid water, after drawing up your line and letting it sink again. When your float goes under water, give a moment's time, and then strike him with a gentle turn of the wrist, which is much more killing than the furious twitches which some delight in. In this way you may catch two or three smelts at once, and a lady might kill her dozen of fish without soiling her flounces. This, although not so exciting as killing dandies might do by way of variety.

Seventeen years later Frank Forester (Herbert, 1849, p. 175) expressed some doubt that the smelt was ever taken by hook and line. He listed the American smelt as "*Osmerus Viridescens;* Le Sueur, De Kay, Agassiz," with a recognizable cut He wrote:

> This highly-prized and delicious little fish does not properly fall within the angler's catalogue of sporting fishes, inasmuch as it is questionable, at least, whether it is ever taken with the hooks I have heard it positively asserted that it has been captured, both with the fly and with its own roe, but I consider the fact doubtful, to say no more—the fish having probably been confounded with the Atherine or Sand-smelt, a small fish commonly known in this country as Sparling, and much used as a bait fish.

Later in his discussion of the smelt, however, he says:

> It would by no means surprise me to find, that, during the time when Smelt run up our streams, they may be taken freely, either with a very small bright fly, or with morsels of shrimp or pellets of their own roe, upon a number-twelve Limerick Trout-hook, and thrown like a fly, on the surface. Should such prove to be the case, they would afford very pretty light fishing at a time when there is no other sport for the angler.

The author was evidently somewhat uninformed concerning smelt fishing, which was commonly practiced in the vicinity of Boston even in his time.

Twenty years later the commissioners of fisheries of Massachusetts, in their report for 1869, said that it had been both maintained and denied that smelts would not take the hook after they had been three or four weeks in tidal or fresh water. The commissioners suggested that the truth was very likely that "as the spawning season approaches, the gravid fish cease to feed (as among other Salmonidæ), but as there may be several successive runs, which spawn at different times, there are always fish that will bite, up to a certain season." However, nearly 50 years ago smelt angling had locally become a recognized sport, according to Genio C. Scott (1875). He wrote as follows:

As affording sport, the smelt is no mean game. Late in autumn, when ice begins to border the streams, the angler rigs a long perch-rod with a small multiplying reel, and a fine line rigged with half a dozen small trout or minnow hooks on short snells fastened to the main line, six inches apart, and baited with pieces of shrimp or bits of clam, and resorts in boat up small tidal streams, anchors and angles for them during the flood tide, when it is not uncommon to take from a fourth to half a dozen of these pearly beauties at a time, as fast as he can bait his hooks and cast them near the boat. There is nothing prettier than these gems dangling and shining at the end of the line, when they emit the odor of fresh cucumbers. On the approach of winter, anglers of all ages are seen on the bridges and along the saline streams of the coast, from Delaware Bay to the eastern boundary of Maine; and as an article of commerce, thousands are sold in New York markets, the average retail price being twenty cents a pound. The smelt is eminently the winter sport for the angler, succeeding the white perch in small tidal creeks. This fish will also take the fly when sunk to their feeding level near the bottom.

As has been seen, as early as 1868 or 1869, taking smelts by any other method than by hook and line was prohibited by law in Massachusetts, excepting in a few specified instances. Thus, either one or both of two conditions were recognized—growing scarcity of smelts or the paramount importance of the hook and line fishery, which, as has been stated, was largely that of sport-fishing, although some fished in that way for the market.

The report of the commissioners of fisheries of Massachusetts for 1875 said that smelts had been very plentiful that fall, as high as 80 dozen having been taken with a single rod in one day.

"As evidence of the popularity and attraction of smelt fishing to our eastern friends," said Forest and Stream in 1874, "it is on record that ninety-five smelters were counted on the wharf at Marblehead, Mass., at one time on Friday of last week, successfully engaged in this exciting sport."

No further reference was made to smelts in the Massachusetts commissioners' reports until that for 1880. However, in some of the intervening years notes on smelt fishing or angling appeared in Forest and Stream. In that journal, in an article entitled "Game fishes of Connecticut," the author says:

This little fish is certainly worthy of the angler's notice. It is very abundant in the eastern third of the coast and is taken around wharves and mouths of tide-water creeks.

The Massachusetts report for 1917 indicated that smelt angling about Boston was still of considerable attraction and importance. The following is extracted from the report:

This year, to ascertain the magnitude of the smelt fishery and just what value it has as an asset of the Commonwealth, an investigation was conducted which resulted in some surprising revelations. On one Sunday morning along the coast at and adjacent to Hough's Neck no less

than 2,326 persons fishing for smelt were actually counted, leaving out of consideration the number who were out during the very early morning. In notebooks which were placed at every pier and yacht club for the purpose of registration as a part of the general census, 144 persons reported their catch to be 1,095 dozens. Computed roughly, this averages more than 90 fish apiece, or 6½ pounds figured at the rate of 14 fish to the pound. Continuing on this same basis the 2,326 persons observed in the act of fishing on this morning might easily have taken about 15,119 pounds, or 7½ tons, of smelt, with an approximate value of no less than $3,023.80. But even this is not the full money value, for in addition to actual market value these fish surely must be considered as of some worth from the viewpoint of providing recreation. As a very conservative estimate let it be considered that the sporting value to the fishermen of catching these fish averaged 10 cents per hour, and each person stayed out for three hours. This gives a total of 6,978 hours with a value of $697.80 to be added to the actual market value of the fish of $3,023.80.

Writing from Quebec under date of November 21, 1903, Chambers (1903a) said:

> There is an unusual run of smelt at present in the St. Lawrence, and the small boys who can steal a few hours from school or books to fish with rod and line from the wharves on either side of the harbor of Quebec are enjoying the fun of making big scores.

Again he wrote (1893):

> The wharves are lined with fishermen of all sizes, ages and tackles. Forty rods on one barge, all catching, is not an unusual sight. Even the ladies enjoy the sport from the decks of the Quebec Yacht Squadron.

LOCALITIES

Massachusetts.—Black Rock, North Cohasset, Marblehead, Gloucester, Hull, Paddocks Island, Hingham, Weymouth, Quincy Point, Inner Brewster, Spectacle Island, Thompson Island and other places in Boston Harbor. (Forest and Stream, 1874.)

Black Rock. ("S. K. Jr.," 1876.)

Hull Bay, Neponset, Dorchester Bay, Hingham, Downer Landing, Ware River, Black Rock, Annisquam River, Ocean Spray, Apple Island Flats, Winthrop Flats, Merrimac River, Neponset River, Weymouth River. (Cutter, 1885.)

Nantasket, Weir River, Bumkins Island, Paddocks Island, Strawberry Hill, Hull, the little bight or "hook" that makes the land between Hull Yacht Club pier and the steamboat landing. (Hallock, 1893.)

Hull, Hingham, Nantasket, Downer Landing, Quincy, Dorchester Bay, South Boston Bay, Peddicks Island. (Smart, 1894.)

Dorchester Bay, around Boston. ("Hackle," 1895.)

Weir River in Hingham, Weymouth River, anchorage of the Nantasket steamers at Nantasket. ("Hackle," 1896.)

Bays and inlets along the Massachusetts coast; Cohasset. ("Special," 1899b.)

Cohasset. ("Special," 1900.)

Essex River. (Fishing Gazette, New York, March 16, 1907.)

Maine.—According to the personal recollections of the present writer, smelts were caught at the wharves in Portland, Me., in Back Bay, at the mouth of the Presumpscott, and in other places about Portland; also in Mill Creek at Falmouth Foreside, Yarmouth River, and Harraseeket or Freeport River, at South Freeport and Porters Landing. Ice fishing localities are mentioned in connection with the commercial fisheries.

Canada.—According to Chambers (1893), angling was carried on at all the watering places on the lower St. Lawrence, Muncy Bay, Caconne Riviere Ouelle, Kamoureska, Riviere du Loup, and at Quebec.

ANGLING SEASON

Massachusetts.—July 23: "Smelts are now being caught at Black Rock, North Cohasset, Mass., with hook and line and pole. The bait, shrimp, is now quite scarce. The catching of these fish, which are excellent eating, furnishes hours of sport to many eastern anglers from now [July] through the winter months." (Forest and Stream, 1874.)

October 29: "Large numbers are being caught." (Forest and Stream 1874.)

September 11: "Smelts are now plenty." ("S. K., Jr.," 1876.)

October 31: "Smelts begin to run up the harbor after food and continue to do so until the weather becomes freezing." Hull Bay is mentioned at about the best place in the vicinity of Boston during the last of October and there the fishing continues "until snow flies." Merrimac River affords good winter fishing, as also Neponset and Weymouth Rivers. (Cutter, 1895.)

"At this season they afford much sport to the Angler." (Hallock, 1893.)

October 20: "Smelt fishing has been on in the waters adjacent to this city (Boston) for some weeks." (Smart, 1894.)

November 2: "Smelt fishing around Boston is booming just now." ("Hackle," 1895.)

February 8: Weir and Weymouth Rivers are mentioned as being productive, and the principal points to which Boston fishermen go. ("Hackle," 1896.)

July 22: "The rod and line smelt fishermen are having some success in the bays and inlets along the Massachusetts Coast." ("Special," 1899b.)

July 29: Smelt fishing fair. Many dozens taken by summer boarders in the vicinity of Cohasset and Falmouth. ("Special," 1899c.)

August 15–September 1: "About July 1 you begin to get the smelt fever. About August 15 to September 1 you begin to get smelt." ("Grif," 1900.)

September 29: "Smelting along the Massachusetts bays and inlets is already good and promises soon to be better. Cool, frosty nights will increase the sport." ("Special," 1900.)

March 16: It is safe to say that the ice smelt fishery in Essex River, which was closed down Thursday last until June 1, will be an established pursuit at Essex next winter." (Fishing Gazette, New York, March 16, 1907.)

Maine.—In Portland smelts have been caught as early as September, but October and later afforded the best fishing. November was always the best month at Freeport, Me.

Canada.—In Quebec, by reference to certain specific dates, Chambers (1893) indicates a season from August at least through November. Under date of November 4, 1893, he wrote: "Here in Quebec it [smelt fishing] is now at its zenith," and again: "Good smelt fishing is to be had in August at all the watering places on the lower St. Lawrence, * * * and at Quebec from the beginning of October to late in November."

BAITS

Smelts are more or less capricious, sometimes taking one bait when they will not take some other kind, and at another time bait previously refused will be taken with avidity. Almost all fishing is done with natural baits. The following notes have been extracted from articles elsewhere quoted.

Shrimp.—"Shrimp and minnows." (Forest and Stream, 1874.) "Shrimp is in great demand; clam worms used in fishing through the ice." (Cutter, 1885.) Shrimp (Hallock, 1893). "* * * sea worm is the great bait for night fishing, while the shrimp, the best bait for day fishing, he finds almost useless for night use. Bloodworms are fair, but can not compare with the sea worm." ("Hackle," 1895.)

The bait principally used here is shrimp, which can be netted in the marshes or bought at fish stores. * * * . Sea worms are good, also; they can be found on any beach or under the rocks. Another favorite is the bloodworm, a long thick almost white worm found near the salt water. It has a large vein filled with blood running through it, and is tough and lasting. Small minnows are sometimes used, and I have found them a good bait at night for large fish. Common garden worms are also used by some. ("Grif," 1900.)

At Freeport, Me., the most commonly used bait was young killifishes (*Fundulus heteroclitus*), although occasionally shrimp (Crangon) was used. The killifishes, called "minnies," were preferred, as they lived longer in a minnow bucket and were not so easily stolen from the hooks by the smelt.

"The fish seem to take worms, beef, and pork equally well [at Quebec]." (Chambers, 1903a.)

METHODS

They "are taken in tidal currents along the coast with a light rod, hooks and line, baited with shrimp, two 6-inch snoods, with their hooks attached, being bent on to the ends of a wire spreader shaped like a letter A." (Hallock, 1893.)

Concerning the use of shrimp as bait, the same author (1893) says:

Every boat is provided with a bait car filled with sedge grass or seaweed which keeps the shrimp fresh and active. The shrimp costs $2 a quart at the market, but if one wishes, and knows how, he can net his own shrimp in the creeks with a long-handled scoop. A gill of shrimp will answer to start with, but it will take about $5 worth to stock up a bait car for an afternoon's fishing.

Then the author facetiously adds:

Hooks are put on lengthwise, the point into the tail, through the body and out at the head. Shrimp prefer it that way. By the time the novice has learned the trick most of the bait is gone. Just then the fish begin to bite sharp and he has to borrow. At the finish, after reckoning up all expenses of the outing, the boat hire, the bait, the rig, the car fares, the luncheon, and the Waukesha water, the amount of fun and fish required to balance the account is considerable.

This [shrimp] should be placed on the hook tail first, the point of the hook almost coming out through the head. Some insist on breaking off the sharp little spike on the head of the shrimp, but this I consider unnecessary. ("Grif," 1900.)

One thing I have never seen in print about this fish, yet known by every initiated brother, is the manner in which it sometimes takes the bait. This is called sucking, and many a good freshwater fisherman has been perplexed on raising his line to find the hooks skinned when he had not felt even a nibble. If you should ever get a chance to see the fish at low water (if you look close), you may see a smelt advance to the bait in a leisurely manner; about an inch from it he will stop, then opening his mouth very wide he will make no offer to touch the bait, but by suction will draw it toward and into his mouth; and all this time the mouth has never closed. And now is the time

to hook him, for if he is given a moment you will see your bare hook rejected from the still open mouth. Again, he may reject the bait after drawing it in, and the bait is often blown up on to the gut snell. ("Grif," 1900.)

In the Gulf of St. Lawrence they are often taken with small scarlet (ibis) flies while fishing for sea trout." (Hallock, 1893.)

According to Chambers (1893), in Quebec they use "a bamboo rod, piece of cord, and half a dozen small hooks, some folks put the whole half dozen on their line at once in the same manner as flies, but with a few shot for sinker, and three fish at a time is a common occurrence. Some connoisseurs use worms for bait, but the majority a bit of red meat and then a smelt cut up, which these small cannibals seem to prefer."

Some of the young fishermen string as many as a dozen hooks on their smelt lines, and it is by no means unusual to see them haul out three and four fish at a time when the conditions are favorable." (Chambers, 1903a.)

The rigs used at Freeport, Me., usually were cane poles, although sometimes a trout rod was employed; a linen line, with or without some sort of float or bob; and a wire (usually brass) spreader. The most common spreader was simply a bowed wire with a loop at the center for the attachment of the line, and a loop at each end for the attachment of snelled hooks. Occasionally a four-hook spreader was used, being formed by two bows of brass wire crossed at right angles and soldered. Even one of six hooks has been seen. These multiple spreaders were denominated "bird cages."

FISHING CONDITIONS

Smelts also like to gather around the lobster cars and under the floats at the boat houses.

When the waters commence to run out of the estuaries and inlets the smelts are on their feed. Voracity drives out caution then, and suspicious fish which have been wary until now lose all their shyness snatching the tempting bait with avidity, and without reserve. (Hallock, 1893.)

On the other hand, another writer ("Grif," 1900) wrote:

The flood tide is almost invariably the best for fishing, and in the ebb as a rule they seem to slack off, yet, like all rules, this is occasionally broken. * * *.

Forester's theory of that ferry having any effect on smelt can hardly be correct, as I have seen them caught under and over hawsers, and in places where tugs and steamers were constantly keeping the water in a turmoil. At a favorite spot for night fishing, a culvert runs under the road and the flow of water through is regulated by gates, and, until these close, and the water stops running through, you can't get a fish; yet 2 minutes after the gates close they may be biting all along the line. Whether it is because they are afraid of being drawn into the sluice or not I don't know, yet the fact is that they don't bite until then. At this place, while fish are frequently caught at night, it is, indeed, a rare thing to catch even one during the day.

At Freeport, although smelts were caught during the day, the best fishing was on cold frosty nights. Day or night, they could be caught from the first of flood tide to nearly high water, but after the beginning of ebb they did not bite as well. The best day fishing was while the water was more or less turbid, especially after a heavy rain. After the beginning of very cold weather, when the water cleared up so that the bottom could be seen at several feet of depth, no smelt could be caught, although shrimp and killifishes were still common, especially the shrimp. During

the winter, especially in the latter part of the season, fishing through ice was practiced by some.

The best time is when the tide begins to flow to about three-quarters full, and then at the finish of the ebb. (Chambers, 1893.)

CATCHES

1874.—July 23: "Large numbers are being caught." (Forest and Stream, 1874.)

1876.—September 11: "Smelts are now plenty, and as high as 40 dozen to a boat have been taken at Black Rock." ("S. K., jr.," 1876.)

1885.—"Mystic River in years past was a famous place, but in later years very few were caught there." (Cutter, 1885.)

October 31: "From 10 to 20 dozen, the average catch by an angler." (Cutter, 1885.)

1894.—October 20: "Good catches have been made in all directions." (Smart, 1894.)

1895.—November 2: "Smelt fishing around Boston is booming just now, and both the sportsmen and regular market fishermen are getting great numbers * * *. They are averaging larger this year than for seasons past, * * *. One of the best catches, as regards quantity, which I have heard about was made by two market fishermen on one day last week. In a little less than three hours' time they captured 533 fish, weighing 72¾ pounds." ("Hackle," 1895.)

1896.—February 8: A few days prior to February 8 a young man caught 40 pounds in a very short time, and "they were beauties as to size and quality. The anchorage of the Nantasket steamers at Nantasket has also provided good sport during the past week. An aquaintance took 80 pounds there on the turn of the tide a few mornings ago, and he estimates that fully 700 pounds were taken that day at this place by all the fishermen present." ("Hackle," 1896.)

1899.—July 22: One boy took several dozen each trip off Cohasset. ("Special," 1899b.)

July 29: "Smelt fishing is reported fair at several points along the south shore. In the vicinity of Cohasset and Falmouth many dozens are being taken by the summer boarders. * * *. Smelt fishing continues to improve. The boys are getting a good many dozen off the 'Punkins' and at other points near Falmouth." ("Special," 1899c.)

1900.—February 24: "Bucky Holmes and I have caught as high as 50 dozen in a day, using two rods each; another day three of us caught 70 dozen, and I have known market fishermen to go about a hundred dozen in a day." ("Grif," 1900.)

At Freeport, in the old days, several dozen smelts taken by one fishermen in a few hours were not an uncommon catch. In later years smelts appeared to be scarcer, and where the present writer used to fish as a boy, now no one fishes. In recent years he tried the fishing occasionally, but has caught none since 1893. On November 8, 1893, he caught 9 smelts, 6 to 7½ inches long. On November 9 he caught 17, and on the 10th 7 smelts, using "minnies" for bait.

FRESH-WATER SMELTS

Throughout the geographical range of the smelt there are localities where they are permanently fresh-water residents. They are so-called "landlocked" or fresh-water smelt. It has been assumed that in times long past some smelts remained in fresh-water lakes and formed fresh-water races and perhaps species.

Bloch (1796) recognized two kinds of smelts in Germany, one of which was marine and the other a fresh-water form. According to him, the fresh-water smelts occur in many lakes that have sandy bottoms, and they are rarely taken except when especially searched for in those places.

Reuter (1883), who does not distinguish between salt and fresh-water smelt, says that in Finland the smelt is distributed over the whole country, as far north as 68°.

Goode (1884) says that the smelt is found landlocked in cool lakes, especially those of Norway, and also in many of the lakes of northern Germany, and even as far south as Bavaria.

Fresh-water smelts are mentioned by Pallas (1811) in certain lakes of Germany and Russia; Lake Pskov. In Great Britain Regan (1911) cited Rostherne Mere in Cheshire as inhabited by the fresh-water form. Smitt (1893) does not distinguish the Swedish fresh-water form as specifically distinct from the salt-water form. Jordan (1878) wrote:

> In regard to the American smelt, there are several landlocked forms in the waters of Maine which have been described as species, but which are probably local races.

However, only two fresh-water forms of Maine smelts have been described and named as distinct species, and these by Cope in 1877, one from Wilton Pond and the other from "Cobossicontic" (Cobosseecontee) Lake, in Kennebec County, in southwest Maine. He stated that Wilton Pond is near the head of the southwest branch of the Kennebec River in southwest Maine.

Cope also remarked that landlocked Osmeri occur in the lakes of Norway, and according to Professor Esmark, of Christiania (Oslo), they are found in Lake Mjosen, which is 500 feet above the sea and discharges into a stream that has a very high fall; also in Nors Vandsjo, near the town of Moss, and in the Stinksild.

In Canada, Halkett (1913) records a fresh-water smelt, under the name of *Osmerus mordax* Mitchill, from Lac des Isles, Gatineau District, some 60 miles north of Ottawa. In a footnote (on p. 55) he says:

> It is known that this species of fish exists land-locked in fresh water lakes in New Brunswick, Nova Scotia, and in the State of Maine, but its occurrence in a lake so far away from the sea as Lac des Isles, is perhaps worthy of mention.

In a letter Dr. Philip Cox, of the University of New Brunswick, informed the present writer that a diminutive fresh-water smelt occurs in Lake Utopia.

That smelts occur in tributary waters of the St. Lawrence is indicated by Chambers (1903), who stated that they were landlocked in some Canadian lakes as well as in the United States, mentioning particularly Lakes St. John and Memphremagog.

For many years it was known to occur in Lake Champlain. Thompson (1842), who did not realize that it was a permanent inhabitant of Lake Champlain, said that it occasionally made its appearance there and was caught in considerable numbers.

In waters wholly in the North Atlantic States fresh-water smelts are found naturally only in New England, and there, so far as is positively known, only in New Hampshire and Maine, although according to the following report they occur in ponds on Cape Cod. Concerning these fish, however, there may be some doubt about their having been naturally landlocked. Forest and Stream for April 18, 1889 (p. 259), contained the following account:

Landlocked smelt.—From Cape Cod, Mass., we have received some specimens of a fish known there as a fresh-water smelt. The examples are about 5 in. long, and represent the average size of the adult fish. The species is found in two or three large, perfectly landlocked ponds, which have no visible outlet and are remote from salt water. We are informed that no stream ever has connected these ponds with the ocean. The fish are never seen except for a few nights during the first week in April, when they come to the shore to spawn. They can then readily be taken with dip nets or landing nets. Under proper conditions bushels of them can be taken in a single night. Few persons know of their existence; unless the ponds are visited at just the right time and with a light the fish cannot be seen. This smelt is a very delicate and toothsome little species having the flavor of a salt-water fish. The ponds contain perch and pickerel. What a paradise these waters would be for the black bass. Landlocked smelt are now pretty widely distributed, being recorded from numerous lakes and ponds in Maine and New Hampshire, and forming one of the best of the natural foods introduced by the fishculturists into waters stocked with the larger *Salmonidæ*. The only changes that we can observe as the result of landlocking are a reduction in size and in the strength of the teeth. The specimens obtained were caught on the night of April 3, and appeared to be spent females. Sea smelt spawn in March and April.

In New Hampshire it appears that the smelt occurs indigenously in Winnepesaukee and Squam Lakes. In Maine, however, it is widely distributed in coastwise lakes and ponds, some of which are a considerable distance inland. The principal river basins all comprise some smelt waters. Foster and Atkins (1868) say:

Smelts are scattered all over the State. It seems probable that we have more than one species. Whether either of them is identical with the salt water smelt we cannot say, but the resemblance is very close.

NAMES

The fresh-water smelt appears seldom to have any distinctive name given to it. In Sweden it seems that large smelts are known as "slom" and smaller fish as "nors." Bloch (1796) wrote:

The fish is known by different names. They call it Stint in Germany; kleiner Stint, löffestint, kurzer Stint, and Stintites, in Livonia; jern Lodder and send Lodder in Lappland; nors in Sweden; spiering, in Holland; smelt in England and Denmark; lodde, rogn-sild-lodde, röpe, kröckle, in Norway; sjiro iwo, in Japan; and eperlan d'eau d'ouce in France.

Wherever it occurs in Canada it appears to be known to the English-speaking inhabitants as smelt, whenever it is recognized at all. Locally in Lake Champlain it is the "ice fish." W. M. A. Cowen, of Ticonderoga, N. Y., said (1900):

Formerly a resident of Essex-on-Lake Champlain, I have caught several thousand smelts, but never one ice fish (according to local name). * * * . Ice fishing, I think, is father to the name of ice fish, although I have frequently caught yellow perch and bluefish from the same hole.

SIZE OF FRESH-WATER SMELTS IN VARIOUS WATERS

Bloch (1796) stated that the fresh-water smelt is only 3 or 4 inches long. Reuter (1883) indicates the mature fresh-water smelt of Finland vary in size from 1½ or 2

inches to 10 inches in length. Smitt (1893) says that in the largest Swedish lake, Wener, the fish frequently attains a length of a foot to the extreme tip of the caudal fin, but in a footnote he says that Jernow (Vermlands och Dals Ryggradsdjur, p. 108) ascribes a length of nearly 15¾ inches. In Lake Malar, Smitt remarks, it frequently attains a fair size, something over 10½ inches, but in the smaller lakes it seldom exceeds a length of from 4 to 7⅘ inches.

Nordqvist (1910) indicates that 3-year-old smelts obtained by him in one lake were 94 to 112 millimeters (about 3$\frac{7}{10}$ to 4⅖ inches) long, but that occasionally larger fish were caught. In a neighboring lake the fish were somewhat larger.

Of the Lake St. John smelt (in Canada) Chambers (1903) wrote that they "present a beggarly, half-starved appearance as compared with the St. Lawrence fish. They more nearly approximate to the smelt found by Cope in Wilton Pond, Kennebec county, Maine, and described by him as *Osmerus spectrum* in 1870."

Halkett (1913) stated that the Lac des Isles smelts are dwarfed but otherwise the external characters appear to agree with the ordinary *Osmerus mordax*. Cox wrote the presesnt writer that the smelts of Lake Utopia, New Brunswick, are diminutive.

Smelts from Memphremagog Lake, as represented by specimens in the collection of the present writer, range from 6½ to 7$\frac{5}{16}$ inches, and average about 6.9 inches. In a collection from Lake Champlain 79 specimens taken in 1911 ranged from 5.4 to 11.2 inches and averaged a little over 7.1 inches, but much larger ones have been reported.

At a meeting of the Boston Society of Natural History in 1857, Dr. H. R. Storer presented specimens of smelt from Squam Lake, N. H. He said that when full grown this smelt seldom exceeded 6 inches in length, and was extremely attenuated.

The report of the New Hampshire commissioners on fisheries for 1870 stated that smelt occurred in Lake "Winnipiseogee" and several ponds in the vicinity, those in the smaller ponds, "contrary to the usual course of things, being much larger than those in the lake." It was said that the largest measured only 6 or 7 inches in length, and those in the lake itself were seldom found to be over 4 inches long.

The present writer has specimens from lake Winnepesaukee, 32 of which range from 2.7 inches to a little over 4 inches, and averaged about 3⅓ inches in total length; also 71 specimens from Lake Massabesic, N. H., run from about 4 to nearly 5⅜ inches, and average about 4.6 inches.

The more extensive available data concerning Maine smelts makes it desirable to refer to the particular waters represented by river basins.

PRESUMPSCOT BASIN

Sebago Lake.—May 1, 1878, Atkins received from J. R. Dillingham, of Songo Lock, a box of 36 smelts, all spent. Seven were large and ran in size as follows: One of 9.6 inches weighed 4 ounces; one of 9.4 inches weighed 4.4 ounces and another of the same length weighed 3.2 ounces; one of 9.2 inches weighed 4 ounces and another of the same length weighed 3.6 ounces; one of 8.6 inches weighed 3.2 ounces. They averaged 9.2 inches and 3.7 ounces. Twenty-nine of the smaller form ranged from 3.9 to 4.3 inches and averaged 4.1 inches.

In 1898 the late Frank Meserve, resident near and well informed concerning the lake, stated that the large smelts attained a length of 1 foot, and three of them had been known to weigh a pound. In 1907 George Moses, a well known guide of the region, fishing through the ice, caught a dozen smelts ranging from 12 to 14 inches in total length, and reported one that weighed 1¼ pounds.

A collection of 566 smelts made by the present writer during the summer and fall with hook and line ranged in total length from 6 5/16 to 15¾ inches. A collection of 102 specimens of the small form, in breeding condition, taken in the Songo River in the spring of 1901, measured in total length from 4⅛ to 5.9 inches and averaged 4¾ inches.

Panther Pond.—April 17, 1910, 64 smelts ranging from 3⅓ to 4¼ inches and averaging nearly 3.9 inches in total length were taken from a tributary brook where they were spawning.

Long Lake.—According to Foster and Atkins (1868) the smelt of this lake had been reported to exceed half a pound in weight.

Mead (1883) stated that they ranged from 8 to 13 inches in length and would average 6½ ounces in weight. He said that a lot of 19 specimens averaged 6⅓ ounces each. The largest of the lot measured 11½ inches in length and weighed 7 ounces.

ANDROSCOGGIN BASIN

Lake Auburn.—A young man from Auburn informed the present writer that the smelts of Lake Auburn ran about 2½ to 3 inches, never exceeding the latter size.

Taylor Pond.—According to the same informant the smelt of this pond are only about 2½ inches long when in breeding condition. To clean them for cooking the preparator merely pinches off the heads or snips them off with a pair of scissors.

Sebattus Pond.—The smelt of Sebattus Pond were stated by Atkins, in a note dated May 8, 1868, to be abundant but of small size. Two specimens measured by the present writer in May, 1898, were 3 3/16 inches and 3⅜ inches long, respectively.

KENNEBEC BASIN

Wilton Pond.—Atkins received 60 specimens from Wilton Pond on May 1, 1868, which he said were mature but so small that he at first thought they were young fish.

One of the specimens from this pond, which in 1870 Cope made the type of his new species *Osmerus spectrum*, was said to be a medium-sized example, measuring 3½ inches in length, in breeding condition.

A collection of smelts from this pond, sent to the present writer by the late H. O. Stanley a number of years ago when he was one of the commissioners of inland fisheries and game of Maine, ranged in total length from 2½ to 3 9/16 inches and averaged 3 inches in total length. With them, however, was one specimen 5⅞ inches long. These were all in breeding condition, and the small fish were translucent, but the larger fish was darker and more like the ordinary fresh-water smelt of moderate size.

Great Pond.—In 1875 the largest smelts taken by Atkins in Tilson or Palmer Brook, North Belgrade, were two females, each of which was 12 inches long. On

the night of April 21, 1875, in the same brook, about 250 were caught, 36 of which weighed 13½ pounds, an average of 6 ounces each. The largest female was 12 inches long and weighed one-half pound. The majority of the females were from 11 to 12 inches long and the males from 10 to 11 inches, but some of the females were less than 11 inches. The present writer has seen but two smelts from Great Pond, one of each sex, each measuring about 10⅔ inches in total length.

In a letter to the present writer dated January 22, 1908, Atkins stated that the smelts found at North Belgrade were the largest that he had ever seen—some 15 inches long and weighing two-thirds of a pound each.

Mount Vernon Pond.—Eight smelts from a pound in Mount Vernon, examined by the present writer, ranged in total length from $3\frac{3}{10}$ to a little over 5 inches, and averaged 4⅖ inches.

Snow Pond.—On March 20, 1906, Prof. Wm. L. Powers, in a letter to the present writer, said:

> I have found that very large smelts are taken from a brook that flows into Snow Pond on the day that the ice leaves the pond. * * *. A man in Augusta telephoned me that he saw some weighed that came from there, and the combined weight was 6 pounds. * * *. The four fish were sent to Boston and exhibited in the market.

Messalonskee Lake.—A female smelt taken by Atkins from a stream flowing into this lake measured 12 inches in length, and one taken from Morrisons Brook on April 20, 1869, was 14⅞ inches long.

Cold Stream Pond.—Under date of April 3, 1878 (in his notes), Atkins mentioned that a Mr. Stillwell brought some smelts from this pond, the largest of which were 7 and nearly 7⅖ inches long and weighed over 1½ ounces each.

Cochnewagn Pond.—Smelts caught here by Atkins, April 30, 1878, he divided into four classes—(*a*) 12 males and 1 female 6.7 to 6.8 inches long; (*b*) 6 males and 2 females 5.1 to 5.7 inches long; (*c*) 8 males and 5 females 4.75 to 5.1 inches long; and (*d*) 12 males and 5 females nearly 3 to nearly 4 inches long.

Cobbosseecontee Lake.—Sixty-one smelts obtained by the present writer ranged in total length from 3.6 to 5.2 inches and averaged about 4.4 inches. Cope had five specimens upon which he based his new species *Osmerus abbottii*, which he said measured about 4 inches in breeding condition.

China Lake.—Smelts of China Lake are said to be remarkably large; some of them are said to weigh over 1 pound. The present writer has seen no examples from this lake.

GOOSE RIVER BASIN

Swan Lake.—Two specimens from this lake were received from E. D. Merrill in 1899, taken with a hook and line. They measured, respectively, 10½ and 6½ inches in total length. According to Merrill, smelts in this pond attain a weight of a pound.

PENOBSCOT BASIN

Sebec Lake.—According to B. M. Packard, proprietor of camps on Sebec Lake in 1900, the smelts of this lake were very abundant and of two adult sizes—the larger 8 to 14 inches and the smaller 4 to 5 inches in length.

Toddy Pond.—April 17, 1878, Atkins said that he was informed that the smelts that ascend Sucker Brook from Toddy Pond were about 4 inches long. A collection of 48 specimens examined by the present writer ranged in total length from 2⅞ to 4⅞ inches and averaged 4.1 inches.

Heart Pond.—In the present writer's collection are 11 specimens from this pond, which range in total length from 3⅜ to 4 inches and average nearly 3⅞ inches.

UNION RIVER BASIN

Green Lake.—One hundred and fifty smelts were received by Atkins on April 19, 1878, from Reeds Pond, as the lake was then called, of which eight averaged nearly 4.7 inches in total length. He said that the general average would be very little above this, for examples of about 4.9 inches occurred.

A collection made on April 20, 1906, examined by the present writer, consisted of 36 specimens, and another made on May 7, contained the same number, making 72 in all, which ranged in total length from 3⅜ to 4 1/16 inches and averaged about 3.5 inches and 3⅔ inches in each lot, respectively. This collection comprised the small form only. A collection of eight individuals taken on March 28 of the same year ranged from 5¼ to 6⅛ inches and averaged 5.7 inches.

ST. CROIX BASIN

Grand Lake.—Atkins (in 1879) wrote: "The smelts are among the most diminutive of this genus, averaging in length but little more than two inches." The present writer made a large collection of these little smelts in the salmon traps of the United States hatchery at Grand Lake Stream; they ranged from 2.1 to 2⅔ inches and averaged about 2⅓ inches in length. They were translucent but mature fish, as indicated by the presence of well-developed eggs. Among these fish were two specimens of a larger form about 3⅕ and nearly 4 inches long.

Location and size of smelt and authorities for same

Locality	Size	Authority
Germany	4 inches	Bloch, 1796.
Finland	1½ or 2 to 10 inches	Reuter, 1883.
Finland	3 7/16 to 4⅛ inches	Nordqvist, 1910.
Lake Wener, Sweden	12 inches	Smitt, 1895.
Do	15¾ inches	Jernow.
Lake Maler, Sweden	10½ inches	Smitt, 1895.
Smaller lakes in Sweden	4 to 7 or 8 inches	Do.
Lake St. John, Canada	Similar to Wilton Pond, Me	Chambers, 1903.
Lac des Isles, Canada	Dwarfed	Halkett, 1913.
Lake Utopia, New Brunswick	Diminutive	Cox.
Lake Memphremagog	About 6 to 7½ inches	Kendall (notes, 1913).
Lake Champlain	6 to 12 or 13 inches	"Heathcote" 1895.
Do	15 inches; 3 to a pound	Cheney, 1895.
Do	14 to 16 ounces	Cowen, 1900.
Lake Champlain (Port Henry)	1¼ pounds	S. F. Lane.
Do	6 1/16 to 10¾ inches	Kendall (notes, 1911).
Lake Champlain (Presberry Point)	13 inches	Do.
Lake Champlain, N. Y	15 and 18 inches	Cobb.
Lake Champlain, Vt	Average, 7 inches	Do.
Sqam Lake, N. H	4 inches	Storer, 1857.
Lake Winnepesaukee, N. H	6 inches	Do.
Do	2 7/16 to 4 inches, average 4 7/16 inches	Kendall (notes).
Lake Massabessic, N. H	Small form, 4 to 5⅝ inches; average 4⅝ inches	Do.
Sebago Lake, Me	9¼ to 9⅝ inches	Atkins, 1868.
Do	Small form, 3 5/16 to 4 7/16 inches	Do.
Do	12 inches; average ½ pound	Meserve (in 1898).
Do	Large form, 6 1/16 to 15¾ inches	Kendall (notes).

Location and size of smelt and authorities for same—Continued

Locality	Size	Authority
Sebago Lake, Me	Small form, 4½ to 5⅝ inches	Kendall (notes).
Panther Pond, Me	Small form, 3½ to 4¼ inches	Do.
Long Lake, Me	Over ½ pound	Foster and Atkins, 1868.
Do	13 inches to 6½ ounces	Mead, 1883.
Lake Auburn, Me	2½ to 3 inches	Merrill.
Taylor Pond, Me	2½ inches	Atkins, 1868.
Sebattus Pond, Me	Small	Kendall (notes, 1898).
Do	3⅝ and 3⅞ inches	Atkins, 1868.
Wilton Pond, Me	Very small	Cope, 1877.
Do	3½ inches	Kendall (notes).
Do	2½ to 3½ inches	Powers (letter, 1906).
Snow Pond, Me	4 fish averaged 1½ pounds each	Atkins (notes, 1875).
Great Pond, North Belgrade, Me	10 to 12 inches	Kendall (notes).
Do	10¾ inches	Do.
Mount Vernon Pond, Me	3⅞ to 5 inches	Atkins, 1869.
Messalonskee Lake, Me	12 and 14⅞ inches	Atkins (notes, 1878).
Cold Stream Pond, Me	7 to 7⅞ inches	Do.
Cochnewagn Pond, Me	3 to 6⅝ inches	Cope, 1877.
Cobbosseecontee Lake, Me	4 inches	Kendall (notes).
Do	3⅜ to 5¼ inches	Kendall (notes, 1899).
Swan Lake, Me	6½ and 10½ inches	Pope (in 1923).
China Lake, Me	Very large	Packard (in 1900).
Sebec Lake, Me	8 to 14 and 4 to 5 inches	Atkins (notes, 1878).
Toddy Pond, Me	4 inches	Kendall (notes).
Do	2⅞ to 4⅛ inches	Do.
Heart Pond, Me	3⅜ to 4 inches	Atkins (notes, 1878).
Green Lake, Me	4⅞ inches	Kendall (notes, 1906).
Do	3⅜ to 4⅞ inches, small form	Do.
Do	5¼ to 6½ inches, large form	Atkins (notes, 1879).
Grand Lake, Me	2 inches	Kendall (notes).
Do	Small; 3½ to 4 inches	

Creaser (1925) ascertained that at 7¾ inches the smelt of Crystal Lake, Mich., weighs 1.5 ounces, and states that this is about the average 2-year-old size. Three-year-old fish weighed from 2 ounces, when 8¼ inches long, to 3 ounces, when 9½ inches long. Those of larger size, about 11 inches, weigh about 5 ounces.

SIZE CLASSES

Whether there be one or more species of fresh-water smelts in some New England lakes and in Lake Champlain or not, there are two distinct sizes of smelts in each, which in the spring ascend affluents to spawn, the time varying considerably in the different lakes. There is also a difference in the spawning time of the two sizes, perhaps a month between the height of the season of one to the height of the season of the other, of which fact Sebago and Green Lakes in Maine are examples. The two sizes are usually denominated, respectively, "large smelt" and "small smelt."

