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EXPERIMENTAL OBSERVATIONS ON SPAWNING, LARVAL DEVELOPMENT, AND SETTING IN THE OLYMPIA OYSTER *OSTREA LURIDA*

By A. E. Hopkins

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EXPERIMENTAL OBSERVATIONS ON SPAWNING, LARVAL DEVELOPMENT, AND SETTING IN THE OLYMPIA OYSTER, *OSTREA LURIDA* [1]

By A. E. Hopkins, *Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

The native oyster of the Pacific coast has never been produced in great enough abundance to reach markets all over the country. Toward the end of the nineteenth century extensive commercial use was made of the crops growing naturally on tide lands of Puget Sound and Willapa (Shoalwater) Bay, in the State of Washington, resulting in almost complete depletion in most of the favorable localities. In 1902, according to Galtsoff (1929), 154,000 bushels of oysters were produced; in 1904, 170,000 bushels reached the market; while in 1926 only about 58,000 bushels were grown. Since this time production has been at an even lower level. The native Willapa Bay oyster has been almost completely destroyed so that it is now difficult to find in the local markets. The native oyster is unique in the United States in that it never attains a shell length much greater than about 5 centimeters (2 inches), and for this reason is used primarily for special dishes such as cocktails and pan roasts. It is too small to serve on the half shell.

Oyster growers commonly market them in 2-bushel sacks, containing about 5,000 oysters, or about 2,500 to the bushel. Most of the native oysters now grown on the

[1] Bulletin No. 23. Approved for publication Oct. 14, 1936.

Pacific coast are produced in the southern portion of Puget Sound in the vicinity of Olympia, Wash. They are sold on the market as Olympia oysters, and a distinction is made between them and the same species grown in other localities.

According to Stafford (1914) the species was described by Carpenter, who gave the name, as follows: "*Ostrea lurida*, n. s. Shape of *edulis:* texture dull, lurid, olivaceous, with purple stains." The species is known to occur in bays and estuaries from British Columbia to southern California. However, in some respects the oysters are quite different both in appearance and marketability with respect to their place of origin. Townsend (1893) hardly considered the native oyster of San Francisco Bay of commercial significance, although present in large numbers. The same species, farther north, at that time was bringing good prices in the markets. This was due in part to the difference in climate in the two localities, and in part to the fact that growers were beginning to cultivate their grounds and care for their crops systematically, instead of merely harvesting the natural supply.

Because of their susceptibility to the hot sunshine of summer and the freezing winds of winter, native oysters in Washington thrived only where they were relatively protected. Natural beds were found where the oysters were covered with water at low tide because of the slope of the tide land, or where seepage from underground would keep them moist in summer and relatively warm in winter. Pot holes would contain oysters while the intermediate ground, which becomes completely exposed at low tide, would be bare.

At the end of the last century, a few years after the appearance of Dean's work (1890) describing the method of oyster culture employed in France, the oystermen began to build dikes or structures on the tide lands which would keep the beds covered at low tide. The dikes are, in principle, closely similar to those described and pictured by Dean as the "oyster parks" used in France. Whether or not the French system furnished the original inspiration for the mode of oyster culture that was developed in Puget Sound within a few years is not known, but owners of natural ground began to build dikes around the beds so that the oysters would remain covered with water at low tide.

After a few years of experimentation, during which it was demonstrated that dikes make it possible to grow oysters on ground previously unused as well as to reduce mortality due to freezing, the entire industry in Puget Sound undertook systematically to dike the natural beds and expand to other grounds. Until very recent years most of the dikes were built of concrete, set well down into the bottom. The thickness of these dikes varies from about 6 inches to nearly 12 inches, depending upon the location. Now dikes are usually built of creosoted lumber, which lasts a long time and is more readily handled (figs. 1, 2, 3). Also, breaks due to settling are less frequent and more simply repaired. Dikes have been constructed on relatively level mud flats and on sloping banks. In the latter case the dikes are arranged in terraces, involving a great amount of hand labor for leveling. In all cases, when new ground is made, the rather soft natural bottom has to be surfaced with gravel to make it hard and firm as well as to maintain a relatively constant level in spite of the swift tides.

In southern Puget Sound, according to the tide tables of the U. S. Coast and Geodetic Survey, the maximum range of tide is 20 feet, from −3.8 to +16.2 feet. Most of the oyster grounds are between the −1-foot and the +3-foot tide levels, though some dikes require a tide as high as +8 feet to cover them. A few natural beds are in sloughs or shallow channels where they are never exposed. On the other hand, the natural beds of the same species in Yaquina Bay, Oreg., are covered by from 10 to 20 feet of water at low tide. In Puget Sound oyster growers have found

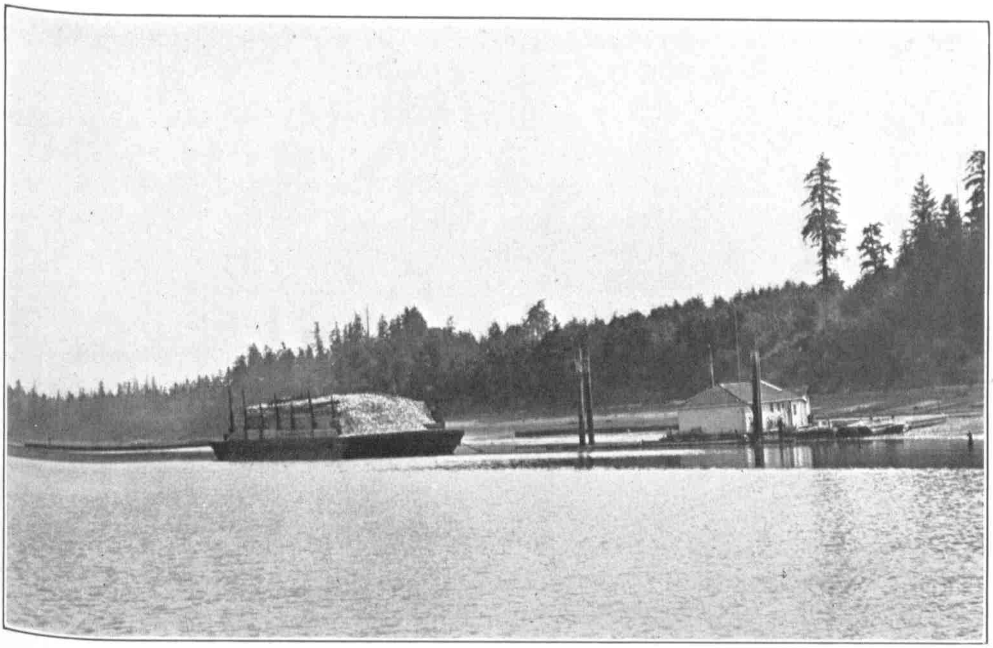

FIGURE 1.—Scowload of Japanese oyster shells near a culling house ready to be planted on the diked ground.

FIGURE 2.—Egg-crate fillers as spread from scows at high tide on diked ground being placed so that they will be completely covered at low tide.

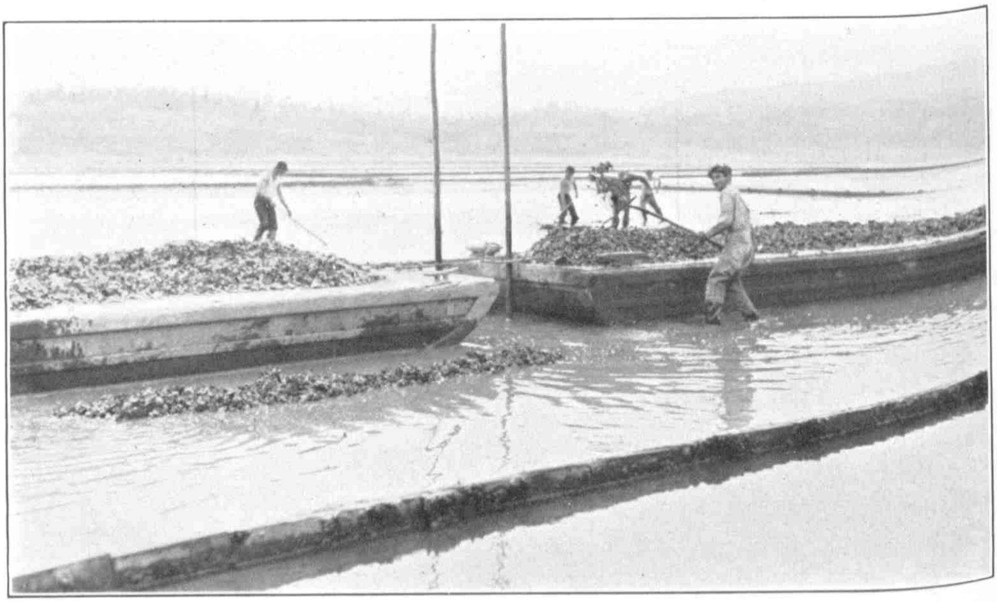

FIGURE 3.—Crew of men taking up seeds for transplantation to market grounds.

that the higher dikes are best for catching seeds while the lower grounds produce a superior product for market.

METHOD OF CULTIVATION

Although Galtsoff (1929) gave a description of the Olympia oyster industry and the methods of cultivation in use, it is necessary to review these matters briefly because of their bearing upon the experimental work which is described below. After spawning is well under way in June the oyster growers plant cultch, either shells or manufactured collectors, on the seed grounds. Until about 1930 the only cultch available was the native shells from the opening houses, but with the recent plantings of Japanese oysters a great quantity of these large shells is obtainable (see fig. 1). The development of the concrete-coated egg crate filler has also made larger plantings of cultch possible (see fig. 2). The spat which are caught are generally left on the seed ground for about 3 years before they are transplanted to growing grounds. Seeds are usually moved in April and May, permitting planting of new cultch on the same ground a short while later. Generally the seeds moved in spring are culled the following winter, though only the largest oysters reach market.

All oysters are taken up by hand since the grounds are exposed when the tide is low (see fig. 3). At low tide on one day a place to set a scow is cleared by forking the oysters to either side. The scow is staked in position at high tide and, when the ground is again exposed, the oysters forked onto it. As soon as depth of water permits, the scow is towed to the culling house and the oysters unloaded into a "sink float", made of two logs and a bottom, so that the oysters are washed free of mud as well as protected from weather conditions. They are taken up in wheel barrows from the sink float and loaded onto the large table in the culling house, where by tedious hand labor the marketable oysters are separated from the mass of shells and smaller seeds which are returned to the ground. The workers also separate the "slipper shells", or "cups", *Crepidula fornicata*, and the whelk or native snail, *Thais lamellosa*, and spread them high upon the beach to die and dry so they may be used as cultch. Cullers are paid extra for the snails and "cups" which they remove.

The culled oysters are spread in another sink float where they are frequently forked over until the water washes them thoroughly clean. As required for market they are packed in 2-bushel sacks and shipped to the opening houses. The cullers take up the oysters, return the seeds to the beds, and prepare the oysters for market and are paid on the basis of the number of sacks shipped. Japanese do almost all of this work as well as the shucking in the opening houses.

The small size of the Olympia oysters, in proportion to that of the Eastern and Pacific (Japanese) species, renders them much more expensive to handle. The average age of the marketable oyster is about 4 years, and about 5,000 of them are required to fill a 2-bushel sack. Ordinarily about 3 gallons of meats are obtained to the sack, so that a gallon contains about 1,600 oysters, as compared with 150 to 250 Easterns and about 50 to 200 Pacifics.

ENEMIES OF THE OYSTER

Although during the last few years there has been no apparent large mortality due to parasites, there are various organisms taking a constant toll of the crops. Ducks have given more trouble near Olympia than any other enemy (Galtsoff, 1929) and several species of these find the small size, single, native oysters an ideal, readily accessible food supply. Combating these is most difficult; and although some years ago a strenuous campaign was waged against them, the growers now appear to accept the damage passively.