The two categories of smelts of some lakes are greatly different in size from those of other lakes. Sebago Lake, for example, has large smelt ranging from about 10 to 15 inches or more in length and up to a pound or so in weight, and small smelt not exceeding about 6 inches, with an average length of not over 4 or 5 inches. In Grand Lake, of the western St. Croix system, the large smelt does not exceed 4 or 5 inches in length and the small ones not much over 2 inches. The latter, even so small and transparent, are adult fish bearing eggs and milt.

The above two examples represent the extremes of variation, but there are other waters where the large and small smelts are relatively not as large and small. Some other lakes apparently contain only one class of smelt, either the large or the small race, as the case may be. Wherever the two categories occur they have long been recognized and are usually regarded as distinct.

Mead (1883) wrote:

About all the streams emptying into Long Pond and Sebago Lake are visited every spring by large numbers of smelts. Of these we have two kinds or varieties, known locally as the "large" or "big smelt" and the "little smelt." The point of difference, so far as common observation goes, is in the size and a slight variation in the time of coming to the brooks to spawn.

Concerning these two sizes J. G. Rich (1883) asks: "Are they both alike? Will the small fellow grow to be like the first run, and come up first next year?"

Mead again wrote (North Bridgton, 1885):

It would be a work for the scientists to fully explain the different varieties of smelts and their habits. That they belong to the salmon family all agree, but in this particular locality [Maine] there are three different varieties, commonly called the big, salt-water, and little smelts. The salt-water smelts, *Osmerus viridescens*, are common in all the rivers, creeks and streams along our coast. They are said to bear transferring well, even into waters entirely land-locked and fresh, but always with a diminution in size. The big smelts are like the salt-water variety in some respects, but are larger and darker colored. They are over ten inches in length, and average nearly a quarter of a pound in weight. Many occur much larger than this, and one was weighed here a few years ago that was caught through the ice with hook and line, and turned the scales at eleven ounces. A few are mentioned even larger, but they are rare, to say the least. The little smelts are but miniature representatives of their larger relations, weighing less than half an ounce each. Some have thought that these little fellows are only the young of the larger variety, but this can hardly be true, as they seem to be fully developed and are ready to spawn as they ascend the streams to their breeding grounds. They do not run up the streams until about a week later than the larger ones, and are much more abundant. They are also found in many localities where the big smelts do not occur. They vary somewhat in size, in different places, and are said to be larger in Norway Lake, only twelve miles away, than they are here. In the last mentioned lake no big smelts are found.

On April 28, 1911, Wilfred Rivers, a fisherman of Phillipsburg, Quebec, on Missisquoi Bay, Lake Champlain, told the present writer that they sometimes got a few small smelts, not over 3 or 4 inches long, and that they had spawn in them. These small smelts, he said, were sometimes entangled in the nets or mixed with larger fish when fishing through the ice with seines. No hook-and-line fishing for smelts or "ice fish" was done for the market in this region.

It has been suggested that if one or the other of the two sizes were to be transplanted the result might indicate the relationship of the two forms; for if the small smelt developed into large smelt or large and small smelts, or if large smelts when transplanted should develop into small smelts only, or into both categories, it would show that the two were merely different groups, probably age or year classes of the same species.

An instance of what are apparently two races or distinct sizes of transplanted smelts is that of the Rangeley Lakes in Maine. Small smelts of 4 or 5 inches are very numerous, but large ones, up to 10 inches at least, have been caught. According to the late Arthur Oakes, of Rangeley, the large smelts are restricted to Mooselucmaguntic Lake, while only small smelts occur in Oquossoc. This fact at first seemed to indicate that small smelts would grow large when placed in favorable waters, for the first smelts planted in those waters were from Weld Pond, where the fish, as has been shown, are very small. However, it subsequently developed that

smelts were later introduced from Swan Lake, where a large "race" or "size" exists. The latter were planted in Mooselucmaguntic.

Again, there is Square Lake, in Aroostoko County, where no small "race" or "size" has manifested itself as adult breeding fish, but smelts up to 10 inches or more are common. These smelts were derived from Swan Lake stock, according to L. T. Carleton, formerly commissioner of inland fisheries and game.

Still again, Sunapee Lake, in New Hampshire, affords an example of waters stocked with smelts that seldom, if ever, attain a large size. At least there are no breeding runs of large smelts. The source of the smelt eggs planted in Sunapee Lake is not definitely known, but probably they were either from Squam or Winnepesaukee Lake. The majority of the smelts now taken in Sunapee Lake are small, running about the size given for smelts of Winnepesaukee Lake; but even these little smelts are caught on baited hook in deep water and have been known, as elsewhere stated, to do likewise after spawning while still remaining in the brook. Nothing of this sort is known of the small smelt of Sebago Lake, which appear to subsist exclusively upon plankton; so if these fish originated in Squam Lake they have degenerated in size. That such is the case is indicated by a note in Forest and Stream of October 23, 1890, under the title of "Sunapee Lake Fishing," which says:

> The smelt which was introduced more than 20 years ago occasionally reaches 10 inches in length. It is extremely abundant, and is often washed up on the eastern shore of Sunapee by strong winds.

On the other hand, Cheney (1896c, p. 429) wrote that in November, 1896, while walking on the beach of Sunapee Lake, N. H., with Commissoner Wentworth, they picked up a number of smelts thrown up on the sands by the high winds and water. These were of two sizes, one from 1¾ to 2 inches long and the other 3 to 3½ inches long. They regarded the smaller size to be of the previous spring's hatching, while the larger ones were supposed to be adults that, had they lived, would have spawned the following year.

Still further evidence in this direction is that only the "large" form of Green Lake smelt was introduced into Crystal Lake, Mich., for the reason it was the large form only that was propagated at that station at that time. Creaser (1925) indicates that there was a spawning run of large fish only at Crystal Lake. The smallest smelts secured, which were 2-year-old fish, were 6½ inches in total length. Older fish had attained a length of 12 inches.

The forgoing are rather insufficient data upon which to generalize, but they suggest that in some waters there are "races" that do not attain a large size under any circumstances, and that the large race sometimes decreases in size so as to appear like the small race; but in such instances the habits are like those of the large race.

HABITS OF FRESH-WATER SMELTS

FOOD AND FEEDING

It has been stated that the food of the fresh-water smelt varies according to the size of the fish, and it may be added, according to its age. The character and arrangement of its teeth indicate its carnivorous propensities, while its comparatively

close-set gill rakers suggest rather minute planktonic food, at least at certain stages of its growth.

Concerning the fresh-water smelt of Germany, Bloch (1796) said that they live on worms and small mollusks. Reuter (1883) says that in Finland the food of the smelt consists of fish fry, worms, larvæ, fish roe, and young water cockles, and it does not even spare its own kindred, but gormandizes unmercifully on the smaller specimens, especially when it has returned to the lakes after spawning. Mead (1883) said:

> As to the food of the smelt I am not informed. That the larger kind sometimes feeds on the smaller, I have recently learned from a neighbor who found one in the stomach of a smelt that he was preparing for the table.

Nordqvist (1910) states that according to A. Luther, in Lake Lojo, in South Finland, the smelt subsist chiefly upon Corethra larvæ, and that I. Kutschin found smelts in Lake Ilmen and Wolko River (in Russia) 10.2 and 11.9 centimeters (about 4 and 4⅗ inches) long had been feeding exclusively upon little smelts; and that the stomachs of little smelts 3 to 6 centimeters (about 1⅕ to 2⅜ inches) long contained principally Cyclops, Diaptomus, Hyalodaphnja, *Bosmina lacustris*, *B. coregoni*, and some other Cladocera.

B. Heynermann is also mentioned as having smelts 9.5 to 14 centimeters (about 3¾ to 5½ inches), caught in Lake Wigry in Russia, which had eaten Entomostraca (*Bosmina gibbera*, *B. longirostris*, *B. cornuta*), Cyclops, Diaptomus, Hyalodaphnia Diaphasoma, and Bythotrychus. One smelt had swallowed Leptodora. Larval and young smelts up to about 7 centimeters (about 2¾ inches) were said to live principally upon Entomostraca.

The fact is that no one has made a special study of the stomach contents of the smelt. Anglers know what it will take as bait, at least on occasion, and perhaps some of those who have dressed smelt for the table or cut them up for bait occasionally have had their attention attracted to the stomach contents, but there are no published records. Examination of the stomach contents of the small smelt of Sebago Lake indicates that it subsists almost or quite exclusively upon Entomostraca, and, as shown later, the large smelt varies its diet but little from that of both "small" and young smelts.

It has been impossible to learn much concerning the food of smelts from other waters in New England by examination of specimens in hand, because the majority of them were taken in the breeding season in the brooks, when they virtually cease to feed.

The small smelts of Sebago Lake apparently never take a baited hook; but smelts of similar sizes, even the smallest of adults, in Sunapee Lake, N. H., are caught in that way. This fact suggested that adult smelts there, although small, did not feed exclusively upon such minute objects as did those of Sebago Lake, but fish ranging from a little over 1 inch to a little over 5 inches in length, taken in Sunapee Lake, were found to subsist largely upon Entomostraca, although some insects, a few crustaceans, and a few smelt eggs were found in the stomachs of some of those examined. Young smelts, like many other young fishes, subsist upon the minute floating animal life known to the scientific man as plankton, which in fresh water consists mostly

of minute crustaceans. Prof. A. A. Doolittle, of the Central High School in Washington, D. C., examined some smelts for the writer, and the following notes are taken from his report:

Concerning the food of the smelts of Sebago Lake he wrote that all were collected in the summer and fall, from July 15 to September 20, over a period of 6 years (1906 to 1911). Specimens of all sizes from about 7/8 inch to over 14 inches in length were examined. After passing above the 6-inch mark the food seems to change from an entomostracan diet to one of fish, usually small smelts. The number of Entomostraca found in fish under 6 inches in length varies greatly, but will average for the various lengths about 20 1/3 to each one-tenth of an inch of length. Many smelts far exceed this limit, a specimen about 5 1/8 inches long having in its alimentary tract 2,100 Entomostraca, or about 400 to each one-tenth of an inch of length.

For the small smelts Cyclops and Daphnia are the prevailing genera of Entomostraca entering into the food. For the larger forms there are added many more robust genera, viz, Epeschura and Lida.

Detailed table showing stomach contents of smelt from Sebago Lake

Date	Length in inches	Stomach contents and remarks
May 30, 1916	4 1/8	Insect remains.
June 25, 1907		Smelt about 1 7/8 inches long. This 1 only, of 5 smelts, contained food.
June 25, 1910	13 1/8	Smelt, 4 3/4 inches long.
Do	12 1/8	Backbone of small fish, probably smelt.
Do	12	Smelt, 4 1/2 inches long.
June 27, 1910	11 1/2	Partly digested smelt.
Do	11 3/8	Backbone of small fish.
Do	11	Smelt, 4 1/8 inches long.
Do	10 5/8	Bait.
Do	9 3/4	Portion of insect.
July 6, 1909	11 1/4	Backbone of small fish.
Do	9 3/4	Piece of smelt 2 3/4 inches long.
Do	9 1/2	Almost digested young smelt.
Do	9 1/2	Backbone of smelt, 3 1/8 inches long.
Do	9	Partly digested small smelt.
Do	9	Smelt, 4 1/8 inches long.
July 21, 1910	9	Piece of fish.
Do	8 1/2	Small fishbones.
Do	9 7/8	Nearly digested smelt.
Do	12 1/8	Partly digested smelt.
Do	12 1/2	Nearly digested fish.
Do	11 5/8	Partly digested smelt.
Do	10 3/4	Nearly digested fish.
Do	10 7/8	Do.
Do	10	2 small smelts, partly digested, largest 3 3/4 inches long.
July 22, 1910	8 3/4	Partly digested young smelt, 1 1/4 inches long.
July 23, 1908		Caught on 2. 0 salmon hook; bait, chub, 4 inches long. Insect and crustaceans.
July 24, 1910	8 1/2	Backbone of small fish.
July 25, 1906	9 1/8	Partly digested smelt; may have been about 3 1/2 inches long.
Do	9 1/8	Pieces of backbone of small fish, probably smelt.
July 27, 1910	10 1/8	Partly digested smelt.
Do	11 1/4	Do.
Do	10 3/8	Do.
Do	12 3/4	Do.
July 28, 1909	9 1/8	Partly digested young smelt.
Do	9	Fragments of nearly digested smelt, 2 1/8 inches long.
Do	13	Bone of small smelt.
July 29, 1907	7 3/8	Bait, young suckers.
Do	12 5/8	Mass of mucus and vegetable matter.
Do	11 3/4	1 Mysis (?).
Do	11 3/4	Small amount of unrecognizable material.
Do	13 1/4	2 gravel stones and vertebræ of small fish (smelt ?).
Do	10 1/8	2 may-fly larvæ and some Entomostraca.
July 30, 1903		1 young smelt; only 1 out of 24 smelts from to 8 1/4 11 1/8 inches long contained any food.
July 30, 1909	9 1/4	Bones of small smelt.
Do	10 1/2	Partly digested smelt, 4 1/8 inches long.
Do	13 1/4	Partly digested smelt, 4 1/8 inches long.
Do	12 1/2	Partly digested smelt, 4 1/8 inches long.
Do	10 3/4	Partly digested smelt, 4 1/8 inches long.
Do	10 1/4	Partly digested smelt, 3 7/8 inches long.

Detailed table showing stomach contents of smelt from Sebago Lake—Continued

Date	Length in inches	Stomach contents and remarks
July 31, 1909	13	Smelt, 4 1/4 inches long.
Do	10	Nearly digested smelt, between 4 and 5 inches long.
Aug. 1, 1906	13 1/4	2 gravel stones and bones of smelt.
Do	11 3/8	2 May-fly nymphs and some Entomostraca.
Do	8 3/4	Some Entomostraca (Cyclops and Daphnia).
Aug. 1, 1910	11 1/8	Nearly digested smelt.
Do	12 1/2	Partly digested smelt.
Do	11 3/8	Nearly digested smelt.
Do	10 1/16	Backbone, 3 inches long, of partly digested fish.
Aug. 3, 1908	10	Partly digested smelt, 3 1/16 inches long.
Do	9 3/4	Partly digested smelt.
Do	13 1/8	Partly digested smelt at least 4 1/2 inches long. Intestine full of vertebræ of smelt and some Entomostraca, which may have been from ingested smelt.
Do	13	Smelt, 4 1/16 inches long.
Aug. 5, 1909	8 3/4	Nearly digested smelt.
Do	9 1/2	Smelt, 4 1/8 inches long.
Aug. 6, 1909	9 3/8	Young smelts.
Aug. 7, 1908	10 1/4	Apparently fragments of amphipod.
Do	12 3/8	Partly digested smelt about 4 1/8 inches long.
Aug. 7, 1909	7 3/4	Young smelts.
Do	6 7/8	?
Do	6 7/8	?
Aug. 8, 1909	8 5/16	Small aquatic larvæ of insects and nearly digested small fish.
Aug. 8, 1908	12	Nearly digested young smelt.
Do	13 3/4	1 smelt, 4 1/8 inches long.
Aug. 9, 1907	10 1/2	Backbone of young smelt.
Do	9 1/8	Nearly digested small fish.
Aug. 9, 1910	11 3/4	Small insect.
Do	12 5/8	Partly digested smelt, 4 5/8 inches long.
Do	10 3/4	Partly digested smelt, 2 inches long.
Do	9	Nearly digested smelt, 3 3/4 inches long.
Aug. 12, 1909	12	Backbone of smelt, 2 3/4 inches long.
Do	10 5/8	Backbone of smelt and some brown stuff.
Aug. 13, 1910	12 1/4	Partly digested smelt, 2 1/2 inches long.
Do	11 1/4	Nearly digested smelt, 2 7/8 inches long.
Aug. 14, 1909	13 1/8	Backbone of small fish, probably smelt.
Do	11 5/8	Do.
Do	11 1/16	Backbone of small smelt.
Do	8 1/2	Young smelts.
Aug. 16, 1908	10	Few bones of small smelt.
Do	8 3/8	Partly digested smelt at least 1 1/16 inches long.
Do	9 3/4	Bait.
Do	11 1/8	Partly digested smelt at least 4 1/8 inches long.
Aug. 16, 1909	11 3/4	Smelt, 4 inches long.
Do	12 5/8	Smelt, 5 inches long.
Do	10 3/4	Larval insect.
Do	10 1/16	Young smelt, 1 1/8 inches long.
Do	10 1/16	3 young smelts, 1 1/4 to 1 1/8 inches long.
Aug. 16, 1908	10	Few bones of small smelt.
Do	8 3/8	Partly digested smelt at least 1 1/16 inches long.
Do	9 3/4	Bait.
Do	11 1/8	Partly digested smelt at least 4 1/8 inches long.
Aug. 18, 1909	14	Smelt, 4 3/8 inches long.
Do	13	Smelt, 4 inches long.
Do	9 7/8	Smelt, 4 1/8 inches long.
Do	7 3/8	Young smelt, 2 1/4 inches long; one stickleback (Pungitius) 1 1/16 inches long.
Aug. 20, 1909	12 5/8	Backbone of young smelt.
Do	10 1/4	Young smelts.
Aug. 21, 1907	12 1/4	Partly digested small smelt.
Do	----------	Bones of smelt, perhaps 3 or 4 inches long.
Do	----------	Small flylike insect.
Do	----------	Carapace, head, and wings of similar insect.
Aug. 22, 1916	11	Small smelt, 3 inches long.
Do	10	Small smelt about 3 1/4 inches long.
Do	9	Small smelt about 3 1/8 inches long.
Do	8 3/4	Small smelt about 3 inches long.
Aug. 23, 1908	13 1/16	Bait.
Do	12 1/2	1 smelt about 4 1/16 inches long.
Do	10 1/4	Bait.
Do	9 7/8	Do.
Do	12 1/2	1 smelt, 4 1/4 inches long.
Aug. 24, 1908	13 1/2	1 partly digested small fish and some bait.
Do	11 1/4	Bait.
Do	9 1/16	Fragment of party digested smelt nearly 3 inches long.
Do	9 1/8	Fragment of partly digested smelt about 2 1/2 inches long.
Do	9 5/8	Piece of smelt.
Aug. 25, 1907	14 1/4	Piece of smelt belly—bait; caught on 2.0 hook line, bait smelt 6 3/4 inches long.
Do	13 3/4	Backbone of 3 1/2-inch smelt; caught on same hook and bait dead.
Do	12 3/4	Insect nymphs.
Do	12 1/2	Bait, redfin shiner, 4 3/8 inches long, on 2.0 salmon hook.
Do	13 1/8	Empty.
Do	11 3/4	Do.

Detailed table showing stomach contents of smelt from Sebago Lake—Continued

Date	Length in inches	Stomach contents and remarks
Aug. 25, 1907	12	Redfin shiner bait, 3 inches long, and smelt belly.
Do	11¾	Redfin shiner bait, 3¼ inches long.
Do	11½	Empty.
Do	11	Backbone of smelt, 2½ inches long.
Do	11⅜	Empty.
Do	9⅜	Piece of smelt bait.
Do	10½	Bait, 3½ inches long.
Do	10⅛	2 smelts baits and partly digested smelt, 3 inches long.
Do	9⅝	Fragments of fish and larval insects.
Do	9⅛	Flylike insect.
Aug. 28, 1907	10	Insect.
Do	10⅝	Smelt, 3½ inches long.
Do	9 1/16	Bones of 2 little smelts.
Do	9 1/16	Insect like above.
Do	8½	Portion of insect.
Do	11⅞	Smelt, 4⅝ inches long.
Aug. 28, 1908	9¾	Partly digested young smelt.
Do	10⅝	Translucent young smelt, 1⅜ inches long.
Do	14	Backbone of smelt.
Do	10 1/16	1 smelt about 4½ inches long, head forward; also bones of small fishes, mostly smelt.
Do	10½	Small yellow glutinous bodies apparently attached to slender white aggregated spicules.
Do	10	Bones of a small fish.
Do	9¾	Partly digested small fish.
Do	8¾	Partly digested small smelt.
Do	9⅛	Smelt, 5 inches long, head forward, occupying whole length of the alimentary tract.
Aug. 30, 1907	10⅛	Insect.
Do	9⅝	Fragments of fish and larval insects; bones of young smelt.
Do	9⅛	Insect.
Aug 30, 1910	9¼	Several little smelt bones.
Do	8⅛	Larval insects.
Sept. 8, 1910	13½	Smelt, 4½ inches long.
Do	12½	Do.
Do	11½	Partly digested smelt.
Do	12½	Do.
Do	10⅜	Nearly digested smelt.
Sept. 10, 1908		Nearly digested smelt and 1 fresh-water sculpin (Cottus) that had just begun to be affected by gastric juice.
Sept. 10, 1910	12⅞	Partly digested small smelt, 3½ inches long.
Do	14	3 smelts, 2 partly digested, largest, 4½ inches long.
Do	11¼	Bones of small smelt.
Sept. 11, 1908	11⅛	Partly digested smelt, 4⅛ inches long.
Do	10	Fragments of smelt, a portion of it 3 inches long.
Sept. 16, 1908	9 1/16	Young smelt nearly 2⅝ inches long.
Do	10¼	Smelt nearly 4 inches long.
Sept. 17, 1906	10¼	1 young smelt.
Do	10⅖	2 larval Diptera.
Sept. 18, 1910	8¾	Small smelts.
Do	8¾	Young smelts.
Sept. 22, 1908	8	Smelt, 2¼ inches long.
Do	9⅜	Do.
Do	10⅛	Bones of young smelt.
Sept. 23, 1908	9½	Insect larvæ and partly digested small fish.
Do	8½	Do.
Sept. 26, 1910	12¼	Bones of smelt.
Do	9½	Larval insects.
Do	9	Do.
Sept. 28, 1906	12¾	Bones of smelt, 3 or 4 inches loug.
Do	11½	Bones of small fish.
Do	10⅝	Do.
Do	9	Young chub bait.
Do	8 11/16	Insect larvæ.
Do	8⅞	Partly digested small smelt about 3 inches long.
Oct. 1, 1906	7¼	Partly digested small fish. 8 others empty.
Do	8⅞	Small fish, possible bait.
Oct. 20, 1909	13 11/16	Backone of small smelt, 1¾ inches long.
Oct. 23, 1911	13¼	Nearly digested smelt.
Do	10½	Bait.
Do	9¾	2 partly digested smelt.
Do	10¾	Empty.
Do	9	Do.
Do	9¼	2 partly digested small smelts.
Do	12¼	Empty.
Do	7½	Bait.
Do	7½	Do.
Do	8½	Empty.
Do	9½	Do.
Oct. 27, 1909	11⅛	Partly digested small smelt; piece 1½ inches long.

Detailed table showing stomach contents of smelt from Panther Pond, Me., April, 1912

Approximate size, in inches	Stomach contents	Approximate size, in inches	Stomach contents
8 7/16	1 small smelt and 1 May-fly nymph.	9 7/16	1 small smelt with spawn.
9 1/16	Smelt eggs and parts of fish.	8 9/16	Parts of fish and 2 May-fly nymphs.
8 1/4	1 May-fly nymph and parts of fish.	8 5/16	1 Mayfly nymph.
8 3/16	1 May-fly nymph.	8 3/16	Do.
8 1/8	1 nearly digested small fish.	9	Parts of smelt and May-fly nymph.
9	1 small female smelt with spawn.	9	Nearly digested small fish.
9	Parts of small fish.	8 1/16	Parts of fish, May-fly nymphs, and parts of 2 or 3 others.
8 2/16	Do.	9 1/16	Parts of smelt with spawn.
8 1/16	1 May-fly nymph.	9 1/16	Do.
9	1 small smelt with spawn.	8 1/16	Piece of smelt.
8 1/16	1 small smelt with milt.	11 1/16	Parts of smelt with spawn.
8 9/16	Parts of nearly digested fish.		

The above listed 23 smelts were all of 94 specimens that contained food.

One of six smelts received from George Moses in January, 1907, contained one small salamander and a piece of fish, the latter probably bait.

Detailed table of stomach contents of two smelts from Pennamaquan Lake, Me.

Date	Length, in inches	Stomach contents and remarks
Aug. 30, 1893	3 5/8	Entomostraca. Seined amongst sedge and rushes in shallow water with sandy bottom.
Do.	3 1/2	Entomostraca. The smelt were as silvery as salt-water smelt.

Detailed table of stomach contents of eight smelts that contained food out of 23 specimens killed by dynamite in Wilton Pond in the spring of 1904

Length, in inches	Stomach contents	Length, in inches	Stomach contents
3 9/16	Gnat larvæ.	3 1/8	Minute unidentified material.
3 7/16	Do.	3 1/4	Do.
3 7/16	Do.	3 5/8	Small diptera.
3 7/8	Caddis-fly larvæ.	3 9/16	Caddis-fly larvæ.

Detailed table of stomach contents of 22 smelts, all out of 78 specimens examined from Lake Champlain on February 16 and 17, 1911, that contained food

Length, in inches	Stomach contents and remarks	Length, in inches	Stomach contents and remarks
8 3/4	2 partly digested small fish, probably smelt.	7 3/8	1 partly digested small fish.
7 9/16	1 partly digested small smelt.	7 1/16	1 small smelt in good condition.
8 3/16	Do.	8	Nearly digested parts of fish
8 1/2	Do.	7 3/8	1 small smelt.
7 7/8	Partly digested small fish, probably smelt.	7 1/16	Nearly digested parts of fish.
8	Small piece of backbone of fish.	6 3/8	Small smelt in good condition.
7 3/4	Nearly digested small fish.	6 1/2	Parts of small smelt.
7 1/8	2 small smelt.	6 3/8	Parts of nearly digested fish.
7 1/8	1 partly digested small smelt.	6 1/8	Backbone of a small fish.
5 3/4	Do.	6 1/2	Nearly digested small fish.
7 3/8	1 partly digested fish.	6 9/16	1 small fish.

Detailed table of stomach contents of 5 smelts that contained food, out of 12 taken from Memphremagog Lake, April 23, 1894

Length, in inches	Stomach contents	Length, in inches	Stomach contents
6¼	Larval stone fly.	6 7/16	Crustaceans.
7	Nymphs of May fly.	7	Young smelt, 2 7/16 inches long.
6½	Larval insects.		

The following notes and tables were drawn from the report of Prof. A. A. Doolittle, of Central High School, Washington, D. C., to some smelts from Sunapee Lake, N. H., and Aroostook County, Me., were submitted for identification of stomach contents.

Concerning the smelts of Sunapee Lake, Professor Doolitte said in effect that the fish taken in April were spawning fish; they had eaten very sparingly of Entomostraca, only 2 of the 12 examined having taken Entomostraca, an average of 23 for each of the feeding fish and of less than 4 for each of the 12 smelts. Insect larvæ and pupæ were taken, an average of 4½ for all the smelts examined.

The specimens collected on August 12, 1910, were removed from the stomach of a brook trout caught in about 80 feet of water, or at least where the water was that deep. Only 2 of the 6 examined had eaten recently, the food consisting of 13 Entomostraca. After October 13 the Entomostraca food became very much more abundant, although of the 30 smelts examined only 60 per cent had in the alimentary tract when examined. For those feeding, the average was 203 Entomostraca, or an average of 120 for all.

Size or age of the smelts did not seem to effect the activity of the fish in feeding. There was a scattering of insect larvæ among the Entomostraca, an average of one-half an insect for each of 30 specimens. Parasites were abundant in the alimentary tract, consisting of tapeworms, diatoms, and threadworms. Most of the specimens taken in the fall were found dead upon the beach; they can hardly be regarded as fully normal individuals, but no relation between parasites and the amount of food taken can be determined from the data in hand. The main food, as determined, was Entomostraca, mostly of the genera Cyclops and Bosmina.

Detailed table of results of an examination of the stomach contents of smelts from Sunapee Lake, made by Prof. A. A. Doolittle in 1910

Date	Length, in inches	Number of smelts examined	Number of smelts eating Entomostraca	Number of Entomostraca eaten	Miscellaneous food
Apr. 22	3–4⅛	6	1	16	30 insects.
Apr. 23	3⅛–4½	6	1	30	22 insects; smelt eggs.
Aug. 13	1 1/16–1⅝	6	2	13	
Oct. 13	2 1/16–5⅜	6	4	482	1 insect.
Oct. 15	2⅛–2 1/16	3	2	474	
Oct. 17	2¼–4½	6	3	1,491	8 insects; 3 amphipods.
Oct. 26	1 9/16–2⅛	3	1	142	
Oct. 30	2 9/16–4⅛	6	3	152	6 insects.
Nov. 8	2 9/16–4 7/16	6	5	910	

Later, 13 other specimens were examined by Professor Doolittle. Seven of these were removed from the stomach of the brook trout previously mentioned, and six were picked up on the beach at Soonipi Park. The following tables give the results of the examination.

Young smelts taken from the stomach of a brook trout, August 13, 1910

Length, in inches	Entomostraca (Cyclops)	Length in inches	Entomostraca (Cyclops)
1	0	3⅛	0
1⅜	4	3⅛	0
1⅝	0	4⅛	0
2⅛	9		

Smelts washed up on the beach at Soonipi Park, October 15 and 26, 1910

Length and stomach contents	Oct. 15			Oct. 26			Remarks
Length, in inches	55	55	58	50	56	56	The Entomostraca were all species of the open lake.
Cyclops	0	131	4	0	0	125	
Halopedium gibberum	0	3	4	0	0	0	
Daphnia hyalina	0	38	8	0	0	0	
Daphnia obtusirostris	0	117	172	0	0	0	
Bosmina obtusirostris	0	0	0	0	0	17	

Specimens from Square and Cross Lakes (5 from each), from a little over 3⅛ inches to about 8$\frac{1}{10}$ inches in length, were examined. They were collected on July 2, 8, and 12, 1903, washed up on the beach. Only two Entomostraca (Cyclops and Bosmina) and eight insects were found in the alimentary tracts. Those from Cross Lake were very fat but heavily parasitized. The following table shows the details:

Locality	Date	Length, in inches	Number examined	Number eating Entomostraca	Number of Entomostraca eaten	Miscellaneous food
Square Lake	July 2, 1903	3⅛–6⅞	5	0	0	6 insects.
Cross Lake	July 8 and 12, 1903	4$\frac{9}{10}$–8$\frac{1}{10}$	5	1	2	2 insects.

Creaser (1925) observes that smelt on the spawning ground eat very little, stating that Dr. Jan Metzelaar examined 110 individuals from Cold Creek, Beulah, Mich., and found most of them empty, but a few contained an insignificant quantity of smelt eggs and the débris to which the eggs were attached.

Creaser's observations concerning the stomach contents of smelt caught in the lake are similar to those made at Sebago Lake. Doctor Metzelaar examined the stomachs of 147 smelt taken at Crystal Lake about September 1. Of these, 20 were totally empty. Three contained young rock bass (*Ambloplites rupestris*), 78 contained the remains of lake shiner (*Notropis atherinoides*), 35 more contained remains probably of the same species, 25 had insect larvæ or purpæ, either midges (Chironomidæ) or May flies (Hexagenia). In volume, 98.3 per cent was fish and 1.7 insect food.

HABITAT

According to Reuter (1883) the smelt of the inland waters of Finland always live in "shoals" (schools) and prefer, except during spawn time, deep water on sandy bottom.

Nordqvist (1910) states that in the lakes of Finland the smelt is found chiefly at a depth of 12 meters (about 39.37 feet), but that it occurs in shallow lakes as a result of introduction. He says that it appears to do better in lakes that have dark or turbid water than in those of clear, colorless water, and that it occurs at the same depths summer and winter, just as they do in the Gulf of Finland.

During the summer and fall the smelts affect rather deep water, or cool water. The depths at which the smelt is found in the larger lakes vary from 60 to 100 feet, more or less. They do not thrive in shallow ponds unless the water is cool enough for them, but are known to occur in ponds not over 30 or 40 feet deep. According to George Moses, who has for many years fished for smelts in Sebago Lake, the smelt is caught in just as deep water in the winter as in the summer. Mead (1883), quoting Jesse Plummer of Raymond, Me., says:

> When fishing for cusk at the "Images" in the month of June I have, while sitting on the rock, run my line to the depth of seventy-five or one hundred feet, and in a cusk caught I have found fresh smelts, which goes to prove that they resort to the very deep water during the summer.

Cheney (1894b) stated that the smelt of Sunapee Lake, N. H., were caught in deep water in June and July, with hook and line. The water was from 58 to 63 feet deep. He took the bottom temperature at this place in August, 1890, and found it 52° F., while at the surface it was 68° F. He said that in many places the bottom temperature was 42° F., and in one place it had been found to be as low as 38° F.

In 1910 the present writer caught smelts in Sunapee Lake with hook and line in about 90 feet of water, where the temperature on August 16 was 52° F. at the bottom. The surface temperature was 69.5° and that of the air was 65° F. The smelts ranged from 4½ to 7½ inches in length. The character of the bottom was not ascertained.

On February 16 and 17, 1911, the present writer found smelt fishermen at Port Henry, on Lake Champlain, fishing at various depths. One man was fishing in 38 feet of water and said that the largest smelts were found in deeper water, down to about 70 feet. Another man was fishing in about 25 feet of water and was doing very well in number of fish caught, but they were not very large, running about 8 or 9 inches. It was said that smaller fish could be caught near shore where the water was only 8 or 10 feet deep.

At a place called "The Reef" they were fishing in about 40 feet of water. This is in accord with the statement of Cowen (1900) to the effect that larger smelts were to be found in water 40 to 60 feet in depth.

While the present writer has caught smelts with hook and line during the summer and fall in water as shallow as 60 feet and as deep as 100 feet in Sebago Lake, it was found that the best fishing was at a depth of about 70 feet over a bottom of gray clay. Seldom were very large smelts taken at the lesser depths, but not infrequently small smelts were caught at a depth of 70 feet or more. On one smelt ground on July 8, 1911, where the water was 90 feet deep, the temperature at the bottom

was 46.5° F., at 60 feet 48° F., at 50 feet 53.75° F., and at the surface 70° F. At another place, at the bottom in a depth of 70 feet, an excellent smelt ground, the temperature was 44° F. on July 11, 45° F. at 60 feet, 49° F. at 50 feet, and 80° F. at the surface. The bottom was composed of gray clay. The fish caught were the large form of smelt, but as many of these had eaten both the adult small form and young translucent smelts, this suggests that they occur together at the same depths, although it is possible that the large smelts may sometimes ascend to lesser depths in pursuit of food. An occasional insect, such as an adult dipterous fly found in their stomachs, adds weight to this possibility, which is further supported by the fact that in the dusk of the evening the large smelts sometimes take the bait at a few feet below the surface. However, this occurs only over the greater depth and has been observed only when hauling in a line from the lower depth, so the smelts may have followed it up to the top.

The schooling of the small form and of young smelts at and near the surface is described later in this paper. While it has not been observed, it is possible that the large smelts pursue the smaller fish toward or even to the surface. They may even school at the surface, but there is no evidence to that effect.

BREEDING SEASON

The fresh-water smelt differs very little from the salt-water form in its breeding habits. It ascends tributary streams in the spring of the year and the runs take place at night, but, of course, they are not influenced by tides, as appears to be the case with the salt-water species. According to Bloch (1796), the German fresh-water smelt spawns in March, when it leaves the lakes and ascends the rivers in great numbers and deposits its spawn upon the sands of the bottom.

Reuter (1883) states of the fresh-water smelt of Finland that, like most of the Salmonidæ, it is a wandering fish. The largest variety as a rule chooses the most rapid and deepest waters for spawning, while the smallest, on the contrary, spawns on banks in the lakes or on long shallow shores and at the mouths of rivers.

According to Reuter's account, the spawning times of the large and small Finnish smelts are the reverse of those forms in Maine. He said that the smaller and younger fish spawn earlier, at the end of March and beginning of April, the larger and older individuals in April and sometimes in May. The spawning period lasts one or two weeks, spawning taking place at night, especially during stormy weather, and commonly during a snowstorm. Reuter recognized no specific significance in the variability of size and habits, saying that the smaller varieties chiefly belong to lakes where there is but a scanty supply of food, but added that in the larger lakes and in the sea both varieties were found.

According to Nordqvist (1910), in the northern regions of Finland the spawning season occurs later than in the southern districts, and that the spawning time is not determined by a definite water temperature.

Of the salt-water smelt in New Brunswick, A. Leith Adams (1873) says:

> As soon as the ice breaks up and drifts seaward, sculls upon sculls of this savoury fish push their way up the rivers, where they bite bait readily, and are captured by nets.

Of the fresh-water form he says:

Again, at the same season the individuals of the landlocked lakes, impelled by the same instinct as the others, issue from the deeper waters, and crowd many brooks and streams so densely that the struggling mass is often lifted out of water by sheer pressure from below and behind; indeed, so plentiful are they then in the brooks running into Lake Utopia, before noticed, that I have been told by by persons who captured them by thousands, that there is no difficulty in filling a landing net at every haul.

According to the report of the Massachusetts commissioners of fisheries and game for 1917 (1918, p. 75), the introduced smelt of one of the lakes in the Berkshire Hills has become very plentiful, and in the spawning runs exhibit a similar phenomenon to that mentioned by A. Leith Adams. He says:

In fresh-water lakes, as Onota Lake, Pittsfield, the season, lasting seven days, varies with the time the ice leaves the lake, since the fish start running up the brooks about ten days after the ice has gone. The fish lie around the mouth of the spawning brook two or three days before starting their run, which occurs at night, the fish returning to the lake at daybreak. During the first three nights the large ones pass up, then for a few nights the medium sized, and finally the small ones, evidently yearlings. So many fish run up Parker Brook from Onota Lake that they actually force each other out of the water on the grass and gravel sides of the stream. The spawn is deposited, one layer of eggs upon another, to a depth of about 2 inches, which inevitably results in millions of eggs being annually lost under natural conditions. When so covered the bed of the brook has the appearance of one large yellow sheet.

The report of the commissioners of fisheries of New Hampshire for 1870 says of the smelts of "Lake Winnipiseogee" that they ascend the brooks for spawning just at the time the ice leaves the lake, which usually occurs about the last of April. The report stated that the fish ran in the streams about a week, depositing their ova upon moss, sticks, and stones, to which the eggs adhered by a "glutinous substance." After the spawning season the smelts were said to disappear, not to be seen again until the following spring.

Concerning Sunapee Lake, N. H., Cheney (1896) wrote:

In New England lakes the fresh-water form of the smelt begins to run up the streams to spawn as soon as the ice breaks up in the spring, and at no other time are they observed in the streams or shallow water. Commissioner Wentworth, of New Hamshire, writes me that last fall, or perhaps I should say this winter, the ice formed on Sunapee Lake and Pleasant Pond, in New London, to the thickness of 8 in., and then broke up in a thaw, and at once the smelts began to run, something never before known. He does not say the smelt had ripe spawn, but they acted as they do at spawning time. Smelt run up a stream in the night, spawn and return to the lake or sea before morning, and as they run in great schools the spawn probably develops rapidly, and it would be curious to know that atmospheric changes could influence the development of fish spawn to change the spawning season several months. Anyway, we have yet quite a bit to learn about fish and their habits before we know it all, much as we think we know.

In 1910 the present writer made observations upon the smelts of Sunapee Lake during their entire breeding season. In Pike Brook, one of the principal tributaries of the lake, the first run of smelts occurred on the night of April 13. The runs continued to increase in numbers of fish until the 19th, on which night the smelts fairly swarmed in the brook. The run continued constantly large until the 25th, when they rapidly decreased in numbers until the night of April 30, when only a few stragglers were observed in the brook. After April 21 those remaining in the pools decreased in numbers. For some time, however, the brook was so high and roily

that had there been smelts there they could not have been seen. Subsequently the only smelts observed during the daytime were not over a dozen in each of the two pools under special observation on the 22d and 23d, only one smelt on the 24th, and a small school in the hatchery pool on the 25th.

The information concerning the breeding season of the fresh-water smelt in most of the lakes of Maine is derived from observations of several persons, but largely from unpublished notes made by Atkins many years ago.

Long Lake.—Mead (1883) referring particularly to Sebago waters, wrote:

"When the first frog peeps" smelt may be looked for with an almost sure chance of success. The time of their running up brooks but a mile or two apart varies. I have known the "big smelts" plenty the tenth of April; this year they were in the height of their run in the brooks emptying into Long Pond about the twentieth of April; they vary with the seasons. The smelts almost invariably ascend the brooks in the early part of the night and return to the ponds towards morning; a few times only have I ever seen them in the brooks by day-light. Both kinds (for I shall treat them as distinct kinds) come to the same brooks; the males of the "big smelts" are the first to appear probably to prepare the spawning beds. After making their appearance in "old bachelor" style for a few nights, females will begin to straggle along, and for the last few nights both males and females are taken in about equal numbers. The "run" lasts from one to two weeks. About the last of the run of the larger kind, the "little smelts" come to the same brooks and to all appearance on the same errand, straggling at first, but in multitudes finally; their run lasts about the same length of time as that of their big brothers, extending about as many days after the large ones have disappeared as they were behind them in making their first appearance. After the spring run, very little is seen of either kind for the remainder of the year.

Two years later, under date of April 25, the same observer (Mead, 1885) said that the run of smelts exceeded anything for many years. He stated that one party caught 480 large smelts the night before in Rogers Brook, and that he heard good reports from all the brooks on Long Lake. He said:

I am led to believe that the main army of smelts do not come to the brooks every year, and it may be that they pass over several years. For a number of years the run was so small that it appeared that they were diminishing rapidly. Fifty smelts to a net per night has been considered a good catch for a number of seasons past. It may be that on some particular year they were not disturbed and a large amount of spawn was left, but as all the brooks responded at the same time, I incline to the first view. The run this year is something like old times.

Again, two years later than this, signing his initials only, the same correspondent ("J. M.," 1887), under date of May 28, wrote that the run of smelts was equal to that of any recent season; that the water was unusually high and probably a larger number than usual escaped the dip net. He said that a few days after the water fell he visited Rogers Brook and was attracted by what appeared to be frost on a space a foot or more in width upon the brook margin, but upon closer inspection he found that it was smelt eggs left by the receding water, which had turned white by exposure to the air.

Sebago Lake.—The late Frank Meserve, in 1898, told the present writer that the smelts begin to run at about full moon in April, the large smelts preceding the small ones, and the runs of each size last about a week. It is said that they run in almost every stream, large or small, but usually are found later in the smaller streams than in the larger ones. He stated that the smelts ascended Crooked River as far as Edes Falls.

On April 23, 1901, the present writer obtained from the late "Nate" Paul, at Songo Lock, about a dozen and a half large smelts and a peck and a half of small ones. Some were ripe and some were spent. According to Paul the large smelts ran earlier than the small ones, the latter appearing about the 13th of April.

Ben Jones stated that smelts are found at one given place in Crooked River for about a week or 10 days, and that they leave suddenly. On April 28, 1903, one smelt found dying in the lake off Broad Cove emitted eggs upon gentle pressure.

In 1906 "Nate" Paul told the present writer that the large smelts begin to run as soon as the ice is out, and sometimes before. He said that he had known them to run up and back again before the ice was out of the lake, but that straggling fish sometimes remain in the stream after the main body had left.

In 1908 Ben Jones said that smelts sometimes ascend Crooked River as far as Edes Falls, much depending upon the height of the water.

On April 11, 1910, George Moses said that a few large smelts had been caught at Songo Lock, but that small smelts had not yet entered the river, although they had been seen at the "bar" at the mouth of the river. A few small smelts were taken at Songo Lock on the night of April 11, according to report.

Panther Pond.—Small smelts were running up a tributary brook about April 28 or 29, 1901. It was said that they run about a week earlier in the brooks of this lake than they do in the tributaries of Sebago Lake.

Rangeley Lakes.—According to the Maine Woods of 1904, on April 30 of that year smelts were running up Dodge Pond Stream "in bushels" from Oquossoc or upper Rangeley Lake. The same paper in 1905 indicated that the spawning period extended over a week or 10 days from time the ice went out. Again, in 1907, smelts were reported to be very much in evidence in Rangeley Stream about the middle of May. Rangeley Stream connects Oquossoc with Mooselucmaguntic Lake, therefore the smelts come up from the latter lake. The same paper (of April 28, 1910) reported that smelts had begun to run early in 1910, large quantities having been taken from Kennebago Stream during that week and the week before. The smelts were said to be of good size and fine quality, and the quantity unlimited.

It may be noted here that Kennebago Stream flows into Mooselucmaguntic Lake. The smelts of that lake were large smelts from Swan Lake stock, while the smaller smelts of Oquossoc Lake originated from Weld Pond stock, a very small smelt. (See Square Lake.)

Sebattus Pond.—On May 8, 1868, Atkins wrote in his notes that the smelts ascended the brooks in great quantities about 10 days earlier than in Cochnewagn Pond brooks in Monmouth. This year they were very plentiful on the night of April 30.

Cobbosseecontee Lake.—Smelts were found very abundantly at Fullers Meadow, East Winthrop, on April 30, 1868. On the night of May 4, 1868, Atkins found some smelts in a little brook that runs across a sandy beech from Brainards Meadow, East Winthrop; and on May 5, at the entrance of the meadow, he found the bushes and all the rubbish on the bottom covered with smelt spawn, most of it apparently in good condition; but there were enough white ones plainly to be seen scattered over the weeds. He was informed that on April 30 smelts were very plentiful at this place. The water was about 4 feet deep. In the sand shore brook very few eggs were

found, and a few dead and dying smelts were observed. The eggs were all fertile. Atkins stated that although the brook was muddy that day he believed it was naturally very clear.

Belgrade Lakes.—According to Atkins, information received on April 19, 1868, was to the effect that in Messalonskee Lake the smelts usually run about the 10th to the 15th of April, sometimes earlier and sometimes later; they contine to run about a week. The first appearance in the brooks this year was on the night of April 12, and on the 19th they were about done.

On April 15, 1869, only 10 males and no females were caught in one brook; they were the first to appear in that paticular brook but they had run in another brook on the 12th. This season was said to be about 10 days behind the previous season. In one stream on the 16th a few, mostly males, were caught. It was thought that the lateness of the season was due to high water in the streams, which overflowed their banks. On April 15 it was stated that there was more than a foot of water all over the fields. In another brook scarcely any smelts were taken until the night of the 18th, when one man got about half a bushel, and about a bushel in all were taken. In another brook the fish were said to be scarce and a catch of four dozen comprised more males than females. On the night of April 20 the brooks were still very high and only a few fish were caught. On April 21 it had rained nearly all day and the brooks very high. It cleared in the evening but only two fish were caught in one brook, but in another many were taken. One informant told Atkins that smelt did not run after 9 o'clock.

On April 15, 1875, Atkins fished in Tilsons or Palmers Brook at North Belgrade during a heavy rain beginning at 9 p. m. and stopping at 3 a. m. the following morning. Six "drives" at intervals of one hour and one-half hour yielded 94 smelts, of which 68 were males and 26 females. On the night of the 17th, in the same brook, four men got only one smelt up to 10 p. m. and then left. Later Atkins heard that on Saturday about 40 smelts were caught, and on the night of the 18th 247 were taken, which were said to comprise many more females than males

On April 19, in the same brook, three "drives" one and one-half and two hours apart yielded 83 smelts, 46 of which were males and 37 females. On the night of April 21, in the same stream, 250 smelts were said to have been taken, and of 36 fish bought by Atkins 7 were males and 29 females.

On the night of April 22, in the same brook, two drives were made between 8.30 p. m. and midnight and 34 smelts were caught, 17 of which were males and 17 females. Some were ripe and a few spent. In another brook (Eldreds) on the same night 300 smelts were caught, while in another only 45 fish were taken.

Great Pond.—On May 6, 1875, Atkins found the pond about three-fourths covered with ice. About 10.30 a. m. he found the temperature in Eldreds Brook to be 45° F. Smelt eggs were thick at the mouth of the brook and for about 7 or 8 rods and some at possibly 10 rods or more from the pond. No eggs were observed in the pond, and a little to one side of the mouth of the brook in the pond and in the brook they stuck to stones, sticks, leaves, and moss; to the latter better than to anything else. He said that it was a moss that grew abundantly on the shores of the brook, especially some distance up. Atkins judged that in the 7 rods of the lower part of the brook,

where it was about 5 feet wide, the good and bad eggs would count 30 to the square inch, which would give 2,592,000 eggs to the brook.

Cochnewagn Pond.—Atkins found that on May 7, 1868, the smelts of this lake had not begun to run, but that night he remained on the brook until midnight and managed to get about 20 small smelts and 3 "full-sized" ones. All were ripe. He said that the brooks were very small and that in none of them did the smelts run up more than 4 or 5 rods. The temperature of the brook at midnight was 43° F, and that of the lake on shore was 45° F. On the night of May 12 Atkins tried again for smelts at Monmouth. He succeeded in getting one "full-sized" fish. They had not begun to run in any quantity. On May 2, 1878, Atkins received a box of smelts that were caught in the brooks of this lake on April 30. The ice had left the lake on the 9th of April. All of the smelts appeared to be in breeding condition, the very smallest being a female with ripe eggs.

Toddy Pond.—In his notes Atkins said that the lower several rods of Sucker Brook, which flows from Heart Pond into Toddy Pond, was the spawning ground of a variety of smelt. He visited the brook on April 17, 1878, and found that the stones, roots, and moss were well covered with smelt eggs and many were hanging in bunches. In the afternoon the temperature of the brook was 46° F. A boy about 17 year of age, whom Atkins met, said that the smelts enter the brook before the suckers do. The boy had visited the brook on April 16 and found that there were very few smelts remaining in it.

Unpublished observations of Charles G. Atkins at Sidney, Me.—Messalonskee Lake

Date	Hour	Locality	Temperature, ° F		Remarks
			Water	Air	
1869					
Apr. 15	2 p. m.	Woodcocks Brook	37		First smelt; 10, all males.
Do	5.40 p. m.	do	33		Snow averaged more than 1 foot deep all over the fields; brooks very high; season 10 days behind last season. Smelts began to run on night of Apr. 12.
Do	8 p. m.	Morrisons Brook	38		Got 4 or 5 males and 2 females.
Do	10 p. m.	Woodcocks Brook	32		
Apr. 16	10.30 a. m.	do	33		A few smelts, mostly males; only 1 female.
Do	2 p. m.	do	35		
Apr. 17	7.20 a. m.	do	33		
Do	12 noon	do	34		
Do	2 p. m.	do	32		
Do	5.15 p. m.	do	32		Rise of 12 inches of water.
Do	10.15 p. m.	do	32		
Apr. 18	7.10 a. m.	do	32		
Do	9.28 a. m.	do	32		
Do	11.10 a. m.	do	32		
Do	1 p. m.	do	33		
Do	11.15 p. m.	do	33		A good many caught to-night, about 2 bushels; 2 men caught half a bushel.
Apr. 19	7 p. m.	do	33		Scarcely any smelts taken; succeeded in getting spawn to cover 8 dishes. Males yielded but little milt.
Do	9.25 p. m.	do	33		Brook very high.
Apr. 20	10 a. m.	do	35		Water falling.
Apr. 21	do	do	36		Much lower.
Do	4 p. m.	do	39		Muddy; only 2 fish caught.
Apr. 22	9 a. m.	do	36		Much lower.
Do	6 p. m.	do	41		
Do	7 p. m.	Morrisons Brook	45		
Do	9 p. m.	do	43		
Do	2.30 a. m.	Woodcocks Brook	33		
1875					
Apr. 14	7 p. m.	Mouth Tilson Brook	40		Clear and cold.
Do	9 p. m.	do	38.5	29	

Unpublished observations of Charles G. Atkins at Sidney, Me.—Messalonskee Lake—Continued

Date	Hour	Locality	Temperature, °F		Remarks
			Water	Air	
1875					
Apr. 15	7 a. m	Taylors Veranda		33	Hazy; partly cloudy; southeast light breeze.
Do	9 a. m	Spring near Cooper's shop	40.5		
Do	do	Open brook, same place	33		
Do	do	Spring in swamp	44		
Do	10.30 a. m	Brook in woods	37		Hazy and mostly cloudy.
Do	do	Spring at head of brook	41		
Do	9 p. m	Tilson Stream	39		Cloudy; wind southeast.
Apr. 16	do	do	38	40	Rain in morning; wind northeast.
Apr. 17	do	do	38	30	Wind northeast and north; cloudy; snowed a little in afternoon; cleared 10 p. m., colder with northwest wind.
Apr. 18	9 a. m	Brook in woods	34.5		
Do	6 p. m	do	36.5	31	
Apr. 19	8 a. m	do	33.5	35	Snow squall.
Do	1 p. m	Mouth Tilson Brook	40.5	40	
Do	3 p. m	do		40	Cold northeast wind.
Do	5 p. m	do		32	
Do	10 p. m	do	34.5	25	
Apr. 20	4 a. m	do	34	18.5	Violent northwest wind, clear; snow in the afternoon.
Do	10 a. m	Brook in woods	34	28	
Do	11 a. m	do	34		
Do	do	Mouth Tilson Brook	36		
Do	6 p. m	Brook in woods	33		
Do	9 p. m	do		17	
Apr. 21	6 a. m	do		13	
Do	7 a. m	do		14.5	
Do	8 a. m	do	33		
Do	do	Spring	41		
Do	1 p. m	do		30	
Do	3.30 p. m	Brook in woods	36	33	
Do	4.30 p. m	Spring in woods, low, covered with snow water.	43		
Do	6 p. m	do		25	
Apr. 22	7 a. m	do		29	Wind northwest; clear.
Do	11 p. m	Tilson Brook	40	35	
Apr. 23	7 a. m	do		35	
Apr. 26	1 p. m	Eldreds Brook	40	40	Cold, blustering wind.
Apr. 27	2 a. m	Brook near Cooper's shop	33.5		Cold night; froze, light northwest wind.
Do	do	Brook in woods	38.5		
Do	8 a. m	do		38	
Do	1 p. m	do		51	
Do	2 p. m	do	46		
Do	do	Judkins spring	41		
Do	3 p. m	Brook at Cooper's shop	43		
Apr. 28	6 a. m	do	33	32	Ice on pond still firm.
Do	1 p. m	do		54	
Do	3 p. m	do	46.5		
Do	do	Spring in swamp	44		
Do	do	Brook in woods	48		
Apr. 29	7 a. m	Brook at Cooper's shop		35	
Do	1 p. m	do		59	
Do	5.30 p. m	do	33.5	30	
May 6	10.30 a. m	Eldreds Brook	45		

Notes on breeding season of fresh-water smelt

Locality	Season	Authority and remarks
New Brunswick	As soon as the ice breaks up	A. Leith Adams, 1873.
Onota Lake, Mass	About 10 days after ice is gone	W. C. Adams, 1917.
Do	Mar. 23 to Apr. 2	W. C. Adams, 1921.
Lake Winnepesaukee, N. H	As soon as the ice leaves, about the last of April	Commissioner of New Hampshire, 1870.
Sunapee Lake, N. H	As soon as the ice breaks up	Cheney, 1896.
Do	Apr. 13 to 30	Kendall (notes, 1910).
Long Pond	"When the first frog peeps"	Mead, 1883.
Sebago region, Me	Apr. 10 or later	
Do	Apr. 25	Mead, 1885.
Do	May 27, small form	Mead, 1887.

Notes on breeding season of fresh-water smelt—Continued

Locality	Season	Authority and Remarks
Sebago Lake, Me	Full moon of April	Meserve (in 1898).
Do	Apr. 13 and later, small form	Paul (in 1901).
Do	As soon as the ice is out, large form	Paul (in 1906).
Do	Apr. 11	Moses (in 1910).
Panther Pond	Apr. 28 or 29	Moses (in 1901).
Rangeley Lakes, Me	Apr. 30	Maine Woods, 1904.
Do	From time ice is out	Maine Woods, 1905.
Do	Middle of May	Maine Woods, 1907.
Do	Apr. 21 and later	Maine Woods, 1910.
Lake Auburn	Just after the ice is out	A. D. Merrill (in 1900).
Sebattus Pond	Apr. 30	Atkins, 1868.
Wilton Pond	May 1	Do.
Cobbosseecontee Lake	Apr. 30	Do.
Do	May 5	Do.
Jamies Pond	May 4 and 5	Do.
Do	May 13	Atkins (notes 1875).
Great Pond	Apr. 14 to 23	Atkins (notes, 1878).
Do	Apr. 22 to 26	Do.
Messalonskee Lake	Apr. 10 to 15	Atkins, 1868.
Do	Apr. 12 to 19	Do.
Do	Apr. 16 to 18	Do.
Do	Apr. 15 to 21	Atkins, 1869.
Cochnewagn Pond	May 7, last of run	Atkins (notes, 1875).
Do	Apr. 30	Atkins (notes, 1878).
Sebec Lake	As early as April or even in March	Packard (in 1901).
Toddy Pond	Apr. 16, very few left	Atkins (notes, 1878).
Do	Apr. 18, first spent male	Atkins (notes, 1903).
Green Lake, Me	Mar. 28 and 29, large form	Race (in 1906).
Do	May 7, small form	Do.
Do	Mar. 25 to Apr 15, large form	Story (in 1921).
Do	May 5 to May 20, small form	Do.
Do	Mar. 25 to Apr. 15, large form	De Rocher (in 1922).
Do	May 5 to May 20, small form	Do.
Do	Apr. 1 to Apr. 20, large form	De Rocher (in 1923).
Do	May 10 to May 13, small form	Do.
Sisladobsis Lake	February	Atkins (notes, 1879).

Creaser (1925) writes that spawning takes place at Crystal Lake before the ice breaks up in the lake as a whole. In 1923 the spawning started on April 10, which was somewhat later than in 1922, when it was all over by April 8. The run of 1925 was very heavy and was concentrated over the period of April 2 to April 8. At Beulah the smelt ran up a small permanent stream known to the residents as Cold Creek. This stream is not over a mile long and has its headwaters in a cedar bog; in the portion used by the smelt it flows through the village and enters the south end of the Lake.

SPAWNING HABITS

At Sunapee Lake efforts were made, night and day, by the present writer to ascertain if there were any peculiar habits or movements connected with the spawning. The following is a detailed account of the observations made:

The first observations were made on the night of April 15, 1910, when smelts were found making their way some distance above the mouth of the brook at the outer edge of the beach. After reaching the head of the channel they seemed to have some hesitation about entering the dead water above, swimming back for a short distance several times before going in. But this action may have been due wholly or in part to the lantern or the writer standing near the place. Whenever startled by anyone approaching the brook they would run down a short distance, but when "dipped" at with nets they strove to get upstream notwithstanding efforts made to drive them back by splashing the water in the brook.

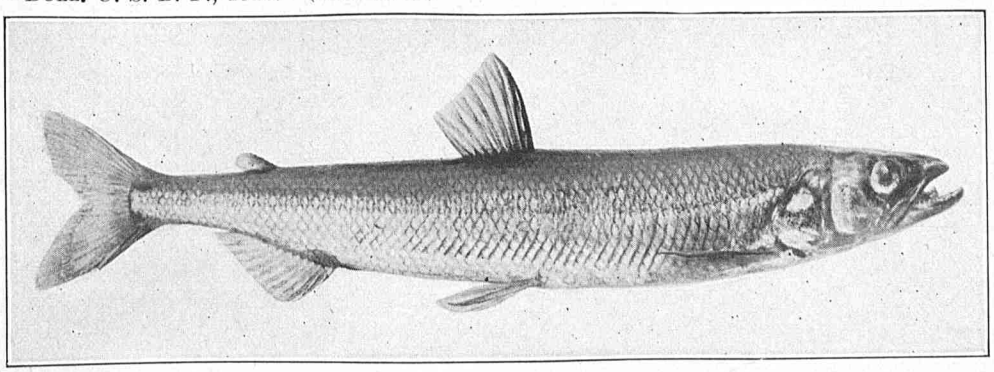

FIG. 14.—Fresh-water smelt. Large form from Sebago Lake, Me.

FIG. 15.—Mouth of Blodgett Brook in August. Deadwater just below bridge

During the day of April 16 in one pool the smelts occupied an eddy between two currents, circling about in the eddy, but not heading in definite order, sometimes downstream, sometimes up, and sometimes crosswise, and often some heading in one direction and some in another. In another pool above this a school occupied an eddy, swimming about irregularly and slowly to some extent, and generally rather stationary or drifting irregularly, but with their heads generally toward the slow return current at almost right angles to the bank.

In another pool a school, startled by the writer's step on the bank, darted downstream as far as a shoal ripple, then slowly returned with heads all directed upstream, some smelts above others, but all in the same direction. The smelts when undisturbed did not all occupy the same level in the water; some were near bottom and some farther up in the water, even near the surface at times, but they were all the time rising and settling again, swimming back and forth individually and to some extent collectively, but irregularly in the latter case. There was no evidence that they were at this time spawning. In the first pool mentioned a few eggs were seen attached to dead leaves, moss, and sticks, but they were white and may have been extruded when the fish were disturbed the previous night by dipping. Further observations show that the smelts very slowly moved about in the eddy in a comparatively large "circle" or rather ellipse, but in a very irregular manner.

Two smelts, one large and the other small, were seen to come rather quickly to the surface together, breaking water with their backs. Probably this was not significant, as no more were seen to do it, or anything like it, during a long watch. No evidence of pairing was observed.

Later, in another place, a small school of smelts was seen lying at the foot of a pool in which was considerable current. They were comparatively motionless, just above a shallow ripple, heads all upstream, merely drifting from side to side, when with one or two quick flirts of the tail they kept themselves from going backward. They scarcely moved upstream at all at any time, and when there was such a movement it was only on the part of one or two of them, not the whole school.

At 9 p. m. the smelts had mostly gone out of the deep holes and were scattered along the brook, generally on the ripples, but on the morning of April 17 the schools were all in the deep holes where they were seen the day before.

On the night of April 18 the writer observed some smelts in the brook by the hatchery that were evidently spawning, making no attempt to go farther up the brook. There were, however, others above and some running up by them. Those watched were in shallow water on sand, fine gravel, and pebbles, and headed upstream where the current ran quickest, but nearer the shore they would lie on the bottom with their heads in no particular direction. Sometimes they were so near shore that their backs were nearly out of water. There were some rather quick movements made by those in quick water, but evidently for the purpose of maintaining their position where they were swinging from side to side but not going forward, sometimes, however, turning and running down or to one side a short distance. But those in the still water lay comparatively quiet, some of them actually resting on the bottom, but they all moved about to a slight degree.

On the night of April 19 further observations were made on the smelts that fairly swarmed in Pike Brook. They did not seem to be disturbed by lantern light but, of course, it is possible that their movements may have been more or less modified by it. No very peculiar movements were observed. There appeared to be no pairing, each fish lying by itself, quietly on the bottom, slightly on its side in a sort of a curve. Sometimes one would lie near another and occasionally one would dart forward under the edge of a partly submerged sod.

During the day of the 20th the smelts were all in pools, usually stationary with heads pointed upstream, occasionally swimming a little and now and then turning to one side or downstream.

During the day of the 22d a fair-sized school was seen in the pool by the hatchery, but there was none in the deep pool where they were caught with hook. There were three or four "scattering" smelts in other places. In the night the fish were scattered mostly in shallow and quick water. Some that were probably spawning were observed. There was one group of 8 or 10 or more individuals side by side and before and behind, in rather quick water, neither going forward nor backward, but swinging back and forth with the current like a bunch of moss, those ahead with a slighter motion than those farther behind. A few others in pairs, or single, were in stiller, shallow water apparently spawning, moving about slightly but usually with the head upstream. There was some current here. They seemed to some extent to lie on their sides, and they moved up into shallow water until their noses were out of water on the gravel. One fish got on top of a stone with half of its body out of water and stayed there some time without seeming to mind it. There seemed to be no contact of bodies except apparently accidentally or incident to the swinging or waving in the current. On the other side of the brook on a rather steep slope of sand and clay bank in shallow water, quite a number were seen likewise stationary. Their movements were similar to the others just previously mentioned. No lantern was used in watching the first two lots mentioned. While the smelts mentioned remained stationary, many others were shooting up, over, and among them on their way up the brook.

There was a good run on April 23. At 8 p. m. some up under the over-hanging bank on a steep shelving bottom were watched. Their heads were upstream and they were swinging or waving from side to side, their bodies occasionally, perhaps, brushing against a neighbor, but no other contact was noticed and apparently no pairing or any approach to it took place.

The spawning period varies from three to six weeks at Sunapee, lasting on an average not over a month. The runs gradually increase in numbers of smelts to the height or middle of the season, then rapidly decrease in number of individuals. No smelts were actually seen leaving the brooks until April 18, when some were reported to be drifting tail first out of the mouth of King Hill Brook at 8.30 p. m. It is possible that they were really an inrun that settled back toward the lake upon the approach of the observer. On April 24, well up Pike Brook, at 9.30 p. m., a good many smelts were evidently running downstream head first, but at the mouth smelts were streaming in in large numbers. At no other times, however, were any seen actually descending the brook, although a decreasing number was observed in

the brook each successive day until May 1. But there was plenty of time in which they could have migrated unobserved.

It frequently has been stated and generally supposed that after spawing smelts invariably return to the lake on the night of their ascent. The writer's observations on the marine smelt in small coastwise brooks revealed that, when undisturbed during the night, large numbers, if not all, remained in the brook the next day, and often some smelts lingered in the brooks long after the spawning season was over, becoming emaciated and weak. Those remaining after the spawning season, so far as examined, always proved to be males.

These facts led to the suspicion that possibly fresh-water smelts might have a similar habit; and at Sunapee Lake it was found to be a fact that if the smelts were undisturbed during the night before the next day large numbers were found along Pike Brook as far up as they could ascend, but mostly congregated in the deeper pools. On April 16, 1910, notwithstanding the fact that there was some "dipping" during the first of the night before at the mouth of the brook, schools of smelts were found all along the brook, from just below the hatchery up 200 or 300 yards, in every little pool, and the same conditions obtained on the 17th. On the 20th smelts were observed in the pools, but there were not as many as could have been expected from the run of the night before. After the 20th no large numbers were observed during the day, but groups of a few or individuals here and there were sometimes seen (Kendall, 1914).

At Sunapee Lake it was observed that smelts, sometimes at least, begin to feed before descending to the lake. On April 20, 1910, in a large deep pool, some smelts appeared to be feeding, moving leisurely here and there as though picking up or looking for something floating in the water. In the afternoon the writer, using a tiny hook with a small piece of earthworm for bait, caught six of the smelts, which proved to be spent or partly spent males, still having rather large milts. Two were 4, one 4¼, two 4½, and one 4⅝ inches in length. There were many more bites, but the fish could not be hooked. Some of the fish would come up to the bait slowly, open their mouths, and take it in; some would dart at it quite smartly; some would not notice it unless it were moving rapidly; and some would pay no attention to it whatever. The latter were the larger smelts. The stomachs of three of the larger fish caught contained smelt eggs and several insect larvæ, apparently mosquito or possibly midge.

SEX PREDOMINANCE

The preceding notes suggest the predominance of male fish, at least during the early part of the season. According to Atkins, of 185 smelts taken April 26, 1875, 131 were males and 54 females; but on the other hand, on April 21, 1869, of two dozen smelts caught the majority were females.

Sixty-four smelts taken in a brook entering Panther Pond on April 17, 1910, comprised 48 males and 16 females. Of 526 smelts caught with hook and line in Sebago Lake, 218 were males and 308 females, but these were not breeding fish.

The best available data on sex predominance are afforded by observations made at Sunapee Lake in 1910. The following table shows that in this instance males predominated during nearly the entire breeding season.

Proportions of male and female smelts, and range in size of each sex

Date	Number examined	Number of males	Number of females	Size of males	Size of females
				Inches	*Inches*
Apr. 18, 1910	493	465	28	4–7	4–7
Do	871	771	100	4–7	4–8½
Apr. 19, 1910	1,336	1,000	336	3¼–7¼	4–8
Apr. 24, 1910	213	186	27	3⅜–5⅝	3½–4¾

SCHOOLING AT THE SURFACE

The present writer knows of but two published references to the surface schooling habits of fresh-water smelts. One of these is that of Mead (1883), who wrote under the heading "October Frolics":

I have made mention of seeing smelts come to the surface of the lake for a frolic, or "sun bath," food or in migrations, I cannot say which, if either. One calm October day I was out on Long Pond in a boat with a party of young gentlemen. Some one noticed ripples on the water and remarked that a breeze was coming. Soon another said "it must be a queer breeze, for it only stirs the water in patches." After watching the phenomenon a few minutes one of the party suggested that it must be caused by smelts, as he had heard of them making their appearance in this way. Soon they came nearer, and by keeping perfectly still we had an opportunity to witness what was a novelty to many of us. The disturbance of the surface of the lake was caused by the smelts throwing themselves quite or nearly out of the water as though enjoying a lively game of gymnastics. Where fifty to a hundred would come to the surface, thousands were moving below in a direct line, in close order and with as much precision as a regiment of soldiers would march in review. The number of such schools in sight, as far as we could see in either direction, gave us some idea of the immense numbers of little smelts the pond contained. The dropping of an oar or the splash of a paddle would send them down out of sight as quick as thought.

The other reference is to smelt of Lake Champlain (see p. 326).

The present writer often has observed the schooling movements of smelts in Sebago Lake. Such schools, however, were always made up of the small form and young smelts. The schooling was not restricted to "October frolics," but on almost any calm day, particularly toward evening, the fish might be observed, sometimes moving in a definite direction, sometimes apparently simply loitering in one or another locality or moving about in no definite direction. The school manifested itself by a rippling of the surface of the water, and when near enough and moving quickly caused a sound much like that of a fine rain upon the water. The larger fish, which were judged to be adults of the small form, often would leap from the water, sometimes almost vertically but more often in a forward movement, much in the manner of a porpoise. When near enough to be seen, always there were fish below the surface that appeared not to jump at all, and often these fish were in tiers, about as described by Mead.

The following are chronological notes of some of the observations made by the present writer, which indicate that schooling takes place at no particular season of the year. It should be mentioned that the supposed adult fish never were seen near shore, but young smelts in the translucent stage often were.

June 15, 1899.—During the forenoon the sky was overcast and there was an easterly breeze; later it became calm. From Whites Point nearly to Squaw Island,

a distance of fully 2 miles, schools of smelts covering an area of many acres were seen moving eastward, rippling the water much in the manner of a school of mackerel, frequently leaping from the water. Again, in the "Notch," between Raymond Cape and Fryes Island, numerous schools were observed, also moving eastward. Again, at about 5 p. m., other schools were seen behaving like those just mentioned.

June 11, 1901.—The lake was calm and the water covered with insects, such as beetles, ants, moths, spiders, etc. Copepods and other entomostracans were observed in the water. Early in the morning smelts were observed schooling in the "Notch" and a few larger fish were breaking water.

September 17, 1906.—In the "Notch" three schools of young smelts were seen rippling the surface, sounding like light rain.

September 28, 1906.—While fishing in the "Notch" the writer observed smelts, perhaps 5 or 6 inches long, swimming by the boat near the surface during a calm. Other fish apparently were feeding upon them.

June 29, 1907.—Young smelts, from a little over 1 inch to nearly 2 inches in length, averaging a little over $1\frac{7}{16}$ inches in total length, were seen schooling near the entrance to Camp Cove. Specimens were secured.

July 28, 1907.—Three schools of small smelts were seen on the Jordan Bay side of Raymond Cape during a calm. Some other fish appeared to be feeding upon them.

July 29, 1907.—On the abruptly shelving west shore of the basin, just below Whites Bridge, large schools of small fish of several species were hovering close to shore. In a 25-foot seine, amongst other species, a number of young smelts, mostly about $1\frac{1}{2}$ inches long, were caught.

September 7, 1907.—In the outer half of Camp Cove, both in the forenoon and afternoon, many large and small schools of young smelts were seen at the surface rippling the water like the patter of fine rain. They were pursued by yellow perch. Specimens were obtained by first catching the perch and opening them. The smelts were nearly 2 inches in length.

September 13, 1907.—Many schools of young smelts were seen in the vicinity of Squaw Island at the surface over about 8 feet of water. These smelts appeared to be in tiers 2 or 3 feet deep.

September 20, 1907.—Near the shore of Whites Bridge, just below the causeway, several large schools of young smelts were seen and some were collected. These fish appeared to be moving about in an irregular manner, but 2 schools of larger size were seen just below the bridge heading against the swift current. Some were seen under the bridge. These fish would work their way up a short distance and, apparently unable to stem the current, would settle back again. They continued these movements until late in the afternoon. On September 21 no smelts were to be seen there.

July 31, 1908.—A school of young smelts, rippling the surface like rain, was observed on the west side of Fryes Island.

May 27, 1910—A school of smelts was observed in Broad Cove, pursued by other larger fish. One dead smelt, $3\frac{1}{4}$ inches long, was found on the bottom below the spot where the fish where schooling.

May 29, 1910.—A school of young smelts was seen offshore in Broad Cove. Several good-sized yellow perch were seen lying quietly on the bottom below the place where the smelts were.

June 7, 1910.—George Moses reported a large school of smelts not far from shore, "gilling" and jumping from the water. Temperature of air was 50° and of surface water 51° F.

June 12, 1910.—In the notch off Loon Island and Harpers Point numerous schools of smelts, individuals of which were "popping" from the water, were seen. The fish apparently were about 4 or 5 inches long. They were over deep water some distance from shore. Another observer reported smelts schooling off the "Straight Shore."

May 29, 1916.—The water was dead calm all the morning until 1.30 p. m.

July 5, 1916.—A large school of young smelts was observed behind the wharf and boathouse. They were still there on July 6, and a collection was made.

The only other waters in which the present writer has seen smelts schooling at the surface was in Little Sebago Lake on August 6 and 7, 1900. There they were observed in large numbers and numerous schools of the very small smelts that occur there. They were pursued by white perch. On October 30 of the same year several schools of tiny smelts were observed at the head of Lake Auburn. In Sebago Lake it was possible usually to get near enough to the schools of fish to ascertain their identity, but not always.

On September 11, 1908, off the northeast end of Fryes Island, many schools of small fish were observed near the point of the island, acting like the perch seen at Whites Bridge, mentioned later. These schools extended from among the bowlders, in comparatively shallow water, off into the lake toward Broad Cove. There were many fish but they could not be seen distinctly enough for positive identification; yet very probably in this case they were smelts, as some other larger fish were rising amongst them causing them to "rush." While the writer has seen smelts thus attacked, he never saw yellow perch or white perch harassed in this manner by other fish.

As smelts so frequently are seen schooling and are positively identified, one is prone to regard as smelts all schools of small fish when seen out in the open lake; but it has been found that such schools are not always composed of smelts.

Off the lower end of Raymond Cape, Sebago Lake, on September 8, 1908, the present writer observed a small school of fish that acted like small smelts; and in the bight above Whites Bridge and below Whites Point there were many schools, some large and some small, that behaved in a similar manner. Just below Whites Point one of these schools was approached near enough to ascertain that the fish were young yellow perch, apparently about 1½ to 2 inches long. All of these schools were heading out into Jordan Bay. In the Connecticut Lakes, N. H., in 1904, similarly acting schools of small fish were found to be composed (in part, at least) of redfin shiners (*Notropis cornutus*).

On July 27, 1909, between the head of Fryes Island and the west shore of Raymond Cape, Sebago Lake, many small fish, perhaps 4 to 6 inches long, were seen breaking water. They did not appear to be smelts, although their behavior was

similar; they looked like small chubs, or some such fish, and may have been redfins or chub minnows (*Couesius plumbeus*). The next day, off the head of Fryes Island, more of the same were seen but could not be positively identified.

MORTALITY

It has been stated that a very pronounced mortality occurs among fresh-water smelts at or shortly after the breeding season. This phenomenon does not appear to have been noticed in connection with breeding marine smelt. While this mortality has been noticeable at the breeding season, or shortly thereafter, it appears not to be restricted to that season; nor has the present writer ever seen it so extensive and intensive as has been reported. Forest and Stream of May 10, 1883 (p. 290), gives the following account of great mortality of smelts in Lake Champlain:

Smelt washed ashore.—The Burlington (Vt.) Free Press of May 5 reports a hard night for the smelt: Last Wednesday night was a disastrous one for the smelt in our lake. Thousands were washed in with driftwood and cast upon the beach of Burlington Bay. Two men who were on hand at the time gathered up fifty dozen, taking them in their hands as the waves rolled them in. A south wind blowing fresh all day had raised a heavy sea, and the next morning the beach presented the appearance of a general shipwreck. The driftwood lined the sands, piled up in high, long windrows. In the midst of this lay the mangled bodies of the unfortunate smelt, several hundred occasionally in the run of a few feet, and as many more buried beneath the sands. What a ghastly parody on the act of swimming, these creatures of the deep wrecked in their own element and cast up by the waters. Last winter fishermen thought themselves fortunate to capture a few dozen of these wily smelt in a day's fishing, and some had concluded the species were dying out. The sudden appearance of several thousand thrown up in one night would not certainly be an argument in favor of this theory. The greater part of the fish were stranded on what is called Job Reed's Bay on Rock Point, and what the destruction was in other parts of the lake we are unable to say. Before these fish were much sought after for food this general destruction in windstorms was of frequent occurrence, and the farmers who owned the land adjoining the lake were accustomed to gather them up and feed them to their hogs. This might appear to be a reversion of those days of plenty. It is likely that a large school of smelt allowed themselves to drift in from the lake and being caught before they were aware on the shallows, and entangled and bruised amid the churning driftwood thus met their untimely fate.

The following year the American Angler for March 1, 1884 (p. 138), quoted the following from the Plattsburgh Republican:

The Smelt fisheries of Lake Champlain have greatly declined within a few years. During the summer of 1882, for about a week, the lake was covered with these delicate fish which had evidently died nearly simultaneously, as they suddenly appeared floating, flecking many square miles of surface, and as suddenly disappeared, after uniformly going through the process of decay. This strange thing happened immediately after an extraordinary display of the aurora borealis, and an accompanying "electric storm" which greatly interfered with the telegraph system of the whole country for several hours, and the question has naturally occurred whether the sudden death of these fish may not have been in some way connected with a shock from Nature's electric battery. The mortality of the smelt furnishes a field for investigation by the scientists who are holding a "Crowner's 'quest" on the tilefish.

A correspondent of Forest and Stream, under date of May 20, 1899, wrote that smelts had been remarkably numerous in all the trout and salmon waters of Maine and New Hampshire, with more than the usual number of dead and dying at the surface. Maine Woods of May 12, 1905, referring to the Rangley Lakes, reported "lots of dead smelts floating on the surface." In 1890 Forest and Stream stated

that smelts often were washed up on the eastern shores of Sunapee Lake by strong winds. Halkett (1913), in a footnote (p. 55), says:

> Whilst engaged in some fisheries matters in the month of May, 1903, I found some specimens of the American Smelt floating dead on the surface of the water of Lac des Isles, in the Gatineau district, P. Q.

The following are chronologically arranged notes made by the present writer upon dead and dying smelts seen in Sebago Lake:

July 20, 1898.—A dead smelt, 11½ inches long, and a dead sucker were found at the surface in Witch Cove.

June 16, 1899.—Found one wounded smelt at the head of the "Notch," not quite dead. It bore tooth marks of some larger fish.

April 28, 1903.—Two wounded but still living smelts, 3⅓ and 5½ inches long, were found at the surface. One had a fungused wound, the other a fresh cut at the base of the tail.

April 29, 1903.—Off Broad Cove, 3 living smelts, 5¼, 5½, and 5¾ inches long, respectively, were picked up at the surface. Two of them apparently had been wounded. One was a male with fungus about the wound; the other a female, 5½ inches long, with swollen and inflamed vent. Eggs were discharged freely upon light pressure.