For some years the great problem of oyster growers has been the "cup", *Crepidula fornicata,* which was presumably introduced into these waters with Eastern seed oysters. Although not a parasite, the species multiplied until many of the diked beds contained far more "cups" than oysters. Since the growers first became uneasy about them, they have paid the cullers extra for separating them out, and in this way have considerably reduced their numbers. However, even now it is not unusual for equal numbers of sacks of oysters and "cups" to be culled from a bed. The species appears to thrive much better in the diked beds than on the natural seepage grounds.

Several kinds of predatory snails are found on the grounds. The native whelk, *Thais lamellosa,* occurs in great abundance; and the writer has found that these drill some adult oysters and, in places, a great many spat. They appear to attack mussels primarily. They were previously unrecognized as an active enemy but are now culled out along with the "cups." Also, their habit, during the breeding season in late winter and early spring, is to come together in large clusters around a shell or rock where the egg cases are deposited. During this time they may be taken up in sacks and placed on the beach to die. The moon snail, *Polynices cewisii,* is frequently seen on oyster grounds but is primarily a clam borer and probably seldom attacks oysters.

The Eastern oyster drill, *Urosalpinx cinerea,* introduced with seed oysters from the Atlantic coast, may be found in some places, though only in Samish Bay where Japanese oysters are now grown is it relatively abundant. Of greater potential importance is the Japanese oyster drill, *Tritonalia japonica,* which has been introduced with seeds from the Orient. Few Japanese seeds have been planted near the important Olympia oyster grounds and no damage to native oysters has yet been noted. However, in Samish Bay, this drill has propagated rapidly and for the last few years has been causing tremendous mortality among the Japanese oysters. After a visit to Samish Bay in 1928, Galtsoff (1929) wrote:

> Although at present there is no evidence that *Tritonalia japonica* is destructive to oysters, yet as a matter of precaution it is desirable to restrict the planting of Japanese species to the waters in the northern part of Puget Sound and not to extend them to the areas where high-priced Olympia oyster bottoms are located.

When the writer first visited this ground 4 years later a great many drilled shells were found. In 1935 there was evidence of still greater mortality.

The rapid propagation of the species to dangerous proportions indicates the problem which Olympia oyster growers may soon face, especially since the thin-shelled, slow-growing native oysters would probably be more easily attacked than the relatively heavy-shelled Japanese oyster. Unfortunately, Galtsoff's suggestion was not followed, and it is known that the drills have been introduced near some of the native beds. On one ground in Oyster Bay a number of drills have been found, introduced presumably with Japanese oyster shells from Samish Bay. At the time of writing nothing is being done to prevent rapid spread of the pest to other grounds.

At times starfishes become abundant enough to destroy many oysters, but these are readily removed from the cultivated beds. One of the greatest problems of growers is to maintain their dikes against the "crawfish" or mud-shrimp, *Upogebia pugettensis,* (MacGinitie, 1930) which has a habit of burrowing under the dikes and opening passages which are rapidly enlarged by flow of water.

AIMS OF INVESTIGATION

A great many comprehensive experimental studies have been made on the biology of the oyster of the Atlantic coast, *Ostrea virginica*, but the only significant investigation on the practical phases of the biology of *O. lurida* was that of Stafford (1914, 1915, 1916, 1917, and 1918). He made his observations in British Columbia, in the northern part of Puget Sound, where the system of oyster culture had not been developed to an extent comparable to that in use near Olympia. Townsend's (1893) early paper gave the first general description of the industry on the Pacific coast. Recently Coe (1931a, 1931b, 1932a, and 1932b), Hori (1933), and Hopkins (1935, 1936) have furnished more specific information about the species.

The primary purpose of this investigation, which was undertaken in the spring of 1931 and continued through 1935, was to make an analysis of spawning activities and setting habits of larvae with reference to environmental conditions. By developing such information, it was hoped that oyster growers might be assisted in the catching of sufficient seed oysters to restore and expand the industry. In the following pages the more important of the results are described.[2]

HYDROGRAPHICAL OBSERVATIONS

The usual methods were employed for the taking and testing of water samples at different depths and under different tidal conditions. Specific gravity was measured with hydrometers certified and corrected by the National Bureau of Standards. A Hellige hydrogen-ion comparator was used with phenol red to determine the pH. Temperature of water samples was tested with standard thermometers, and in addition, continuous records of water temperature on the oyster grounds, at the level of the oysters, were made with a frequently checked thermograph.

GENERAL DESCRIPTION OF REGION

Puget Sound is an extremely irregular, deep body of water extending roughly 200 miles north and south in British Columbia and the State of Washington. It is continuous with the Pacific Ocean through the Straits of Juan de Fuca. The Sound is broken up into numerous bays and inlets which are generally quite deep except at their upper ends. Natural beds of native oysters were originally found in many of the small bays but were soon exhausted in all except a few localities where conditions necessary for successful propagation were especially favorable.

The several bays near Olympia, Wash., have continued to produce oysters, while beds in other places disappeared, largely because of favorable environmental factors and because of the development of the system of diking the grounds and planting cultch employed by the growers. These bays are separated from the ocean by more than 150 miles of water, yet changes in salinity are relatively slight, due to the great depth throughout the Sound.

[2] I wish to express my thanks to Charles R. Maybury, director of the Department of Fisheries and Game of the State of Washington and to Charles R. Pollock, supervisor of fisheries, for their cooperation in maintaining the laboratory and supplying an assistant and boats. Since the division of commercial fisheries became an independent department in December 1932, the director, B. M. Brennan, has continued to support this work under trying financial conditions and he deserves much credit for what has been accomplished.

It is a pleasure to express my thanks to the growers of Olympia oysters, all of whom have willingly given every possible assistance. I am particularly indebted to J. J. Brenner, E. G. Brenner, and D. I. Ginder, of the J. J. Brenner Oyster Co.; Ole Hanson and J. S. Waldrip, of the Olympia Oyster Co.; G. W. Ingham, Olympia Oyster Investment Co.; E. N. Steele; Charles Brenner; W. J. Waldrip; J. B. Bowman; J. H. Post; and the late Mrs. Minnie Blass.

A large part of the credit for this work is due to H. H. Adams, who served during 5 years as a most capable and efficient field assistant.

In figure 4 a portion of a chart (from U. S. Coast and Geodetic Survey, chart no. 6460) is reproduced to show the general contours of the most important bays in which Olympia oysters are cultivated. All of the observations here described were made in the area illustrated. The most extensive and successful grounds are in Totten Inlet, commonly called Oyster Bay. Mud Bay (Eld Inlet) is next in importance. Oakland Bay and Little Skookum (Skookum Inlet) also contain important grounds, but during the last few years, since a pulp mill began operation in the vicinity, they have been almost entirely out of production. (See Hopkins, Galtsoff, and McMillin, 1931; Hopkins, 1931a). The location of cultivated grounds is indicated on the chart. These are on the mud flats in the upper ends of the bays and on the relatively narrow beaches along the shores adjoining deep water. Altogether there are only something like 400 to 500 acres of producing grounds. Budd Inlet, on which Olympia is located, originally contained widespread beds of natural oysters, but has been condemned on account of sewage pollution.

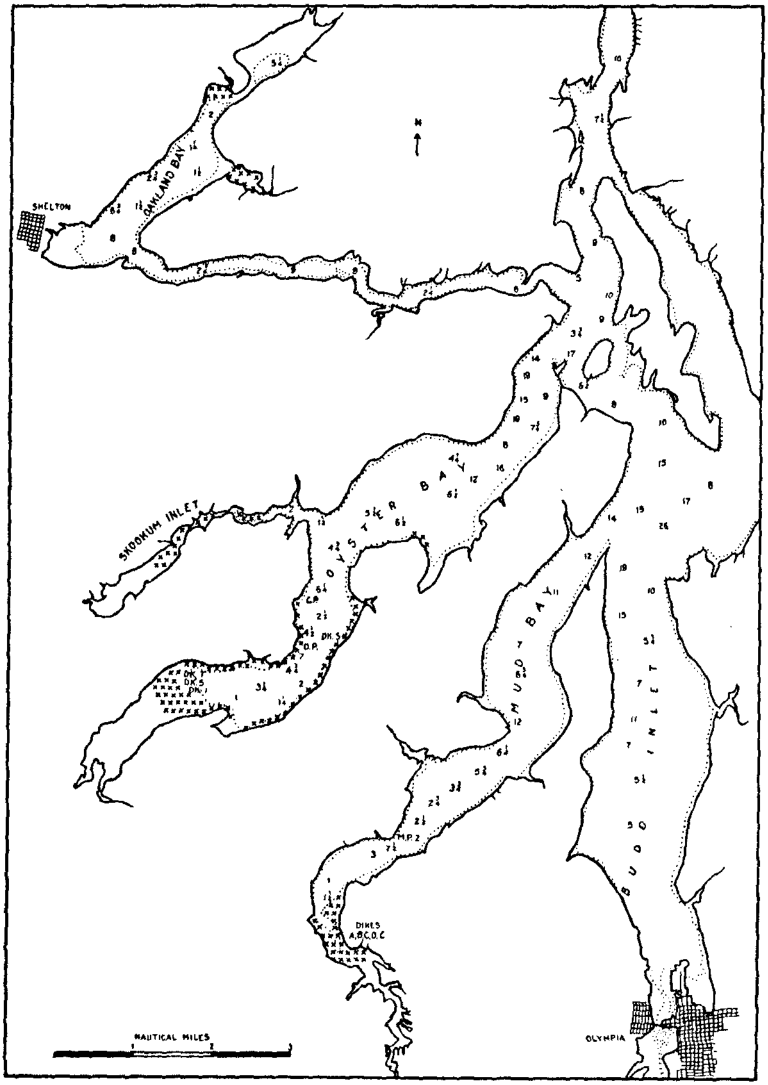

FIGURE 4.—General contours of oyster-producing bays near Olympia, Wash. Numbers refer to depth in fathoms. Location of diked beds is shown by x's. Dikes in which most observations were made are indicated. Depth samples were taken in channels off Corters Point (C. P.), Maple Point (M. P.), and Deepwater Point (D. P.).

TEMPERATURE

A Bristol recording thermometer was installed on a frame well above the high tide level but with the bulb fixed at the level of the oysters in the dike below. Protected though they are by a few inches of water at low tide, the oysters are nevertheless subjected to considerable variations in temperature as affected by both tides and seasons. The thermograph records were analyzed by averaging the readings on each hour of the day. This is necessarily not strictly accurate, but undoubtedly the error involved is within that inherent in the instrument itself.

A graph (fig. 5) is reproduced to illustrate the daily maximum, minimum, and average temperatures during winter (December 1932, January and February 1933) and summer (June through August 1933). This well represents the extremes, for during summer, at low tide, the water frequently reached 25° to 30° C., and during winter dropped to almost −2° C., or close to the freezing point of seawater. In the latter instance a great many oysters which were not well covered with water of high salinity were frozen and killed. The minimum temperature during summer and the maximum during winter show only slight fluctuations, since in summer the extreme low tides are during the day and in winter at night, the local temperature of the air not greatly affecting that of the water around the oysters at high tide. The difference between winter maximum and summer minimum is about 10° C.