Down through the Notch several other smelts of about the same size were found. Some were nearly over to the south shore or mouth of Whitney Brook. They were fungused. Some had a slight redness under a small portion of the growth; others, perhaps, had lost some scales; otherwise there was no evident cause of the fungus. The fish were somewhat emaciated but not more so than any spent fish. There seemed to be more or less localized areas of redness, as though the capillaries were engorged or there was an extravasation of blood. The most conspicuous pathological condition was that of the gills, which were infested with small, white, parasitic copepods (*Ergasilus centrarchidarum*, according to C. B. Wilson). There were many copepods on all of the dead and dying fish. It is hard to say whether these copepods were the cause of the death of the fish or were present because the fish were weak, dying, or dead. Judging from the number of smelts found and the number of crows that were collecting, there must have been a good many fish in this condition.

April 30, 1903.—In the Notch three fungused smelts, 5¼, 5½, and 5¾ inches long, were picked up. They were infested with parasitic copepods on the gills, as were those of the day before.

September 25, 1906.—In Jordan Bay a dead smelt, 12¼ inches long, was found at the surface. Nate Paul, of Songo Lock, said that he had never noticed any dead smelts after spawning, excepting some that had been injured by dipping.

August 18, 1907.—In a fresh northwest wind one smelt was washed ashore at Whites Bridge.

August 26, 1907.—On a sand beach at Crib Point two dead smelts, each about 5 inches long, were found.

September 5, 1907.—One dead smelt was found at the surface in Jordan Bay. In a letter from George Moses, dated November 17, 1907, it was stated that just after a big storm he found a lot of little smelts and white perch washed up on the beaches at Fryes Island and on Raymond Cape.

May 7, 1910.—Pleasant and calm; 30 dead and dying smelts, from 4½ to 5½ inches long, were found by the "straight shore" in "slicks," where there were many insects. The smelts were more or less fungused, especially about the tail, but occasionally on some other part of the body. When the tail was affected the fungus extended at least a third of the length of the fish. There were copepods on the gills of all.

May 16, 1910.—Off the straight shoe one fungused dying smelt was found.

June 8, 1910.—A dead smelt, 5 inches long, was washed up on the shore of Raymond Cape, but no lesion or visible mark of injury was to be seen.

Observations made in other waters, in 1903, were as follows:

June 29.—Two dead smelts, each about 5½ inches long, were found on the beach of Square Lake at Cummings camps.

June 30.—In the morning dead smelts 6 inches more or less long were found floating at the surface in coves near the camps.

July 2.—Many smelts, 5 or 6 inches long, and other dead fish were found on the beach. The associated fish were large and small common suckers, few large and small common chub (*Semotilus bullaris*), chub minnows (*Couesius plumbeus*), some large redfins (*Notropis cornutus*), fair-sized "cusk" (*Lota maculosa*), and two little whitefish (*Coregonus stanleyi*).

July 3.—During a fresh blow many fishes were washed up on the beach, but no smelts.

July 4.—A few dead fish, but no smelts, were found.

July 6.—Smelts in dying condition, with fungus on front of the head, were found near the beach.

July 8.—On the east shore of Cross Lake numerous dead smelts from 5 to 10 inches long were found; some were old and others fairly fresh. Some redfins and suckers also were found.

July 10.—At the surface on Cross Lake some large dead smelts with fungused heads and one large chub minnow were found.

July 12.—On the shore of Cross Lake several fresh dead smelts, some chubs, and suckers, and one dead whitefish were found.

The present writer once wrote (Kendall, 1914, p. 75) that after the spawning period for some days, even weeks, many dead and dying smelts are found at the surface and washed up on the beach, bearing no lesions or marks of injury. It was formerly thought that perhaps it was due to the exhaustion and starvation of the spawning period, which causes them to succumb to slight changes of temperature, or inability to obtain sufficient food soon enough to enable them to recuperate. But throughout the season more or less dead of various sizes and ages are found washed up on the beaches. At Sunapee Lake some dead and dying adult fish, ranging in length from 3¼ to 7 inches, were observed near the mouths of brooks during the spawning season. Such fish, however, did not occur there in such large numbers as have been observed in other waters during and following the spawning, and young and adults were found throughout the seasons of 1910 and 1911.

Seldom were any lesions observable, and those at any time present were usually a congestion about the vent, which was ocassionally accompanied by a growth

of fungus in the same place. This condition was rendered insignificant as a result of the spawning function alone, as a number were found in October in a like condition. That the death at spawning time was only coincident, was indicated by the finding of several of them that were not quite ripe, and some ripe fish that had not been in the brooks; and young or yearling fish 2¼ to 3 inches long also were found at the beginning of the of the spawning season.

A few instances of dead fish that evidently had been in the brook were noted. They were spent, and their stomachs contained smelt eggs besides insects. This fact indicates that the death, even at spawning time, perhaps, could not be ascribed to weakness from starvation, especially when the dead and dying fish that had not entered the brook were found to contain some food.

The dead and dying fish picked up on the beaches were more numerous during the spring and fall than in the summer. This may be due to the fact that smelts reside mostly in deep water during the warmer months, and though they die in those months they would be snapped up quickly by trout and salmon. It may indicate that in the fall, as the water becomes cooler, the fish approach the surface and perhaps the shore, as indicated by the presence of insects in the stomachs of those examined.

The presence of dead smelts along the beaches could not be connected with any sudden change of temperature, although they usually and most abundantly appeared during or shortly after strong winds. The latter probably accounts only for their being washed up, although possibly smelts swimming in shallow water might be washed up and thus killed by the heavy seas raised by the strong winds. But this would not account for those found when there had been no strong winds. Intestinal parasites were found in many but not all of the October smelts examined, but this partial freedom from parasites seems to eliminate them as a factor in the mortality.

Therefore, the cause of death of so many smelts throughout the season is as yet unsolved. After all, those found dead on the shores or floating at the surface are few compared with the multitudes that live in the lake, and it is perhaps quite natural that there should be deaths due to obscure causes, as among higher animals.

ENEMIES OF THE FRESH-WATER SMELT

When an organism preys to any extent upon another it is usually accounted an enemy of the latter; so those animals that subsist upon the smelt are enemies of the smelt, and in turn the smelt is an enemy to the organisms upon which it feeds.

Probably at no time during its term of life, from the time it is deposited as an egg in the stream to the end of its existance, is the smelt free from enemies. Some of the habits of the smelt, at some stage of its existance, render it particularly subject to the aggressions of various predatory fishes. While there are no direct observations to support the assumption, it is quite likely that some mammals, such as the mink and raccoon, and some birds, such as the loon, sheldrake, heron, and kingfisher, prey to some extent upon smelts. There is circumstantial evidence to that effect.

The comparatively deep-water summer resort of the smelt probably is its safest retreat; but even there, in some localities, there are fish that feed upon them. Even

some shore fishes have been caught in the deep-water smelt habitat and occasionally been found to contain smelts.

The surface schooling of young and small smelts exposes them to greater dangers; and the schooling of young smelts in shallow water near shore, while perhaps to some extent an advantage, may expose them to dangers not encountered in the open lake or in deep water.

In streams to which smelts resort to breed, even in those inaccessible to large predacious fishes, they are by no means immune. In such places the mink, racoon, and perhaps other mammals, and birds such as the herons and kingfishers have their opportunity.

Spring spawning, while in some ways advantageous, has its disadvantages. Various spieces of cyprinids and suckers, not present in the breeding places of smelts at other seasons, are often numerous in the spring. In some localities there are permanent or year-round inhabitants of the gravel shoals where smelts spawn, which, judging from their known habits in other localities, may consume many smelt eggs and possibly recently hatched smelts. These fishes are not known to be present in the majority of natural smelt waters, but one or another species is common in some of the waters where the smelt has been introduced, and they occur in tributaries of Lake Champlain. These fishes are the little fresh-water sculpins or "miller's thumbs," locally known in Maine as "rock cusk."

Study of the food and feeding habits of the coresidents with the smelt sufficiently extensive so that all of the possible enemies may be positively designated has not been made. However, doubtless any predacious fish that comes in contact with smelts will eat them, but positive statements should not be made until the facts are known. There are available more or less definite records concerning the following species: Landlocked salmon, brook trout, lake trout, whitefish, eel, black bass, pike perch, yellow perch, white perch and burbot.

LANDLOCKED SALMON (SALMO SEBAGO)

The most conspicuous of these is the landlocked salmon. In fact, only one of the lakes naturally inhabited by landlocked salmon and apparently not by the smelt is known, and it is a question whether or not the salmon of that lake (Ontario) were landlocks. In some ways it would appear that smelts had been a factor in "landlocking" the salmon. There are no instances of the successful stocking of any lake with landlocked salmon when smelts also were not introduced.

Mead (1883) said:

> The smelt seems to be the favorite food of the land-locked salmon, and to their abundance is attributed the fair proportions of the *Salmo sebago*. When the smelts come up the brooks the salmon come to the bars and take up their quarters. In case of large streams like Songo River they move, with their base of supplies, several miles up stream, and when the smelts return to deep water, *Salmo* is not long in following suit. 'Tis then the angler sets up his rod and trolls for the land-locked. The little smelt is the most "taking" bait for the salmon or "red spot" yet discovered, either for trolling [or] still fishing. What the blue-backed trout is to the Rangeley Lakes the smelt is to Sebago—food for the larger fish.

Concerning this dependence of landlocked salmon upon smelts for food at Green Lake, Me., Bean (1892) asks: "What brings the landlocked salmon into shallow water

and the mouths of streams early in the season, say in May and June?" Then he answers the question himself, saying: "Smelt. These toothsome little fish form the favorite food of the salmon. They run up into the mouths of streams to spawn and are followed thither by the landlocks as well as big brook trout." Farther on, speaking of the smelt fry, which, he said, on July 1 were one-half to five-eighths inch long, he said they were just right to feed young salmon and trout in the hatching troughs and that the wild trout also helped themselves to the same delicate food. Writing of the smelt of Lake St. Johns, Canada, Chambers (1903) said:

> They are a favorite article of diet with the ouananiche, which, it has been suggested, might attain a larger size if a superior variety of smelts was planted in the lake for their benefit.

The following table shows a few of the many detailed notes made by the present writer upon the stomach contents of some of the landlocked salmon caught by him in Sebago Lake, Me.

Salmon			Smelts found in stomach		
Date	Weight, pounds	Length, inches	Number	Length, inches	Remarks
Apr. 23, 1903	----------	19.3	6	2, 3, 3½, 5	The other two were nearly digested.
June 25, 1907	5⅛	----------	14	3¼–4⅞	
July 24, 1907	2	----------	Many.	----------	Young and 1 adult.
July 25, 1907	2	----------	Many.	----------	Young.
July 26, 1907	8	----------	12	4–4½	
Aug. 1, 1907	16	----------	Numerous.	----------	Adult small smelts.
Aug. 23, 1907	7	27	26	3⅛–4⅛	
July 15, 1909	2	----------	Many.	----------	Young smelts among other things.
July 16, 1909	----------	----------	Some.	4⅜–5	Two comparatively fresh and others partly digested.
July 20, 1909	4	----------	2	4¼–5	Partly digested.
May 15, 1910	2¼	----------	5	5½	Each.
May 16, 1910	----------	----------	1	5½	Disgorged.
July 15, 1910	2½	16	4	----------	Partly digested.
July 16, 1910	----------	17	4	4	Do.
Sept. 18, 1910	1	----------	Few.	----------	Do.
Sept. 20, 1910	----------	12	Few.	----------	Do.
Sept. 26, 1910	----------	12¼	Few.	----------	Do.
May 13, 1916	----------	15	Several.	4¾	Do.
May 29, 1916	Small.	Small.	Several.	2–2½	Do.
May 31, 1916	----------	14	Several.	----------	Young.

BROOK TROUT (SALVELINUS FONTINALIS)

In connection with landlocked salmon, two mentions were made of brook trout as smelt eaters. Mead (1883) said it was a "taking" bait for "red spot," and Bean stated that wild trout fed upon young smelts.

A correspondent of Maine Woods, writing from Mooselucmaguntic Lake, Me., on May 24, 1907, cited an instance of a 3-pound trout that contained 37 whole smelts, and he did not know how many more. He affirmed that it was a true smelt story, for he put them on the wharf and the boys counted them.

At Sunapee Lake, N. H., on August 12, 1910, the present writer caught a trout, a pound or so in weight, which was gorged with young smelts.

LAKE TROUT (CRISTIVOMER NAMAYCUSH)

A Leith Adams (1873) wrote:

> The smelt is a favorite prey of the great spotted lake trout, which, with the brook trout, pursues them during winter, the former chasing the sculls to the influent waters, whilst the latter follows them up stream.

WHITEFISH (COREGONUS CLUPEAFORMIS)

While this species is known to subsist to considerable extent upon small fishes the following note made by the present writer at Sebago Lake on June 12, 1910, appears to constitute the only record of whitefish eating smelts. One specimen that the writer caught while fishing for smelts contained three partly-digested smelts, the most intact of which (nearly complete) measured 3 inches in length. It also contained one stickleback (Pungitius) 1¾ inches long.

EEL (ANGUILLA ROSTRATA)

The following notes were made by the present writer at Sebago Lake: August 14, 1908, one eel 29½ inches long contained one young smelt; September 11, 1908, one eel over 24½ inches long contained a smelt 5½ inches long; September 16, an eel 28 inches long contained one smelt $2\frac{5}{16}$ inches long; July 30, 1909, a 3-pound eel contained two smelts; August 8, 1909, an eel 23½ inches long had its stomach distended with grasshoppers, one black beetle, one smelt 3¼ inches long, and a partly-digested young perch or black bass.

BLACK BASS (MICROPTERUS DOLOMIEU)

Cheney (1894b) wrote that black bass do not feed to any extent on smelts, as they inhabit different portions of the water or a lake in which both fish are found. He said:

> Comparatively the smelt is a deep-water fish and the black bass a shallow-water fish. In the spring when the smelts run up the tributary streams to spawn, the bass have not come on to the shores and shoals to spawn, so they do not meet as a rule, yet occasionally a bass has been found with smelt inside of him.

On July 29, 1907, one young black bass $1\frac{9}{16}$ inches long was found by the present writer near shore at Sebago Lake. It had swallowed a young smelt 1¼ inches long, a portion of which protruded from the mouth of the bass. Young smelts were present near shore in great numbers.

On August 4, 1907, the present writer, while trolling for salmon in Sebago Lake, caught a 1-pound bass that contained a smelt 5½ inches long. This smelt may have been found dead or dying near the surface. On August 12, 1909, a black bass of about 1½ pounds contained a few partly digested young smelts. On August 7, 1910, off a point in Little Sebago Lake, Me., where the bottom shelves off gradually for about 50 yards and then within a few feet suddenly drops to a depth of 50 or 60 feet, large black bass gorged with smelts were caught in the deeper portion.

PIKE PERCH (STIZOSTEDION VITREUM)

The only references to pike perch feeding upon smelts are those of Bainbridge Bishop (1896), quoted in connection with the Lake Champlain fishery, where he states that while fishing for wall-eyed pike in about 100 feet of water he observed that very often the pike would chase and drive schools of smelts to the surface. He stated that some of the pike that he caught would throw smelts from their mouths after they were in the boat. In another place he wrote:

I have taken fair-size smelt from the mouths and throats of wall-eyed pike all through summer and fall months.

Again he says: "Smelt are the natural food of wall-eyes in Champlain and make the best of bait." Also, previously quoted in the same connection is the statement of "Ferris" (1896), who wrote that he had many times observed that after getting them in the boat they would disgorge one or more smelts.

YELLOW PERCH (PERCA FLAVESCENS)

The present writer made the following observations in Sebago Lake and vicinity on June 29, 1907. A yellow perch of the estimated weight of 1 pound, caught in Thomas Pond, contained four smelts, each about 4 inches long. September 10, 1907, in a cove perch were seen pursuing schools of young smelts at or near the surface. Five 10-inch perch were caught and were found to be gorged with these little smelts. From five perch 99 smelts were taken and from one 10 smelts were taken, making a total of 109 young smelts from 6 perch. These young smelts averaged nearly 1¾ inches in length. The perch were swimming with their backs out of water amongst the smelt, making a smacking sound as they took the smelt.

On September 2, 1908, Ben Jones, superintendent of the State fish-cultural weirs in Crooked River, stated that he had seen yellow perch devouring young smelts just above the weir in the spring of the year, when, as he judged, the smelts were about 1 inch long.

On August 5, 1909, an 11¼-inch perch was found to contain many partly digested young smelts. On August 18 of the same year a large school of yellow perch was seen breaking the surface and making the smacking sound mentioned above. Three were caught. They were found to have been feeding upon young smelts and were gorged with them. On June 4, 1910, a 12-inch perch caught in 65 to 80 feet of water contained a partly digested smelt about 3 inches long. A 13-inch perch taken in the same place contained two smelts 2 and 2½ inches long, respectively, tails excluded.

WHITE PERCH (MORONE AMERICANA)

On August 7, 1900, at Little Sebago Lake, Me., white perch were observed by the present writer to be pursuing and feeding upon small smelts schooling at the surface.

BURBOT (LOTA MACULOSA)

On July 30, 1903, George Moses told the present writer that he had often caught "cusk" that contained smelts; and, again, in October, 1906, he said that he had found them "full of smelts."

On August 9, 1907, a "cusk" 16¼ inches long, caught by the present writer in Sebago Lake, after being taken into the boat disgorged one smelt slightly over 1 inch long. Another, on August 21, disgorged a partly digested smelt that before ingestion probably had been between 4 and 5 inches long.

On August 14, 1908, while fishing for smelts, the present writer caught a "cusk" on smelt bait, which weighed 2 pounds 1 ounce. It disgorged many young smelts from 2 to 2½ inches long. A "cusk" weighing 3 pounds, caught on July 30, 1909,

contained one smelt. On June 27, 1911, a "cusk" 22¾ inches long contained two heads of large smelt, portion of the body of a large smelt, two partly digested small smelts, and two small fresh-water sculpins (Cottus); also a nymph of a stone fly. This fish was taken in about 70 feet of water.

PARASITES

Besides the previously mentioned vertebrate enemies, there are invertebrate animals that are regarded as more or less inimical to smelts. Concerning invertebrates that are actually harmful to smelts very little is known. Parasites of fishes have received some study by various specialists, but very little attention has been given those of the fresh-water smelt. Of those known to infest the smelt none has yet been shown to be actually injurious under ordinary conditions. The most conspicuous of fresh-water smelt parasites is a small degenerate crustacean known as a copepod. However, this animal is not peculiar to the smelt but has been observed attached to the gills, fins, or skin of other fishes.

To the gills, of some smelts taken by hook and line from Swan Lake, Me., and sent in by A. D. Merrill in May, 1898, many parasitic copepods were found to be attached; and on various occasions the present writer collected many dead and dying smelts on the surface of Sebago Lake. Thirty of these fish were from 4½ to 5½ inches long and were more or less fungused. Parasitic copepods were numerous on all of them, principally upon the gills but occasionally elsewhere. Some of these copepods were submitted to Prof. Charles Branch Wilson for identification, and from him the following letter was received:

> I find the parasites on the gills of the smelt taken from Sebago Lake to be *Ergasilus centrarchidarum* Wright. They do not usually occur in sufficient numbers to injure their hosts, but under favorable conditions may breed rapidly enough to destroy the fish. The physical condition of the fish has much to do with the effect produced upon it by the parasites, hence the latter produce pernicious effects during the fish's breeding season, when it becomes thoroughly exhausted and weakened. The minnows and darters usually catch enough of the larvæ of the parasites during their free-swimming period to keep them within due bounds, the small top minnow being especially serviceable in this respect. This is the same form that was found at Culver [Indiana] last summer [1906], and it probably infests the fish in all fresh-water ponds and lakes to some extent.

The other parasites of the smelt that have received scientific notice are "worms." The first to attract attention is a small leech, which in connection with the smelts up to the present time has been found in Lake Champlain. Cheney (1895, p. 229), writing concerning the icefish of Lake Champlain, said:

> I found that the smelts caught at Port Henry had an attachment which was entirely new to me, in the form of a sucker. The sucker was very like a worm, a little thicker than an ordinary knitting needle, dark gray, somewhat mottled in color, and they seemed to be jointed in the body. They were from one to two inches in length, and the sucker which occupied one end of the body looked like the end of a tin horn reduced in size. These suckers could be seen about the holes in the ice after the fishermen had removed them from the smelts, wriggling about on the ice or in the icy water. They made no mark on the smelt, nor did they do them any apparent harm, and they were entirely new to me.

Both at Port Henry and at Presberry Point on February 16, 1911, the present writer found some smelts infested more or less by these leeches. Sometimes a bunch

of them, about the size of a hickory nut, was said by the fishermen to be found on one smelt. Some of these were saved and identified by Prof. J. Percy Moore, of the University of Pennsylvania, as *Piscicola milneri*. It is not evident that they are harmful to the smelt.

Henry B. Ward, who studied the internal parasites of Sebago salmon in 1906, mentions but one internal parasite of the smelt. In the salmon he found a new trematode, which he named *Azygia sebago*, and it was the only trematode found in the salmon. In order to ascertain if the smelt played any part in the life history of this distome, he examined 52 smelts, and in 46 of them he found specimens of *Azygia sebago*. He said:

> The parasite occurred in the stomach only and the infestation was small, from 1 to 14 distomes being found in each host, with an average of only four to a fish. In most cases the parasites which were taken from the stomach of the smelt were immature, not having yet reached that size at which the production of ova begins; they were on the average 3 to 4 mm. long, or in some cases even smaller, running from 1.5 to 2.5 mm. [less than $\frac{1}{10}$ inch] in length. Single specimens reached a length of 6, 7, and even 10 mm. [nearly $\frac{4}{10}$ inch]. In one case, indeed, there was none shorter than 6 mm., and the specimens varied from that to 10 mm., so that one can not fairly maintain that they never reach the size attained in the salmon. Nevertheless, after the account is cast up the average shows distinctly that the distomes do not reach their full size in the smelt and, so far as collections made during July and August can indicate, those taken from this host are usually small in size and sexually immature. I did not obtain any information as to the source from which the smelt acquires infection, but in view of the universality with which smelt form the food of the salmon in Sebago Lake the latter undoubtedly owe to them the major portion of their infestation with this parasite.

In a footnote Ward states that these distomes occurred equally in both sorts of smelt and those from the smaller smelt were larger than those from the larger fish. "This," he said, "is, of course, a mere accident, but it serves to show that the two types of smelt conduct themselves alike toward the parasite."

Professor Doolittle found some smelts from Sunapee Lake with the alimentary tract containing parasitic worms, such as tapeworms, distomes, and threadworms. Subsequent examination by D. R. Crawford, of the Bureau of Fisheries, of 94 specimens from nearly $1\frac{7}{8}$ to about $4\frac{3}{8}$ inches long revealed that 27 were more or less infested by cysts of some parasitic worm in the walls of the stomach, and one was heavily parasitized, having cysts in the liver as well as in the stomach. Each of two specimens contained a small worm. The 29 parasitized smelts ranged from about $2\frac{1}{2}$ to a little over $4\frac{1}{6}$ inches, averaging nearly 3 inches. Ninety-four specimens were found dead and dying along the beach at Soo-Nipi Park on April 22 and 23 and November 8, 1910. Parasitized fish were found in both April and November. Of 71 smelts from about 4 inches to nearly 5.3 inches long, from Massabessic Lake, N. H., on April 14, 1904, 34 were infested with cysts in the stomach, the majority heavily so. These were all spawning fish and had no food in their stomachs.

As previously remarked, it is not known how harmful or harmless the parasites mentioned (or any other parasite) are to the smelt. As Doctor Wilson said, the copepod parasite is a menace only when conditions for its undue increase or other conditions are very favorable. He mentions that certain small fishes, by eating the parasite while in its free-swimming stage, ordinarily keep it within due bounds; but such fishes as darters and top minnows, which he mentions, do not occur in Sebago

Lake, for instance, although there are various species of minnows that may consume some of the young parasites along with other "plankton", and the small and young smelts, being almost exclusively plankton feeders, may be largely instrumental in keeping this parasite reduced.

OTHER ANIMALS

Various animals other than those mentioned have been accounted enemies of the smelt because they subsist upon it more or less, which may assist in this direction. Loons and crows are known to feed extensively upon the dead and dying copepod-infested fish, and thus destroy many egg-bearing copepods. If everything that eats smelts is to be convicted on that account, then the smelt is one of its own worst enemies. By referring to the detailed table of stomach contents of smelt in Sebago Lake, it is seen that a large proportion of the food of the large smelt consists of the young and the small form of smelt.

One of the most pronounced "natural enemies" of the smelt has been stated to be the landlocked salmon. With one or two exceptions, there is no one who would regard the smelt as an enemy of the salmon. On the contrary, its presence in salmon waters appears to be essential to the existence of the salmon.

If the distome parasite described by Ward as present in salmon is harmful to the salmon, then logically, in accordance with custom, this little worm is to be regarded as an enemy of the salmon. If Ward is correct in suspecting that the smelt acts as an immediate source of supply of the parasite to the salmon, then the smelt is to be regarded also as an enemy of the salmon. Ward found the parasite as common in the small smelt as in the large one. The possibilities, then, are that the small smelts transmit the parasite to both salmon and large smelts, as both subsist largely upon the small smelt. Therefore, if the parasite is harmful to the large smelt, to be consistent the small smelt should be reckoned among the enemies of both the salmon and the large smelt.

The foregoing affords possible examples of certain "enemies" that are both harmful and beneficial, but it has not yet been determined which exceeds the other. If such conditions obtain, probably under ordinary natural conditions there is a balance, and it is only when the balance is disturbed that the parasites become a detriment.

The paramount enemy of fish is man, for he is the great disturber of balances. He not only has been and still is to a great extent the most wanton and selfish destroyer of fish themselves, but if he suspects any other animal of eating any particular fish that is the object of his own pursuit, he immediately denounces it as an enemy to the fish and himself. He does not realize to what extent the existence of his favorite fish may depend upon one or another of the so-called enemies. If he sees a loon or a flock of sheldrake feeding in a salmon lake his imagination runs riot, and the birds are forthwith indicted for alleged destruction of salmon, when the fact is they are doing good work in cleaning the lake of dead and dying copepod-infested fish. Once the present writer heard his guide damn the crows and loons because the birds beat him to the dead smelts floating at the surface, which he desired for salmon bait. The sportsman observes a few heron along the still water of some trout stream; the heron is then, without benefit of clergy or jury, convicted of

destroying trout, when the birds were actually feeding upon suckers; and the sucker is condemned by the same judge for alleged destruction of trout eggs.

The same sort of situations extend through the whole field of so-called "enemies." The term "enemy," then, is an unfortunate misnomer when the balance has not been upset in favor of an alleged enemy. Under such circumstance the animal may actually become not only a menace but a destructive agent. However, the extermination of this, in the majority of cases, is not so likely to remedy the situation as it is to render some other factor more detrimental. Efforts directed toward control should be constructive rather than destructive. The aim should be to restore the balance as nearly as possible by renewal of the lost parts of the mechanism rather than by the removal of any more parts. While, as has been stated, some of the most highly esteemed game fishes are pronounced smelt eaters, they are not regarded as enemies by the sportsman. In fact, many anglers regard the smelt as undesirable and obstructive to angling. This question is discussed on subsequent pages.

HARMFULNESS OF SMELT

There is an occasional individual who rather inconsistently pronounces the smelt to be an enemy of certain game fishes. More than a quarter of a century ago Bainbridge Bishop (1897) entered a protest against the introduction of smelts into trout and salmon waters. By means of a long argument entitled "Are smelts a menace?" he evidently believed that he had proved his case. But while his objections to the indiscriminate distribution of fishes into waters not previously containing them is sound, his argument against the smelt is based upon false premises and is fallacious and misleading. The fault in his article was apparently attributable to his lack of knowledge concerning the habits of some of the fish discussed and concerning the smelt in particular. The article contains so much of interest and value that it is quoted here at length and is followed by comments on certain inconsistent and incorrect statements.

I see that the Fish Comissioners congratulate themselves that it took them only six years to fully stock two of the most beautiful trout and landlocked salmon lakes in New England, and that the lake trout there caught are larger and fatter than common. Just so; the adult trout fatten on the smelt and the smelt can fatten on the young trout and landlocked salmon; so the wheel goes round. The smelt being 1,000 to one in the majority, any novice can figure out what the result will be.

Let the Fish Commissioners be assured of one thing—they have effectually stopped the breeding and increase of trout and landlocked salmon in these lakes for all time to come. As an object lesson, look at Lake Champlain from Westport to Cumberland Head. It is an ideal lake trout water in every respect. For the last fifty years there has been once in a while a fine lake trout caught, but like angels' visits they are few and far between. Why do they not increase and become plenty? For answer I would say it was this: smelt have free access to this lake from the sea, and have partially or practically become landlocked, that is, they can be found at all times of the year in all the deeper parts of the lake and in the identical depth of water that would naturally be inhabited by the young and adult trout.

The planting of lake trout and landlocked salmon in Champlain, with the idea that they would breed and increase, is fallacious in the extreme. It will only result in a waste of time and money.

Although if landlocked salmon could be made to breed in the streams running into Champlain, that is above where the smelt go, and would stay there till they grew of a size that the smelt could not destroy, we might be hopeful of a favorable result.

Young lake trout and landlocked salmon have no more chance among smelt than young lambs have in a pack of wolves. Anyone who has fished through the ice for smelt, and has seen them dart a yard or more and strike a heavy sinker or large bait, can judge whether they are predatory fish or not. The boys catch them without a hook, by simply tying a white rag to a line for bait; the smelt strike this and hold on and are drawn out of the water. I have seen quite a number caught in this way. The smelt's mouth is large and well armed with sharp, hooked teeth. They are well equipped for business, and they breed like the plague of flies in Egypt. A pretty style of fish this to introduce into lake trout and landlocked salmon waters. Remember, when hungry they will attack a fish of nearly their own size and weight. This I know to be absolutely true. The most unfortunate part of the whole business is this, that the smelt live nearly the whole year round in the identical depth of water that trout, both young and old, frequent.

The introduction of smelt into the great lakes would be almost a national calamity. The day it is done foretokens the extinction of the trout fishing, both commerical and sporting.

Being myself an old fisherman and something of a student naturalist, I call upon the Fish Commissioners to rise and explain.

Mr. Bishop's diatribe, just quoted, elicited a reply in defense of the smelt from H. O. Stanley (1897), then one of the fish and game commissioners of Maine. He wrote:

I notice in your paper June 5 an article by Mr. Bainbridge Bishop entitled, "Are Smelts a Menace?". The writer, I should judge, is not familar with the habits and characteristics of the fresh-water smelt of Maine, which is the variety we are introducing into the lakes in Maine. This fish does not feed on the young of other fishes. In that respect they are as harmless as the sucker. Even if they did, they do not come into waters where you would find the young trout and salmon, *i. e.*, near the shore. This smelt is only found in deep water away from the shore, feeding mostly from the surface.

If the gentleman has ever been in Maine, the home of the landlocked salmon, and is familar with their origin, he must know that every lake where they are placed by nature abounds in smelts. He should also know that we cannot successfully raise fine salmon without smelts for food. In every lake in Maine where you find the smelt, there you find the finest trout, salmon and pickerel, and in greater abundance. In every instance where we have introduced the smelt, the salmon and trout have at once increased in size and quality in a very marked degree.

I think the gentleman need borrow no trouble about any harm coming to the trout and salmon by the introduction of the fresh-water smelt. We think so much of them in Maine that we are introducing them into every pond adapted to them in the State.

Mr. Bishop's accusations against the smelt, above quoted, were preceded by a reference to alleged damages to trout following the introduction of pickerel into certain waters, which he supplemented by the following warning:

It is a serious matter to disturb the balance of nature. Men should consider carefully before venturing to do so.

This is sound advice that should be applied to every proposition to introduce any nonindigenous species, not excepting the smelt, into any body of water. If in the past the commissioners of inland fisheries in Maine had considered the possible results of indiscriminate fish-cultural distribution in that State, present problems of inland fisheries conservation might have been avoided. However, as Stanley said, every lake naturally inhabited by landlocked salmon contained smelts; and, as stated elsewhere, the smelt may have been an important factor in the "landlocking" of salmon. Furthermore, as indicated by Stanley, there is no known instance of the successful establishment of introduced landlocked salmon where smelts also have not been introduced.

If Bishop referred to the large form of smelt he was quite correct in regarding it as something of a fish eater, in which respect it may be considered as relatively voracious, as already indicated by some instances mentioned in this paper in connection with the food of smelts; but under no natural conditions are they a menace to young trout and salmon, for the young of the latter two species do not occur in the deep-water resort of the smelt, and the smelt is not seeking food when it ascends streams to spawn, where young trout and salmon occur.

Nordqvist (1910) states that the fishermen at Lake Oppmanna, in southern Sweden, assert that the smelt destroy pike-perch fry in great quantities.

From what is known of the food and feeding habits of the smelt, under any circumstances only the large form could be regarded as to any extent dangerous to trout or salmon. A 14 or 15 inch smelt is quite a formidable fish of prey so far as dental equipment and capacity are concerned, but such smelts are not of common occurrence. With a few exceptions the smelts of natural, landlocked, salmon waters in Maine are comparatively small. One of these exceptions is Sebago Lake. There is no evidence that any scarcity of salmon in that lake can to any extent be attributed to the smelt.

There is no evidence that salmon ever eat the adults of the large form, although it probably does not discriminate between the young of the large and small forms. Therefore, in the introduction of smelts solely for salmon or trout food it would be advisable to select the small form; for, unless the small form, under favorable conditions, attains the size of the other, two services thereby would be rendered — (1) provision of food of suitable size at all times for the trout and salmon, and (2) avoidance of any possible danger from a potentially predatory large smelt.

It is known that in Lake Champlain salmon once existed in considerable numbers, and there can be no doubt but that the smelt (large smelt at that) was a contemporary inhabitant of the same lake; but there is no evidence that the smelt was in any way concerned in the extinction of Lake Champlain salmon or that it was a contributory cause of the scarcity of lake trout.

For the reason that there are still those who regard the smelt in inland waters with disfavor on account of some imaginary harmful trait or other, as depicted by bishop, this article has been given the prominence it has received here, although it is something over a quarter of a century old. An example of another common objection to the smelt is found in some extracts from a letter received by John W. Titcomb then fish commissioner of Vermont, and published in Forest and Stream of June 27, 1896, as follows:

> May 8th I reached Sunapee Lake and thought I would try the fish for a few days before writing to you, as I intended doing. * * * . The poor fishing was laid to the smelt, as they had come in shore and run up the stream and then gone back to deeper water, and are followed wherever they go by the salmon and trout. Now it is a question in my mind whether smelt are or are not an advantage, and from what I learn at Sunapee, and I have been there now a number of times, I am about convinced that they are a disadvantage in more ways than one.
>
> They no doubt spoil fly-fishing, as the trout and salmon are forever after the smelt, and after the first week or so after the ice leaves it is almost impossible to catch the smelt for bait, and even if they are caught they cannot be kept alive more than a few minutes, and consequently it is about impossible to obtain bait, and even if it could be got it is of very little use when dead. Of course

minnows, shiners, and small suckers, can be caught and kept alive; but where there are smelt in the water a piece of maple sugar for bait would be almost as effective as any other fish but smelt. No doubt of the smelt being great food; but if it spoils fishing with rod and tackle where is its advantage? It certainly may ruin the fly-fishing, as it no doubt does the bait fishing, to a very great extent.

There is no fly-fishing at Sunapee at all, and the only way it is accounted for there is the smelt.

In 1899, a correspondent of Forest and Stream ("Special" 1899a) after discussing the abundance of breeding smelts and the number of dead and dying at the surface, wrote: "Later these little fish disappear—no one knows whither—and the trout and salmon that have been feasting on them are forced to seek other food.

In another place, speaking of the fishing for salmon and trout in New England, he said: "The last reports say that the smelts are fast disappearing, and there is no doubt but what fishing will be better very soon."

In the May 20, 1899, issue of Forest and Stream a correspondent, writing of New England spring fishing, said that in Richardson and Mooselucmaguntic Lakes there were millions of smelts, many of them dead from spawning, and that the trout were gorging on them and would not take artificial flies or other bait till the smelts were gone. Yet, he added, "Still a few trout were taken."

Maine Woods of May 12, 1905 (p. 2), having reported "lots of dead and dying smelts on the surface of Rangely Lakes," said:

> It is a mystery yet unsolved why smelts die in this manner nearly every spring, but one thing seems pretty certain about it; the fish [trout and salmon] can not be caught at the time the smelts are dying. Trout and salmon both feed on smelts, and if one is caught it is found to be full of them. The period, however, is short, beginning as soon as the ice is out and lasting a week or ten days, when the supply runs out and the fish are ready for something else.

In the report of the division of fisheries and game of Massachusetts for 1921, concerning artifical propagation of the smelt, it was reported that no collections of fresh-water smelt were made for distribution. It said:

> The run at Laurel Lake, Lee, was scattering, and apparently the smelt are dying out—a source of gratification to local fishermen who believe them to be a detriment to the fishing.

Commenting on the statements contained in the letter above quoted, Mr. Titcomb (1896) wrote:

> It certainly would be unreasonable to think of depriving a body of water of desirable fish food for the purpose of forcing a fish to rise to the surface to take flies or artifical food.

This is a very pertinent remark, for where there is not sufficient food the fish can hardly attain a size to make them worth catching. Where insects afford the only food supply trout do not attain a very large size, and it has been proven that if there are no smelts the salmon as a rule do not thrive.

It seems to be a peculiar trait of some men to account for phenomena by the most prominent or conspicuous condition that may be a possible cause. In other words they are prone to jump at conclusions without sufficient verification. This is particularly characteristic of some anglers. If in any lake the water is high or low and the fishing good or poor, it is good or poor because the water is high or low, as the case may be. Good fishing or poor fishing in a lake abounding in or free from smelts is ascribed to the abundance or lack of food supply, and those persons have

in mind the one body of water and the immediate conditions obtaining there upon which to base their conclusions.

Smelts abound in Sebago Lake, Me., and they are apparently just as abundant one year as another, but the fishing varies; one year or at one portion of the season the fishing is good, at another bad. Which is the smelt accountable for? In Sunapee Lake also there have been seasons of good fishing, notwithstanding the smelts, and there were times of poor fishing before Sunapee knew the smelt, if the reports of the State commissioners can be trusted.

As for fly fishing being ruined by the abundance of smelts or other food supply, other waters where the smelt abound and where fly fishing is unexcelled need only be cited to controvert the contention. One of these is Grand Lake, in the western St. Croix waters. In any body of water one principal reason that fish are not taken on the fly is that they are not fished for with the fly. Notwithstanding the prevalent opinion that salmon never take the fly in Sebago Lake owing to the smelt, whenever anyone has persistently fished with a fly salmon have been caught by that means, and one usually has to persistently fish by any method to land many fish. Furthermore, the writer has examined hundreds of Sebago salmon, and while the majority, when they contained any food at all, had smelt in their stomach, many have been found having insects only, and some containing both insects and smelts or some other fish.

These remarks apply mainly to the landlocked salmon and it may be added that the writer has still fished for smelts and salmon on the same "grounds" and used live smelts, live shiners, and pieces of smelt for bait for salmon, and has caught just as many on shiners as on smelt and nearly as many on the "cut bait" as on live bait.

In trolling for salmon, while a fresh dead smelt is regarded as the best bait they are often taken on shiners and artificial lures, even while smelts are running and dead and dying strew the lake.

In the two weeks prior to mid-September in 1924 fly fishing for salmon and trout at upper Rangeley Lake was reported as very good on certain days. Some 6 and 7 pound salmon were thus taken. As previously stated, smelts abound in Rangeley Lake, and the fact is that salmon and smelts occur together in the deeper water during the summer months. It can not be for lack of smelt food that salmon take the fly or other baits at other season than in the spring, and it hardly can be attributed to the abundance of smelts that trout and salmon fail to take the fly or other lure in the spring. The writer was told by an angler who has fished Rangeley Lakes for 50 years or more that he seldom had found more than one or two smelts in a salmon at one time, but often caught trout on a fly and found them to be gorged with smelt.

It is quite possible that abundance of some food, as the smelt for instance, may modify the fishing. Perhaps fewer fish are caught than would be the case if there were no smelts. There is one more thing, however, and that is that landlocked salmon would not attain a very large size in any considerable numbers if deprived of smelt food or its equivalent in some other species.

FRESH-WATER SMELT FISHERIES

It appears that in northern Europe, particularly in Germany and Sweden, far greater attention has been given to the commercial possibilities of the fresh-water smelt than they have received in this country. Bloch (1796) stated that at the first freezing they were brought in quantities to the markets from the neighborhood of Müggel and other neighboring lakes. Every year tons upon tons from the lakes were said to be seen in the markets. Quoting Linnæus, Bloch said that at Upsal, Sweden, they formed heaps, which sent forth a bad odor in the streets. He said that they were taken in small-mesh nets, and that the smelt did not live long, dying soon after being taken from the water. He added that the fish was so common and cheap that it was hardly worth transporting.

According to Reuter (1883), in Finland, during the spawning time the smelt is caught in great quantities in seines and hand nets, and enormous quantities of quite young smelt fry, the so-called "Siniäisiä," are collected in certain districts. The smelt is caught all winter by nets as well as by bottom fishing. By "bottom fishing" probably is meant hook-and-line fishing.

In the lakes of Finland, according to Nordqvist (1910), the best fishing time is from the time the lakes are frozen over until the ice is covered with snow.

In two neighboring lakes that lie not far from the west shore of Lake Ladoga, the smelt is fished only in the winter, under the ice, mostly with very fine-meshed drag nets about 180 meters (a little over 180 yards) long and up to 25 meters (a little over 25 yards) deep. He mentioned one net which, when the size of the thread was considered, had a mesh opening scarcely more than 2 millimeters square (about .08-inch bar), but other nets had larger meshes.

In this country the fresh-water smelt fishery was restricted for the most part to Maine, New Hampshire, and Lake Champlain. In the New England States the fishery, if it may be called such, was largely carried on in the spring during the breeding runs of the smelts in the streams, although for a good many years there has been some hook-and-line fishing through the ice. In Lake Champlain hook-and-line fishing is the only method employed.

There never has been much more than a local marketing of fresh-water smelts caught in the spring, except in one locality to be mentioned later. Most of the spring fishing was in the way of sport, most often by dip nets, and always at night. A graphic description of this sort of fishing long ago on a stream flowing into Long Lake, near Bridgeton, Me., was written by J. C. Mead (1885) under the pen name "North Bridgeton." It is worth quoting at length:

> On the 21st of April the word went round that the "big smelts" had put in an appearance in the streams the evening before. This was enough to bring over a dozen men and boys to the banks of a certain well-known brook near the head of Long Pond. A part of these carried dip nets, and the most of the others bundles of pitch-wood or jacks, although two or three, one of whom was the writer, carried no equipments of any kind, but went "merely to see the fun."
>
> The evening was warm and very still, and a moon nearly at first quarter helped to prolong the lingering twilight. A fire had been kindled at some little distance from the stream, and as it had been agreed upon to keep away from the water until it was fully dark, all hands were grouped around the fire and were indulging in the usual gossip and jokes of such occasions. All at once

some one asked, "Where's Amasa?" A glance through the intervening alder thicket brought the answer, for in that direction a figure could be dimly seen standing in the brook and busily plying a long-handled dip net. This was sufficient to send everybody to the water, and jacks were soon flaring at intervals along the banks and showing fish by thousands. And now began the excitement. Those who had nets worked them, and those who came "just to see the fun" forgot that this was their object, and waded into the ice cold water, catching the fish in their hands and throwing them ashore. Boys screamed and men shouted. The air as well as water was full of fish, and the sedate man, regardless of shoes and stockings, was knee-deep in the current, his hands grasping here and there, while the pockets of his overcoat and the crown of his hat were full of wriggling fishes. Two dozen fish averaging nearly eleven inches in length, were captured with a single sweep of a dip net. The piles upon the bank were fast increasing to proportions far beyond a market stall, when a rational thought seened to strike some of the cooler heads. "Let's stop this, boys; it's nothing short of murder, for we have all we can make any use of." For once men were reasonable, and boys, as usual, followed in their lead. The fish upon the bank were gathered up, and Rodger's Brook with its swarming waters was left to itself. But in a very short time over three hundred weight of a species of fish than can hardly be surpassed in table qualities were on their way to the village. The express the next morning showed plainly that distant friends had not been forgotten, while a large box placed in front of a store with a "help yourself" attached was speedily relieved of its contents.

But this was only the work of one evening, and the next night the fish would be even more abundant. The word had spread, and long before dark everything for miles around that could be called a dip net was on its way. In place of a net one fellow carried a large corn popper with an extension lashed to its handle, and another had a tin pan with its bottom punched full of holes and nailed to a pole. Quaint as these implements were, both, it is said, did good service. Through the evening and well into the night dozens of jacks and torches sent their brilliant glare along the stream and into the surrounding forest. No doubt the excessive light frightened the fish and kept many back in the lake, but still hardly an individual went away without fish enough for any reasonable demands. On either this or the preceeding night two men, one to carry a light and the other to handle the net, could have filled an ox cart. This last statement, of course, is on the supposition that the two men could have had the stream all to themselves. As it was, the large number of fishermen, especially on the second evening, rapidly scattered the fish and drove the most of them back into the deep water of the lake.

The above is only a partial account of what happened on a single stream, and we hear similiar reports from nearly every tributary of the Sebago waters. At Bear Brook, in Harrison, but little more than a mile away, the run has been longer and probably even more fish have been taken. * * *.

* * * They are caught some through the ice in winter and in very deep water almost always. Those caught through the ice, or with hook and line at any time, are generally larger than those taken in the streams in breeding time. On the whole, smelts in these parts are something of a puzzle, and the people who see the most of them simply expect them to put in an appearance at about such a time, kill them by the thousands when they do come, and think no more about them until their next appearance.

The same author previously wrote in the American Angler (Mead, 1883):

Commonly, smelts are caught with dip-nets having long handles, sometimes with the hands, and I have heard of the spear being used the present season at Stevens' Brook. For a few years they have been taken in considerable numbers with the line through the ice; but as usual, where nets and spears get into use on any fish, line fishings ranks last in order.

In fishing with dip-net it is customary to pair off—one man takes the net and his comrade in battle takes a torch of pitch-wood or something of the kind. The torch-bearer "shines his light" so as to give the best view of the brook possible—the "net man" gets his eye on his game, and with a long sweep of his net with the current, dexterously bags his fish, "head on." It is fun for the boys when a novice comes to the front and dips against the current and the startled fish scoots cleverly off ahead of the net and safely takes a new position.

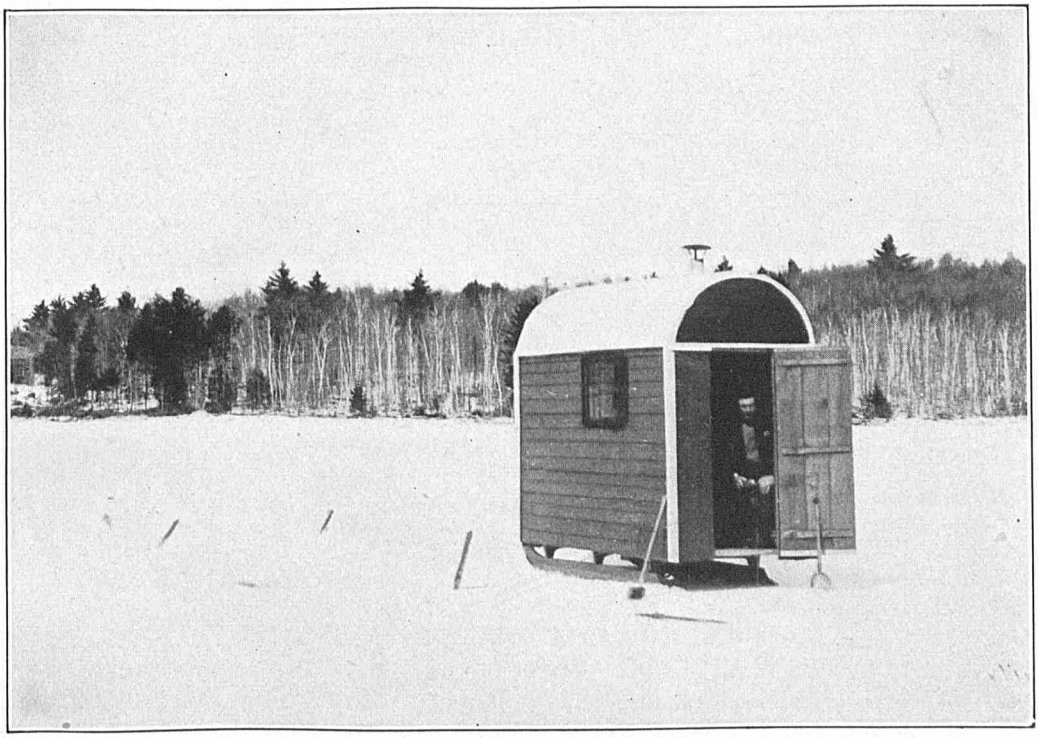

FIG. 16.—Smelt-fishing house on the ice at Sebago Lake, Me.

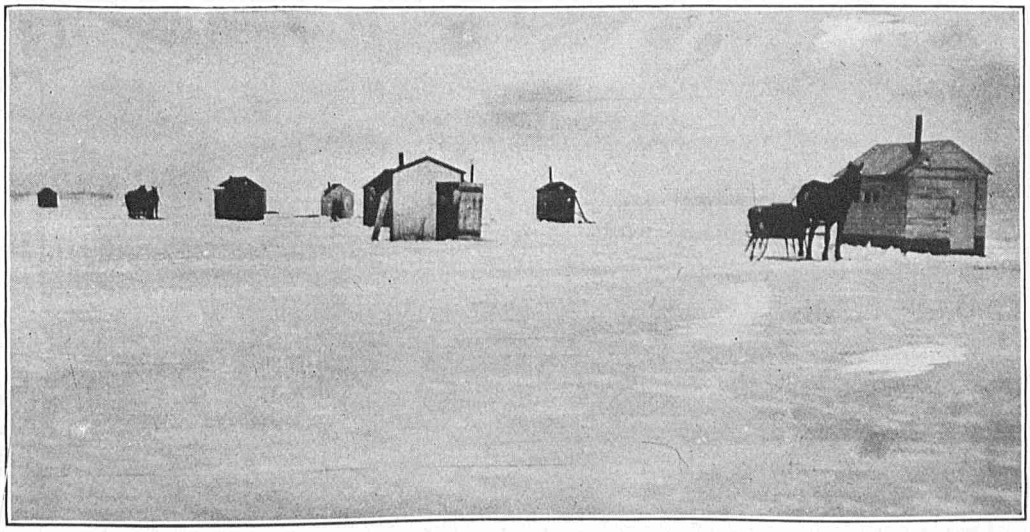

FIG. 17.—Group of smelt (icefish) fishing shacks on the ice at Port Henry, Lake Champlain, February, 1910

Catching with the hands is easily done; it is as simple as picking up "wet corn cobs." The roughness of the smelt in the water, or when fresh from it, makes it an easy matter to retain a hold on them.

Spearing is done after the manner of "jabbing suckers," I suppose, and is not a sportsman-like manner of killing anything but sharks and sword-fish. The same may be said of netting.

I do not dwell upon these methods for their merits as true sport, but simply to show the pratice of the times. Both nets and spears are prohibited by the laws of the State, but no penalty. Smelts are protected "above tide water," but nothing in the law is understood to apply to the fresh-water smelt. Some attempt has been made to call attention to the necessity of some act to regulate the taking of these smelts, but so far without success.

Fishing through the ice is practiced on Sebago Lake in February and March—usually in about sixty-five feet of water. Small hooks are baited with bits of pork or something of the kind, and are lowered toward the bottom.

Cheney (1894b) thus describes the method of fishing for smelts in Sunapee Lake, N. H.:

The tackle used in catching smelts is a hand line of small size, although the size is not material, and a fine leader 9 feet long. Have the leader tied with loops, three in number, exclusive of the two end loops for attaching snelled hooks. To one of the end loops of the leader fasten a sinker of sufficient weight to take the line quickly to the bottom. A pear-shaped sinker, with wire swivel and 1¼-oz. in weight, is what I have used. Fasten three snelled hooks, number 9 or 10, to the three loops in the leader and your smelt line is complete. Fish very near to the bottom and be constantly on the alert, for smelt bite very delicately and it requires some experience to hook them. For bait use earth worms untill you get a smelt, and thereafter bait the hook with pieces of cut-up smelt, which they seem to prefer to any bait which can be offered to them on a hook.

The present writer observed the method of smelt fishing in Sunapee Lake and even caught some smelts himself in 1910 and 1911. The hook-and-line fishing was done principally to secure bait for salmon and trout. The sinker was fastened at the end of the line and two or more hooks were put on a little distance above. No leader was used. As toll bait a paper bag of oatmeal was lowered to the bottom and then broken, letting out the meal, which was supposed to attract the smelts. Usually earthworms were used first, then a small piece of the belly of the smelt. The smelts, as elsewhere shown, were small—smaller than any that the writer ever caught on a hook elsewhere. They were just right for trout and salmon bait. As stated elsewhere, the depth of water was 80 or 90 feet.

A line with one or two hooks below the sinker was employed by summer fishermen in Sebago Lake, Me. In fact, one man used the same rig that he used in winter. As an innovation, which proved satisfactory, the writer used a brass wire spreader fastened to the line just below the swiveled sinker, with a snelled hook at each end. His preference for the large smelts was a No. 1 sprout hook. The fishing was usually in about 70 feet of water—sometimes more and occasionally less.

The bait varied according to what was available; sometimes only earthworms could be had, and with that possibly a smelt would be caught; then a short strip from the belly of the fish was used. Earthworms, while occasionally readily taken, as a rule were not very satisfactory. Usually the most successful baits were the young of suckers, chubs, or other minnows, from an inch upward in length; but occasionally the smelt would not bite readily on this bait but would take the piece of smelt with avidity. When a large smelt bites, one has no doubt of the fact, at least he is sure that he has a bite, but the bite by a larger fish, such as "cusk," salmon, or

whitefish, is often similar. It has previously been mentioned that large smelts often take a comparatively large bait, such as smelt or shiner intended for salmon, even a bait 5 or 6 inches long. (See page 383.)

Formerly there was limited winter fishing for smelt in Sebago Lake. To what extent it is now carried on is unknown to the writer, but he is inclined to believe that there is no market fishery as there used to be. For several years large smelts commanded a uniform price, year after year, of 25 cents a pound to the fishermen. Formerly one man and his family had virtually a monoply of the smelt fishery in the spring at Songo Lock, so it is claimed. The "monopoly" was due to an advantageous position on his own shore near the lock where the smelts congregated in a vain attempt to ascend. It is reported that he used to dip tons of these smelts every spring and ship them to market in Boston and New York, where for the large smelts he received 25 cents a pound. There is now a law prohibiting the capture of large smelts in this locality during the spring breeding run. Under certain regulations small smelts may be dipped.

A letter from Dr. Edward Paine, of Waterville, Me., in reply to a letter of inquiry concerning smelts in China Lake, stated that the large smelt were taken in 60 to 85 feet of water. He said that when he first began fishing for them they were caught only in the winter. One fall, before the lake froze, he tried for them and caught a few. The next year some one "stumbled upon the idea of fishing for them early in the morning." Now the summer fishing for smelts is in the early morning. They commence biting about daybreak and continue for two or three hours. Often a peck of smelts is caught with live bait to start with, and after a smelt is caught a piece of cut bait is used. Doctor Paine wrote:

> The smelt does not rank as a game fish, but considering the sport it affords and the fine food qualities it should rank above some so-called game fish.

In Sebago Lake the present writer has fished for smelts at all times of the day excepting very early in the morning. In view of Doctor Paine's statement, perhaps early morning fishing at Sebago might yield larger catches; but very satisfactory catches have been made at other times of day, and the largest numbers and largest fish usually were taken in the late evening from just before sunset until dark. The followining computation of catches of smelts was made from an equal number of trials at four different periods of the day—morning, forenoon, afternoon, and late afternoon or evening.

	Per cent
Morning	21.2
Forenoon	17.9
Afternoon	22.3
Evening	38.6
	100.0

The foregoing figures represent the times when fish were caught, with the exception of one forenoon when none was caught. So, of course, they do not show the many failures to catch smelts at any time of day. While the time of day, in many

instances, doubtless affected the fishing, other factors, such as weather and kind of bait used, undoubtedly were concerned.

As a rule better results were obtained on a cloudy day than on a bright, clear day. A ripple on the water during a hot day favored the fishing. Often fish were caught in very rough water. The season also probably has its influence. One of the largest catches was made on a calm, clear day (September 11), but a fairly large catch also was made on July 17, while it was clear and calm.

In the matter of baits, on some occasions at no time of day would they take any sort of bait. Sometimes they would take one kind and not another, or at one time of day one sort of bait and at another time in the same day shift to another. By using a spreader with two hooks it was easily ascertained what the choice of two baits seemed to be.

In a period from August 15 to October 1, both inclusive, the baits used consisted of "live bait," comprising mostly young chubs (*Semotilus bullaris*), young redfins (*Notropis cornutus*), and young suckers (*Catostomus commersonii*); "smelt bait," consisting of a small strip from the belly or side of the smelt; and earthworms to a limited extent, especially when live bait was not available. Sometimes the smelt would take dead "live bait" as readily as live minnows, especially if perfectly fresh; but stale minnows or bait of any kind, or even iced smelt, usually were refused, though the smelt pick up dead minnows when they are thrown overboard, even though soft, as shown by stomach contents later.

For the purpose of computation, the baits used are divided into the following seven categories: (1) Live bait, (2) smelt bait, (3) worms, (4) live bait and smelt bait, (5) worms, live bait, and smelt bait, (6) worms and live bait, and (7) cut bait other than smelt. Each category represents the baits taken at any one or more fishings, but does not signify that other baits were not tried. For instance, in the "live bait" category there were four instances when smelt bait also was used, but no smelt would bite it. In the category of "worms, smelt bait, and live bait" there was one instance when early in the day the smelt would notice earthworms only, but later readily took "live bait" and "smelt bait," the latter being the most attractive. Still later the smelts would not bite at all. In another instance, in the same category, in one of the largest catches the smelts took with avidity anything that was offered them, but the smaller smelts seemed to prefer live bait while the larger smelts took smelt bait readily.

The usual size of "live bait" was from 1 to 2 or 3 inches in length, but often they would take very large shiners and smelts used for salmon bait. Instances of this kind have already been mentioned, one of which was when a smelt took another smelt nearly half as long as it was itself.

As a rule young chubs appeared to be better bait than young redfins or suckers, but often it made no difference which was used. Occasionally young white perch and yellow perch were tried when nothing else was available, but they were not of much use. A small piece of fish of any kind frequently would secure a smelt, which was then used for bait. In the instance of "cut bait other than smelt," the initial bait was a piece of young pickerel.

	Per cent
Live bait only	11.7
Smelt bait	8.5
Worms only	1.5
Live bait and worms	11.5
Live bait, smelt bait, and worms	12.9
Live bait and smelt bait	53.0
Cut bait (not smelt)	.9
	100.0

The inference to be drawn from the foregoing figures is that live bait and smelt bait together are the best baits, and that live bait is somewhat better than smelt bait. It is quite possible, however, that in some instances where the two baits (live and smelt) were used, if only one or the other had been employed alone about as many smelts would have been caught. Besides, it has been mentioned already that at times they bite almost anything; yet the figures show that with a supply of live bait, which may be supplemented by smelt bait after one smelt is caught, the chances of making a good catch are better than with any other baits.

ICEFISH OR SMELT OF LAKE CHAMPLAIN

For many years the smelt of Lake Champlain has been caught through the ice, principally in February and March, which fact probably gives the fish its local name—"icefish." For a long time, however, it appears that the icefish was not generally recognized as a smelt. Nearly 50 years ago the question concerning the icefish of Lake Champlain arose, and from time to time for nearly 30 years discussions pertaining to its identity and origin appeared in sportsmen's papers and magazines. Notwithstanding the fact that each time the icefish was authoritatively identified as a smelt, the question would not down. Under date of February 22, 1876, Cheney wrote to Forest and Stream (vol. 6, No. 4, March 2, 1876):

> In your last issue you mention the range of smelt, and I do not think it is generally known that they are caught in Lake Champlain. About a year ago, while at Port Henry, I was told by the landlord of the hotel where I was staying that it was about time for "icefish" to make their appearance. As the name was new to me, I asked for a description of the fish, judging that icefish was a local name. Being informed that they were only taken through the ice during February and March, and that they were unknown until within a few years previous, I sent the description, as given to me to Seth Green, but from my meagre statement he was unable to give the fish its proper name. I published my inquiries, and found that they were veritable smelts. And here again comes in the question of range. They are caught little, if any, south of Port Henry; are more numerous about West Port; are taken at or near Burlington, Vt., and are unknown in Plattsburg, or thereabouts, at least by fisherman I questioned while there this winter, and I could not learn that they were caught at other than the places I have named. Of course, these come in from the St. Lawrence, but are they caught to any extent in that river?

In a later issue of Forest and Stream, under date of March 21, 1876, C. H. Morse, of Boston, stated that he had taken many dozens of that "delicious fish" near Burlington, Vt., when he was a youngster, and could say that they were taken in several localities in that part of the lake, one of the favorite places being near either end of the Burlington Breakwater.

A communication in the American Angler for March 7, 1884, stated that the fish were called icefish or frostfish and were caught through the ice in great quantities for about a month, in the latter part of February and the first part of March.

The question regarding the identity of the icefish again arose in 1886. Someone who signed "Peter" to his inquiry sent some specimens to Forest and Stream for identification, and they were identified as smelt, *Osmerus mordax*.

Again Cheney (1895) stated that about 20 years before he first heard of the "icefish" of Lake Champlain, and "found upon an introduction that they were the smelt * * * ." The following year (1896a) Cheney again wrote:

> More than twenty years ago I first heard of the "ice fish" of Lake Champlain, and when I saw them I found them to be the common smelt; but from that time to this the identity of the fish has been questioned at recurring intervals. Last year, when I saw smelts being taken at Port Henry, over 1 ft. in length and weighing ½ lb. each, and was told that even larger ones were caught through the ice at Port Henry and Westport, I was obliged to admit that I had never seen smelts of such great size; nevertheless that is what they were. Last week I was at Port Henry and the identity of the "ice fish" was once again discussed, with the added information that the fish were now sent quite regularly to New York city, where they were pronounced to be different from the smelt. I had some packed to bring home with me, and asked to have several of the very large ones put in the box to have the matter of species set at rest. The man who furnished the fish told me that after Mr. Cobb's visit to the lake the United States Fish Commission had sent for specimens to determine just what "ice fish" really were, and that specimens had been forwarded to Dr. Hugh M. Smith. I asked Dr. Smith about them and he writes me: "The specimens of 'ice fish' recently sent us from Lake Champlain were the salt-water smelt (*Osmerus mordax*). There were five examples, the largest being more than 1 ft. in length and weighing ½ lb. The females were filled with ripe spawn. I have never seen such fine smelts on the New England coast, although they are sometimes taken in Maine and Massachusetts fully as large as those under consideration. As you know, this species is landlocked in some of the Maine lakes, and Prof. Evermann took specimens in Lake Memphremagog; the fish in the latter lake, however, are quite small. In your opinion, do the Lake Champlain smelts come up the St. Lawrence River each year for the purpose of spawning, or are they permanent residents of the lake?"

Concerning the origin and habits of the fish in Lake Champlain, many of those who finally recognized it as a smelt thought that it annually ascended the St. Lawrence River and thence up into the lake, but as early as 1882 at least one view was that the fish was a perennial resident. A reference to the smelt in the American Angler, however, attributed their presence to transplanting, saying: "A few smelts put into Lake Champlain several years ago have led to their permanent establishment."

Two years later the same paper (American Angler, 1884) again said: "The Lake Champlain smelt is of comparatively recent date, as it is little more than a dozen years ago that they made their first appearance." Then, again, in 1890, the American Angler repeated the foregoing statement.

Cheney (1895) presumed that they must have worked their way up into the lake from the St. Lawrence. Again, in 1896, Cheney wrote:

> I believe that smelts are not permanent residents of Lake Champlain, as they are caught only through the ice in February and March, and a search for them by anglers in the summer and fall months has proven fruitless. In New Hampshire, where the smelt is landlocked, I have caught them in June, July, and August, and if they remained in Lake Champlain permanently they would be found by those who have peristently sought them. Another reason for thinking that they come from the St. Lawrence only to spawn, for it will be noticed that they are caught in the lake

just before the spawning season, is that they have two runs of smelt in that river, one of small fish and one of large fish, such as are mentioned by Dr. Smith; the large fish of the lake answering to those known to run up the river. The landlocked smelt that I have caught in New Hampshire are much more slender, length for length, than the Champlain fish, showing that the latter are accustomed to rich pasturage probably not found in the lake. In Lake Champlain the large and small smelts are caught together, showing that the schools must mingle after they reach the lake, and they mingle in more than one way, for large smelts have been caught with small smelts inside of them, showing that the big fellows feed on their small brethren. One big smelt has been convicted of eating seven small ones at a single meal.

It appears, however, that although general ignorance concerning the smelt prevailed, there were some who were better informed. Cheney's discussion, just quoted, elicited from Bainbridge Bishop (1896) a reply that is so replete with interesting information concerning the smelt of Lake Champlain that it is quoted in full here.

NEW RUSSIA, N. Y.—*Editor Forest and Stream:* I am surprised at the article on Lake Champlain ice fish in your paper of March 28. I am afraid the anglers our friend Cheney interviewed were a stupid and a queer lot. While having the greatest respect for friend Cheney and his writings (from what I have seen for the last twenty years), I beg to differ with him, and would say, be it known to all it may concern, that as a rule Lake Champlain smelt and herring do not migrate to salt water, but at the approach of summer retire to the deepest part of the lake, where they find 200 to 400 ft. of water. Here they stay at the bottom most of the time. When the broad lake freezes over they work up in shoaler water, where the fishermen take them through the ice. They are caught later in the winter at Port Henry, it being further away from the deeper part of the lake.

I have seen smelt in the lake every month in the year, and have caught them in most of the summer and fall months. While trolling off Cedar Beach in very deep water with a lake trout rig I caught a smelt 14 in. in length. This was in July. I was running a good-sized dace 150 ft. below the surface, using 1½ lb. lead. Also in August while trolling I caught a ½ lb. smelt in the middle of the lake opposite Westport, where I was running a minnow 200 ft. below the surface. When camping in August at Apple Tree Point, a little north of Diamond Island, I used to go out before sunrise to fish for wall-eyed pike in about 100 ft. of water. Very often the pike would chase and drive schools of smelt to the surface. They would leap out of the water by hundreds; they were fair-sized smelt.

In September I was fishing on a reef far out in the lake opposite Westport. This reef has 18 ft. of water on it, breaking off suddenly to 200 feet. A strong current was running from the deep water over the reef. Pike were biting finely. Once in a while the water would fairly boil close around the boat, caused by the smelt coming to the surface, driven up by large fish. Some of the pike threw smelt from their mouths after they were in the boat. Game protector Goper Liberty was with me at the time. Once while anchored on this reef in a still time with the current running as before, suddenly I noticed great quantities of air bubbles rising to the surface all over the reef. This was a mystery, but it was soon solved by the appearance of thousands of smelt leaping from the water apparently disabled and in trouble. It seems that the current brought them up from deep water and the diminishing pressure expanded their air bladders to such a degree that it brought them to the surface in distress, notwithstanding that they expelled part of the air before they broke water.

I have taken fair-sized smelts from the mouths and throats of wall-eyed pike all through summer and fall months; this was when fishing in and near very deep water; and have frequently used smelt so taken for bait with good success. My friend, Samuel P. Avery, Jr., tells me that he picked up a dead smelt on the shore of his island at Button Bay. He went out on his favorite reef and with this single smelt caught five fine wall-eyes. Smelt are the natural food of wall-eyes in Champlain and make the best bait. I have never found smelt in black bass taken in Champlain

Sometimes smelt come to the surface toward night, and in cloudy weather when the lake is still observing persons can see them swimming about in large schools, making a wide and curious

ripple on the water. This is generally seen at the middle of the lake, where the water is the deepest. Smelt can be caught in Lake Champlain in any of the summer months by going to the right place and using the right means, but I do not think to much advantage, as they lie in deep water and are more scattered than in winter; still, by a little effort enough can be caught to use for bait.

Here I want to raise a note of warning to those that think of introducing smelt to feed lake trout; they are ferocious little brutes and persistent destroyers of small fish living in all depths of water; they would destroy the young trout. This I think is one reason lake trout are not more plenty in Champlain.

But meanwhile Cheney had been enlightened by another distinguished observer. In the April 18, 1896, issue of Forest and Stream he stated that his friend, Rowland E. Robinson, had written him a letter concerning the question of residence and migration of the smelt, from which he quoted as follows:

Hon. M. F. Allen, of that place [Ferrisburg, Vermont], told me a few years ago of catching pike-perch off Split Rock, in Lake Champlain, that were gorged with smelt. I do not recall the date, but it could not have been earlier than the middle of June, and may have been in July or August. Mr. Allen is an old angler, well acquainted with the varieties of fish common in our waters, and could not have been mistaken in the identity of the smelt.

I well remember seeing an occasional specimen among the great hauls of other fish taken in the old days of unrestricted seining on the then famous fishing ground at the mouth of the Lewis Creek, the Sungahneetook, or Fishing Weir River of the Waubanakees. These facts go to show that the smelt remain in the lake during at least part of the summer.

Cheney then went on to say that the author of "Uncle Lisha" was the first person to his knowledge residing on or near Lake Champlain to call the smelt of the lake by its proper name, or, in fact, to admit that it was a smelt. Cheney then continued:

That Mr. Robinson has himself observed the smelt among the fish caught in the lake, and that Senator Allen bears like testimony, should settle the question of their presence in the lake in summer. There is a whitefish found in Lake Champlain the young of which might be mistaken for the smelt when found inside of other fish, unless the observer was familiar with both species, but this would not apply to either of the gentlemen quoted. A strange thing about the smelt is that they have not been caught by those who have searched for them in the summer months. My information on this subject comes from fishermen at Port Henry only. A year ago, when smelt fishing through the ice was at its height, I visited the fishermen on the ice, and questioned them as to their knowledge of the smelt in the summer months. All agreed that although search had been made for them they had not been taken. Another strange thing is that no one seems to know anything about where they spawn.

Another very interesting response to Cheney's communication was contributed to Forest and Stream by a correspondent signing himself "Ferris" (1896). He wrote:

I think your correspondent in Forest and Stream of March 28 wrong in his opinion that Lake Champlain ice fish or smelt are not permanent residents of the lake. Perhaps for those who are interested in this matter a few of the incidents coming under my personal observation may prove of interest.

At Thompson's Point, situated on the shore just across from Split Rock lighthouse, is no doubt one of the best fishing grounds for the American pike perch to be found along the lake. On the point are nearly two score of cottages, among them being that of Justice J. D. Brewers, of Washington, D. C. Here each season are to be found many of the disciples of Izaak Walton enjoying their summer outing.

On the reefs just off the point I have caught many a fine string of pike, and very many times have observed that after getting them in the boat they would disgorge one or more smelt. This

will more often happen if the fish is caught in deep water, say 35 to 60 ft. If the smelt is in a fair state of preservation, he makes a far more attractive lure than any live bait we are able to get.

Again, I have seen in the gray of the morning and at twilight thousands of smelt jumping on the surface in much the same manner as yellow perch do.

Mr. Harrington, a friend of mine here, caught last July three smelt in less than 20 ft. of water which appeared to be as firm and hard as any caught through the ice.

These facts, I think, are sufficient to prove that smelt can be found in Lake Champlain twelve months in a year if one only knew where to look.

Cheney (1900) called attention to an interesting point in relation to the restriction of the fishery to ice fishing. He said:

A few weeks ago when I was in Port Henry, no smelts had been taken, as the ice had not formed on that portion of the lake where the smelts are generally caught, for they are caught only in certain localities. This week, on my way to New York, I met a gentleman from Port Henry, who told me that "icefish" had not yet been caught at that place, but as he had promised some to friends, he thought they could be caught from a boat as well as from a shanty on the ice, and he had sent two men to the smelt grounds to fish for them, and they had caught but one fish, about six inches long, and he could not explain why it was so, for he was sure that within twenty-four hours after the ice had formed at that place where the men fished from boats, the ice fishermen would catch half a ton of "ice fish". This is very strange that on the same ground with same bait and same tackle and method of using it, the smelts will not bite just before the ice forms, and will bite directly after it does, and there is no reasonable explanation why it should be so that I can advance.

Cowen (1900) wrote that he had caught smelts in summer, stating that his impression was that great numbers remain in the lake, but do not take bait on account of the abundance of other food. He said that he had observed that as soon as surface water runs into the lake in the spring smelts will not bite so readily.

During the long discussion concerning the identity of the icefish, even ichthyologists were divided in opinion concerning whether it ascended the St. Lawrence or not. That the smelt occurred in Lake Champlain over 80 years ago, and over 30 years before Cheney announced that the icefish was a smelt, Zadock Thompson (1842) wrote:

The smelt is one of those migratory species of fishes, which pass a part of the time in salt water and a part in fresh. Though not a constant visitant in our waters, he occasionally makes his appearance, and is sometimes taken in Lake Champlain in very considerable numbers.

If the fact had been generally known that smelts equaling in size any Lake Champlain "icefish" had been caught in certain lakes of Maine, where they were permanently resident, it would have suggested to some of those interested that a like situation existed in Lake Champlain. However, it is now positively settled that the fish is a so-called "landlocked" smelt.

Nothing appears to be known concerning the breeding habits of the smelt of Lake Champlain, but as the smelts of New England lakes ascend streams to spawn it is quite possible, as predicted a number of years ago by the late A. N. Cheney (1895), whose writings have been quoted extensively in this paper, that if looked for at the proper time the Champlain smelt might be found breeding in some tributary streams. It has been stated that it appears possible to catch smelts, or icefish, only at certain localities in Lake Champlain, and it has been a source of wonder why they could not be caught elsewhere.

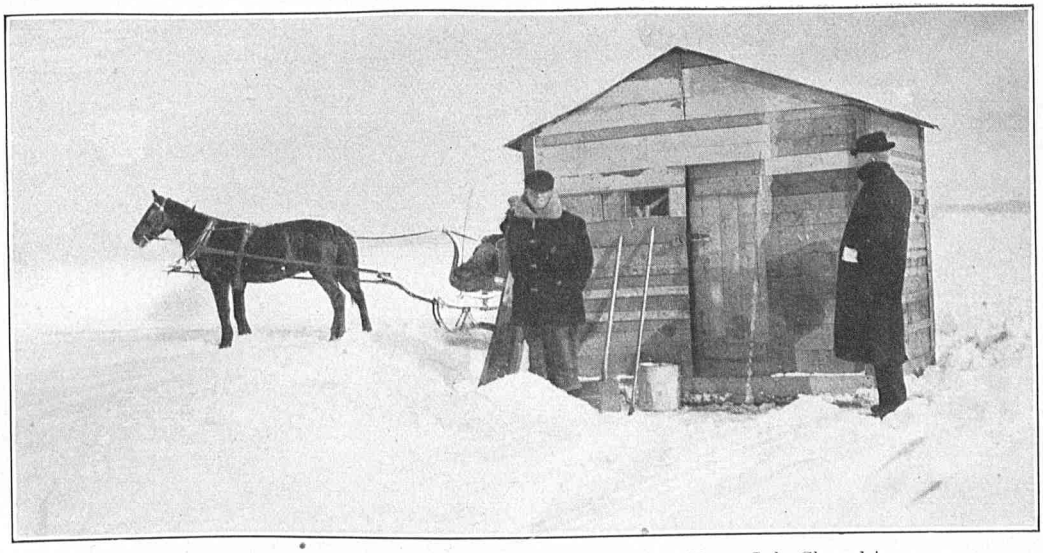

FIG. 18.—"Close up" of a smelt-fishing shack on the ice at Port Henry, Lake Champlain

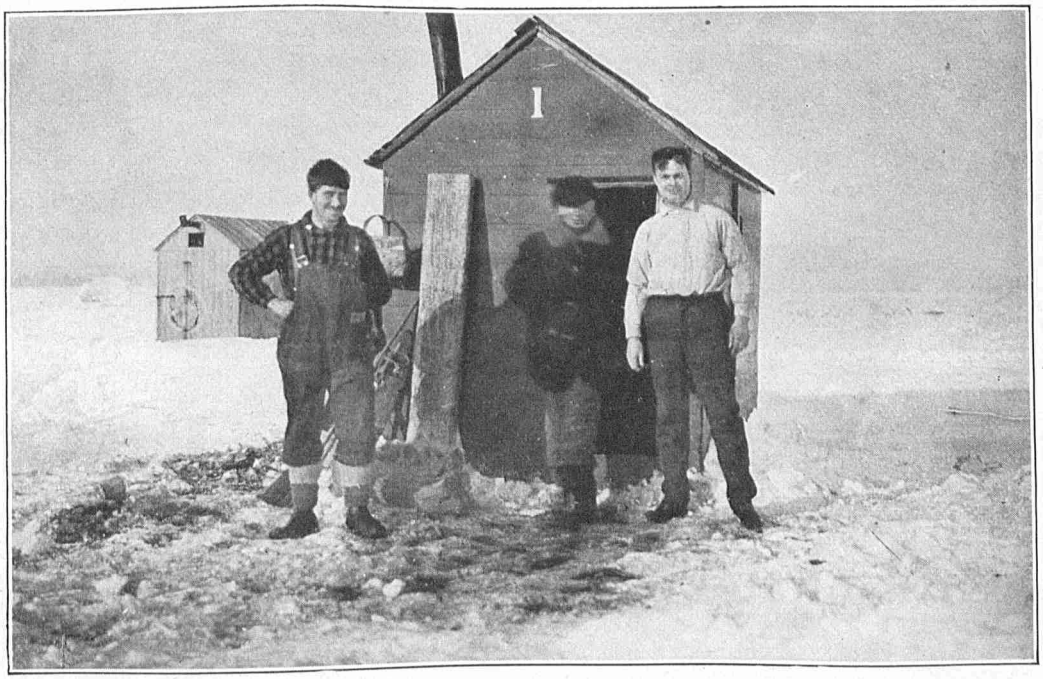

FIG. 19.—Smelt-fishing shacks on the ice, Port Henry, Lake Champlain

FIG. 20.—Another type of shelter for smelt (icefish) fishing on Lake Champlain. It is made of canvas

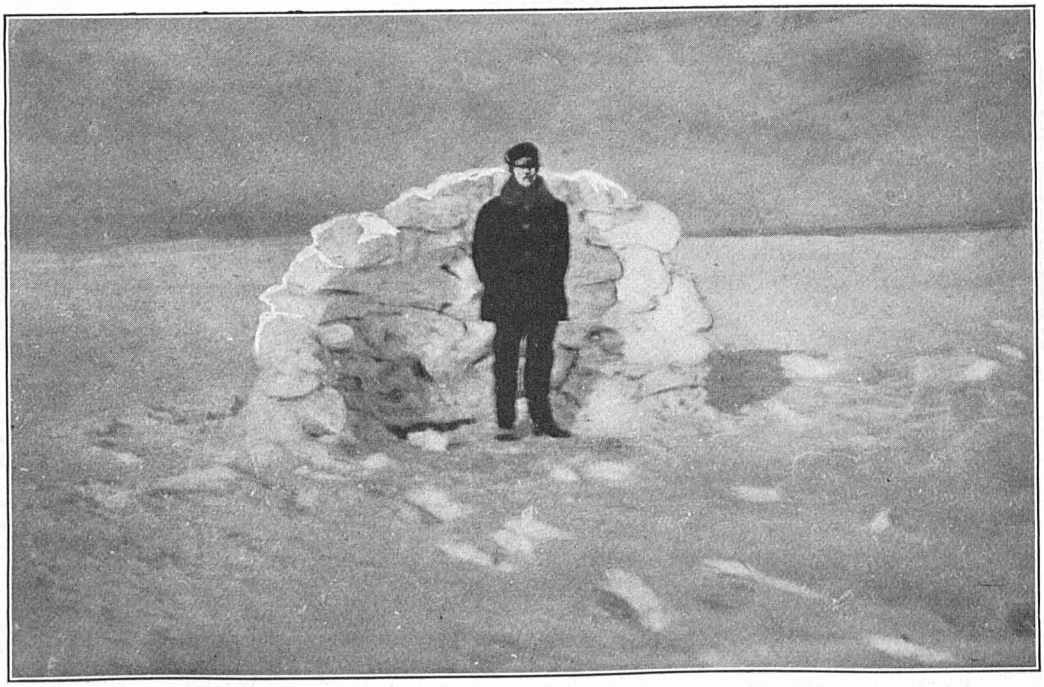

FIG. 21.—Still another sort of shelter for smelt (icefish) fishing on Lake Champlain. This is made of snow

As observed in Sebago Lake, Me., and other localities, the fresh-water smelt seems to prefer certain depths of water and kinds of bottom, the kind of bottom seemingly depending to a great extent upon the character of the surrounding country. In one locality the proper bottom seemed to be an outcropping of a stratum of gray clay on each side of a ridge. Either way, between or beyond these outcroppings, no fish could be caught. In Lake Champlain, near Port Henry, a similar condition seems to exist. A fisherman stated to the present writer that on each side of the place where he was fishing there was a channel, and the fish were caught between the top of the interchannel area and one or the other of the two channels. Fishing was carried on in water from 30 to 70 feet deep, and usually the larger fish were taken in the deeper water.