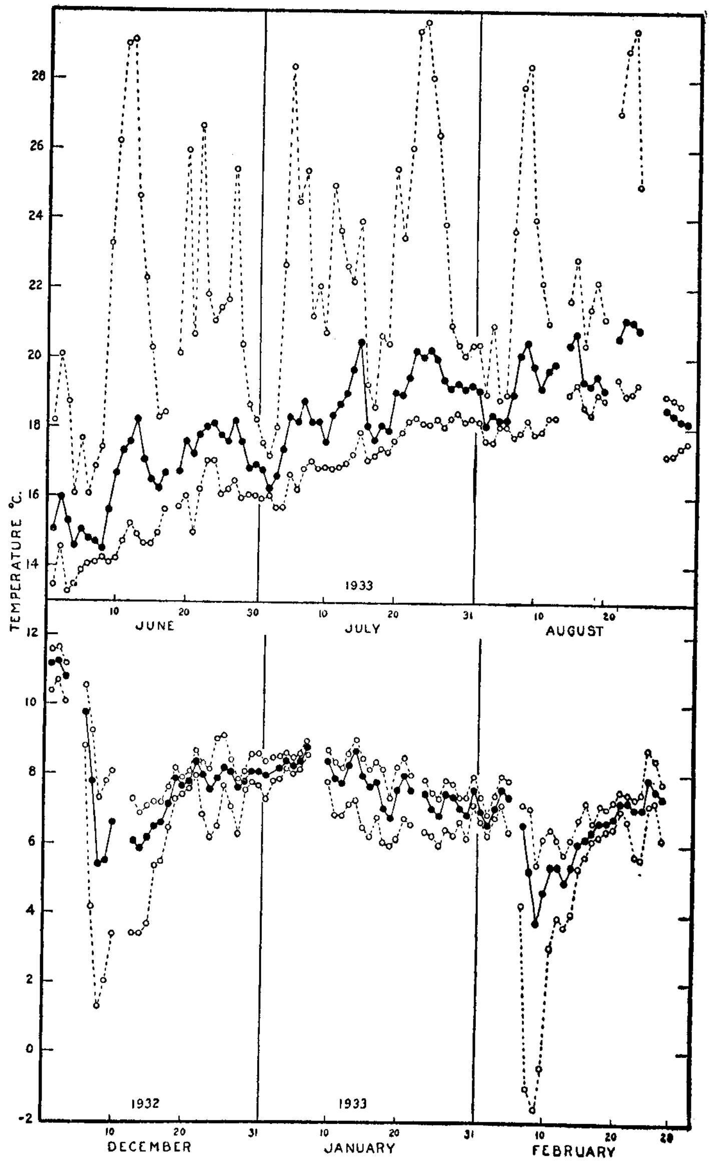

FIGURE 5.—Daily average, maximum, and minimum temperature on an oyster bed in Oyster Bay during winter and summer, as shown by thermograph records.

In order to show in detail the changes in water temperature in the dikes during a 24-hour period, as influenced by the range of tide, a graph (fig. 6) is given on which the continuous temperature records during 4 days are reproduced. Neap tide and spring tide temperature records are shown for typical days during both winter and summer. In the record for August 2 it will be noted that during the several hours that the dike was exposed by a −1.7-foot tide the temperature rose gradually from about 19° to about 30° C., and that when the flood tide poured over the dike the temperature dropped about 5° almost instantly. The other summer record was taken a few days later when low tide occurred at about 5 o'clock of a cool morning, and although the dike was not quite exposed there was a marked drop in temperature. The picture for temperature variations during winter is almost the reverse, the low tide occurring at night when the air is coolest. In all cases the variation is slight except at low tide when the water is shallow and readily reacts to sunshine and atmospheric conditions. That is, it is the surface water which responds readily to weather conditions; and the oysters may be under 16 feet of water at high tide and 3 or 4 inches a few hours later.

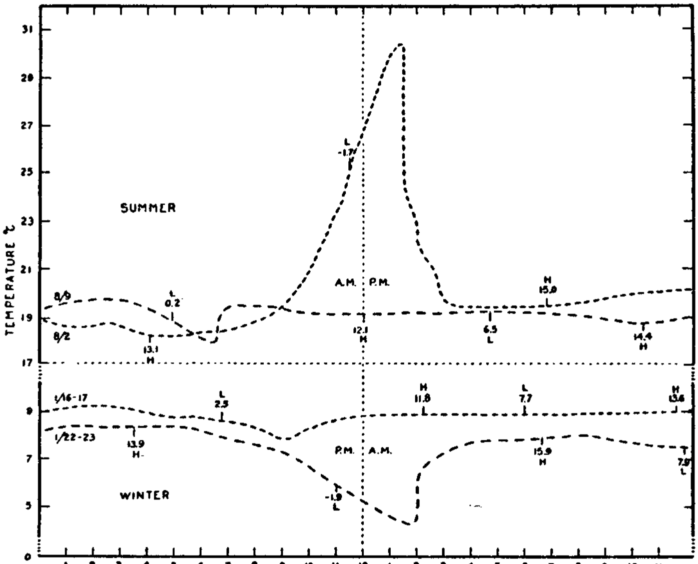

FIGURE 6.—Reproductions of portions of thermograph records showing variations in water temperature on oyster ground during four 24-hour periods, two in summer and two in winter. The most variable records refer to spring tides, the others to neap tides. Time and height (in feet) of high (H) and low (L) tides are indicated.

Seasonal variations in water temperature from year to year are relatively uniform, but the differences between successive seasons are sufficient to have a considerable bearing upon the spawning of oysters. In table 1 the monthly averages for 4½ years are given, as calculated from thermograph records obtained in Oyster Bay. The highest average water temperature is usually in August, the lowest in January or February. The annual variation is represented graphically in figure 7 for the 2 years (1933, 1934) when the temperature values were most widely different from one another. The spring rise in the curve for 1934 occurred about a month earlier than in 1933, accounting for a comparable difference in the time of spawning. Included on the graph are monthly averages of daily readings of maximum and minimum air temperature at Olympia. These records were supplied through the kindness of Charles F. Norrie, official weather observer. Water temperature is clearly correlated with air temperature.

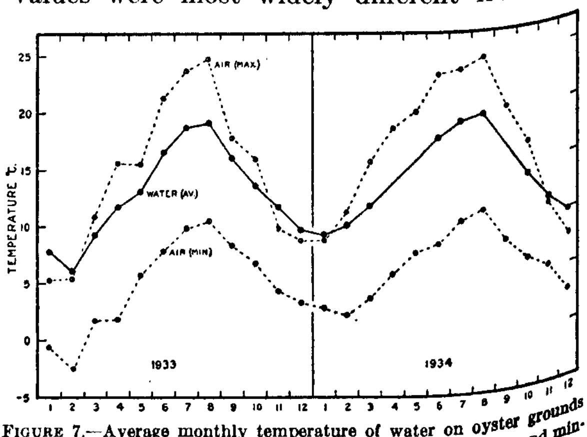

FIGURE 7.—Average monthly temperature of water on oyster grounds during 2 years as related to monthly averages of maximum and minimum daily air temperature at Olympia.

Other aspects of the temperature conditions are considered in later sections referring to the comparison of Oyster and Mud Bays in salinity, pH, and temperature.

TABLE 1.—*Average monthly water temperature in dike in Oyster Bay, calculated from thermograph records*

[Temperature °C.]

Month	1932	1933	1934	1935	Month	1931	1932	1933	1934	1935
January	7.28	7.70	9.38	7.66	July	18.2	18.10	18.71	19.27	19.48
February	6.36	6.07	10.07	8.88	August	18.45	18.61	19.12	19.79	19.45
March	8.56	9.30	11.83	9.22	September	17.04	17.09	16.07	-------	18.60
April	10.61	11.76	-------	12.03	October	13.15	14.61	13.69	13.90	15.41
May	14.02	13.06	-------	15.46	November	9.92	11.70	11.78	11.41	8.95
June	17.00	16.64	17.67	17.93	December	7.88	7.89	9.61	9.78	9.38

TABLE 2.—*Comparison of dikes 5 and S in salinity, temperature, and pH*

Date	Dike 5				Dike S			
	Tide and depth	Temperature	Salinity	pH	Tide and depth	Temperature	Salinity	pH
1932		° *C.*				° *C.*		
Jan. 5	F—6 ft	7.4	27.72	8.0				
12	E—10 ft	7.3	27.17	8.0				
19	F—10 ft	7.3	27.36	8.0				
27	E—10 ft	6.2	25.48	8.0				
Feb. 4	E—7 ft	5.0	26.34	8.0				
11	E—8 ft	6.3	27.35	8.0				
24	E—4 ft	7.4	24.27	8.0				
Mar. 2	E—7 ft	7.1	25.24	8.0				
8	E—4 ft	8.0	21.98	8.0				
15	E—8 ft	8.0	25.93	8.0				
22	Exp	8.2	24.60	8.2				
29	E—8 ft	8.3	24.61	8.2				
Apr. 12	Ebb	10.1	24.13					
19	Exp	12.1	21.14	8.4				
26	Exp	15.0	22.75	8.0				
May 3	Exp	18.9	24.94	8.0				
10	Exp	15.6	26.24	7.8				
17	Exp	23.3	26.33	8.4				
19	Exp	13.9	25.87	7.8				
21	Exp	14.4	26.82	8.0				
24	Ebb	14.4	26.76	8.0				
31	Exp	19.4	26.24					
June 2	Exp	19.4	26.17	7.8				
4	Exp	15.0	27.32	8.2	Exp	16.1	27.32	8.0
6	Ebb	17.8	26.63	8.0	Exp	17.5	27.49	8.4
8					Exp	20.3	27.11	8.2
13					Exp	18.9	27.23	7.8
15	Ebb	13.9	28.04	8.0	Ebb	13.6	26.64	8.0
17	Exp	29.4	27.74	7.8	Exp	14.4	27.65	8.0
20	Exp	20.0	27.12	7.8	Exp	12.2	27.47	8.2
22	Exp	18.9	27.31	8.0	Ebb	21.7	26.30	7.9
24	Exp	19.4	27.81	7.9	Exp	20.6	27.85	8.0
27	Exp	18.3	27.64	7.7	Exp	16.4	28.03	
29					Exp	15.5	28.07	
July 1	Exp	24.4	27.18	8.0	Exp	21.9	27.07	8.0
4	Exp	18.3	27.69	8.0	Exp	17.8	27.86	8.0
6	Exp	28.9	29.42	7.4	Exp			
8	Exp	20.0	28.15	8.0	Ebb	22.8	28.12	7.8
11	Exp	16.1	27.16		Exp	15.3	27.97	
13	Exp	16.7	27.60		Exp	15.5	28.03	
15	Exp	16.4	27.63		Exp	15.5	27.98	
18	Exp	25.0	27.94	7.8	Exp	18.6	27.99	7.9
20	Exp	20.5	28.21	7.8	Exp	18.6	28.21	7.9
22	Exp	21.1	28.21	7.8	Exp	21.4	28.57	7.8
25	Exp	16.1	28.33		Exp	16.1	28.59	
27	Exp	16.1	28.13		Exp	15.8	28.59	
29	Exp	17.2	26.80	8.0	Exp	16.1	27.69	8.0
Aug. 1	Exp	17.2	28.01	7.8	Exp	17.8	27.69	7.8
3	Exp	20.0	28.16	7.8	Exp	18.3	28.35	7.8
5	Exp	22.2	28.24		Exp	25.0	28.30	7.8
8	Exp	16.1	28.40		Exp	16.1	28.60	
12	Exp	15.3	27.61		Exp	15.5	28.01	
15	Exp	16.7	27.89		Exp	16.4	28.03	
19	Exp	18.9	28.17	7.8	Exp	18.9	28.31	7.9
22	Exp	16.1	26.88		Exp	16.1	27.27	
26	Exp	18.9	28.17	7.4	Exp	16.4	27.54	7.6
29	Exp	18.0	28.69		Exp	16.9	28.82	
31	Exp	17.8	28.28	7.9	Exp	16.1	27.97	7.9
Sept. 2	Exp	16.1	28.30		Exp	16.7	28.55	
5	E—Surf	16.7	28.69		E—Surf	16.7	28.53	
9	Exp	13.0	29.08		Exp	13.3	26.97	
12	Exp	17.2	28.56		Exp	17.8	28.71	
16	Ebb	15.5	29.00		Ebb	16.1	28.36	
19	Ebb	14.4	28.94		Ebb	14.4	29.04	
23					Ebb	16.1	28.78	8.0
26	Exp	13.3	28.21	7.8	Exp	13.3	28.65	7.8
30	Exp	17.3	28.59	7.8	Exp	17.1	28.87	7.6
Oct. 4					E—Surf	15.4	29.28	
7	F—Surf	14.4	28.99		F—Surf	13.6	29.22	
11	1 ft	12.8	28.26	7.4	Exp	17.8	27.47	7.8
14	E—18 in	15.0	28.04	7.8	Exp	15.0	28.64	7.8
17	E—4 ft	14.2	28.33	7.9	E—Surf	13.4	28.48	7.9
21	E—7 ft	13.3	28.64	8.0	E—5 ft	13.3	28.98	8.0
24	F—3 ft	12.3	29.13	8.0	F—4 ft	12.4	23.57	8.0
28	F—Surf	12.1	28.73	8.0	F—Surf	12.2	28.84	8.0
31	E—6 ft	11.4	28.08	8.0	E—4 ft		29.02	8.0
Nov. 4	E—8 ft	10.1	28.93	8.0	E—Surf	10.1	28.04	7.9
7	F—6 ft	11.0	28.48	7.9	F—4 ft	11.1	28.66	7.9
14	E—6 ft	10.3	27.21	7.9	E—5 ft	10.2	26.62	7.9
21	F—8 ft	10.4	26.92	7.8	E—6 ft	10.4	26.33	7.8
28	E—Surf	10.2	25.61	7.8	E—6 ft	10.1	26.22	7.9
Dec. 5	E—8 ft	9.2	26.53	7.8	F—8 ft	9.4	25.21	7.8
19	E—8 ft	6.4	26.25	7.9	E—8 ft	6.4	26.65	7.9

NOTE.—F=flood; E=ebb; Exp.=exposed.

SALINITY AND pH

Because of the predominant deep water in Puget Sound and the relatively small streams flowing into the southern portion the variations in salinity are not often great, save on the surface. Samples were taken during summer in the exposed dikes, while throughout the rest of the year, when low tides occurred at night, samples were taken at surface and bottom at the same places. Description of conditions is here limited chiefly to Oyster Bay and Mud Bay, in which most of the experimental work was done. Since the two bays offer marked hydrographical and biological differences, it is necessary to go into some detail in describing the relative values of salinity and pH as a preliminary to the presentation of biological work.

On the chart (fig. 4) it will be seen that the two bays are not markedly different in size, though Oyster Bay is somewhat longer. In both, most of the oyster beds are located at the upper ends where there are relatively level, or gently sloping, bottoms exposed at low tide. More fresh water enters Mud Bay through creeks and seepage than goes into Oyster Bay, but no large stream enters either. Low salinity probably never accounts for any mortality in these bays, though in periods of very heavy rain the creeks sometimes wash quantities of silt over some of the beds.

TABLE 3.—*Comparison of temperature, salinity, and pH, at low tide in 4 dikes in Mud Bay*

(Dike A adjoins shore; others in order to edge of channel)

Date	Dike A			Dike B			Dike C			Dike D		
	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH
1931	°*C*			°*C*			°*C*			°*C*		
June 1	19.4	27.25	------	21.7	27.31	------	20.5	27.18	------	20.5	27.12	------
June 5	20.0	27.07	------	20.8	27.07	------	21.1	26.88	------	21.1	26.88	------
June 13	15.7	25.90	------	------	------	------	16.0	25.78	------	15.8	26.05	------
June 17	17.8	26.27	------	17.9	25.91	------	18.3	26.31	------	18.3	26.30	------
June 22	16.7	26.58	------	17.0	26.31	------	17.2	26.45	------	16.7	25.28	------
June 25	13.5	24.60	------	13.6	26.27	------	13.5	25.75	------	13.9	24.43	------
June 29	18.0	24.99	------	17.8	25.84	8.0	18.3	24.58	7.8	17.8	25.17	7.8
July 1	18.3	25.95	------	18.9	25.62	------	19.4	25.84	------	19.7	25.95	------
July 3	17.2	26.65	------	20.0	26.08	------	20.8	26.18	------	21.4	26.18	------
July 9	19.4	26.26	8.0	19.7	26.02	7.8	19.4	25.90	7.8	19.4	25.87	7.8
July 13	16.3	27.06	7.8	16.7	26.94	7.8	16.4	26.82	7.8	16.7	26.82	7.8
July 17	21.1	27.81	8.0	21.7	27.75	8.0	21.7	27.60	8.0	23.6	27.57	8.0
July 20	22.2	27.93	8.0	22.2	27.48	8.0	21.7	27.75	8.0	22.2	28.07	8.2
July 23	17.2	27.83	8.0	17.2	27.83	8.0	17.2	27.83	8.0	17.2	27.83	8.0
July 25	19.4	27.75	8.0	19.4	27.06	8.0	20.0	27.50	7.8	20.0	27.48	7.8
July 29	25.8	28.42	8.0	26.1	28.40	7.8	25.8	28.27	7.8	26.9	28.01	7.8
Aug. 3	26.3	28.12	8.0	26.4	27.79	8.0	25.5	27.75	------	26.4	27.69	8.0
Aug. 7	14.7	28.13	7.8	15.0	27.95	7.8	15.3	27.98	7.8	15.3	27.98	7.8
Aug. 12	21.4	28.65	8.0	21.1	28.51	8.0	20.5	28.36	8.0	21.1	28.10	7.8
Aug. 21	15.0	28.59	7.8	15.0	28.41	7.8	15.0	28.60	7.8	15.0	28.30	7.8
Aug. 24	17.5	29.72	------	17.5	28.51	------	17.5	28.31	------	17.5	28.19	------
Aug. 26	18.9	28.82	------	18.9	28.31	7.8	18.6	28.15	7.8	19.3	28.24	7.8
Sept. 5	17.8	25.52	7.4	18.5	27.84	7.4	18.3	27.63	7.4	18.6	26.58	7.4
Sept. 10	15.5	28.65	------	15.5	28.35	7.8	15.5	28.06	------	15.5	27.92	------
Sept. 26	16.7	28.51	------	16.1	28.19	------	15.8	28.26	------	15.0	27.78	------
Oct. 8	11.7	28.44	7.8	11.1	27.88	7.6	10.5	27.64	7.6	11.1	27.65	7.7

In order to indicate the general results of tests on oyster grounds throughout the year, and the close comparison in salinity and pH of the water on various grounds, the values are given in table 2 for samples taken in two dikes in Oyster Bay, 1932. During the summer season samples were taken at low tide when the dikes were exposed and the water quite warm, while at other times of year bottom samples were taken. The day-to-day variation in salinity is not great, and although dike 5 is well up the bay and dike *S* about 2 miles away (see chart, fig. 4) there is little difference to be noted.

TABLE 4.—*Comparison of average monthly values of salinity and pH in a dike in Oyster Bay and one in Mud Bay during 2 years*

Date	Oyster Bay, dike 5			Mud Bay, dike B			Date	Oyster Bay, dike 5			Mud Bay, dike B		
	Number of samples	Average salinity	Average pH	Number of samples	Average salinity	Average pH		Number of samples	Average salinity	Average pH	Number of samples	Average salinity	Average pH
1932							1933						
January	4	26.93	8.00	3	27.75	8.00	January	4	24.02	7.87	4	26.49	7.90
February	3	25.99	8.00	4	25.76	7.98	February	3	25.68	8.10	4	25.25	8.10
March	5	24.47	8.08	4	25.37	8.00	March	3	24.70	8.17	2	26.84	8.10
April	3	22.67	8.20	3	27.52	8.30	April	5	25.86	8.30	4	24.92	8.26
May	7	26.17	8.00	4	24.05	8.10	May	11	26.39	8.20	7	24.91	8.12
June	9	27.31	7.91	9	25.84	7.88	June	12	27.36	7.97	12	25.65	8.05
July	13	27.88	7.85	12	25.93	7.90	July	12	28.11	7.92	13	26.68	7.88
August	11	28.05	7.74	10	26.53	7.84	August	11	28.21	7.96	13	26.97	7.94
September	8	28.67	7.80	10	28.00	8.00	September	6	28.29	7.93	7	26.99	7.96
October	7	28.49	7.85	4	28.64	7.87	October	4	27.49	7.90	4	23.59	7.90
November	4	27.88	7.90	5	27.39	7.92	November	4	24.45	7.80	4	27.42	7.75
December	2	26.39	7.85	2	27.48	7.80	December	3	24.64	7.80	1	26.36	7.80

In Mud Bay, however, into which more fresh water flows, there is a distinct gradient (table 3) in the salinity of the water at low tide in a series of 4 dikes from the shore (dike *A*) to the edge of the channel (dike *D*). The first three dikes are on the same level but the last (*D*) is about 1 foot lower. The lower level does not account for the salinity difference. The main body of fresh water from creeks at the head of the bay follows the channel, while the contours of the bay tend to carry the more saline water at flood tide to the west side of the bay.

The variation in salinity between individual samples taken at any time is relatively slight and the values over a period of a year may be best indicated by monthly averages. In table 4 the average monthly salinity and pH are given for 2 full years, 1932 and 1933, in two typical dikes, dike 5 in Oyster Bay and dike B in Mud Bay. The summer samples refer to conditions at low tide when the dikes were exposed. During the rest of the year the values refer only to bottom samples taken at relatively high tide. The more clearly to represent seasonal variations, the data are plotted in figures 8 and 9. The lowest salinity occurs generally during late winter and early spring, depending upon the time of greatest precipitation, and the annual variation, expressed in this manner, is usually between about 24 and about 29 p.p.mille.

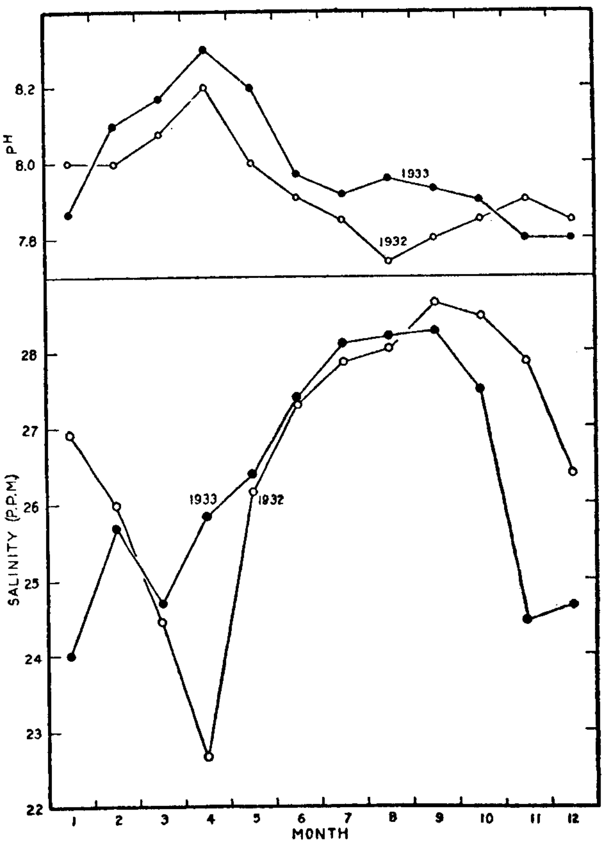

FIGURE 8.—Average values of salinity and pH of water on oyster ground (dike 5) in Oyster Bay during 2 years. Most summer samples were taken at low tide while during the remainder of year bottom samples were taken. Compare with Mud Bay, figure 9.