SMELT FISHERY OF LAKE CHAMPLAIN

As previously indicated, the smelt fishery of Lake Champlain is carried on with hook and line through the ice in winter. Cheney (1895) thus describes the method:

> The smelts, to call the fish by their proper name, are caught with hook and line through holes cut in the ice. The bait is the eye of a smelt or a piece of flesh cut from the fish near the tail, a strip as long and as wide as the little finger of a man's hand. The fish are caught close to the bottom in water from 50 to 60 feet deep, some of the men fishing with a single hook, and some with two hooks, one above the other, all placed below the sinker. A peculiarity of the fishing is the manner in which the fish are brought to the top of the ice after they are hooked. The line is tied to the end of a stick about eighteen inches long. This is moved around and around over the hole as if one were stirring the water with the line; suddenly the fisherman gets a bite, and his right arm shoots up and out to its full extent, and the left hand, also extended, catches the line, the stick then catches the line below the left hand, and this is repeated until the line is reeled in on the end of the stick and the left hand, and the smelt is brought to the top of the ice and the hook pulled from its mouth. * * *.
>
> * * * If the smelts were baited to hold them in one spot it is fair to presume that they would be found in other parts of the lake than those where they are now known. In Sunapee Lake, N. H., the smelts are baited by anchoring a bag of meat or bread, or chopped fish, and thus they are held in one place and landlocked salmon are also attracted by the presence of smelts.
>
> I think the Lake Champlain fishermen make a mistake in placing their hooks below the sinker, at least my personal experience in smelt fishing has taught me that more fish will be hooked by using a leader with the sinker at the extreme end and the hook placed above it. The sinker keeps the line taut, and the smelt biting so gently that it is difficult to distinguish the bite, more readily communicates the sensation of a bite than when the hooks are flying loose below a heavy sinker. There is no effort made to conceal the hook under the bait in ice fishing, the strip of smelt hangs like a wet rag from the bend of the hook, and too, the hooks are so large that it seems strange that the smaller smelts are hooked at all.

Two weeks later another correspondent of the same paper ("Heathcote," 1895) described the fishing method in a little more detail. He wrote:

> The fish pole is about two feet in length, having an eye at the end for the line to run through, and near the base a boat-cleat screwed on to keep the the line on when not in use, and to hold the excess of line Drawing the fish-pole to an easy distance with the right hand, a stick of about two feet long catches the line (with the left hand) about four feet down; then the fish pole again, and so on. The line in this way can be drawn up rapidly, about thirty feet in five seconds. Of course, all that is necessary is to keep a steady pull on the line, and as the fish nears the ice, slow up a little so as not to rub it off against the sharp edges. Some use the thumb of the left hand and the fish-pole in the right, but this is not so fast, and the cold, wet line makes one's hand ache. Then, too, the stick keeps the loops open and free to run out again, whereas when the thumb is used the struggling fish is apt to close up some of the loops while you are taking him off. Then comes the fun to "pick up your dropped stitches."

I knew an old one-handed fisherman who had a way of his own to draw up his fish. When he hooked a fish he would run the length of his line on the ice, the hole being cut so as not to catch the fish as he passed out.

About here they use for bait the flesh of the smelt. The cut is made beginning at the vent on the belly and cutting away from the belly-fin for about three quarters of an inch. Smelt's eyes are also often put on the end of the barb, and I think it pays to cover this up, but not many do it.

This method the correspondent termed "fishing à la Canuck," to the description of which he added the following:

If in a sitting or stooping posture, the fisherman assumes an erect position, on hooking a fish, at the same time raising the short fish-pole to the height of the shoulder with the right hand. Now the two-foot blank pole held in the left hand engages the line near the ice from the opposite or right side, and is immediately raised to the height of the shoulder, in a semi-circle described to the left from below, while the right hand with the fish-pole, decends, describing a complementary semi-circle to the right, from above to the ice, passes in front of the body to the left, and engages the line near the ice from the further side or left. When one hand is up, the other is always down. The arms are held far apart and rigid in order to keep the line taut. The same motion is gone through, only backwards, in holding a skein of yarn on the thumbs of both hands, while (say your sister) winds it into ball. Reverse this motion, that is reel it from the ball of yarn to your two thumbs, and you have the same motion nearly.

In a report upon an inquiry concerned with the fisheries of inland waters, in reference to the smelt fishery of Lake Champlain, an agent of the Bureau of Fisheries[4] wrote:

This fishery is carried on between Crown Point and Essex, the most important points being Westport and Port Henry. As soon as sufficient ice forms the fishermen carry small huts out to favorable positions on the lake, each hut provided with a small stove and a bench or chair, and having about a third of the bottom floored. The fish are caught with hook and line through a hole cut in the ice. For a time the "ice fish" caught in this part of the lake, which are exceptionally large (examples 15 and 18 inches long having been captured), were thought by the fisherman to be a different species from the smelt, as the fish taken in other parts of the lake and known as smelts average about 7 inches in length. At times the catch of "ice fish" is quite heavy, but in 1902 it was small, there being but few fishermen engaged. Nearly all who participate do so because they have no regular occupation, and as last year was a busy and prosperous one in nearly every town and the lake shore there were but few persons out of employment, consequently but few fishermen. In the fishing season at certain hours in the day the buyers visit the huts, gather up the fish caught and bring them to the towns, where they are boxed or barrelled for shipment.

The earliest statistics of the ice fishery of Lake Champlain are those of 1894 and 1895. These were collected by the agent of the Bureau of Fisheries who made the above report. These later statistics are after an interval, then, of some seven and eight years.

In 1894 the catch of smelts on the New York side of the lake was 33,170 pounds, valued at $3,957; in 1895, for the same locality, 39,076 pounds, valued at $4,506. In 1902 the catch was 17,600 pounds, valued at $12,160. From 1894 to 1895 there was an increase of 5,906 pounds and a gain in value of $549, with a slight decrease in the price per pound. In the seven years from 1895 to 1902 there was a falling off in the catch amounting to 21,476 pounds and $2,346 in value, but there was some increase in price per pound.

[4] The commercial fisheries of the interior lakes and rivers of New York and Vermont. By John N. Cobb. Report, U. S. Commissioner of Fish and Fisheries, 1903 (1905), p. 230. Washington.

The fishery on the Vermont side of the lake was comparatively small at all times. From 1894 to 1895 the catch fell off from 2,163 to 1,441 pounds, and in value from $119 to $89, representing losses of 722 pounds and $30; but the average price per pound increased from about 5½ cents to about 6⅙ cents. From 1895 to 1902 the catch increased from 1,441 to 6,000 pounds, and the value increased from $89 to $600, representing increases, respectively, of 4,559 pounds and $511. The price per pound increased 6⅙ cents.

QUALITY AND UTILIZATION

Of the German smelt, Bloch (1796) said that as the flesh of this fish is not easy to digest one would not advise its use by feeble persons and invalids. Fedderson, of Denmark (1870), wrote;

> It is a fish which, according to my opinion, will be more profitable to introduce into lakes where they are absent, on the ground that it is an excellent food for other fish and also has much value as bait on eel-hooks and as hog food, whereas no one can reconcile himself with its penetrating odor and eat it.

Concerning the smelt of Finland, Reuter (1883) also wrote:

> Its unpleasant smell, which is, however, in larger and older individuals less strong, makes it with us in general but little liked, and it is eaten therefore for the most part only by the poorer population and Russians staying here, who, like the English, find a peculiar enjoyment in the singular, strong, cucumber-like smell of this fish.

Reuter also called attention to the great value of the smelt as food for more important fishes such as pike perch and Salmonidæ.

Day (1884) said that in England the smelt is justly held in great estimation for the table, but after spawning becomes insipid. He repeated the statement that it used to be split and dried and was thus considered to add a particular relish to the morning dram of spirits. But referring to the experience of one investigator, he said:

> The gastric juice or fluid of the sparling was so acrid, that when he wiped his hands on his pocket handkerchief, and then used the handkerchief to blow his nose, both his nostrils and lips were inflamed and irritated, and more than once his tongue swelled in an extraordinary manner.

Concerning the Swedish smelt, Smitt (1895) wrote that the rank odor emitted by it offends the taste of many but that the flesh is good, and the belly, between the spawning seasons, is full of fat. Among epicures it is esteemed as a delicacy after the disagreeable smell has been removed by very simple culinary methods. He said that the fish must be carefully gutted, also, especially if it is in breeding condition, to rid it of the numerous intestinal worms that penetrate even into the air bladder. It is best fried and served with lemon juice or vinegar, but often is boiled or stewed in sauces. It is split also and dried for further consumption, and in this state may be eaten, he said, without further preparation. Another method is to soak the fish in lye and afterwards dress it for the table like other "stock fish."

Smitt further remarked that in addition to its utility as human food, the smelt also possess importance as one of the best baits for predatory fishes of greater size; and in several localities where it is taken in too great a quantity for immediate use it is even made into "guano".

Reuter said that the "Siniäisiä," or very young fry, in Finland were salted and prepared and eaten as caviar, and Day remarked that it was said by the French to be a good bait for eels.

John A. Thomas, of Reading, Pa., writing concerning smelts (Thomas, 1876), said that the best he had ever eaten, and he had eaten them from the extreme east to Jersey, were on the south side of Long Island and from the Passaic River. He said these smelts were always small, with the tenderest bones, and having the most perfect cucumber flavor. He said that the best smelts were the "young yearlings" that sought the spawning places for the first time. "There is no other fish," he said, "that would give the same untiring luxury as young smelts"; but when large he said that "they are tough, swift fish, and only fit to boil in a coarse cloth and be eaten with drawn butter."

Hallock (1893) must have had in mind the small fish to which Thomas referred, when he wrote:

> They are much prized for the table, and when cooked and served the backbone cleaves to the flesh unbroken, and all the little bones are chewed up and swallowed incontinently, while a fresh cucumber flavor lingers in the mouth in a grateful sort of way which epicures appreciate.

Also, "Grif's" experience seems to be in accord with that of Thomas, for he wrote (1900) concerning large fish, 15 inches long, weighing 14¾ ounces, "This large fish proved very rank and oily on being cooked, and bore out the practice of fishermen here, who prefer the smaller to the larger fish for home use, claiming they are much sweeter."

The American smelt, large or small, when perfectly fresh is one of the most delicious of pan fishes. It possesses a pronounced odor that in this country does not appear to be objectionable, judging by the esteem in which the fish is held. The usual method of cooking is by frying, after rolling the smelt in corn meal or cracker crumbs. However, if smelts become stale, or if they have been frozen and thawed and have not been cooked immediately, they possess a rank oily taste. Large smelts, if fresh, are no more likely to be "strong" than small ones, but many persons do prefer small fish to very large ones, claiming that they are "sweeter."

It has been claimed that the salt-water smelt is superior in flavor to the smelt of fresh water, but according to the present writer's experience this is not true. In fact, he has thought at times that the fresh-water form was the better, but not having compared the two at the same eating the apparent superiority may have been due to appetite.

In preparation for cooking the smelts usually are eviscerated but often the heads are left on. Some eat them, heads, bones, and all, but unless very small the writer prefers to remove heads, viscera, and tails. By cutting nearly through from just behind the head, ventralward, then pulling forward with the flat of the knife, the viscera are easily drawn out. Any remaining portion may be removed by squeezing along the belly when washing the fish. When served, they may be laid open along the back and the entire backbone removed.

Locally in Maine smelts are sometimes dried, or used to be. They were usually salted over night, entire, then strung on a slender stick, which was thrust through the eyes from side to side, and hung in the sun. Having been sufficiently

dried, they were eaten without cooking, or sometimes roasted on coals or in the oven. The fish dried were those taken in the spawning time. The writer once dried some taken in July, but they proved to be too oily and the flavor was unpleasant.

In Maine the fresh-water smelt, besides being eaten, is often used as bait for landlocked salmon and other fish; and, as previously indicated, it is regarded as necessary to stock with smelt any body of water in which landlocked salmon are to be introduced, as the smelt forms its principal subsistence under natural conditions.

FISH-CULTURAL PROPAGATION

The earliest attempts to hatch smelts "artificially" in this country seems to be that of Charles G. Atkins in 1868, an incomplete account of which was given in his notebook, which the present writer had the privilege of consulting. Under date of May 5, 1868, he wrote:

> At the hatchery house I was greatly surprised to find that a part of the fresh-water smelt eggs that I had brought from Sidney [Lake Messalonskee, Maine] are in a fair way to hatch. The eggs are well developed and the fish lively, writhing, and lashing their tails. I should think about one in ten is alive. They were taken the evening of April 18th.

In another place he stated that on May 5 the eggs were "infested with the white vegetable parasite," but that it was not making much progress.

It is not known how long the eggs obtained at Sidney on April 18 had been deposited, but from the time they were taken until the embryonic stage noted the time was about 17 days. However, another note, dated May 14, 1875, says: "Eggs from Brook-in-the-Woods, North Belgrade, hatched." Computing from his notes, it would appear that it took either 30 or 45 days for them to hatch.

In 1885 Fred Mather attempted to hatch salt-water smelts at Cold Spring Harbor, Long Island, and subsequently published accounts of his experience. Before a meeting of the American Fisheries Society he read a paper on the subject, which was published in the "Transactions" of the society. It appears that his first effort was on March 4, 1885, when from a female fish that had been dead 15 minutes 30,000 eggs were taken on a bunch of coarse meadow grass and suspended in a glass tank with a flow of water from a ⅛-inch cock, and in three days many were dead, and all died when one week old.

On the 5th he repeated the experiment with eggs from a dying female. In 5 days three dead eggs showed, the sixth day 100 dead, seventh day one-fourth of the lot were dead. Up to the 17th, the thirteenth day after taking, there was little change, and on the 20th the eggs were put in a box outside the hatchery in swift water, as they began to show fungus. March 26 about one-half were alive, and these were in bunches covered by dead eggs and fungus. All the outside eggs were dead, and there was little hope of saving any. On April 3 the fish could be plainly seen in the lower eggs by removing the coating of dead eggs and fungus that had covered them for 2 weeks. The eggs were again placed in the aquarium and 2,000 hatched on April 11, and on the 16th 9,000 more hatched and the rest were bad. About one-third of the eggs hatched under conditions that seemed hopeless and under which it would be impossible to hatch the eggs of salmon or trout. When the last eggs hatched the

mass of dead eggs was rotten and foul. The temperature ranged from 40 to 42° F. In taking the eggs the grass was laid in a milk pan and covered with water. The female was manipulated first, and as the eggs do not stick fast until some minutes after being taken, perhaps after impregnation takes place, they were distributed evenly over the grass with the tail of a fish.

Again Mather (1885) said that, knowing nothing of smelt hatching, the literature of which was meager, he determined to try several plans. So, on March 5, 50,000 eggs were taken from a weak female, on stones the size of a man's fist, in water, and placed outside the building in a covered waste trough, which took the water from the house to the ponds. The current was slow but the eggs washed off, refusing to stick in bunches as they did on the grass. The consequence was that the stones were covered with eggs only one layer deep. Three days after this they looked well, but in a week were all dead, though no fungus had formed.

He tried again on March 8, by taking about 70,000 eggs by the dry method on tiles, letting them stand five minutes before adding water, and then placing them in one of the hatching troughs. On the 16th one-half were dead, and on the 24th they were covered with fungus. On April 7 there had been no change, the eggs underneath the fungus were bright and good, but they were left unattended until the 12th, when the trough was found empty. The other attendants pronounced them dead and threw them away. Mather did not feel certain that they were all dead, for his experience that year told him that it required an expert to judge of this. He said that a mass of smelt eggs all rotten on the outside and covered with fungus half an inch thick should be given the benefit of all doubt and be carefully examined before condemnation.

Another trial was made on March 9, when 100 more fish that had been taken in seines were obtained. The first lot were so badly injured by gill nets that they were covered with fungus in a few days. On the 12th 70,000 eggs were taken on tiles and stones in water and placed in a trough that received the flow from nine hatching troughs, and consequently carried a swift current. These eggs were evenly distributed over the tiles and stones several deep, and did not flow off as in previous cases. Not until March 22, 11 days after, were any dead eggs or fungus seen. At 5 days old the formation of the embryo could be seen by means of a microscope, and at 15 days the fish could be seen with the unassisted eye. At this time fungus had spread all over the outside eggs, but underneath there were but few dead ones. On April 6, when the eggs were 26 days old, they were placed in the glass tanks with a flow from above and a siphon outlet, and 4 days later began hatching fast; 2 days later there were 11,000 fry, all that were obtained. The temperature varied from 37 to 58 degrees, and the time of hatching was 30 days. The water used in all these experiments was pure spring water.

The last trial was in the McDonald hatching jars and was the best of all, producing 60,000 fish from 200,000 eggs. They were taken on March 21 by the dry method, let stand five minutes, half a pint of water added, and kept in motion 20 minutes by tipping the pan from side to side and occasionally using the tail of a fish. The object of this was to keep the eggs from sticking together, so that they might be treated as free eggs. After this more water was added and the eggs allowed to rest for 20 minutes. They were then washed twice and placed in a McDonald jar.

They were taken at 5.10 p. m., were all loose at 6.30 p. m., and at 7 p. m. next day many were stuck fast to the jar and the tubes. On March 30 those still loose were placed in another jar, and on April 2 a few dead ones were observed, while four days later the eggs grouped together in bunches that increased in size until on April 15 the bunches were of the size of walnuts and covered with fungus. On the 20th a few hatched, and on the 21st all that were good came out. From this lot they got 60,000 fish in 30 days with a temperature varying from 40 to 65° F.

Concerning the fry, Mather said that they were the most minute of any that he had ever hatched and they were kept with difficulty. A strainer tube inclosing a a siphon such as was used for whitefish was entirely too large, for the fish passed through it with ease. After trying several things and having the aquarium overflow and the fish go out into the trout ponds he devised a spiral wire rolled on a stick of 4 inches diameter and covered with thin muslin, which kept the fish and allowed a small stream to flow out of the siphon that was inserted. The lower end of this siphon was placed in a jar of water to prevent its going dry. It was said that the difficulty with siphon outlets was the tendency to empty faster than the inflow, consequently emptying themselves and then failing to start again, as they will suck no lower than the top of the jar holding the lower end. Of the eggs remaining attached to the first jar and its tubes in a single layer, not one hatched. Most of the fish came from eggs that were in masses surrounded by fungus. Mather said:

> This year's experience upsets that of my eighteen previous years which taught me that the egg of a fish should be clean and free from fungus. I now except the smelt from the rule and think it [not] impossible that the embryo smelt must be protected from too much oxygen and good water by a coating of decayed eggs and fungus.

In the discussion that followed the reading of Mather's paper at the society meeting, H. J. Rice, among other things, said that according to his own experiments since 1876 and 1877 the result served to show greater success in hatching smelt in comparatively stagnant water than in any other manner. He said that the smelt appeared to be a peculiar form among fishes, and was no longer considered as one of the Salmonidæ. According to Rice, young smelts will live in the same water for nine days, and fish-culturists would at once recognize the vast difference in this respect between these minute embryos and those of some of the Salmonidæ, for which a constant change of water is absolutely necessary. The warmer the water the better the smelt appeared to thrive. He said that in the previous season and in the season in question experiments had been in progress to ascertain the feasibility of hatching young smelt in comparatively stagnant water and so far the attemps had been successful. Large numbers were hatched out with comparatively little trouble.

In the same discussion Mr. Lyman said that he recollected that in 1867 and 1868 attempts were made to hatch out some of the large variety called Belgrade (Me.) smelt. The eggs were put in somewhat swift running water in which trout eggs were kept, but none of them hatched.

Mather (1894) read a paper at the twenty-third meeting of the American Fisheries Society, entitled "Improved method of hatching smelts," in which he reviewed previous work in smelt propogation. Mather said that outside of his own articles on smelt hatching in the fourteenth, fifteenth, and sixteenth reports of the society he could find nothing on the subject except an item in the paper of the late Prof.

H. J. Rice on "Salt as an agent for the destruction of the fish fungus" in the thirteenth report. Mather went on to say that Professor Rice records that in 1877 he was studying the embryology of the smelt and found the eggs in masses in the hatching jars and covered with fungus, but not until 1884 did he have a chance to try the effect of salt on killing this Saprolegnia. The eggs were upon blades of sedge, or water grass, after the manner employed by Charles G. Atkins some years before, which "prevents to a great extent, if not entirely, the massing together of the eggs, since the rough surface of the blades allows only a single layer, at most, to adhere to the surface." Still there was much fungus present. The salt killed the fungus and "only about 5 per cent of the whole number failed to hatch." Mather said:

> This is a much better percentage than I can show to-day, and I do not know of any other fishculturist who has hatched this fish within the past five years. Professor Rice did not do the hatching but merely studied the development of the embryos and took the statements of others regarding the percentage; and the latter need salt, also.

Mather then referred to his paper of 1885, entitled "Protecting and hatching the smelt," which has been drawn upon in considerable detail in the paper. Another of Mather's papers was mentioned by him. It was published in the fifteenth annual report of the American Fisheries Society under the title of "Smelt hatching." The paper merely recorded efforts to induce the spawn to adhere to different substances and to vary the flow of water and the amount of light.

The paper was discussed by Frank N. Clark, Mr. Bissel, Dr. R. O. Sweeny, and Mather himself. Mather said that some eggs had been sent to Clark with the caution that they should not be thrown away "no matter how bad they looked on the outside, how much fungus there might be there, nor how foul an odor might arise from them." Clark said that he found the eggs in just the condition that Mather predicted, and that about 15 to 20 per cent of them were good. Mather said that he (Mather) could hatch 40 to 50 per cent in their jars. Continuing his review, Mather said:

> Mr. Bissel raised the question of light, and said "If the light affects the eggs of the smelt, would not the light affect them in their natural condition in a small stream?" Today I can only answer this very sensible question by saying that sunlight will kill our eggs in the jars, and in this year of our Lord, 1894, I have seen smelt eggs hatch on stones in a rapid stream with not over two inches of water over them, and in the brightest of sunshine. This is one of the problems that we have not solved.

Mather went on to say that in his paper before the society in 1887, on "Work at Cold Spring Harbor," he stated that he had planted fry of smelt representing about 50 per cent of the eggs taken. He stated that until 1893 the fish had been stripped and the eggs impregnated by hand, but it was found that by holding the smelt in the hatching troughs until ripe many females spawned in the troughs and also that the percentage of impregnation was very high and that they hatched well. So in 1894 all the eggs were gathered from the troughs, passed through wire screens to separate them, and then put in the jars. At intervals of two or three days, or whenever the eggs seemed inclined to gather in bunches, the operation was repeated, gently forcing the eggs through the screens with the fingers, and after a few such screenings the "foot" seemed to be destroyed.

He explained that the "foot" is a projection on the eggs, which is shaped like the stem and bottom of a wine glass and is the only point of adhesion that the egg of the smelt has, there being no glutinous coating around the egg of the smelt that will enable it to adhere at any point. So the breaking of the hold of the foot made it powerless to adhere to other eggs or to any object, and left the eggs as free and clean as those of whitefish or shad, and enabled the attendant to remove all bad eggs from the top, as was done with other eggs hatched in jars. The figures of results given by Mather for 1894 were as follows:

Eggs taken	31,708,000
Loss of eggs	9,105,000
Fry planted	22,603,000

"The figures show," he said, "that over 71 per cent of the eggs taken produced fry, and the reports of a few years ago show that when we produced 50 per cent, and thought it good, Mr. Clark remarked that it was as good as might be done with adhesive eggs."

In the report of the commissioner of fisheries of Pennsylvania for 1907 (p. 136) Jerry R. Berkhous, superintendent of the Torresdale hatchery, made a report on smelt hatching, having successfully taken 5,000,000 eyed eggs from Cold Spring Harbor to his hatchery, where they hatched in about a week. He said that he found the hatching of smelt eggs very easy by following instructions given him by Mr. Walters of the Cold Spring Harbor hatchery, and Mr. Safford and Mr. Meehan, although he found it quite different from other fish work. He said that the eggs were the smallest he had ever seen. It required 500,000 to fill a liquid quart and they were as small as mustard seed, if not smaller. His experience was the same as that of others in that the eggs would not hatch when exposed to light. There was too much light even when he closed the window shutters, and to give them sufficient darkness he had to hang a dark cloth curtain in front of them. He remarked that the prevailing opinion that small fish give fry of pretty good size did not hold good with his fish, for the fry were so small that he had to use a screen of linen, and double at that, to keep them from escaping after they were in the fry tank. Even then a few managed to struggle through.

They started to hatch about 10 o'clock at night, and in less than half an hour the entire 5,000,000 were hatched. He thought that a single sheet of linen would be sufficient to hold them. They began to hatch when he was in the dwelling house and the watchman called him. When he got to the hatching house he found the little fish passing through the single linen nearly as easily as he could "go through a door."

In 1912 J. F. McClendon submitted to the Bureau of Fisheries an article on "An improved method of hatching the eggs of the smelt," based upon experiments conducted by him in the Embryological Laboratory of Cornell University Medical College, New York City. As the article contains much of interest and has not been published so far as the present writer is aware, it is included here:

As is the case with all migratory marine bony fishes, the smelt migrates during the breeding season from the sea into fresh water. The eggs are laid in clusters, preferably in small streams. Each egg membrane is provided with a pedicle which attaches the egg to some support or to another egg.

At the New York State Fish Hatchery at Cold Spring Harbor, Long Island, the females are not stripped but are allowed to deposit the eggs. The egg clusters are gathered and passed through a sieve to separate them from one another. They are then hatched in regular lobster hatching jars supplied with fresh water. In this place the eggs are laid in about 10 days during the last half of March or the first half of April. The water supplied to the jars is quite cold and the mortality of the eggs is not as great as in the natural streams of the locality.

"However, I found in eggs taken from the hatching jars or from local streams during two consecutive seasons, about one embryo in a thousand with abnormal eyes. The cause of this abnormality has not yet been found; however, it may be remarked that the water contained an unusually large amount of carbon dioxide. The fresh water of Cold Spring Harbor comes from deep springs or artesian wells and is charged with this gas. Also I found various poisonous substances to produce this abnormality in Fundulus embryos.[5]

There is a large mortality among these eggs when hatched in the tap water of New York City, due to the higher temperature and impurities. They hatch better in water redistilled in glass or quartz.

The eggs before being laid contain considerable amounts of sea salts and have an osmotic pressure equal to about half that of the sea. I was interested in determining whether the salts diffused out of the egg when laid in fresh water, as seems to be the case with frogs' eggs, or whether they were retained, as I found to be true of the eggs of the marine killfish (*Fundulus heteroclitus*).

Thirty grams of eggs were soaked 14 hours in 250 grams of distilled water. The water was then analyzed and found to contain only two one-thousandths of a gram of common salt. It is evident that most of the salts are retained by the eggs.

Since the eggs retain the salts in the same way that the adult fish does, it would seem probable that the eggs would live better in salt water than in fresh water. From the experiments with other marine bony fishes, it is probable that the smelt would live indefinitely in more or less diluted sea water, but not in fresh water, although they are normally in fresh water during the short breeding season.

I placed smelt eggs in sea water and in sea water diluted with various proportions of water redistilled in a quartz still. The eggs in sea water developed for three or four days and then died. Eggs in one-half sea water (which is of about the same salt content and osmotic pressure as the blood of the mother), developed much better than in fresh water. This is probably due to two causes: First, the salt in the water being of the same concentration as the salt in the egg, any loss of salt from the latter is prevented. Second, the growth of mould (Saprolegnia) is retarded by the admixture of sea water. Even ⅕ sea water preserved the life of the eggs better than fresh water.

It is suggested that in the hatching of smelt eggs, when the mortality is considerable, that the jars be supplied with a mixture of sea water and fresh water in the proportion of one part of sea water to from one to four parts of fresh water. The water might be mixed by simply connecting the salt and fresh water pipes to the pipe leading to the hatchery by means of a T joint. Care should be taken to maintain a regular flow in both pipes, and the flow of the sea water should never exceed that of the fresh water. The proportion of sea water should be gradually reduced just before the time of hatching, as the eggs hatch better in one-fifth sea water than in one-half sea water. Perhaps it might be more convenient to reduce the proportion of sea water to zero before the eggs hatch.

I am indebted to Mr. Walters, superintendent of the New York State fish hatchery at Cold Spring Harbor, Long Island, for the material on which these experiments were made.

From the department of anatomy, Cornell University Medical College, New York City, April 4, 1913, McClendon sent in an additional note on the same subject, which follows:

This year I installed apparatus for circulating brackish water (and fresh water for a control experiment), using miniature hatching jars. However, the expense of keeping the temperature low in this laboratory would have been great and if exact data are to be obtained experiments should be made at Cold Spring Harbor.

[5] McClendon, J. F.: An attempt toward the physical chemistry of the production of one-eyed monstrosities. American Journal of Physiology, Vol. XXIX, No. III, Jan. 1, 1912, p. 289. Boston.

At this higher temperature there were more deaths in fresh water than in a mixture of one part sea water (from the New York aquarium) and three parts fresh water. Last year I obtained more deaths in fresh water than in equal parts of fresh water and "sea water." But this sea water was surface water of Long Island Sound during the period of heaviest rains. In equal parts of fresh water and sea water of normal density there were as many deaths as in fresh water, and also a large number of abnormalities.

The procedure in the propagation of smelts in Massachusetts was described in some detail in the report of the Massachusetts commissioners on fisheries and game for 1918. This discussion follows:

The method of taking spawn varied according to the purpose for which it was to be used, namely, whether for transfer to the Palmer Hatchery for hatching in the batteries, or whether collected on burlap for planting as spawn. For the benefit of those who are unacquainted with fish-cultural processes a description of the routine is given.

For Hatching in the Palmer Hatchery.—The crew, equipped with rubber clothes, took their stations at the Weir River Falls about dark, and arranged their outfit to be in readiness for the appearance of the fish, which came any time from 7 p. m. to 3 a. m., according to the stage of the tide and the temperature of the water.

Two catchers, with dip nets, took their places at the falls. At the side of the river, close to the water, the sorters were stationed beside two tubs, one for male and one for female fish. Between the tubs sat the strippers and the hardeners occupied the portable house.

Catching.—The catchers, selecting the spots frequented by fish of the sex desired, dip them up in the nets and carry them to the sorters. The males prefer the boisterous waters above, while the females frequent the quiet eddies. By rearrangement of the rocks in the rapids, the number of such eddies was increased, to the advantage of the work. Taking by dip nets was found to be the best method.

Sorting.—The sorters on receipt of the fish from the catchers place them in the appropriate tub. A fish culturist easily recognizes the sex of the fish, both by appearance and by feeling.

Stripping.—This process consists of removing the spawn or the milt, as the case may be, from the fish. Holding the fish in the left hand over a 4-quart pan containing a few drops of water, with the thumb of the right hand bearing on the upper side of the fish, the index finger is allowed to follow down the fish from head to tail, thereby removing the few drops of ripe milt or eggs. The process is repeated until the bottom of the pan is barely covered.

Last year the stripped fish were distributed among the needy of the town, in the belief that the fish died after spawning. This year an experiment of "half stripping" (taking only about half the spawn, and using little pressure) was tried on 300 fish which were afterwards held under observation in a tank. After four days but 2 per cent had been lost, demonstrating that a large proportion, if handled carefully, could be returned to the water after serving our purpose This method was adopted, and we believe that at least 90 per cent of the stripped fish survived.

Hardening.—The spawn when first taken from the fish is exceedingly soft and sensitive, and must be handled with the utmost care. It is also very adhesive, and when deposited in the natural way in the brooks it immediately attaches itself to the bed of the stream. In taking eggs for artificial hatching it is of the utmost importance to prevent adhesion and one of the biggest problems has been to keep the eggs from forming into masses, which, once formed, cannot easily be broken up. Until this tendency could be overcome, successful transportation was out of the question. For this trouble the remedy is soaking in fresh water three or four hours, changing the water frequently to thoroughly clean the eggs of the superfluous milt and the gluey substance which covers the eggs. The eggs increase during the process to six or eight times their original size. After repeated experiments it was found that if pans and other utensils were first treated to a coat of melted paraffine the eggs would not adhere.

All eggs hatched at Palmer were collected and prepared for shipment under the direct supervision of the foreman of that hatchery.

Two methods were tried this year of caring for the eggs when taken from the fish. By one method the eggs were stirred in the pans very little in the hardening process. This lot gave the greatest difficulty, as the eggs stuck together so badly that they had to be separated by putting

them through a screen two or three times, and they would not work so freely in the jar; but the per cent of hatch was nearly the same. The other method was to constantly stir the eggs in the pans of water until time to can them for shipment. These did not adhere or bunch up, and though it required more work at the spawning grounds at time of stripping, it saved much labor at the hatchery.

The foreman as a rule arrived at the Palmer Hatchery with a consignment of eggs about 11 a. m. The eggs were at once placed in large pans and the water changed frequently until 4 p. m. Then they were placed in the hatching jars, 24 ounces to each jar, and from that time until they hatched had to be watched constantly, night and day, to be sure water was running through each jar and that the eggs did not bunch up and smother. The average temperature of the water during the hatching period was 57°; period of hatching, thirteen days.

The capacity of the battery at Palmer is 42,500,000 eggs. Immediately after hatching begins distribution should be started, else the tank will be too full of fish and the screen become clogged, though smelt, being more lively and better swimmers, can be held longer in the tank without loss than either yellow or pike perch.

Of the 110,000,000 eggs received at the hatchery there were hatched and planted 76,125,000 with about 30 per cent loss. In view of the fact that the work is still experimental (last year but a few ounces of eggs were handled, merely to determine whether the fish could be stripped and eggs hatched) the number of fry produced can be considered very satisfactory. With the necessary facilities it would be an easy matter to hatch 200,000,000 instead of only a few fish.

A brief note appeared in the Massachusetts report for 1921 to the effect that a little experimental work was done in hatching spawn in jars at the Weir River field station, using pond water, and 3,000,000 hatched in this way. The spawn hatched in 13 days, a shorter period than when handled in the batteries at Palmer. The fry were permtted to pass directly from the hatching jars into the river.

The United States Bureau of Fisheries has propagated smelts at Green Lake, Me., for a number of years. As has been noted, at Green Lake there are two size classes of adult smelts that constitute distinct runs, the larger form ascending the brooks earlier than the smaller one. According to the superintendent of the station at Green Lake the first of the run of each form is composed almost entirely of males. A descriptive circular concerning the process of collecting the eggs and hatching the smelts at the station says that careful daily observations have to be made in order to determine when sufficient females are present to warrant operations. As soon as the sexes appear to be about equal in number the fish are collected in small dip nets, carried in 10-quart pails to the hatchery, and placed in ordinary hatching troughs, six pails to a trough. Here they remain undisturbed a sufficient length of time to insure the casting and fertilization of their spawn, which usually occurs within two or three days. The fish are then liberated and the coating of spawn at the bottom of the troughs is gathered up by means of a net frame which is of the same width as the trough and tightly covered with cheesecloth. As the eggs tend to adhere to the surface of the trough, special care must be exercised in this process to avoid injuring them. They are placed in large pans and the lumps smoothed out with the bare hands, after which they are measured and installed in hatching jars similar to those used in the whitefish and shad work, about one quart of the eggs of the "large smelt" being placed in a jar, with a water circulation of 3 quarts per minute. It has been customary in the past to allow 1½ quarts of eggs of the "small smelt" per jar, but recently the number had to be increased to 2 quarts owing to a shortage of hatching facilities, and the results were just as good as formerly. On account of

the small size and adhesive nature of the eggs, they are liable to form into clusters after being installed in the jars. This difficulty may be overcome by emptying the jars and running the eggs through a fine screen, and then returning them to the jars.

Some fish-culturists are of the opinion that strong light is injurious to the eggs, and that the rays of the sun should be carefully excluded from the room in which they are undergoing incubation. The incubation period covers about 19 days in a mean water temperature of 42.5° F. The newly hatched fry are so very small and delicate that the bottom and sides of the receiving tank are lined with a sack of bleached white bunting, so shaped as to conform to the outlines of the tank. This not only constitutes a suitable and convenient container for the fish, but is useful for conserving any eggs that may pass from the overflow into the tank. The fry are planted in the natural spawning grounds in Great Brook within a day or two after hatching.

An experiment in the propagation of the "large" Green Lake smelt was described by Supt. E. E. Race in a letter dated March 27, 1909. A few of the females and males were stripped simultaneously in a pan, and the eggs were found to be as well fertilized as those naturally deposited in the troughs, but they could not be separately followed, as it was necessary to hold them with others on the cheesecloth bottoms, the wire being too coarse and only two troughs having been fitted with cheesecloth.

It was found necessary to separate the eggs several times by forcing them through fine netting to break up the bunches, but they seemed to do well in hatchery jars. Race wrote also that he had experimented with eyed eggs and had found that prior to eyeing the more they were handled the better the results. He said that they could be taken from the jar at any time before they were eyed and rubbed through a fine wire screen with the fingers without injuring any of them. As soon as they were eyed they were more sensitive but could be separated from imperfect eggs if care was taken to have the screen mesh a little larger than the egg and the stage of advancement had not softened the shell too much.

It appears that at present the Bureau of Fisheries propagates smelts at Green Lake only. Something of the extent of the operations may be learned from the following reported data: In 1923, 4,300,000 eggs of the large smelt were collected. The loss in hatching was 20,000 and 4,280,000 fry were planted. Of the small smelt 42,000,000 eggs were collected; loss, 1,250,000; shipped 12,750,000; and 28,000 fry planted. In 1924, of large smelt, 18,000,000 eggs were collected; the loss was 700,000; 8,000,000 were shipped; and 9,300,000 fry were planted. No small smelts were handled.

ANATOMY OF THE REPRODUCTIVE STRUCTURES

The gonads or reproductive glands (ovaries and spermaries) of the smelt are unsymmetrical organs, one on each side of the abdominal cavity. The organ of the left side is very much larger than that of the right, and instead of being approximately opposite each other, as in Salmonidæ, they are situated one behind the other. The left gonad is much the larger in both sexes, the right being quite small and not far behind the outlet. Both organs are inconspicuous in an immature smelt, but as the season advances they enlarge and some months prior to the breeding season become quite conspicuous, so much so that often in the fall of the year the smelts have been

thought by fishermen to be in breeding condition. At this time, however, they are much smaller than at the breeding season. Even in the fall the eggs are often bright yellow and the spermaries or milts are white.

These organs are suspended from each side of the air bladder at the upper surface of the abdominal cavity by a thin membrane (figs. 23 and 24), which forms the enveloping membrane of the organ. In the male it completely envelops the spermary, but in the female the ovary is not completely covered by it. If, say in December, the ovaries of a smelt that would have spawned the next spring are carefully examined, it will be seen that the membrane forms the surface of the organ facing the median axis of the abdominal cavity and extends around and up for about one-third or more of what appears to be the other side of the ovary as it seems to be hanging in the abdominal cavity. There is thus a surface apparently not covered by the membrane. As a matter of fact the membrane is not a cover or envelope but is a part of the ovary, and the eggs are formed in crosswise folds of the ovarian membrane. As the eggs develop the ovaries enlarge and may be said to stretch (as do the spermaries also) and gradually come to almost fill the abdominal cavity.

The edge of the membrane, which seems to limit the uncovered egg surface, continues backward from the posterior end of each ovary and is diverted to one side and is attached to the lateral wall of the abdominal cavity forming the lower surfaces of the egg channels, which unite in a common channel (figs. 22, 23, and 24 *g*) near the outlet. Both of these channel membranes, which have been incorrectly termed "funnels," when not containing eggs lie against the membrane of the air bladder, which forms the roof of the so-called "funnel."

The gravid ovaries fill all the space in the abdominal cavity not occupied by other viscera. Upon opening the fish from throat to vent along the median line of the belly and laying the lateral walls aside, at first glance there appears to be one single mass of eggs, in front of which is the liver; posteriorly a small portion of the intestine may be visible. The greater portion of the egg mass is the anteriorly situated left ovary, which extends from the liver to some distance beyond the base of the ventral fins (fig. 22 *a*). Placed closely to the posterior end of the left ovary is the right ovary (fig. 23 *b*), which extends nearly to the vent. The dividing line, which is often difficult to discern, beginning perhaps a little in advance of the ventral fins, extends obliquely from the right side (left as observed) backward to the left side (right as observed). Both ovaries are ventrally convex from side to side, and concave above, thus forming a broad, more or less triangular groove, in which anteriorly the stomach lies. The intestine, at first above the stomach, finally lies in the grooves of the left and right ovaries. These grooves are formed by the left ovary curving over so that the so-called "lower edge" is in contact, or nearly so, with the dorsal surface of the abdominal cavity on the right side, the left ovary curving in like manner in the reverse direction.

The ovarian membrane is so thin that it is easily broken or rubbed off in examination or handling, so that one may easily be deceived into believing that there is no membrane and that the eggs are free in the abdominal cavity.

If the ovaries of a December smelt, previously mentioned, are compared with those of a gravid smelt in April, one is likely to wonder how the comparatively small

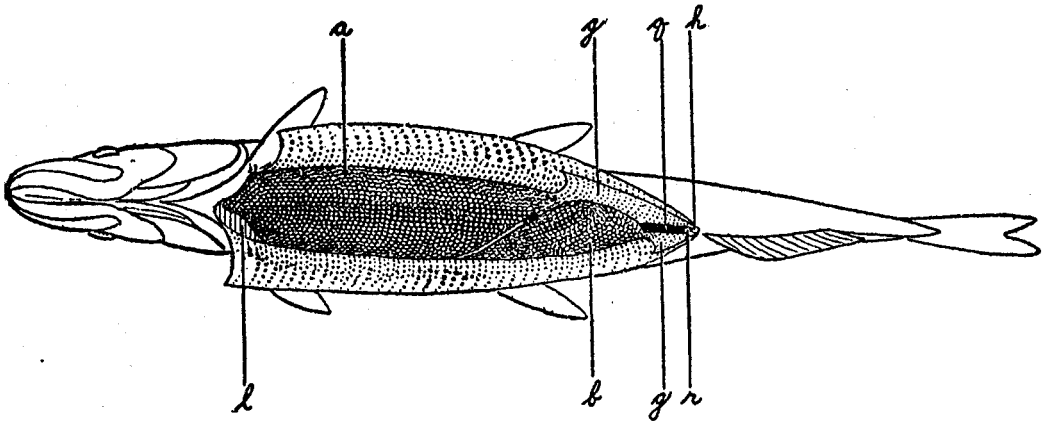

FIG. 22.—Semidiagrammatic drawing made by Walter H. Rich, from dissection by William C. Kendall. Specimen from Sebago Lake, Me. Ventral view of ovaries and oviducts of smelt (*Osmerus mordax*). *a*, Left or anterior ovary; *b*, right or posterior ovary; *g*, lateral expansions of mesovaria and ovarian membranes joining peritoneum of abdominal walls to form oviducts; *h*, genital pore; *l*, liver; *q*, intestine; *r*, anus

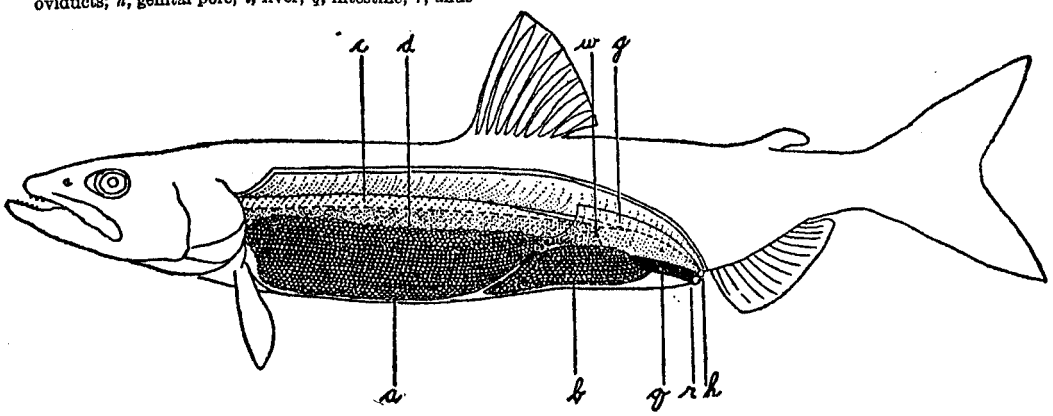

FIG. 23.—Left view of ovaries and membranes of same as Fig. 23. *a*, Left ovary; *b*, left side of right ovary bending up on left side so that its lower portion is dorsally situated; *c*, left mesovarium; *d*, outer edge of ovarian membrane; *g*, posterior lateral expansion of mesovarium and ovarian membrane forming left oviduct; *h*, genital pore; *q*, intestine; *r*, anus; *w*, posterior end of intestinal mesentery with confluent mesovaria

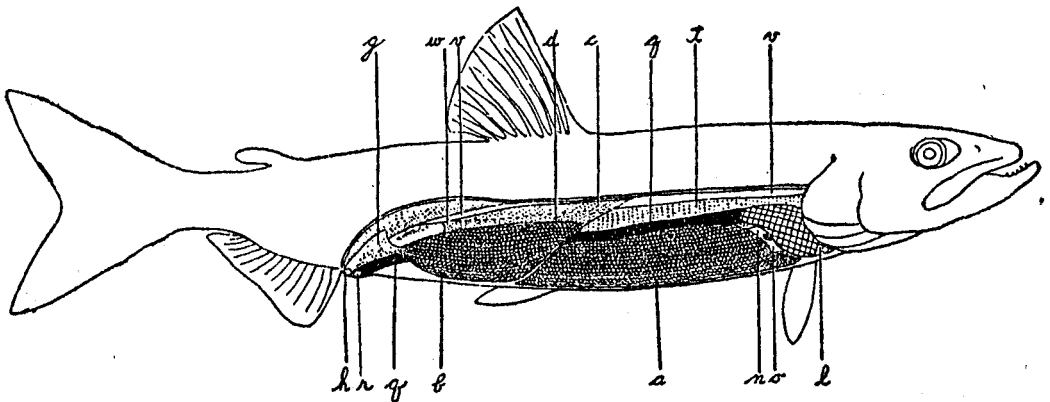

FIG. 24.—Right view of same as Fig. 24. *a*, Left ovary bending up under stomach and intestine forming a groove in which the viscera extend; *b*, right ovary; *c*, mesovarium of right ovary; *d*, outer edge of ovarian membrane, between which and the mesovarium the egg surface not covered by membrane other than the mesovarium is situated; *g*, right posterior expansion of the mesovarium and ovarian membranes forming the short right oviducts or practically the right side of the common oviduct posterior to *w*; *h*, genital pore; *l*, liver; *n*, upper or cardiac arm of stomach; *o*, lower or pyloric arm of stomach; *q*, intestine; *r*, anus; *t*, intestinal mesentery; *v*, air bladder; *w*, posterior end of intestinal mesentery with confluent mesovaria

December organ could produce as many eggs as are present in April. The fact appears to be that as the eggs develop and increase in size the outer ovarian membrane and the egg-bearing cross partitions are so stretched downward that, following the contour of the abdominal wall, they turn up and approach the dorsal surface of the abdominal cavity, so that what may be regarded as the bottom of the ovary is sometimes nearly on a level with the top. The "top," or that portion of each ovary that is not invested with adherent membrane, consists of a narrow dorsal area that is tipped in against the suspending membrane of the ovary. In these passages, formed by the investing membranes, the eggs pass backward into the egg channels previously mentioned. Here again one may wonder how the eggs manage to find their way into these channels from such apparently distorted ovaries. But the problem is not quite as difficult as it would be to try to account for their manner of exit if they were lying loose in the abdominal cavity. At least it may be suggested that near the posterior end of the ovary and close to the mouth of the egg channel, as the eggs pass into the channel, the ovarian membranes and cross partitions shrink or contract so that the eggs are brought necessarily from the "bottom" and the front into line with the channel.

If the eggs are set free in the abdominal cavity, as has been claimed, there appears to be no conceivable way by which they could be extruded, for the reason that, as previously stated, before the eggs of the left ovary have entered the egg channel the gravid right ovary presses the left egg-channel membrane (fig. 23 *g*) against the air bladder and left abdominal wall.

So it seems that the eggs of the small right ovary must ripen and be deposited before the eggs of the left ovary can fill its egg channel. As the eggs of the left ovary enter its egg channel the empty right ovary is compressed between the distented left egg channel and the right abdominal wall. As the right egg channel and ovary are emptied the left egg channel becomes entirely filled with eggs, and these, with the remaining eggs in the left ovary, have the appearance of a single continuous ovary. When both ovaries are emptied the collapsed organs have contracted so that the left is again small and considerably in advance of the right ovary. Both contain visible though minute eggs, which constitute the future crop.

FECUNDITY

The number of eggs deposited by an individual depends upon its size, varying from a few hundred to thousands. According to Smitt (1895), the number of eggs carried by a female European smelt 18 to 20 centimeters (about 7 to 7.8 inches) long was estimated by Norbäck at 50,000 and by Olson at 36,000. Mather (1885) said that he took from a "dead female" 30,000 eggs, and Mr. Walters took about 50,000 from a "weak female." In 1887 he wrote that the little smelt carries from 30,000 to 60,000 or perhaps more eggs, and that from 100 ripe females of good size probably 5,000,000 eggs could be obtained.

A fresh-water smelt 4⅝ inches long received by the present writer from Toddy Pond, East Orland, Me., was found by actual count to contain 5,893 eggs.

In a letter dated March 27, 1909, Superintendent Race of the Bureau of Fisheries' Green Lake (Me.) station, stated that from March 8 to March 19, inclusive, 425 large smelts had been collected; of which, so far as could be ascertained, 200 were

females. The fish ranged in size from five or six to a pound to half a pound each, and averaged about three to a pound. From them 3,460,000 eggs were collected, which would make the average number of eggs per female 17,300.

CHARACTER OF THE EGGS

Smitt (1895) says of the ova of the European smelt that they are light yellow, and their diameter was estimated by Benecke at 0.6 to 0.8 millimeter; but Meek (1916) states that the ova are light yellow in color, but he says they measure about 1 millimeter, which undoubtedly is incorrect.

According to Berkhous (1908), at the Torresdale (Pa.) hatchery, eggs obtained from Cold Spring Harbor were estimated at 500,000 to a quart. This would amount to 15,625 to a fluid ounce.

Superintendent Race of the United States Fisheries station at Green Lake, Me., said that a careful measurement of the eggs of the "large" form of fresh-water smelt showed 31,250 to a fluid ounce, and of the "small" form 46,250 to a fluid ounce.

The eggs are often spoken of as being glutinous or sticky, for which reason they become attached to anything with which they come in contact. Cunningham (1896) describes the means of attachment in an entirely different manner. He says that the outer of the two layers of the egg bursts at one point and separates, turning inside out as it does so and remaining firmly attached to the inner layer over one small circular patch. The separated membrane is adhesive when the egg is first shed, and attaches itself to objects in the water, for example the piers of bridges or posts in the river where the fish spawns, or the stones of the river bed. The eggs are thus suspended from their support by the flexible outer membrane. He states that the micropyle is in the center of the circular patch over which the suspending membrane remains attached. This description appears to be based on Ehrenbaum's account (1894).

After fertilization a considerable space is formed between the inclosing membrane and the body of the egg. The shape is round and the breadth of the inclosing membrane varies from 0.9 to 1.3 millimeters (about 0.04 to 0.05 inch). The yolk is composed of small globules, and contains several oil globules of different sizes. The whole egg is fairly transparent but less so than marine buoyant eggs.

INCUBATION

It is estimated that it requires from 2 to 6 weeks from the time the eggs are deposited until they hatch, according to the temperature of the water. Smitt (1895) says that according to Blanchère the eggs are hatched in 8 to 10 days; according to Feddersen in 12 days; and according to Sundevall in 18 days, "a discrepancy of observation which in all probability depends on the different temperature of the water during the period of incubation." Cunningham (1896) says:

> The development is rather slow and took at a temperature of 46° to 53° twenty-seven days. In the earlier part of the spawning season, from the end of March onwards, the water being colder, the development would take longer.

Regan (1911) says that the eggs hatch out in from one to three weeks, according to the temperature. Meek (1916) says that there is much variation in the time

of development due to differences in temperature, but that it may be said to be from 8 to 27 days. Concerning the smelt of the Elbe, Ehrenbaum (1894) says that four to five weeks are necessary.

In one of Mather's experiments (1885) it seems that the eggs began to hatch in 36 days, the temperature of the water ranging from 40° to 42° F. In another they hatched in 30 days with the temperature at 37° to 58° F. At five days old the formation of the embryo was visible by means of a microscope, and in 15 days the embryo could be seen with the naked eye. In another they also hatched in 30 days with temperature ranging from 40° to 65° F.

Concerning the smelt of Finland Reuter (1883) stated that the roe is developed in about three weeks.

In 1909, Race wrote that the incubation period of the "large" form of the fresh-water smelt at Green Lake, Me., was 30 days with a range of temperature from 33° to 34° F. The period of the "small" smelt was 24 days with the temperature ranging from 45° to 48° F.

In his report for the fiscal year ended June 30, 1922, Superintendent John A. Story of the Green Lake (Me.) station of the Bureau of Fisheries wrote:

> The advance run of smelts was very favorable. On April 26 many smelts were in the brook and 40 quarts were caught. More could have been caught, but on careful examination it was found that nearly all were males, there being about 25 males to one female, and it was decided that the next night would be the proper time to take them, as more females would then be in the brook. That night a cold rain set in, continuing all next day, which drove all the smelts back to the lake and practically no smelts came back into the brook. Other brooks were visited, but very few smelt eggs were obtained from the smelts caught April 26. These were left to hatch in the trough in which they were deposited. The dam board at the foot of the trough was removed to make quick water over the eggs and allow the fry to run out as fast as hatched. These eggs hatched in 18 days with practically no loss, the temperature registering 51.55° F.

In the report of the same station for 1924 Mr. DeRocher stated that in the case of the large smelt "eye spots" appeared in 20 days.

DEVELOPMENT

According to Cunningham (1896) the newly hatched larva is 5.5 to 6 millimeters long (0.24 inch, or less). The mouth is already open, but beneath the head; the yolk is much reduced, and the oil globules all united into one, which is situated near the front end of the yolk sac. The primitive fin membrane is narrow; the intestine ends near the end of the tail, far behind the yolk sac, as in the larvæ of the herring family. The pigment is very scanty; there is some in the eyes and specks on the yolk sac and along the lower edge of the body. The whole larva is delicate and transparent.

The present writer's observations upon the American Atlantic smelt, which have been in comparatively small brooks, indicated that the tiny transparent young do not remain long in the place of their birth. Probably, because the eggs are more or less suspended above the bottom, the current of the water takes the majority of young smelts downstream almost as soon as they are hatched, thereby being subjected to all sorts of vicissitudes, and comparatively few survive to attain the adult age. It is a provision of nature to offset such contingencies that the smelt is so

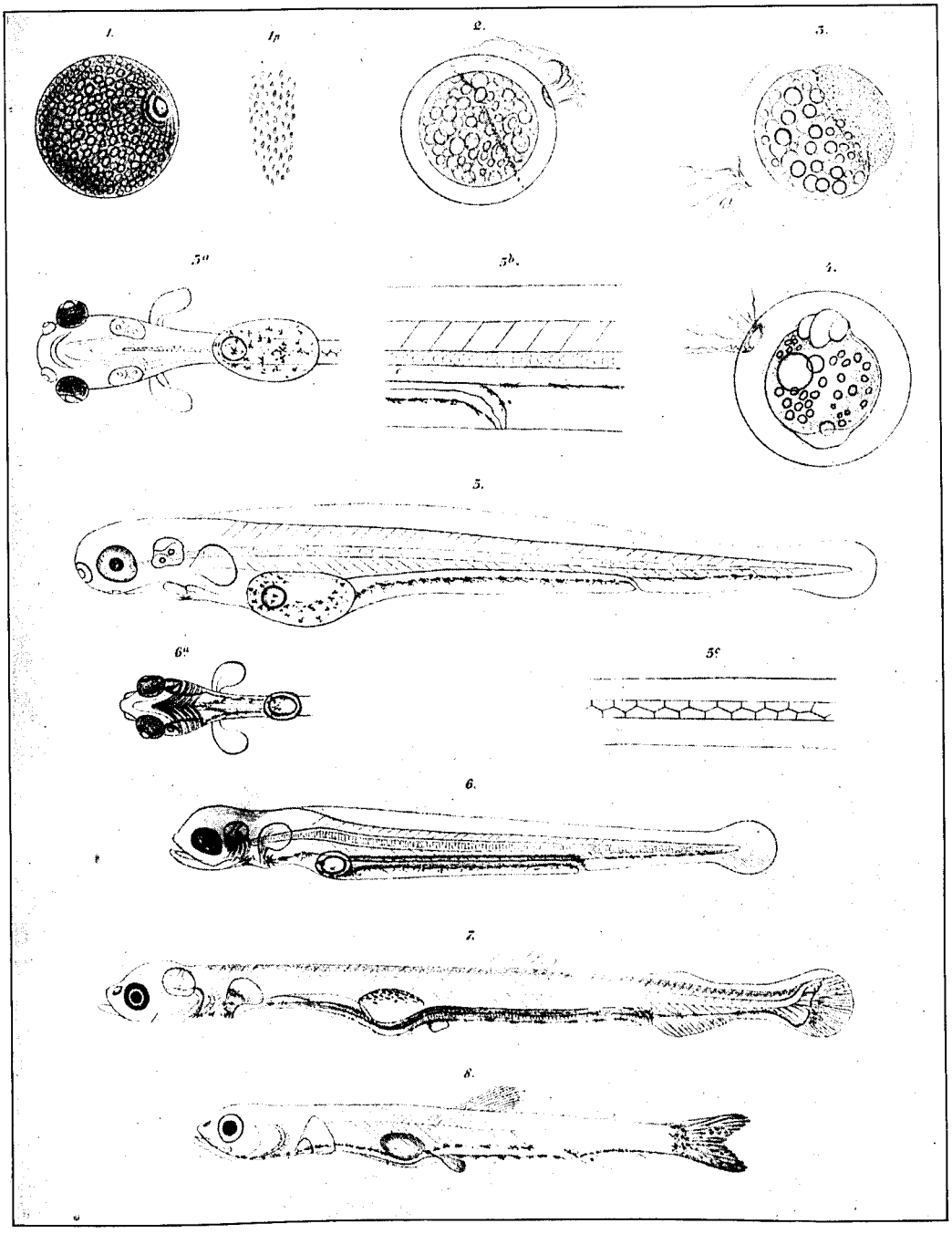

FIG. 25.—Embryology of the Elbe River smelt, from Ehrenbaum. 1. Mature, unfertilized egg, collected before absorption of water. Diameter 0.75 millimeter. 1*p*. The pores of the *zona radiata externa* of the egg greatly magnified. 2. Mature egg immediately after placing in water containing sperm; the *zona radiata externa* is ruptured and on the point of turning back on itself, whereby it remains only near the micropile, suspending the egg. 3. Egg with developed (yellowish) transparent yolk, 6 hours after fertilization. Diameter 0.90 millimeter. 4. Egg with embryo of 9 days; large yolk and few oil globules. 5. Smelt larva immediately after hatching on April 19. Length 5.5 millimeters. 5*a*. Showing underview of anterior portion of the same larva with its inferior mouth and extended pectoral fins. 5*b*. Posterior portion of same larva greatly magnified, also the corda cells. 5*c*. Underview of the corda of the same larva. 6. Smelt larva of April 24, 6 days old. Length 6.3 millimeters. 6*a*. Anterior portion of the same larva. 7. Larva of May 27, 15.5 millimeters long. 8. Larva of June 17, 28 millimeters long

prolific. Notwithstanding the adversities they encounter, their rapid migration, whether active or passive, is necessary for the survival; for the conditions of their birthplaces do not afford the requisite quantity of suitable food, which is to be found only in more open or tidal waters.

Observations by Ehrenbaum (1894) upon the smelts of the Elbe River showed that the newly hatched fry were 5 to 6 millimeters (about 1/5 to nearly 1/4 inch) in length. They were found to attain from a little over 0.55 to 0.7 of an inch in length in one month. In three months they reached 1.25 to 1.45 inches. In five months the lengths were found to range from 1.73 to 2.36 inches. In the month of August the range of length was from 1.57 to about 2 inches. It was determined also that the smallest mature smelt was about 4 inches long and 2 years of age, but many larger fish were found to be immature.

According to Sundevall, on their first exclusion the fry of Swedish smelt are 5 millimeters long and perfectly transparent; they are characterized by the universally backward position of the vitelline sac (yolk sac), the distance between it and the insertion of the pectoral fins being more than half of that between these fins and the tip of the snout. In August, according to Yarrel (1836), the English smelt has attained a length of 75 millimeters (nearly 3 inches).

Cunningham stated that the larvæ of smelts (*O. eperlanus*) have been kept alive for 15 days after hatching in an aquarium. On the sixth day by the growth of the ower jaw the mouth had become terminal and the yolk was nearly all gone, but the fins had not begun to appear. The larva at this age was 6.3 millimeters long (1/4 inch). The youngest larvæ captured in the river were taken on the 5th to 8th of May and were 6 to 8 millimeters long (the largest nearly 1/3 inch), and had begun to feed on the minute Crustacea, called "copepods," the usual food of young fishes. The larvæ were extremely abundant in the estuary of the Elbe. A small net only 2 feet 8 inches across the opening placed in the current for a quarter of an hour captured on one occasion (May 28) a number calculated to be 107,000. These specimens were 14 to 20 millimeters long (three-fifths to four-fifths inch) and were still very transparent, but the first dorsal and the ventral fins had appeared. These larvæ were still very slender in proportion to their length and were remarkable for the great size of the air bladder. In the middle of June the little fish were four-fifths inch to $1\frac{7}{5}$ inches long and had nearly reached the form and character of the perfect smelt. They were still, however, transparent and without scales and silvery coat. Even in August the young smelts, now $1\frac{7}{5}$ inches to $1\frac{4}{5}$ inches although more pigmented and less transparent, had not acquired their scales and silvery garment. The development of these last characters of the perfect fish takes place in September and October, when the young are 2 inches to 2.4 inches long.

In 1913 Masterman, from a study of the scales of British fish, indicated that smelts 1 year old averaged 4.48 inches, 2 years old 7.24 inches, 3 years old 7.55 inches, and 4 years old 8.85 inches. From the foregoing figures, then, it may be concluded with a fair degree of safety that the Atlantic smelt of American rivers spawn at the end of the second year and may average at that age between 6 and 7 inches.

According to Cunningham "after October the smelt, young and old, descend toward the sea, and return toward fresh water at the end of February and in March.

In the Elbe Ehrenbaum found that while the smallest ripe fish were 4 inches long, others which were as large as this were immature. He also observed that in the first half of the summer, before the young of the year had got beyond the larval stages, young immature smelt of 2⅘ to 3⅗ inches in length were very abundant, and also caught in very large numbers for eel bait. This shows the usual growth of the year-old fish, some of which spawn for the first time when two years old and 4 inches to 6 inches long."

The growth of the smelt from the fry stage is comparatively rapid, though the size attained in a given time is variable, as indicated by the following measurements:

Smelt fry obtained from the stomachs of sticklebacks (*Gasterosteus*) in the tidal portion of Casco Bay, Me., creek, only a short distance below high-water mark, on May 13, averaged less than 0.2 inch in length. Judging from the presence, in some instances, of incompletely absorbed yolk sac the fish could not have been hatched long.

On August 3 translucent young smelts, ranging in size from 1.2 to 2 inches, were caught at an island in Casco Bay several miles from any possible breeding place. On October 14 young smelts, still translucent, caught in the same bay, ranged from about 2 to 2.56 inches in length. On December 11 others, also translucent, ranged from 2.4 to about 3.6 inches long.

Again, on the following February 10, similar young smelts ranged from about 2.6 to 3.56 inches in length. Still again, on March 5 following, specimens ranged from 2.4 to about 3.75 inches in length. While only the last three collections were consecutive in the same period, inasmuch as they represent a brood of the year previous to the one just considered—that is, fish about 15 months old—they are probably fish that would breed for the first time in the following year—that is, at 2 years of age.

In the same brook, on April 20 of the same year in which the previously mentioned newly hatched fry were obtained, 12 breeding smelts were taken, consisting of equal numbers of males and females that ranged from about 6 to 7.8 inches and averaged 6.52 inches in length. They represented the smaller fish and at the same time the size of the majority, but not necessarily the average, for probably some larger fish that may or may not have been older were present. This would indicate a gain of 3.28 inches in about eight months from the preceding August.

As the foregoing figures are not exact, and as only the last three periods mentioned in reference to the series of young fish were consecutive in the same year, they might be considered insufficient data upon which to base a generalization. However, the figures so closely approximate conclusions reached by certain European authorities respecting the common smelt of northern Europe, that they may be regarded as to some extent representative of a general situation. In this country, at least, virtually no observations upon the rate of growth of the fresh-water smelt have been made.

Concerning the smelts of Finland, presumably a fresh-water form, Reuter (1883) said that the fry grows rapidly where there is abundance of food, but under other circumstances its growth is easily stopped.

Young smelts obtained from the stomach of a trout (*Salvelinus fontinalis*) in Sunapee Lake, N. H., by the present writer on August 13, 1910, measured 1.1 to 1.4

inches. Several picked up from a beach at the same lake on October 15 and 26 measured from nearly 2 to 2.28 inches. This possibly indicates an increase in minimum and maximum lengths, respectively, of 0.9 to 0.88 inch in a little over 2 months.

At Sebago Lake, Me., in July (18 to 29) of various years, young smelts were found to range from 1.2 to 1.5 inches; in August (8 to 28) they ranged from 1.4 to 2.5 inches; and on September 10 in one year 109 specimens from the stomach of a yellow perch measured from a little over 1 to 1.9 inches, averaging 1.7 inches. There is no way of telling whether only one or both classes of these "large" or "small" smelts were represented. The figures would suggest that both were represented.

It has been indicated already that the marine smelt appears to attain maturity at 2 years of age. From the report of the New Hampshire commissioners of fisheries, for 1872, it would seem that this obtains with fresh-water smelt. The report says:

> Two years since we placed some of the ova of the smelt in some brooks running into Massabesic Lake, as a matter of experiment, and we have reliable information that full grown smelts have made their appearance in one of those brooks, for the purpose of spawning, this spring. As there were no smelts there previous to placing their ova in those brooks, we learn the fact that the smelt matures in two years.

STOCKING WATERS OR TRANSPLANTING

Bloch (1796) wrote that it was possible to transfer and stock other waters with the éperlan, provided that the place where they were sent was deep and the bottom sandy. He said that the fish was so common and so cheap that it was hardly worth transporting, but as it was very prolific it might serve as food supply for Sandre and trout.

Smitt (1895) said that in lakes where the smelt is wanting it may easily be introduced and is very useful as food for other fishes, particularly the pike perch, as Nilsson pointed out. He said that the impregnated eggs may be transported from one lake to another or, with a little care, the spawning smelt may be conveyed alive during the cool season in vessels filled with pure water.

On this point Reuter (1883) wrote that smelt propagation is best managed by fructified roe, or also by transportation of adult fish, but as the smelt lives only a short time if it is taken from the water the transport ought to be made in roomy vessels and during low temperatures, and the fish to be transported should therefore be caught from among younger, earlier spawning individuals.

Day (1884) related that Colonel Meynell, of Yarm, in Yorkshire, kept these fish for four years in a fresh-water pond, which had no communication with the sea; and he observed that Yarrell states that they continued to thrive and propagated abundantly. He said that the pond being frozen over did not affect them, and they did not lose either flavor or quality (Wern. Mem. December 17, 1825). Day further remarked that according to Southwell, Mr. Egerton acclimatized smelts in fresh water in a lake at Roselherne Manor, Knutsford, Cheshire, and that many were kept alive in tanks in the Norwich fish market until required for use.

Concerning these fish Day said that W. Wankly of Grange-over-Sands, Lancashire, sent an account of them to Land and Water, and observed he was much struck with the very rapid growth of the sparling from October to March—in October,

10 or 12 together weighed no more than 1 pound; in March the fish were 4 ounces to 6 ounces each, and occasionally one or more in a take weighed close to 8 ounces.

In this country there are not many reports concerning rehabilitation of coastal streams with smelt by fish-cultural operations. Mather (1894) gave a table showing the number of fry and eggs planted in one stream in Connetquot River, a small stream rising in the center of Long Island, north of Yaphank, and flowing into Great South Bay near Bellport, from 1885 to 1894, both inclusive, amounting to 55,000,000. Concerning these facts Mather said:

> That we have made rapid strides in the work of smelt hatching is shown by the table giving our yearly plantings, where it will be found that of the 55,000,000 fry and eggs distributed in ten years almost half the number was sent out this spring. It should also be borne in mind that this great result was obtained from an insignificant stream that never contained smelts before—is was stocked by the New York State Fishery Commission.

In this country, too, there are a few instances of the successful transplanting of marine smelts into fresh water. The report of the commissioners of fisheries of Massachusetts for 1868 (p. 20), states that smelt were introduced in Jamaica Pond near the close of the preceding century, and live there entirely cut off from salt water.

The Massachusetts report for 1870 stated that a number of mature smelts had been put in Flax Pond, in Wareham, the preceding spring, and that fall great shoals of little smelts were seen about the edge of the pond, showing the success of the attempt.

The possibility of the natural occurrence of fresh-water smelt in Massachusetts is suggested by an article in Forest and Stream for April 18, 1889 (p. 259), which said:

> From Cape Cod, Mass., we have received some specimens of a fish known there as fresh-water smelt. The examples are about 5 inches long and represent about the average size of the fish. The species is found in two or three large, perfectly landlocked ponds, which have no visible outlet and are remote from salt water. We are informed that no stream ever has connected these ponds with the ocean. The fish are never seen except for a few nights during the first week in April, when they come to the shore to spawn. They can readily be taken with dip nets or landing nets. Under proper conditions bushels of them can be taken in a single night. Few persons know of their existence. Unless the ponds are visited at just the right time, and with a light, the fish can not be seen. This fish is a very delicate and toothsome little species, having the flavor of a salt-water fish. * * * . The only changes that we can observe as the result of landlocking are a reduction in size and the strength of the teeth. The specimens obtained were caught on the night of April 3 and appeared to be spent females.

Of course, if the ponds never had any outlets the smelt must have been introduced by some means or other, perhaps by the hands of man or possibly by the feet of birds.

It appears that smelts have been introduced with some success into other ponds of Massachusetts, of which Onota Lake near Pittsfield, is a notable example.

Fresh-water smelts appear to be unknown in Rhode Island and Connecticut, and in Vermont are recorded only from Lake Champlain. In New Hampshire they occurred naturally in Winnepesaukee and connecting waters; and, according to the reports of the commissioners of fish and game, they have been successfully transplanted into some other waters of the State.

In Maine there are numerous instances of successful introduction, as in Moosehead, Rangeley Lakes, and the Eagle Lakes in northern Aroostook County. There appear to be no records of successful plantings of the fresh-water smelt in New York waters, but there are a few records of the transplanting of the salt-water smelt, some of which were unsuccessful and others at least temporarily successful.

A correspondent of the American Angler on October 7, 1882 (p. 228), stated that some smelt furnished by a Mr. Blackford were put into Otsego Lake, which seemed one of the best to test them, but that circumstances not favorable to a successful plant may have prevented success in this case, as none of the product had been seen in the lake. He regarded the experiment as worth repeating.

Early methods of transplanting consisted of transplanting eggs or adult spawning fish, as indicated by a correspondent of Forest and Stream on October 23, 1890 (p. 271), who said that the smelt usually were transported as fish but that a Mr. Aiken had established them in Webster Lake, N. H., by the "novel method of taking the fertilized eggs after they had been glued to stones in the spawning brook. Stones with the eggs upon them were placed in a little tributary of Webster Lake, and now the waters are teeming with smelt."

Another method was mentioned by Cheney (1876), who wrote:

> Commissioner Stanley told me in New York recently that he could stock any lake with landlocked smelt for $25. So the question of food for salmon is not a difficult one. In some localities where the landlocked smelt abound there are no facilities for hatching the eggs artificially for the purpose of transplanting. Where such is the case and it is desired to transplant smelt, brush may be cut and thrown into a stream where the smelt run to spawn, and the eggs adhering to the twigs can be transplanted in cans of water to the stream or lake to be stocked.
>
> Commissioner Wentworth, of New Hampshire, told me that at Sunapee Lake, N. H., smelt were caught for salmon bait and put into an old half-sunken row boat near the shore. The smelts spawned in the boat and the fry hatched and literally swarmed in the boat after the parent fish had been used for bait. I have seen young smelts at the mouths of the streams in the same lake in myriads in spite of the number of fish ready to prey upon them.

Another interesting but short-distance method is described in the report of the Massachusetts commissioners for 1918, page 145, as follows:

> *Experiment in collecting and shipping Spawn on Burlap.*—Last year the smelt spawn was collected by placing the burlaps on the bottom of the river and allowing the smelt to deposit the spawn thereon naturally, with the result that the eggs were laid unevenly and a large percentage infertile. Attempts were made this year to devise a more satisfactory method by stripping the fish, fertilizing the spawn and spreading it in the quantity desired. It was done in this way. The spawn immediately on being taken from the fish is brought to the spreader, who is stationed before a tank of water 8 inches deep, of just the size to hold horizontally the sheets of burlap. These are 16½ by 20 inches in size, with a strip of lath tacked at two opposite ends to facilitate handling. Quick action is required or the eggs, fresh from the strippers, will lump together and be spoiled. A small quantity of eggs is mixed in a bucket of water and poured into the tank. The eggs settle as sand would do, and adhere wherever they touch the burlap which lies at the bottom. The success of this work depends upon keeping the water moving so that the eggs will settle in a thin, even layer, and not on top of each other, or too many in one place. After allowing one minute for the spawn to settle, the burlap is turned over and an ounce of spawn placed on the other side. A second burlap is put in over it (the tank has a capacity of ten), and the process is repeated until the tank is full. One pan of spawn covers three burlaps. When the tank is full the aprons are transferred to a frame which holds them straight and smooth, and placed in the "Jumbo Hatcher" in which the hardening process is continued further. This piece of apparatus consists of a tank equipped with running water (piped in from the pond), so arranged that the water will run evenly on both sides of the ten

burlaps which are arranged to fit into it. This apparatus could be used for hatching if desired, but this year was utilized only for hardening. The eggs are left to harden from twenty-four to seventy-two hours, at the end of which time the spawn may be transported, but has not reached the eyed stage.

The burlaps were shipped to applicants by express prepaid, packed in baskets of sphagnum moss, which holds the moisture and maintains an even temperature. This method of shipment proved satisfactory only for nearby waters. Considering the slowness of transportation by express, and the present condition of railroad facilities, distribution by automobile would be the best method. Planting is accomplished by the simple method of selecting a place where the water has a fairly swift current, and placing the burlap on the bottom, weighted down with stones at each end.

The report for 1921 states that "several bushels of spawn-covered grass were planted in the Jones River, Kingston, as has been done yearly since 1917."

While considerable success has attended the attempts to stock New England waters with smelts, it appears that some difficulty has been encountered in efforts to stock waters at a greater distance from the source of supply. While living adult fish possibly might be transported, it would hardly seem feasible to transfer them in sufficient numbers to stock a lake, especially one in which predatory fishes occur, for it is likely that all would be devoured before they could breed, although an initial stock of smelt in a small pond might be established if there were no other fish to eat them. To transport fish in breeding condition would be still more difficult, and even if they endured the journey and did not spawn on the way they would not be likely to spawn after they were planted. The most practicable way appears to be by transfer of eggs, in which the difficulty lies in the shortness of the incubation period and the danger of the eggs hatching before arrival at their destination.

The most signal success in stocking distant waters that has come to our attention is that of Crystal Lake in Michigan. It appears that of 20,400,000 eggs shipped to the Michigan Fish Commission from the Green Lake station of the Bureau of Fisheries in April, 1912, 16,400,000 were planted in a tributary of this lake.

In 1922 the result of the introduction was manifested by the appearance of breeding fish in tributary streams of the lake. The Rev. J. Warren Leonard, of Lansing, who was interested in stocking the lake, informed the writer that the smelts ascended one of the streams tributary to Crystal Lake to spawn in such quantities that they were drawn away by wagon loads to be used as fertilizer. This seems like "old times" in the East. The size of the fish was reported to be as large as 9 inches in length. The smelt eggs in this case were of the "large" smelt of Green Lake.

Creaser (1925) shows that on April 4, 1912, 6,000,000 eggs were deposited in Torch Lake, Antrim County, and on April 6, 1912, 16,400,000 eggs were placed in Crystal Lake, Benzie County, Mich. Eggs were planted elsewhere in Michigan, also, of which there is no definite information of locality or results. About 200,000 eggs were sent to the Huron Mountain Club of Marquette County, which were planted in Howe and Trout Lakes in that county. According to Creaser, specimens have been taken or recorded from the following places in Michigan:

1. Crystal Lake, Benzie County, Beulah, Mich. Specimens have been taken in the lake proper in summer and winter and at a great range of depths; from a tributary, Cold Creek, at the village of Beulah; and from the outlet, East Betsie River, which runs into Lake Michigan.