The salinity on the oyster grounds in Mud Bay is more variable than in Oyster Bay, as may be seen by comparing the figures, and heavy rains affect the water more quickly in the former. The hydrogen-ion concentration varies in a more orderly manner during the year and the two bays are similar in this respect. During late winter the pH rises rapidly from a low of about 7.8, reaching the maximum of about 8.3 in April. It then drops rapidly until midsummer, after which it is relatively stable. This is discussed further below.

The mode of sampling on the oyster grounds involves some lack of constancy throughout the year because all samples were taken during the day, so that for a large part of the year the tide was relatively high while in summer the dikes were exposed. A better picture of the high-tide salinity and pH was obtained by making studies in the deeper channels a short distance below the oyster grounds, off Corters Point in Oyster Bay and Maple Point in Mud Bay. That the results may be used to indicate conditions obtaining on the oyster grounds is shown in table 5, in which the surface temperature, salinity, and pH are compared for three places in Oyster Bay during summer. The salinity off Corters Point and Deepwater Point is almost identical with that in the exposed dikes, although in the last the temperature and pH are decidedly different because of exposure to sunshine and warm air and the respiratory activity of oysters and other organisms.

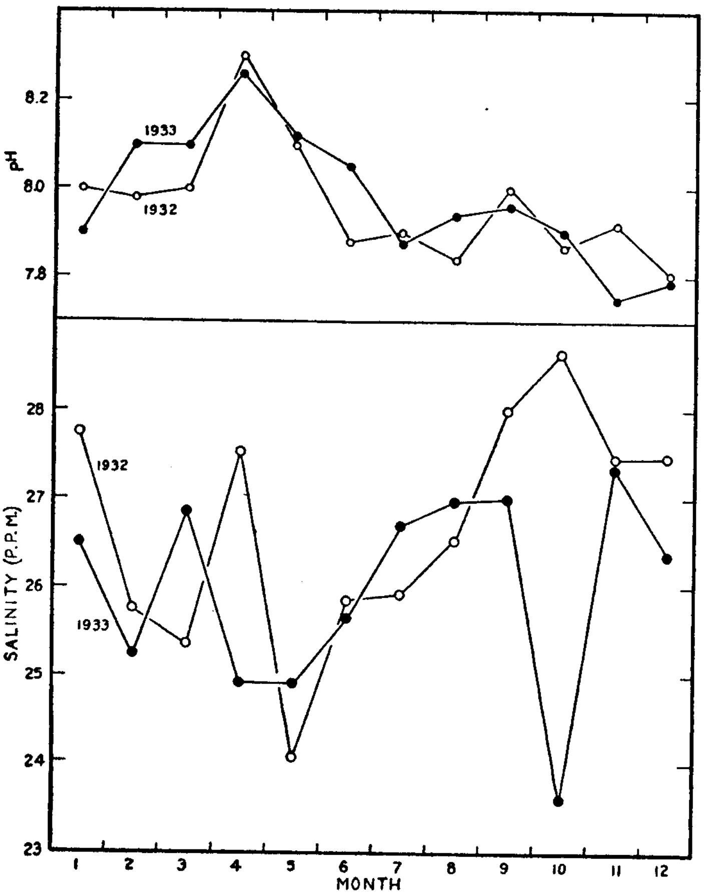

FIGURE 9.—Average values of salinity and pH of water on oyster ground (dike *B*) in Mud Bay during 2 years. Summer samples were taken at low tide while during the remainder of the year bottom samples were taken. Compare with Oyster Bay, figure 8.

To show briefly the annual variation in the waters of the two bays the average monthly values of salinity and pH at surface and bottom for Corters Point (Oyster Bay) and Maple Point (Mud Bay) are given in table 6 for 2 consecutive years. The surface salinity in Oyster Bay throughout the year is generally higher than in Mud Bay, though at the bottom the relationship is reversed and higher salinity prevails in Mud Bay. A similar difference was noted above with respect to the water over the oyster grounds of the two bays at low and high tide. The same average values are reproduced graphically in figures 10 and 11. The lowest salinity is to be found in late winter, near the end of the rainy season, and early in spring the gradual rise in bottom salinity begins. The bottom salinity in Oyster Bay varies during the year from about 26 to 29 parts per mille, in Mud Bay from about 27 to 29.5 parts per mille. The difference between bottom and surface is much greater in the latter bay, indicating the extent of adaptation required of the oysters during the tidal cycles. Shown in the figures also is the monthly precipitation as recorded at Olympia by C. F. Norrie. Rain is markedly seasonal at this place, with almost no rainfall during summer. The low salinity in winter is directly correlated with precipitation, though there is considerable lag in the salinity at the bottom.

TABLE 5.—*Salinity, temperature, and pH in Oyster Bay at 3 different points during summer (see chart, fig. 3)*

Date	Tide	Corters Point			Deepwater Point			Dike 1		
		Surface			Surface			Low tide		
		Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH
		° C.			° C.			° C.		
June 27	F	16.0	27.57	-------	15.0	27.94	-------	22.2	27.66	-------
June 30	F	17.7	26.64	-------	14.4	28.28	-------	18.9	27.36	-------
July 10	-------	15.3	28.40	8.4	15.0	28.37	8.2	16.7	28.40	8.2
July 15	F	18.0	28.60	8.4	-------	28.60	8.4	27.2	28.75	8.0
July 18	E	19.1	28.98	8.4	20.5	28.35	8.2	26.1	28.63	8.2
July 24	F	19.6	28.64	8.4	18.3	28.69	8.4	19.4	28.56	7.8
July 27	F	17.2	29.29	8.4	18.0	29.13	8.4	27.2	29.09	7.8
July 30	F	18.9	29.02	8.4	18.3	28.86	8.4	27.8	28.98	7.8
Aug. 1	E	19.4	29.20	8.4	20.5	28.86	8.4	25.3	29.09	8.0
Aug. 3	E	18.0	29.33	8.4	18.3	29.17	8.4	23.5	28.99	8.0
Aug. 8	F	17.5	27.74	8.2	17.5	29.56	8.2	17.5	28.53	7.8
Aug. 11	F	17.5	29.29	8.2	17.8	29.11	8.2	23.3	29.37	7.8
Aug. 13	E	19.0	29.54	8.2	19.7	28.11	8.2	27.2	28.41	7.8
Aug. 15	E	18.2	29.61	8.2	18.9	29.78	8.2	24.4	29.65	7.8
Aug. 22	F	18.4	29.13	8.2	17.2	28.98	8.2	17.5	29.13	7.8
Aug. 27	F	18.7	29.99	8.2	17.2	29.76	8.2	23.3	29.56	7.8
Aug. 29	F	18.3	29.90	8.1	18.9	29.81	7.7	25.0	29.58	7.8
Sept. 8	F	16.7	29.52	8.0	16.7	29.20	8.0	16.7	28.86	7.6
Averages	-------	17.97	28.91	8.28	17.72	28.92	8.23	23.28	28.81	7.91

NOTE.—F=flood; E=ebb.

TABLE 6.—*Average monthly values of salinity and pH at surface and bottom off Corters Point (Oyster Bay) and Maple Point (Mud Bay) during 2 years*

Date	Corters Point					Maple Point				
	Surface			50 feet		Surface			30 feet	
	Number samples	Average salinity	Average pH	Average salinity	Average pH	Number samples	Average salinity	Average pH	Average salinity	Average pH
1932										
January	4	25.45	7.92	27.68	8.05	4	25.06	8.0	28.91	8.0
February	3	26.68	8.0	27.97	8.0	4	23.88	7.97	28.59	8.0
March	5	24.27	8.02	25.78	8.04	4	23.45	8.0	27.16	8.0
April	3	24.34	8.3	26.86	8.3	4	25.37	8.33	27.89	8.4
May	6	26.94	8.4	27.69	8.4	4	26.94	8.4	28.15	8.4
June	3	27.92	8.4	28.10	8.4	4	27.42	8.2	28.31	8.3
July	3	28.34	8.27	28.38	8.37	2	27.43	8.15	28.28	8.2
August	4	28.32	8.23	28.53	8.3	5	28.31	8.14	28.84	8.36
September	4	28.94	8.3	28.67	8.15	2	29.11	8.15	29.43	8.2
October	7	29.01	8.01	29.20	8.0	5	29.29	7.98	29.58	8.05
November	5	27.26	7.86	28.18	7.93	5	25.45	7.87	28.95	7.92
December	3	25.79	7.73	26.78	7.8	2	26.74	7.8	28.14	7.85
1933										
January	4	23.79	7.87	26.38	7.87	4	26.27	7.83	27.20	7.9
February	4	25.59	8.1	26.21	8.1	4	24.61	8.0	27.47	8.1
March	4	24.10	8.13	26.26	8.15	4	23.56	8.1	27.00	8.1
April	5	26.05	8.28	26.78	8.34	4	24.76	8.27	27.46	8.3
May	12	27.11	8.24	27.66	8.28	8	26.81	8.23	27.92	8.31
June	11	27.75	8.13	28.00	8.18	12	26.29	8.17	28.41	8.23
July	11	28.30	8.15	28.46	8.18	11	27.50	8.05	28.70	8.12
August	11	28.43	8.12	28.57	8.12	12	27.84	8.03	28.51	8.04
September	6	28.67	8.07	28.95	8.13	7	28.32	8.0	28.59	7.99
October	4	27.79	8.1	28.23	8.1	4	27.48	8.02	28.86	8.02
November	4	26.13	7.8	26.96	7.8	4	26.40	7.8	27.30	7.8
December	3	20.53	7.8	25.32	7.8	1	18.58	7.8	27.17	7.8

In these two figures the annual variations of hydrogen-ion concentration are very striking. The lowest pH value is generally in December, when it averages about 7.8. In late winter it rises rapidly, reaching a maximum of about 8.4 usually in April and May, from which it gradually drops during the rest of the year. The time of highest pH is somewhat later than the time of lowest salinity and is probably due to the prolific development of diatoms and other algae in the water which contains large amounts of fertilizing materials such as nitrates, brought in by the inflowing drainage water which is becoming warmer during early spring. The warming water and the brighter light, associated with the presence of necessary chemical substances, permit the active multiplication of plant life, and photosynthesis rapidly removes carbonic acid, raising the pH. Later, however, as available fertilizing materials become fixed by the algae and as the water becomes warmer the respiratory activity of marine animals, including oysters, crustaceans, and others, restores a high percentage of carbonic acid to the water, lowering the pH.

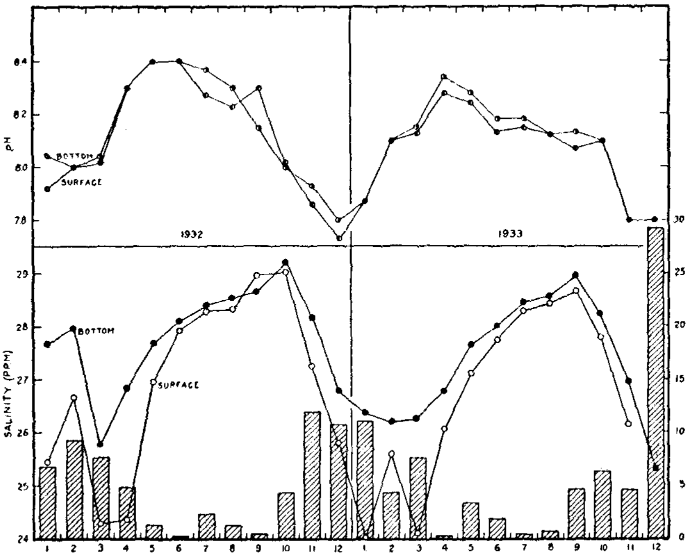

FIGURE 10.—Average monthly values of salinity and pH at surface and bottom (50 feet) off Corters Point (Oyster Bay) during 2 years. Total monthly precipitation (Olympia) is also shown. Compare with Mud Bay, figure 11.