2. Lake Michigan, 5 miles south of Frankfort, Mich., and 1½ miles out in the lake. A specimen was taken in a gill net by commericial fishermen, who report that the smelt is abundant in Lake Michigan, off Frankfort.

3. Howe Lake and Trout Lake, Marquette County, Mich. Dr. Walter Koelz made a trip into this region from August 23 to September 2 and caught smelt in both of these lakes. They were 1 to 4 years old, which indicates that they are established in these lakes. Howe Lake has no outlet, but Trout Lake drains through Pine Lake to Lake Superior. The presence of smelt is accounted for by the egg plantings of 1912 and 1918.

4. Lake Michigan at Northport, Leelanau County, Mich. Dr. Koelz interpreted a description of a strange fish caught by fishermen of this region as that of a smelt.

Creaser states that the foregoing constitutes the knowledge of the distribution of smelt in the upper waters of the Great Lakes. He says that fine mesh gill nets, which caught smelts at Crystal Lake, failed to take them in Torch Lake, Antrim County, which was planted at the same time that Crystal Lake received eggs.

As previously mentioned, the most marked results of these attempts at acclimatization of the smelt in this region appears to be in Crystal Lake. Creaser decided from age determination made from their scales that the smelts of April 17, 1923, were the product of natural spawning in the spring of 1919, 1920, and 1921. He states that large breeding runs in and about Beulah have occurred every spring since 1919. Many 2-year-old fishes were taken April 6, 1925, which were hatched in the 1923 run.

Creaser says that smelt are very abundant in Crystal, Howe, and Trout Lakes, and at Crystal Lake they are caught at all seasons of the year with hook and line, most frequently, however, in the winter through the ice by the perch fishermen. In the winter of 1924 they reported that one-half of their catch was smelt.

He writes that the Michigan State Department of Conservation, through Mr. Craw, tried to catch all the smelt that came into Cold Creek at Beulah during the spawning run of 1925, but for what reason is not stated. Each person was allowed 20 pounds. The game warden kept an account of the number of men at work, as nearly as possible under the circumstances. From those data, on the basis of an average of six smelts to a pound and the prevailing price of whitefish, it is estimated that in seven days 16,000 pounds, or 96,000 individuals, valued at $5,600, were caught. It is quite evident, therefore, that the smelt has become completely established in Crystal Lake, as Creaser says.

A letter from Carl L. Hubbs, University of Michigan, dated April 26, 1924, says: "Just recently we have received a smelt from Green Bay, across Lake Michigan from Crystal Lake. It is evident that the species is spreading in the Great Lakes region."

In a letter to the United States Commissioner of Fisheries, dated March 27, 1909, E. E. Race, then superintendent of the Green Lake station, referred to an experiment that had been undertaken for the purpose of determining how long smelt eggs could be kept alive in transportation. Mr. Race wrote:

> March 17th, in compliance with instructions we packed about 15,000 as taken from the troughs in bunches, and a few that were separated, in a common shipping case with ice hopper. These have been examined several times, and ice added when needed. There are eight trays in the stack, and

the eggs were placed on the second tray under the ice hopper and the last tray near the bottom part of the stack. Yesterday they were found in excellent condition. There was no noticeable difference in the eggs on the two trays, except that on each tray the eggs that were separated showed a larger loss than those which were bunched, and the losses apparently larger on the bottom tray. We estimated that the total loss is less than 5%. Did not count the dead eggs, as it seemed best to close the case at once, and we don't know the exact number in the case, as the number in bunches could not be counted or measured, but approximately the losses thus far have been on the entire lot about five per cent of the number packed.

In another letter, dated April 26, 1909, Race further described the developments in the experiment. He said that the 15,000 smelt spawn packed in one of the regular transportation egg cases, with exactly the same care with which other classes of eggs are packed for long shipments, plainly showed that by packing them as soon as taken and without trying to separate the bunches they can be transported safely a long distance, provided they are kept well iced in transit. The last eggs in the bunches died 3 days previous, having become somewhat foul or sour from being closely packed, and this would seem to indicate that by repacking or giving them a little fresh air daily, 45 or 50 days' shipment would show good results on arrival. The separated eggs all died, while the bunched eggs were still in good condition.

In April, 1912, also, several million smelt eggs were planted in Torch Lake, also in Michigan. On May 18, 1916, 10,000,000 were placed in the waters of St. Mary's River, and on May 30, 1921, 200,000 were deposited in Sturgeon River of the same State, all from Green Lake, Me.

It is quite probable that at least the earlier shipments to Michigan were made under the conditions mentioned above, but the time in transit could not have been more than a few days. The smelt eggs of the first two lots—that is, Crystal Lake and Torch Lake—were all of the same shipment and doubtless were eggs of the large smelt. The others probably were the eggs of the small smelt.

The incubation period of the large smelt is about 30 days with the temperature of the water around 34° F. The incubation period of the small smelt in the same season is about 24 days with water temperature around 48° F.

In Race's experiment, evidently with eggs of the large smelt that had been packed on March 17, the last eggs were dead on April 23, a period of about 37 days, or a week over the incubation period. This would seem to suggest that by keeping the temperature down by means of ice, the limit endurance had been reached, and it is hard to see how it could be expected that under any circumstances eggs could be retained without dying or at least hatching for a period of five or six weeks beyond the incubation period.

It would appear that long-distance transportation of smelt eggs, the incubation period of which is so short at a temperature so near the freezing point, could not be greatly prolonged by reduction of temperature. In the case of eggs of the small smelt it would seem that a reduction of temperature to near freezing, if it did not kill the eggs, would simply serve to prolong the incubation period to the same length of time as was effected in the case of the large smelt.

If it seems desirable and a good policy to stock distant waters, as those of the far West for example, about the only practicable way to transport the eggs that occurs to the writer at this time would be by relays, now "taking departure" from

Crystal Lake, Mich., for example, and stocking some waters farther west, and so on until the most remote point is reached. This procedure would take time and money. Would the desired results, if attained, be commensurate with the cost?

DEPLETION

Seventy-five years ago the early depletion of the smelt fishery was predicted. In 1849 Frank Forester (Herbert, 1849), referring particularly to the smelt of the Passaic River in New Jersey, said:

> The run of them is becoming less and less numerous every successive season, and it is to be apprehended that ere long they will cease to visit us at all.

Twenty-seven years later, according to Thomas (1876), the fish were scarce enough to give rise to his query: "Why can not these fish be made more common?" Nearly a decade later than this, Mather (1885) wrote:

> The catch has been gradually decreasing for the past few years, not only at Locust Valley, but on all Long Island streams * * *.

Some 15 or 16 years after Mather's experiences at Long Island, Cheney (1901) wrote:

> For two years past the State of New York has been unable to obtain smelt eggs on Long Island, though in former years they have been obtained by the millions, as the plant of fry in 1896 was 34,000,000, in 1897 45,000,000, and in 1898 48,000,000, all from eggs taken in Long Island streams. There was a falling off in 1899 to a very few millions, still worse in 1900, and this year [1901] none at all, though the north and south shores were explored at the usual time for smelt to run.

The decrease in the smelt fishery of Massachusetts has already been discussed in preceding pages, but in recent years it has been seen that there were a few abundant local runs.

In Maine, as long ago as 1869, Atkins (1869) said:

> The impression has been quite general that the smelt fishery is over-done, and that unless some radical measures are taken, it will soon fall into as great decay as have the salmon and alewife fisheries. Indeed, in some parts of the State the decline has already commenced, and even where the numbers of the smelts have shown as yet but little diminution, the decrease in size is very marked.

Whether or not the radical measures were taken, for more than 30 years the smelt fishery of Maine continued to yield considerable though fluctuating quantities of smelts, as has been seen from the discussion of the commercial fishery. However, in 1920 the director of sea and shore fisheries of Maine (Crie, 1920), after discussing the probable cause of the depletion of the smelt fishery, expressed the following sentiment:

> Therfore it is quite apparent to anyone who will give the subject the attention it merits that the smelt fishery of Maine is depleted and on the wane and it seems to this Commission that, after God had furnished this great and abundant food supply to the inhabitants of the State of Maine, we are not doing justice to the State or to ourselves unless we enact laws, good rigid and enforceable ones, to protect the smelt in it's season of reproduction, i. e., the spawning season.

Whenever there has appeared to be a falling off in the smelt fishery, as in some other fisheries, quite generally the fact has been attributed to overfishing, although at times some curious opinions concerning the cause of scarcity have been offered.

In explanation of the scarcity on Long Island, N. Y., Cheney (1901) wrote:

In 1900 it was thought that the heavy storms which prevailed at the spawning season prevented the smelts from running into the streams where they were in the habit of spawning, but this would not be an excuse this year. Talking with Mr. DeNyse, he said, quite positively, that he believed the codfish artificially hatched by the United States Fish Commission and which now swarmed in Long Island waters, had preyed upon the smelts to such an extent that they were practically destroyed where they were formerly so abundant. He did not say what evidence, if any, he had of this, except the presence in vast numbers of the young codfish, where formerly smelts were plentiful, but it may be a reasonable explanation of the disappearance of the smelt.

According to Atkins, the scarcity of smelts in the spawning season at Surry in 1878 was attributed by N. Hinckley, Esq., to too much dipping when the tide was out and the fish collected in bodies in tide pools; while in the same year, in the case of Lawrence Brook, Atkins stated that Billy Harriman thought that eels kept the smelts out of the brooks, as, he said, when eels get into the brooks first, as they did this year, it often happens that there is a scarcity of smelt.

Mather (1885) attributed the growing scarcity of smelts of Long Island to overfishing during the breeding season. He said:

Their habit of ascending streams at night and returning to salt water before day renders them liable to capture both ways * * *.

In his notes of 1910 the present writer finds the following remark:

So many boys were after smelts on Porter's Landing brook [Freeport, Me.] that the fish got but little chance to spawn. However, some smelts probably would have been able to ascend if it had not been for the seining in the creek and river just below the brook. Spring seining should be prohibited from March 1.

As elsewhere stated, it has been observed that smelts congregate at the mouths of streams even before the ice is out, for some time before ascending to spawn. It was this fact and the seining of those fish at the time that gave rise to the foregoing remark. That there has been more or less general decline is evident. This and the total depletion of the smelt fishery in some localities are attributable to one or more, and in some instances perhaps to all, of several causes, which may be classified, at least in part, as follows: (1) Interference with reproduction; (2) excessive and wasteful fishing

The first class comprises obstruction and pollution of streams formerly frequented by smelts for breeding, and uncontrolled fishing during the runs in the streams at spawning times. The second principally involves destruction of immature fish in the course of legal net fishing during the open season.

Dams have formed the principal obstructions in many streams, and they are too general for specific citation. Instances of pollution of streams affecting smelts are not as numerous, but the Passaic River in New Jersey is a conspicuous example.

The destruction of smelts on and near the breeding places during the breeding season, formerly a common practice, has been stopped in some localities but still obtains in others. In almost all of the present smelt fisheries, excepting the hook-and-line fishery, destruction of immature fish, especially those about 1 year old and upward, prevails. Every year during the open season, wherever seines are used in the capture of smelts, a vast number of immature smelts and those that would

spawn for the first time in the following spring are caught. In late years there has been a market for these little fish, but usually they have sold for a comparatively very low price. In Boston the tiny smelts are known as "cigarettes," and to the writer one wholesale dealer expressed the wish that the capture and sale of the fish of this class could be prohibited. The market for the "cigarettes" is not constant, consequently many that are caught are thrown away after culling out the larger fish.

In December, 1924, the writer bought 1 pound of these tiny fish in a retail store in Portland, Me., for 30 cents. Forty-one fish made the pound. Amongst the fish there were only eight that showed by the condition of the roes and milts that they would have spawned the following spring. The 8 comprised 2 females each slightly over 5 inches long, 1 female about 6.4 inches long, and 5 males a little over 5¼ to nearly 6 inches long, averaging about 5½ inches. The other 33 specimens ranged in total length from a little over 4½ to about 5.7 inches, averaging not quite 5 inches.

It is almost impossible to avoid taking large quantities of these little fish in drag seines, whatever the size of the mesh, if the mesh is small enough for ordinary smelts. When the seines is hauled the meshes draw together and the small smelts are caught in the jam of larger ones and other fish incidental to the haul. They are all killed, and so long as general and unrestricted seining is allowed great numbers of the fish must be killed and it would be an economic waste to prohibit their sale. Of the North Atlantic smelt-producing States, Maine alone still provides a fishery of considerable commerical importance and value, notwithstanding the long-standing and oft-repeated warning that its exhaustion is imminent. The expressions of alarm concerning the possibility of a ruined fishery have been based upon some notable local or general decline in the fishery, and when the fishery showed marked improvement the improvement usually has been attributed to some beneficent human action.

Apparent declines have been ascribed to sundry causes, as previously mentioned. As a matter of fact, a small catch or a small breeding run in any year may have been or may be, in many instances, due to natural causes. A generally poor breeding season in one year, for instance, might be followed by a poor supply of adult fish, as manifested both by the fishery and the breeding runs two years hence.

A phenomenon well known to smelt fisherman is that of a marked scarcity of small adults smelts and a comparative plenty of large sizes. Such a condition may be occasioned by a poor breeding season two years prior to the occurrence, resulting in a small number of 2-year-old fish but with a normal survival of older fish that have increased in size. Conversely, another manifestation is that of a great abundance of small fish and perhaps a scarcity of large fish, which is the outcome of a good breeding season two years or so prior thereto with a consequent large number of smelt of smaller sizes, the large fish having diminished in number for one reason or another. These two examples will suffice to illustrate how the fishery may be affected by natural fluctuations. Poor as well as good breeding seasons, however, may be influenced both directly and indirectly by the act of man. One of the most potent and disastrous adverse influences is that of interference with the fish during the breeding season.

Foster and Atkins (1868a, p. 29) reported that there was a complaint against Androscoggin fishermen. They wrote:

> It is said that at the mouth of a small stream, somewhere above Bay Bridge, where the smelts are accustomed to run in the spring to spawn, and where it has been the custom to dip them, for several years a seine has been used, and tons of them were taken out when nearly worthless for food. Many were shipped to New York, and commanded a price that hardly paid for transportation.

The present writer has knowledge of similar instances. In some localities smelts are known to congregate in suitable places, usually near or at the mouths of the streams, prior to ascending them when they become favorable. In Casco Bay there are several such localities. There the drag seine is used up to the very last day of the open season (March 31). In Freeport, on one occasion, as soon as the place was free from ice so that the seine could be hauled, one seiner got, in a single haul, a catch of smelts for which he realized $200. It has been customary to seine this place every year just before the spawning run should take place, and this has resulted in a diminished run. This custom, together with the customary intensive and highly destructive dip-net fishing in the fresh-water portion of the brook, could not but seriously affect the number of smelts in the region. Not only were great numbers of smelts prevented from ascending the stream, but those that did ascend were prevented from spawning.

In all the reasons given for poor breeding seasons or scarcity of smelts fault seldom has been attributed to the dip net, but almost always the seine has been the object of attack. The seine has been accused of being one of the most destructive appliances used in the smelt fishery.

This belief is one of the long standing. In a discussion of Mather's paper on smelt culture (1885), Theodore Lyman, formerly one of the commissioners of fisheries of Massachusetts, said that a decline of the smelt fishery some 20 years before was supposed to have been due to the capture of the fish by means of nets stretched across brooks, which prevented the fish from ascending the stream. In an edition of "American Fishes," by G. Brown Goode, which was revised by Theodore Gill and published about 1904, on page 506 a reference is made to the smelt fishery in Casco Bay. It says:

> In this locality twenty or thirty years ago and perhaps later, brush weirs were used to some extent during the fall. There was then a profitable fishery. At the present time there are but two or three weirs, which do a very small business. I know of several weirs that have been abandoned as unprofitable, notwithstanding the cheapness of their construction. They have not paid, of late years, for the labor of erecting them and the time expended in tending them. The seine fishermen do better. These fishermen usually have a large boat or scow, which they can move from place to place, and fish the various arms of the bay, coves, and creeks. Some fishermen get a good many smelts on the beaches of some of the islands without going far from home. [Cf. W. C. Kendall.]

If seine fishing is more destructive than other methods it must be because of some element not possessed by other methods. It is true that the drag seine forms one of the most intensive methods employed in the fishery in Maine, for it is a movable fishery and not restricted to a particular spot, as is the weir or pound net. In order to be caught the smelt is obliged to go to the weir, but the seine can go to the smelt.

The table given on page 256, showing the quantities of smelts taken by the various methods employed in Maine from 1887 to 1908, shows that in 1887 and 1888 the hand line far exceeded the seine in number of pounds caught. In 1898 the seines exceeded the hand lines by a comparatively small margin. In 1905 hand lines again were somewhat ahead, but in 1908 seines far exceeded the hand lines. In 1887 and 1888 bag nets and dip nets were next to hand lines (which were first) in the amount of smelt taken, and took more than double the quanity caught with seines. In 1898 and 1905 bag nets were third, and in 1908 they were the lowest of the six categories. The fact that in the earlier years seines were secondary to the hand lines might suggest that fewer seines were then used than in later years, which is probably the case, and perhaps they were not as effective in taking the large fish then demanded by the market.

While a casual examination of the statistics given in the table on page 257 does not show a positive and permanent decline in the smelt fishery of Maine up to 1916, a closer scrutiny of the statistics, considered with recent verbal reports and opinions of the fisherman and observations in the field, does indicate a decline. A falling off in the line fishery indicates a relative scarcity of fish of the larger sizes, which constitute the catches by that method; and while the gross quantity caught by all methods perhaps does not show such an alarming falling off, the decrease in size of the bulk of the fish marketing, taken by other methods than by line, together with the falling off in the line fishery, is very strong evidence of a declining fishery.

Cases of local depletion and even exhaustion of the fresh-water smelt are on record. The only methods of taking the inland fish have been by hook and line and by net in the breeding season. The line fishery can make no very appreciable reduction in the number of smelt, but fishing during the breeding runs is as destructive in inland waters as it is along the coast.

CONSERVATION

In various States, particularly in Massachusetts and Maine, for many years legislative measures have been enacted aimed at better protection of the smelt and improvement of the fishery, but for one reason or another the desired results have not been attained, as indicated in the foregoing discussion of depletion. In Massachussetts the act approved April 9, 1874, says:

> First, whoever within the Commonwealth offers for sale, or has in his possession, any smelts between the 15th day of March and 1st day of June in each year, shall forfeit for each and every smelt so sold, offered for sale, or had in his possession, the sum of one dollar. Second, whoever takes or catches any smelt or smelts with a net of any kind, or in any other manner, shall forfeit for each smelt so caught or taken the sum of one dollar (proviso—not to apply to smelts caught in Bristol, Barnstable or Dukes counties by persons lawfully fishing with net for perch, herring, and alewives); and in all prosecutions under this act the burden of proof shall be upon the defendant to show that the smelt or smelts, the offering for sale, possession, or catching of which is the subject of prosecution, were legally caught.

Referring to this law, in a discussion of Mather's paper on hatching of smelt (1885), Theodore Lyman, formerly a commissioner of fisheries of Massachusetts, said:

> As you will all recollect, some twenty years ago or rather more, in Massachusetts the smelt fishery had greatly declined. It was supposed to be due to the capture of the fish by means of

nets stretched entirely across the brooks, which prevented the fish from ascending the stream. The law to which Mr. Mather has referred was passed on the recommendation of the Fishery Commissioners of Massachusetts. In two or three years the catch of fish was very greatly improved, so much so, that the bays and streams which had been nearly depopulated, once more became filled with valuable fish. Ever since then, we had a pretty good supply of smelt in our State.

The good results mentioned by Lyman apparently were very local and temporary, as is learned from the more recent reports of the Massachusetts commission, that of 1916 saying in effect that the fishery was in a depleted condition and calling for strenuous and radical measures for its restoration.

In Maine, as early as 1869, a law was passed locally restricting smelt fishing to hook and line, according to Atkins (1869). He wrote:

> The act "to protect smelts in the waters of the Kennebec and Androscoggin rivers", approved March 4th, 1869, aims to lessen the catch by prohibiting the use of any implement but hook and line every alternate year, and at the same time allow the fish to ascend these rivers to the points where they were wont to be taken with hook and line. Undoubtly the first mentioned object would be attained, but whether the latter would is uncertain. It is desirable to substitute for this some act of wider application, and consequently bearing more equally on all who are engaged in this fishery. I suggest whether a prohibition to take smelts except during December, January and February, by any other mode than hook and line and perhaps the dip-net, would not apply well to the whole State. The smelt fishery now commences much earlier in the fall than is for the advantage of the fishermen themselves even,—frequently in October, when fish are with difficulty marketed in good condition, and a great waste and deterioration is the consequence. So in the spring, also, the facilities for marketing in a frozen condition are not good, and as the spawning time approaches the quality deteriorates; yet there are some localities on the coast where the smelts appear in small streams only in the spring, and would be of no use if they could not be taken at that season.

This law appears to have been of local application and intended for the benefit of one class of fishermen only. The shortening of the season would no doubt be of benefit to the smelt, as would the restriction to hook and line and at that time perhaps would not have been very unfavorable to the fishermen. In late years, however, the matter of marketing and deterioration is not so doubtful owing to refrigeration facilities. One of the most striking statements in this discussion is that of the qualifying suggestion that there are some localities on the coast where the smelt appear in small streams in the spring, and would be of no use if they could not be taken at that season. As the smelts appear in such streams in the spring for breeding purposes, it is hardly necessary to indicate in what way they would be of use if not taken. The harm done by taking them at that season in such places has already been shown.

Previously the same commissioner had remonstrated against seining at the mouth of a stream, but while indicating that dip nets were used there nothing was said against the practice. However, later he wrote (Foster and Atkins, 1868a, p. 29):

> We think no smelts should be taken during the spawning season—say from April first to June first. Enough can be taken in the fall and winter, when they are in good condition, and it is wonderful that they can stand the draft that is then made on them.

Commissioner Counce, of the sea and shore fisheries commission of Maine (1888), stated that section 5, laws of 1887, provided that no smelts caught in weirs after the first day of April should be sold or offered for sale in the State, nor should smelts

caught in any manner between the first day of April and the first day of October following. He said:

It will be seen by the above that no smelts can be sold in this State after April 1st, caught in any manner except by hook and line. Many complaints have been made to me by people that could not get smelts to eat unless they were made liable to fine, as the ice seldom leaves our bays and brooks in season for smelts to come up before April 25th, and it would seem that the time should be extended for taking smelts in the spring by dip-net to May 1st. It was formerly May 20th, but was changed to suit the weir men, and certainly it would look hard that the spring fishermen should be entirely shut off that fall fishermen should gain.

Large quantities of smelt were caught in dip-nets last spring and left to lay on the ground to rot, when they might have been sold for $2.00 or more per bushel if allowed to be sold. Therefore I would recommend that dip-nets may be used to May 1st, and that smelts caught in this State may be sold up to that time.

In his report for 1889–90 this commissioner made the same statement and recommendation. The first part of the criticism of the law is quoted verbatim from a recommendation of one of his wardens or deputies, O. S. Despeaux (report of the commisioner of sea and shore fisheries of Maine for 1886, p. 46). His final statement and recommendation should be compared with the same commissioner's statement and recommendation on page 38 of his report for 1886, where he says:

I would recommend that no smelts be sold between the first days of April and October, under penalty of not less than $10 nor more than $30 for each offense, and a further penalty of twenty cents for each smelt so sold except caught by hook and line. Provided, that dip-nets may be used between April 1st and May 1st.

Counce's discussion of the situation is astonishingly inconsistent. His recommendation for an open season during the breeding season of the smelt appears to be based upon local if not merely individual sentiment. Excruciating logic is shown in the argument in favor of the measure, in the allegation that people could not get smelts to eat unless they were made liable to a fine, while large quantities were caught in dip nets and left on the ground to rot. Was it not as illegal to catch them as to sell or eat them? The following discussion is a more rational statement of the case:

Commissioner Donahue (1908) of Maine, in his report for 1907–8, wrote:

The smelt is one of our smallest but also one of the best food fishes, and while it is not of so much commercial value as some of the others it is one that furnishes employment for a large number of men in the winter time, when other employment is not obtainable. The laws regarding this industry come mostly under the head of special laws, which have been passed at the instance of residents of particular localities where the fish are abundant. In other sections of the State, where this fish is not plentiful, little attention is paid to the industry. I assume that these localities where special laws apply are satisfied, and, therefore have no recommendations to make, otherwise than to repeat what I have said in connection with another industry; viz., that the laws are in a very chaotic condition, and for the interest of all concerned parties especially interested in the smelt fisheries should see to it that the present special laws are more accurately drawn and defined.

In this manner the laws of various States differ in the prescribed restrictions and limitations respecting the fishing season, methods of capture, etc. In fact, they differ widely and, it may be said, sometimes inconsistently within the bounds of the same State, and sometimes from one session of the legislature to another.

Again Donahue wrote (1913):

There are innumerable laws, both general and special, governing the catching of smelts; and it is practically impossible for smelt fishermen, when changing from one section to another, to know

when they are violating the laws, as the law between two specific points on the coast in one section is entirely different from that in another section but a few miles distant. The legislature in 1911 passed a law that prohibited taking smelts in any other way than by hook and line or weirs or set nets through the ice, within one-half mile of the coast line at near high water mark, from Cape Small Point on the west bank of the Kennebec and continuing easterly along the coast of Maine to Owlshead on Penobscot Bay. The law is very unsatisfactory and is working great injury to the smelt fishery in the rivers between those two points, as it allows the smelts to be taken in weirs and with set nets through the ice in rivers which are so narrow that such devices catch practically all the fish that come into them. I would advise that the law be repealed and that a new general law be passed, prohibiting the catching of smelts in any river or bay the entrance to which or any part thereof is less than one-half mile in width, in any other way than by hook and line. The present method of catching, viz., with nets and weirs, in those small rivers and bays which the smelt frequent for the purpose of spawning will ultimately destroy the species. There seems to be no good reason why one general law can not be framed that will apply to all sections of the State.

In 1917 the general law of Maine (P. L. 1917, chap. 71, sec. 74) provided that:

No smelts shall be taken or fished for in tidal waters, nor in any brook, stream, or river emptying into tide waters, within one thousand feet of tide water, except by hook and line, between the first days of April and October, under a penalty of not less than ten, nor more than thirty dollars for each offense, and a further penalty of 20 cents for each smelt so taken; and all weirs for the capture of smelts shall be open and so remain, and all nets used in the smelt and tomcod fishery shall be taken from the water on or before said first day of April under a penalty of not less than twenty, nor more than fifty dollars, and a further fine of five dollars for each day that such weir or net remains in violation of the law. But weirs with catch pounds covered with nets, the meshes of which are one inch square in the clear, or greater, or weirs with catch pounds covered with nets which are erected and used for the catching of herring are not subject to this section. But no smelts caught in such weirs after the first day of April shall be sold or offered for sale in this State, nor shall smelts caught in any manner between the first day of April and the first day of October following be offered for sale, sold, or shipped from the State under a penalty of twenty-five dollars for each offense.

Then follow a dozen or more exceptions and no less than 18 special laws applying to separate localities. These laws were in force until the legislature attempted to amend them in 1923.

Chapter 132, Public Laws 1923, "An act to repeal sections seventy-four, seventy-five, seventy-six, and seventy-seven of chapter forty-five of the Revised Statutes, and enacting a new law for the better protection of smelts," says:

Section seventy-four as amended by chapter seventy-one of the public laws of nineteen hundred and seventeen, and sections seventy-five, seventy-six, and seventy-seven of chapter forty-five of the revised statutes are hereby repealed and in lieu thereof the following is substituted:

No smelts shall be taken or fished for in any waters of the state between the first day of April and the first day of October of each year, except by hook and line. Anyone violating any provision of this act shall be punished by a fine of one hundred dollars for each offence. Nothing in this act shall apply to smelts taken in fish weirs or traps maintained and operated for the catching of sardines and herring.

The inland law pertaining to smelts (sec. 26, chap. 219, P. L. 1917, as amended by chap. 244, P. L. 1917, and chap. 196, P. L. 1919, and chap. 218, P. L. 1921, and chap. 32, P. L. 1923), which stated that "it shall be lawful, however, to take smelts in all the inland waters of the State above tide waters with a dip-net in the usual ordinary way," etc., remained in the Revised Statutes.

This act of 1923 resulted in confusion and final announcements by the attorney general and the director of sea and shore fisheries that the law was invalid, with the consequence that there was unrestricted fishing in the brooks flowing into tide water.

The foregoing "samples" of legislation and recomendations pertaining to legislation have been given and discussed to bring out the point that laws have not always been based upon knowledge of actual conditions; and, added to ignorance of conditions, often sectional and political interests were, and still are for that matter, principal considerations in the formation and enactment of laws. This fact has resulted in the multiplicity of laws of local application to the detriment of the general smelt fishery, as indicated by Donahue.

There is no doubt but that a more or less waning smelt fishery has demanded and still demands conservative attention. There are evidently errors of administration of the fisheries that need to be rectified. Laws are necessary but they should be based upon exact knowledge of the conditions and needs of the fishery. This is not all, however. If the laws are to be effective, strict compliance with and rigid enforcement of them are requisite corollaries. Corrective measures must be based upon recognized causes and aimed at them. While individual cases call for more stringent measures than do others, uniformity in intent of purpose is indicated.

There are many adverse conditions affecting the fish supply, and consequently the fisheries, which the most well-observed or rigidly enforced laws can not wholly remove if any fishery at all is to be permitted, but most of them are remediable. Certain of such adverse conditions as may affect the fishery more or less have been suggested in the discussions of the fisheries and of depletion. They are not all, and probably all are not known.

Forty-seven years ago the fishery inspector of New Brunswick (Venning, 1879) wrote that the wasteful and destructive mode in which the smelt fishery was then carried on called loudly for some restrictive measures. He called attention to the enormous waste of young smelts and other fishes that were caught with the marketable fish, saying that he was led to believe that for every ton of marketable smelts exported nearly half a ton of small smelts, young bass, tomcods, and flatfish were wasted. He saw vast quantities of small smelts and tomcods lying on the ice and near the packing house, which he was informed were sold at 10 cents per barrel for the purpose of making compost for manure.

After referring to the enormous waste of young smelts, the destruction of which he believed must have a seriously injurious effect upon the coast fisheries by materially depriving other commercially important fishes of their food, he said that the mode of conducting the fishery should be restrained, and that it was a question for grave consideration whether the proper protection of the fisheries would not require the prohibition of bag nets everywhere, for no fishery could long stand so large an annual drain upon it. He said:

> This is no mere assertion, for we have the experience of the neighboring States in this very fishery, as a warning of the inevitable consequences. In Maine, Massachusetts and New York, where formerly the fish was almost as abundant as it is now in our waters, smelts have become very scarce from the same causes that are at work in this Province. These States are now dependent on our fisheries for their supply, Boston and New York furnishing the principal markets for our

shipments. These States have found it necessary to make stringent laws for the preservation of the species in their waters, and we should not ignore the lesson they teach us.

After quoting certain State laws that restricted smelt fishing to "naturally or artificially baited hook," and from a local newspaper that also decried the conditions described by Venning, he went on to say:

> In view of these facts, the time has come when this monstrous waste ought to be looked at with the eye of common sense. What are the facts? This is but the third season of its existence as a systematic and organized fishery. The returns in the table show that in these three seasons it has grown from nothing to its present vast proportions. These returns, which fall far short of the whole catch, show that 1,213 tons of smelts have been shipped. Add to this large quantity half as much more for small smelts, young bass and tom-cods wasted, and take into account that these returns are only made up to 31st December, that two months more of this destructive work will continue, and we will have the astounding quantity of at least 2,000 tons of smelts and young bass, tom-cods and flat-fish taken from our waters in a single winter. Is it creditable that any fishery can stand this drain?

When one reads this article of Venning's upon the smelt fishery of New Brunswick, and his emphatic warning concerning the imminent exhaustion of the fishery, if he makes a comparison of the statistics representing the period from 1871 to 1878 (p. 261) with those of the period from 1913 to 1924 (p. 262), he will wonder if Venning's alarm, as well as that frequently expressed in this country, was not all "bunk." For it is seen that after a lapse of 35 years, from 1878 to 1913, or the beginning of the period shown by the table on page 262, which represents the export smelt trade of Canada, no evidence of depletion was shown by the quantities of smelts caught. Instead of the 1,213 tons of 1878, mentioned by Venning, in 1913 there were shipped from New Brunswick alone over 3,000 tons of smelts.

In the period from 1913 to 1923 the largest quantity was taken in 1918, amounting to about 3,496 tons. It is true that in 1923 there was a falling off in the quantity to the smallest amount in the 11-year period, but even so over 2,160 tons were shipped. There is no doubt in the present writer's mind but that Venning's expressed alarm was well founded; but if there was that danger of depletion in 1878 the question arises as to how the fishery was not merely maintained but greatly increased in magnitude of annual catches in the latter period.

There is no evidence of much, if any, modification in fishing apparatus, and there was no restriction of the methods to hook and line fishing. An increase in the number of fishermen and the intensity of fishing might account for larger catches but not for the almost uniform quantities for the 11 years, to say nothing of the quantities taken in the 35 years intervening between the two periods represented by the tables. While other factors may have been concerned in the preservation of the Canadian smelt fishery, there are two that appear to be paramount. One is the protection of the fish during its breeding season, and the other is the short fishing season, which extends only from December 1 to February 15 following, a period of two and one-half months, against the season of six months in Maine, with absolutely no protection during the period when, by propagation, the smelt is striving to do its part toward the maintenance of the fishery. In 1878 Venning advised drawing a lesson from the New England States; it now is strongly advised that New England, and Maine in particular, learn a lesson from New Brunswick.

In comparatively recent years a serious decline in the smelt supply of Massachusetts was noted, and the commissioners were concerned with ways and means of rehabilitating the waters. The proposed procedure pertained to accessibility of streams to the smelts for reproduction. Under the heading "The problem of restoration," the report of the commissioners for 1917 (p. 78) said:

> The real problem confronting the Fish and Game Commission is that of providing a spawning ground equal, as far as possible, to that which the smelt enjoyed before the day of dams and pollution, and to institute methods of saving a large per cent of the spawn wasted at present in such places as Weir River. To remove the pollution from the streams entering Boston Harbor will require considerable time, and probably never will be accomplished if present conditions are any criterion. The enlargement of the spawning grounds by removal of dams or installation of suitable fishways is likewise a work of years. The immediate relief of the smelt problem which will save the species from commercial extinction in Boston Harbor consists in saving natural waste of surplus smelt eggs by artificially enlarging the spawning grounds to accommodate the number of smelt which frequent them.

Referring to fishways, the report said:

> In general a fishway is not a practicable contrivance for smelt. At Weir River smelt were observed to shoot some very sharp falls. If the fish could get over the first dam they could reach extensive spawning grounds. However, the return over the dam would probably injure the delicate fish, and therefore it would be necessary to screen the spillway.

In the matter of the installation of fishways for any fish there appears to be a point that has not been taken into consideration. A screen might divert adult fish into a fishway or other passage on their return to the sea, but no practicable screen would prevent the young fish, particularily the very delicate fry of smelt, from going over the falls or dam if there is any overflow whatever. However, in Maine there is probably no lack of suitable spawning places for smelts, because, as has been seen, they ascend mere rivulets even; and probably there are but few instances of serious pollution or obstructions requiring a fishway, except in the rivers, even were fishways practicable. However, while Massachusetts has endeavored by legislation to protect smelts in the spawning places, Maine never has done so. Whatever the extent of natural breeding places, adequate natural breeding by the fish can be assured only by protection at the breeding season, and such protection must be afforded by leaving the fish and eggs undisturbed at the time. The law that permitted the use of the dip net in fresh water beyond 1,000 feet of tide water, and prohibited its use in tidal water, afforded no protection to spawning smelts except in the very few instances where the fish could not ascend above the high-tide limit. If the law had been reversed in its application, and the fishing in fresh water above tidal water and for 1,000 feet below high-tide limit had been prohibited, with a certain amount of dip-net fishing permitted below the 1,000-foot limit below mean high-water mark, the smelt would have stood a much better chance. For in most instances many smelts would have been able to ascend into the protected section of the stream before the use of the dip net would have been practicable below. Those fish would have then been able to spawn and the eggs could have incubated and hatched undisturbed, providing the law had been observed or enforced.

It is suggested, therefore, that all smelt fishing in fresh waters flowing directly into tidewater frequented by marine smelts for reproduction be prohibited during

the reproductive period from March 1 to May 31, and that regulated dipping be permitted in tidal portions of those streams 300 feet below mean high-tide mark three hours after high tide. The size of the dip nets should be regulated and the quantity of smelts that may be taken in any one night by each person should be prescribed. Furthermore, the season of such fishing should be limited according to conditions existing in any locality, and the closed season against all other methods of fishing should begin as early as March 1.

The writer is inclined to believe that some such law would afford ample protection to breeding fish, providing always it is properly observed or enforced. It would be more likely to be observed than would a law aiming to prohibit all "dipping" in the spawning season, for there are local residents near such streams or creeks who, as Counce said, are unable to get a mess of smelts at any other time, and who would be able to secure the fish legitimately under such a regulation, some of whom however, might be tempted to get their smelts anyway, if the law forbade all fishing.

This is not recommended on the ground that because some individuals will steal they be allowed a certain privilege so that it won't be necessary for them to steal, but because of the fact that it does not appear necessary wholly to withhold the dipping privilege from such persons as have regarded the spawning runs of smelts as their opportunity, and who in the nature of the case have nothing in common with the professional smelt fishermen or the smelt industry.

While such fishing should be properly and adequately regulated, there are other factors to be considered in a decline in the number of smelts, and doubtless some of them may be laid at the door of other methods and times of fishing. Sometimes it appears that the professional fisherman is as heedless regarding the perpetuation of the fish supply as is the most wanton youth on a smelt brook. Such being the case, his methods also call for regulation.

Commissioner Donahue referred to the employment of certain devices in rivers so narrow that the gear caught virtually all of the fish that entered them. Reference might have been made to the use of the drag seine in similar places elsewhere, and to the capture of smelts in places where they congregate just prior to ascending the streams in spring, as well as to the great quantities of young smelts caught by seines along with adult fish in the fall. How properly to regulate this factor in the depletion of the smelt supply certainly is a problem unless seining is prohibited. As in the case of dipping it does not seem necessary to abolish seining, but it should be regulated. In fact, all methods of fishing should be regulated. There is a prescribed open season for all methods, but for reasons previously given it should be shortened so as to terminate March 1.

Conservation does not necessarily signify suppression of fishing or prohibition of any particular method of fishing. It does, however, demand proper regulation of time or methods, as well as protection of the fish at critical periods in their life history, in order that the yield of the fishery may be maintained commensurate with the market demand and consistent with the economic preservation of the species.

Obstruction and pollution of many otherwise accessible breeding places may be corrected. The capture of smelts as they ascend the streams at spawning time, as already pointed out, is preventable to a considerable extent. Although the duration

of the breeding season is more or less variable on the coast, to some extent according to seasonal climatic conditions, a closed season sufficiently long to embrace the breeding season of the fish along the entire coast of each State may be prescribed. It may be a question of preventing more or less destruction of immature smelts by present methods of capture. However, reduction in the amount of destruction is possible, perhaps by adopting a modification of the suggestion offered by Donahue; that is, a general law prohibiting the catching of smelts in any river, brook, tidal creek, cove, arm of a bay, or estuary where such places are one-half mile or less in width between mean high tide marks. If, then, the previously mentioned measures pertaining to breeding places and season are observed and enforced, the loss from this source will become less appreciable and great improvement of the fishery will follow. The fact that in spite of so many years of adversity the smelt has endured to the extent that it has indicates that given an even chance it can "come back."

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