In this regard it is of interest to call attention to changes in the pH and salinity of the water in a dike during a complete tidal cycle. In figure 12 the depth of water in a dike is shown throughout a 24-hour period in summer as related to the salinity and pH of the water. During ebb tide the water level became lower than the dike, leaving it exposed at about 1:15 p. m. At about 4:45 p. m. the flood tide came up to the dike level. During the time the dike was exposed the pH dropped from 8.0 to 7.9, because of carbonic acid excreted by oysters and other organisms, and the salinity rose slightly, due partly to evaporation and partly to stratification of the water permitting the less

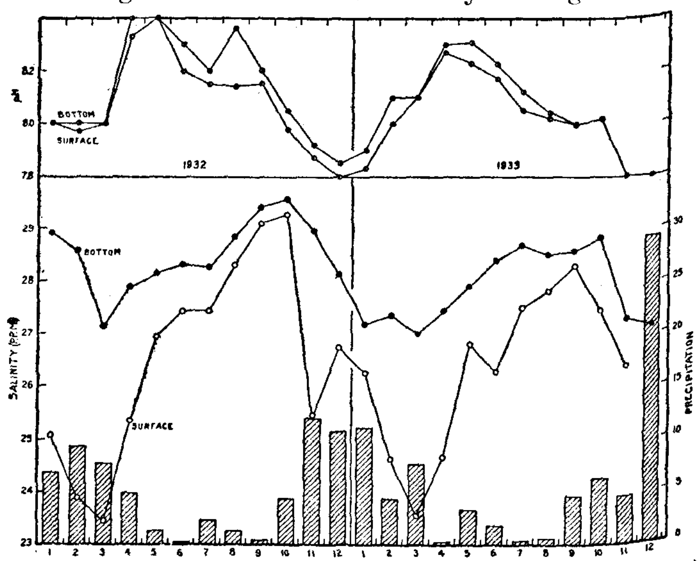

FIGURE 11.—Average monthly values of salinity and pH at surface and bottom (30 feet) off Maple Point (Mud Bay) during 2 years. Total monthly precipitation (Olympia) is also shown. Compare with Oyster Bay, figure 10.

saline to remain at the surface. During the flood tide both salinity and pH rose. Variations during the rest of the period are relatively slight, though in accord with this interpretation.

TABLE 7.—*Comparison of values of salinity, temperature, and pH off Corters Point during 1932 at different depths*

Date	Tide	Surface			6 feet			15 feet			30 feet			50 feet		
		Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH
1932		°C.			°C.			°C.			°C.			°C.		
Jan. 5	E	7.3	26.74	8.0	7.4	27.25	8.0	7.4	27.66	8.0	7.4	28.35	8.0	7.4	28.39	8.0
12	E	6.0	23.96	7.8	6.4	24.89	8.0	7.4	27.86	8.0	7.4	27.86	8.0	8.0	27.39	8.0
19	F	7.0	24.60	7.9	7.1	24.78	8.0	7.2	26.65	8.0	7.2	27.72	8.0	7.2	27.86	8.2
27	E	6.2	26.51	8.0	6.3	26.09	8.0	6.4	26.19	8.0	7.0	27.01	8.0	7.0	27.16	8.0
Feb. 4	E	4.3	26.03	8.0	5.1	27.41	8.0	5.2	27.79	8.0	5.3	27.99	8.0	5.3	27.99	8.0
11	E	5.4	27.98	8.0	5.4	27.66	8.0	6.1	27.68	8.0	6.1	27.68	8.0	6.0	27.77	8.0
24	E	6.4	26.04	8.0	7.2	27.63	8.1	7.0	28.10	8.0	7.0	28.10	8.0	7.0	28.16	8.0
Mar. 2	E	6.3	23.59	8.0	6.4	23.53	8.0	7.2	24.99	8.0	7.3	25.97	8.0	7.3	26.19	8.0
8	E	7.1	23.75	8.0	7.3	23.59	8.0	7.3	23.68	8.0	7.3	25.62	8.0	7.3	24.85	8.0
15	F	7.3	25.53	8.0	7.4	25.32	8.0	7.4	26.53	8.0	7.4	27.11	8.0	7.4	26.39	8.0
22	E	8.1	24.79	8.0	8.1	25.79	8.0	8.1	25.87	8.0	8.1	25.91	8.0	8.1	25.81	8.0
29	E	8.3	23.69	8.1	8.4	23.48	8.2	8.4	24.65	8.2	8.2	24.66	8.2	8.2	25.64	8.2
Apr. 12	E	10.3	23.50	------	10.2	24.02	------	9.1	25.81	------	9.0	26.09	------	9.0	26.17	------
19	E	9.4	25.91	8.2	10.1	27.89	8.2	9.4	25.90	8.2	9.3	27.75	8.2	9.3	27.83	8.2
26	E	15.1	23.41	8.4	13.1	26.00	8.4	10.4	28.16	8.4	10.2	28.03	8.4	10.2	26.58	8.4
May 3	E	12.2	25.91	8.4	11.4	26.18	8.4	11.0	26.58	8.4	--------	--------	------	10.3	26.63	8.4
10	E	12.3	26.80	8.4	12.1	27.30	8.4	12.1	28.53	8.4	11.3	27.20	8.4	11.2	28.84	8.4
17	F	15.0	26.67	8.4	14.3	27.27	8.4	13.1	27.39	8.4	13.0	27.40	8.4	13.0	27.32	8.4
21	E	13.2	27.32	8.4	13.1	27.31	8.4	13.7	26.97	8.4	13.0	27.43	8.4	13.0	27.46	8.4
24	E	13.2	27.41	8.4	13.2	27.74	8.4	13.0	27.66	8.4	13.0	27.69	8.4	13.0	28.30	8.4
31	E	13.4	27.52	8.4	14.0	27.45	8.4	13.2	27.41	8.4	12.4	26.26	8.4	12.4	27.63	8.4
June 6	E	13.4	27.78	8.3	14.0	28.03	8.4	14.0	27.79	8.4	13.3	27.90	8.4	13.3	28.06	8.4
15	E	15.0	27.94	8.4	15.0	28.01	8.4	15.0	27.95	8.4	14.4	28.01	8.4	14.4	28.12	8.4
22	E	16.0	28.03	8.4	16.0	27.99	8.4	15.4	27.84	8.4	15.4	27.95	8.4	15.4	28.12	------
July 8	E	17.2	29.83	8.4	17.0	28.26	8.4	17.1	28.21	8.4	16.3	28.39	8.4	16.2	28.41	8.4
18	E	15.4	28.39	8.2	16.3	28.42	8.2	16.1	28.30	8.2	16.0	28.31	8.2	16.0	27.00	8.2
20	E	17.2	28.51	8.2	17.0	28.59	8.2	17.0	28.30	8.2	16.4	28.30	8.2	16.3	28.48	8.2
29	F	16.2	26.67	8.2	16.0	28.59	8.4	16.0	28.24	8.4	15.4	28.24	8.4	15.4	28.24	8.5
Aug. 3	F	16.3	28.35	8.3	16.3	28.42	8.3	16.3	28.30	8.4	16.4	28.35	8.4	16.4	28.48	8.4
10	F	17.4	28.21	8.2	17.3	28.21	8.2	17.1	28.57	8.3	17.0	28.35	8.2	16.4	28.68	8.2
17	F	18.0	28.30	8.2	17.4	28.41	8.4	17.1	28.31	------	17.0	28.31	8.4	17.0	28.37	8.4
24	F	17.2	28.44	8.2	17.0	28.45	8.2	16.3	28.59	8.2	16.3	28.66	8.2	16.3	28.59	8.2
Sept. 23	F	15.3	28.74	8.4	15.2	29.05	8.4	15.1	28.59	8.0	14.4	29.07	8.0	14.4	28.98	8.0
28	F	16.4	28.91	8.2	15.4	29.07	8.2	15.3	29.00	------	15.1	28.91	8.2	15.1	28.98	8.2
30	E	15.2	28.94	8.2	15.1	29.04	8.2	15.1	29.00	8.2	15.1	29.07	8.3	15.1	29.07	8.2
Oct. 11	F	14.1	28.94	8.2	14.1	29.20	8.1	14.1	29.13	8.1	14.0	29.65	8.1	13.4	29.22	8.1
14	F	14.2	29.11	8.0	14.2	29.11	8.0	14.2	29.00	8.0	15.0	29.28	8.0	14.1	29.23	8.0
17	F	14.0	28.87	7.9	14.0	28.85	7.9	14.0	28.69	7.9	14.2	28.71	7.9	14.2	29.23	7.9
21	F	13.2	29.08	8.0	13.3	28.95	8.0	13.3	29.16	8.0	13.3	20.47	8.0	13.3	29.18	8.0
24	F	12.4	29.11	8.0	12.5	29.16	------	13.0	29.32	8.0	13.0	29.22	8.0	13.0	29.22	8.0
28	F	12.4	29.09	8.0	12.4	29.28	8.0	12.3	28.98	8.0	12.3	29.14	8.0	12.3	29.28	8.0
31	F	--------	28.88	8.0	--------	29.05	8.0	--------	29.36	8.0	--------	29.05	8.0	--------	29.02	8.0
Nov. 4	F	11.0	29.11	7.9	11.0	28.98	8.0	--------	29.29	8.0	11.0	29.32	8.0	11.0	29.43	8.0
7	F	10.3	26.92	7.9	11.1	28.53	7.9	11.1	29.09	7.9	11.1	28.95	7.9	11.1	29.29	7.9
14	E	10.2	27.17	7.9	10.4	27.52	7.9	10.4	27.79	7.9	10.4	28.06	7.9	10.4	27.79	------
21	E	10.4	26.62	7.8	10.4	27.00	7.8	10.4	26.42	7.9	11.0	27.39	7.9	11.0	27.21	7.9
28	E	10.0	26.58	7.8	10.1	26.85	7.9	10.1	26.85	7.9	10.2	27.39	------	10.2	27.20	7.9
Dec. 5	F	9.2	25.39	7.7	9.4	26.59	7.8	9.4	25.96	7.8	9.4	25.95	7.8	9.4	27.11	7.8
19	E	6.4	26.73	7.8	6.4	27.16	7.9	7.1	27.20	7.9	7.2	27.38	7.9	7.2	27.39	------

NOTE.—E=ebb.; F=flood.

TABLE 8.—*Temperature, salinity, and pH of water at different depths off Maple Point (Mud Bay) during 1 year*

Date	Tide	Surface			3 feet			10 feet			20 feet			30 feet		
		Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH
1932		°C.			°C.			°C.			°C.			°C.		
Jan. 5	F	4.3	21.49	8.0	5.4	26.11	8.0	7.2	28.66	8.0	7.4	28.91	8.0	7.4	29.16	8.0
8	E	7.3	27.64	8.0	7.4	27.89	8.0	8.0	29.66	8.0	8.1	28.73	8.0	8.1	28.87	8.0
22	E	4.2	24.33	8.0	7.0	26.82	8.0	7.2	28.30	8.0	7.3	28.75	8.0	7.3	28.95	8.0
30	E	3.4	26.78	8.0	5.3	27.79	8.0	6.4	28.15	8.0	7.0	28.95	8.0	7.0	28.65	8.0
Feb. 6	E	5.3	28.04	8.0	5.3	27.78	8.0	5.3	27.88	8.0	6.0	28.56	8.0	6.0	28.48	8.0
13	E	4.0	21.46	8.0	5.1	27.75	8.0	6.2	28.55	8.0	6.3	28.77	8.0	6.3	28.73	8.0
19	F	6.1	26.13	8.0	6.3	26.13	8.0	6.4	27.61	8.0	6.4	27.84	8.0	6.4	28.57	8.0
26	E	8.3	19.89	7.9	8.3	29.82	8.0	8.0	29.49	8.0	8.0	28.12	8.0	8.0	28.61	8.0
Mar. 3	F	6.1	22.95	8.0	6.4	28.27	------	7.1	27.61	8.0	7.2	27.27	8.0	7.2	27.36	8.0
10	E	7.2	21.28	8.0	8.0	24.00	8.0	8.0	27.43	8.0	8.0	27.88	8.0	8.0	28.17	8.0
17	E	8.3	25.62	8.0	9.0	25.77	8.0	8.3	25.44	8.0	8.1	27.59	8.0	--------	27.73	8.0
26	E	8.0	23.95	8.0	7.4	28.94	8.0	8.0	25.01	8.0	8.1	25.09	8.0	8.1	25.37	8.0
Apr. 1	F	8.4	25.72	8.4	9.0	25.95	------	8.3	27.48	------	8.3	27.90	------	8.3	27.83	------
15	F	10.0	26.96	8.4	10.1	26.60	8.4	10.0	27.56	8.4	9.0	27.31	8.4	9.0	28.01	8.4
21	E	10.3	22.92	8.2	10.3	23.01	8.2	10.3	26.09	8.3	10.2	28.59	8.4	10.1	28.19	8.4
29	F	11.3	25.88	8.4	11.4	26.85	8.4	11.0	26.04	8.4	10.1	27.83	8.4	--------	27.54	------

TABLE 8.—*Temperature, salinity, and pH of water at different depths off Maple Point (Mud Bay) during 1 year*—Continued

Date	Tide	Surface			3 feet			10 feet			20 feet			30 feet		
		Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH
1932		° C.			° C.			° C.			° C.			° C.		
May 6	E	11.4	26.00	8.4	11.3	26.45	8.4	11.3	26.97	8.4	11.1	27.41	8.4	11.1	27.52	8.4
13	E	12.4	27.64	8.4	12.3	27.88	8.4	12.3	27.93	8.4	11.2	28.30	8.4	11.2	28.48	8.4
20	E	12.3	27.03	8.4	12.3	27.17	8.4	12.2	27.32	8.4	12.1	28.13	8.4	12.1	28.56	8.4
27	F	14.3	27.11	8.4	14.0	27.20	-----	13.3	27.54	8.4	12.3	28.01	8.4	12.2	28.03	8.4
June 3	F	14.0	26.74	8.2	14.0	27.30	8.2	13.2	27.66	8.2	13.0	28.19	8.2	12.4	27.98	8.2
10	E	19.2	27.14	8.2	18.0	27.03	8.4	15.4	28.15	8.4	14.0	28.19	8.4	13.4	28.16	8.4
16	E	15.1	27.60	8.2	15.2	27.81	8.4	14.4	28.39	8.4	14.2	28.21	8.4	14.0	28.65	8.4
23	E	15.1	28.21	8.2	15.2	28.12	-----	15.2	28.39	8.2	14.4	28.51	8.2	14.0	28.46	8.2
July 16	F	16.2	26.58	8.1	16.2	27.65	8.2	16.0	27.65	8.2	15.3	27.92	8.2	15.2	28.03	8.2
21	E	16.2	28.28	8.2	16.1	28.45	-----	16.0	28.12	-----	15.2	28.43	-----	15.1	28.53	-----
Aug. 2	F	17.2	28.06	8.2	16.4	28.37	8.4	16.4	28.37	8.4	16.2	28.64	8.4	16.2	28.89	8.4
4	F	20.0	28.33	8.2	18.0	28.66	8.2	17.3	28.99	8.4	17.4	28.82	8.4	17.4	28.91	8.4
11	F	15.3	28.19	8.1	15.3	28.19	8.2	15.3	28.35	8.2	15.2	28.87	8.2	15.1	28.60	8.2
18	F	17.4	28.06	8.0	17.4	28.48	8.2	17.0	28.08	8.4	16.4	28.87	8.4	16.4	28.74	8.4
25	F	16.4	28.93	8.2	16.0	28.82	8.4	15.4	29.08	8.4	15.0	29.22	8.4	15.0	29.08	8.4
Sept. 22	F	15.2	29.63	8.4	15.0	29.22	8.4	15.0	29.34	8.4	14.2	29.47	8.4	14.2	29.69	8.4
29	F	15.2	28.59	7.9	15.2	28.80	8.0	15.1	28.80	8.0	14.4	28.99	8.0	14.4	29.17	8.0
Oct. 5	F	14.3	29.08	8.0	14.3	28.95	8.0	14.2	29.18	8.2	14.2	29.47	8.2	14.2	29.75	-----
11	F	13.1	29.63	8.2	13.1	29.70	8.2	13.0	29.87	8.2	13.1	29.87	8.2	13.1	29.85	8.2
15	E	13.4	28.95	7.9	13.4	29.27	7.9	13.2	29.13	7.9	13.2	29.33	7.9	13.2	29.84	7.9
18	E	12.4	29.20	7.8	12.4	29.22	7.8	12.4	29.13	8.0	13.0	29.38	8.0	13.0	29.16	8.0
25	F	12.4	29.58	8.0	13.0	29.31	8.0	13.0	-------	8.0	13.0	29.23	8.0	13.0	29.28	8.0
Nov. 1	E	10.4	26.96	7.9	11.2	27.11	7.9	11.2	29.70	8.0	11.2	29.23	8.0	-------	29.36	8.0
8	F	11.0	23.53	7.9	11.0	24.71	7.9	11.0	26.40	7.9	11.2	29.72	7.9	11.2	29.42	7.9
17	E	11.4	27.12	7.9	11.4	27.17	7.9	11.4	28.82	7.9	11.3	28.93	7.9	11.3	29.22	7.9
22	F	8.2	22.92	7.8	10.2	28.69	7.9	10.2	28.50	7.9	10.2	28.69	7.9	10.2	28.79	7.9
29	E	10.2	26.73	-----	10.2	27.18	7.8	10.2	28.08	7.9	10.2	28.17	-----	10.2	27.95	7.9
Dec. 6	F	8.3	26.17	7.8	9.0	26.65	7.8	9.0	27.84	7.8	9.1	27.85	7.8	9.1	28.06	7.8
20	F	7.1	27.31	7.8	7.0	27.16	7.9	7.0	28.30	7.9	6.4	28.22	7.9	6.4	28.22	7.9

NOTE.—E=ebb; F=flood.

To indicate in detail the changes in temperature, salinity, and pH at different depths, tables 7 and 8 are reproduced, showing the observations made over a period of 1 year in Oyster Bay and Mud Bay, at the points previously described. In Oyster Bay samples were taken at surface, 6, 15, 30, and 50 feet; in Mud Bay at surface, 3, 10, 20, and 30 feet. These tables give in detail both the seasonal variation in the water and the effect of depth. The surface water is, in some cases, quite different from that below.

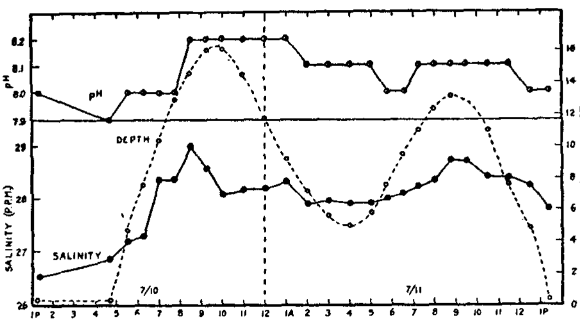

FIGURE 12.—Variation in salinity and pH in a dike in Oyster Bay during a complete tidal cycle. See also figures 34 to 37.

TABLE 9.—*Comparison of temperature, salinity, and pH of water at different depths during winter and summer off Corters Point, Oyster Bay; and Maple Point, Mud Bay*

Depth	Winter[1]			Summer[2]			Depth	Winter[1]			Summer[2]		
	Temperature	Salinity	pH	Temperature	Salinity	pH		Temperature	Salinity	pH	Temperature	Salinity	pH
Maple Point:	° C.			° C.			Corters Point:	° C.			° C.		
Surface	5.8	24.75	8.0	16.5	27.82	8.16	Surface	6.4	26.06	7.9	16.3	28.21	8.28
3 feet	6.7	26.37	8.0	16.1	28.16	8.27	6 feet	6.7	27.05	8.0	16.3	28.29	8.31
10 feet	7.2	28.61	8.0	15.6	28.29	8.32	15 feet	7.0	27.62	8.0	16.1	28.21	8.3
20 feet	7.4	28.61	8.0	15.1	28.53	8.32	30 feet	7.1	27.91	8.0	15.8	28.25	8.32
30 feet	8.0	28.99	8.0	14.9	28.57	8.32	50 feet	7.1	27.93	8.0	15.7	28.36	8.3

[1] December 1931, January and February 1932.
[2] June, July, and August 1932.

Some of these data are given as averages for winter (December, January, and February) and summer (June, July, and August) in table 9 to indicate stratification of the water, for it has been shown by Nelson and Perkins (1931) that the behavior of oyster larvae may be determined by the salinity at different depths. The values for Maple Point (Mud Bay) are plotted graphically in figure 13. In winter the salinity at surface and 3 feet is much lower than at greater depths but in summer the difference between surface and bottom is not so great. However, the pH in summer becomes lower toward the surface, probably because of planktonic animals, while in winter it is uniform from surface to bottom. In Oyster Bay (fig. 14) the salinity, temperature, and pH are almost identical from surface to bottom though during the winter the surface water is less saline and of slightly lower pH. The presence of the deep waters adjacent to the oyster grounds accounts for the high degree of stability indicated by these figures.

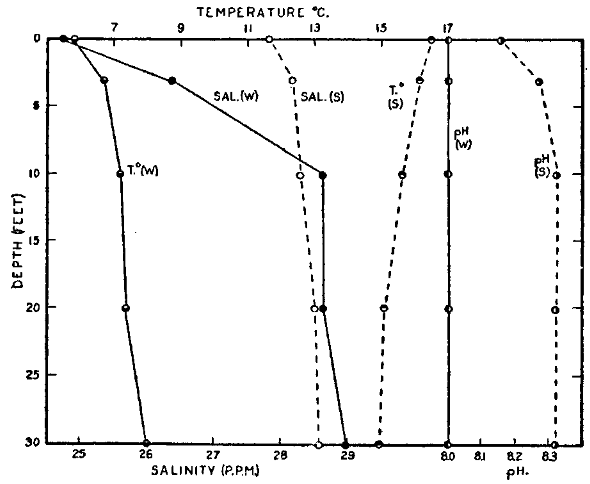

FIGURE 13.—Vertical distribution of salinity, temperature, and pH off Maple Point (Mud Bay) summer (S) and winter (W). Compare Oyster Bay, figure 14.

TABLE 10.—*Comparison of water near mouths of Mud Bay and Oyster Bay at ebb (E) and flood (F) tides during summer*

Date	Tide	Mouth of Oyster Bay						Mouth of Mud Bay					
		6 feet			30 feet			6 feet			30 feet		
		Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH	Temperature	Salinity	pH
		°C			°C			°C			°C		
May 24	E	11.1	28.39	8.2	11.2	28.53	8.2	10.1	28.69	8.3	10.2	28.39	8.3
	F	12.0	27.86	8.0	12.2	27.98	8.2	11.4	28.30	8.2	12.0	28.44	8.2
May 26	E	11.1	28.39	8.2	11.2	28.53	8.2	10.4	28.13	8.4	11.1	28.27	8.4
	F	11.3	27.79	8.3	11.4	28.06	8.2	11.1	27.85	8.4	11.1	28.37	8.4
May 29	E	12.1	27.98	8.2	12.2	27.85	8.2	11.2	28.41	8.2	11.4	28.35	8.2
	F	12.4	27.55	8.2	12.4	27.66	8.2	12.4	27.85	8.2	12.2	27.75	8.2
May 31	E	12.1	28.08	8.2	12.1	28.08	8.2	11.0	28.16	8.2	10.3	28.56	8.2
	F	12.2	27.83	8.4	12.2	27.79	8.3	12.0	28.04	8.2	12.0	28.69	8.2
June 2	E	13.0	28.24	8.2	12.3	28.06	8.2	11.3	28.60	8.2	11.3	28.66	8.2
	F	13.2	27.90	8.2	12.3	28.06	8.2	11.1	28.40	8.2	11.0	28.71	8.2
June 9	E	11.4	27.66	8.2	11.3	27.77	8.2	10.4	28.12	8.2	10.2	28.50	8.2
	F	12.4	27.77	8.2	12.4	27.95	8.2	12.4	28.16	8.2	12.3	28.37	8.2
June 14	E	14.0	27.99	8.4	13.4	28.30	8.4	12.3	28.31	8.4	12.2	28.64	8.4
	F	14.0	27.64	8.4	13.3	27.88	8.4	12.2	28.35	8.4	11.4	28.68	8.4
June 28	E	15.0	28.21	8.2	14.3	27.88	8.2	13.2	28.51	8.2	12.4	28.60	8.2
	F	15.1	28.04	8.0	15.1	28.04	8.0	15.1	28.45	8.4	14.0	28.04	8.4
July 5	E	15.1	28.48	8.2	15.0	28.40	8.2	13.3	28.85	8.2	13.2	28.59	8.2
	F	14.4	28.48	8.2	14.3	28.74	8.2	13.2	28.74	8.2	13.0	28.69	8.2
Average	E	12.8	28.10	8.22	12.7	28.17	8.23	11.5	28.42	8.24	11.4	28.50	8.25
Average	F	13.0	27.87	8.20	12.8	28.02	8.21	12.3	28.24	8.26	12.1	28.41	8.26

NOTE.—E=ebb; F=flood.

Further comparison of the two bays is shown by samples taken during summer at points near their mouths at depths of 6 and 30 feet at ebb and flood tides. (See table 10.) The water entering Oyster Bay is of a lower salinity than that going into Mud Bay, while at the upper end of the latter more fresh water flows in. As a result, in Mud Bay the oysters are subjected to frequent changes in salinity at different stages of the tide while in Oyster Bay the changes are relatively slight. These differences are considered below in the comparison of the spawning and setting activities of oysters in the two places. It may be noted on the chart (fig. 4) that the mouths of Oyster and Oakland Bays are close together but that the latter bay is entered through a long, narrow channel. It is of interest to compare the salinity in the dikes of the two bays at low tide. In table 11 salinities are given for dike 5 in Oyster Bay, a typical dike in Skookum Inlet, and one in Oakland Bay. Larger streams flow into Oakland Bay and elimination is less readily accomplished, so that even during dry summer weather the salinity is lower than in Oyster Bay. Water entering the latter at flood tide is of lower salinity than that which goes into Mud Bay, probably because of outflow from Oakland Bay and neighboring waters. Complete exchange of water with tides is accomplished much more slowly than in Mud Bay, the water in which is therefore higher in salinity as well as colder and not as favorable for the propagation of oysters.

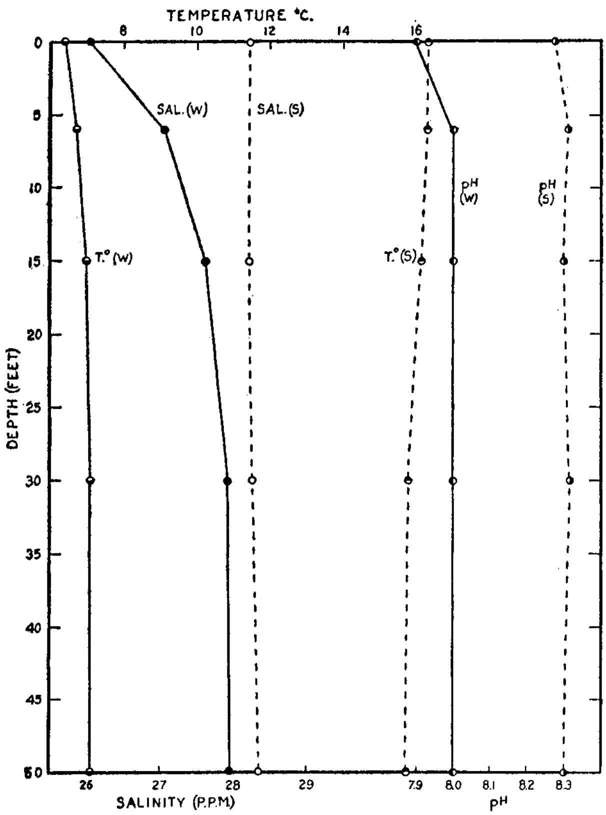

FIGURE 14.—Vertical distribution of salinity, temperature, and pH off Corters Point (Oyster Bay) summer (S) and winter (W). Compare Mud Bay, figure 13.

TABLE 11.—*Comparison of salinity of water in dikes at low tide in Oyster Bay, Little Skookum, and Oakland Bay in summer*

Date	Oyster Bay	Little Skookum	Oakland Bay	Date	Oyster Bay	Little Skookum	Oakland Bay
1933	*Salinity*	*Salinity*	*Salinity*	1933—Continued	*Salinity*	*Salinity*	*Salinity*
May 22	27.17	25.68	23.30	June 21	27.49	----------	25.43
May 24	27.05	----------	24.03	June 23	27.43	27.01	25.10
May 26	26.91	23.86	23.69	June 26	27.16	26.06	25.52
May 29	26.88	25.09	23.66	June 28	28.07	----------	24.65
May 31	27.35	----------	24.22	June 30	27.92	----------	24.94
June 2	27.17	----------	24.71	July 3	27.69	25.25	24.90
June 5	27.50	25.91	24.09	July 5	27.77	----------	25.46
June 7	27.59	----------	24.23	July 7	27.11	----------	25.99
June 9	27.27	25.47	24.37	July 14	27.83	26.97	26.15
June 12	26.77	25.61	25.39	July 17	28.01	26.68	26.05
June 14	27.54	----------	25.76	July 19	28.12	----------	25.91
June 16	27.21	26.10	24.83	July 21	28.21	27.16	24.25
June 19	27.92	25.97	25.10	July 24	28.13	28.22	26.44

SPAWNING

The native oyster of the Pacific coast, *Ostrea lurida*, is biologically similar to the European oyster, *O. edulis*, in that it is hermaphroditic and viviparous. In his original studies of the native oyster, Stafford (1913, 1914) described the hermaphroditism, pointing out that in the gonad, or ovotestis, eggs and sperms may be seen close together. Until the recent work of Coe (1931a, 1931b, 1932a) no further exact information on the mode of reproduction in this species was published. Coe studied in detail the spermatogenesis and life history of this oyster near La Jolla, Calif., and found it to be protandric. He stated that germ cells mature in the 1-year-old oyster and that at first the individual is male. During the rest of its life it is alternately female and male, although at any one time germ cells of both sexes may be found in the gonad because seldom are all of the sexual products discharged before the next phase begins.

Stafford (1915) stated that spawning involves the discharge of eggs or sperm balls from the gonad into the suprabranchial or cloacal chamber from which they reach the mantle chamber. He described this activity as follows:

Eggs and sperms are liberated from the gonaducts into the suprabranchial chamber, and make their way through the water-tubes and gill-slits to the branchial chamber, which also serves as a brood chamber. In doing this they are assisted by the pressure of their mass * * *. Sections of oysters at the spawning season show eggs in the cavities of the gills. They do not pass readily through the gill-slits on account of the narrowness of the latter, but with the increasing mass and pressure the gills become stretched and the slits enlarged, and besides the gills appear in places to suffer disintegration.

This explanation is obviously inadequate, for one has difficulty in understanding how the small increase in pressure due to eggs would force them through the gill apertures. Also, it is clear that considerable coordination would be required to keep the cloacal chamber completely closed and prevent direct escape of the eggs. Galtsoff (unpublished manuscript) studied spawning in *Ostrea virginica* and reached the more probable conclusion that suction, created by opening of the valves during spawning, draws the eggs through the small openings in the gills. Elsey (1935) found that the openings, or ostia, in the gills of *O. lurida* and *O. gigas* have a diameter proportional to that of the eggs. The eggs of the former are about twice as great in diameter as those of the latter, and the ostia are about one-third larger.

As has been described by Nelson (1922), Galtsoff (1930b, 1932) and others, eggs are finally discharged from the mantle chamber in *Ostrea virginica* but sperms are washed out through the cloaca with the water pumped by the gills. Stafford considered that in the native oyster the sperms also pass through the gills as do the eggs. While Stafford may have actually observed the discharge of sperms in this manner, the writer has frequently seen them issuing from the cloaca as in other species. At the time of spawning the sperms of *O. lurida* are in clusters, or balls, made up of from 250 to 2,000 or more sperms, according to the estimate of Coe (1931b), who stated further that in contact with sea water the matrix in which the sperms are imbedded disintegrates, permitting them to swim free. Both Stafford and Coe considered that eggs are fertilized by sperms brought into the branchial chamber where the eggs are held, with the water pumped by the gills. Stafford thought self-fertilization might occur, though according to Coe's interpretation this is unlikely. It is uncertain whether the sperms from one individual will stimulate spawning in functionally female specimens, as described by Galtsoff (1930b, 1932) for other species, though such is probable.

The eggs are held in the anterior end of the mantle or branchial chamber adjacent to the gills and labial palps. Here they develop for a considerable period. It is remarkable that they are not swept out along the "waste canals" in the walls of the mantle which normally function to eliminate particles of silt and other rejected material. Stafford (1914) estimated that in British Columbia the period of development within the maternal "brood chamber" is about 16½ days, while Coe (1931a) suggested "a period of approximately 10 to 12 days, perhaps" in southern California. Stafford's work on this species is published in a series of six papers (1913, 1914, 1915, 1916, 1917, 1918) some of which are frequently referred to below.

SIZE OF BROODS

Oysters have always aroused interest because of the very large numbers of eggs which they discharge. Various means of estimating the number of eggs spawned by an individual have been employed with highly divergent results. Galtsoff (1930a) gave a brief review of the literature on the subject and indicated that previous estimates for the average-size female of *O. virginica* vary from about 9 millions to about 60 millions. He made what is apparently the most thorough and accurate study by causing oysters to spawn and then making statistical counts of the eggs. He found that a female of *O. virginica* discharged from 15 millions to about 114 millions in a single spawning period, and that after spawning had occurred the meat still contained a large quantity of eggs. During three periods of spawning one specimen of *O. gigas* discharged a total of about 92 million eggs. The number of eggs spawned by a single individual throughout an entire season would be considerably greater than these counts.

These species are of the oviparous type while the Olympia oyster is viviparous. In the waters of the United States are two viviparous species of oysters, *O. lurida*, on the Pacific coast, and *O. equestris*, described by Gutsell (1926) on the South Atlantic coast. The latter is too small to be of commercial use. *O. edulis*, the European oyster, is also of this type and although the largest of the three it is much smaller than the common American oyster. Because of their small size the viviparous oysters cannot be expected to discharge the large quantities of eggs described above, but they have a considerable biological advantage in that every specimen is presumably capable of functioning each season as a female, while in *O. virginica* only about half of the individuals are female. In the latter sex-change occurs, as recently studied by Coe (1932c, d), but not with the frequency found in the native oyster. The fact that the larvae are carried in the limited space of the branchial chamber in viviparous species would also appear to set a limit to the size of the broods.

Moebius (1883) estimated, by an apparently satisfactory method, that the average brood of *O. edulis* consists of about one million larvae. Stafford (1918) stated that the much smaller native oyster bears broods of about the same size, although his method of estimating the number is not clear. In order to establish with reasonable accuracy the number of larvae produced, counts were made of a number of broods.

A gravid individual was carefully opened and the larvae rinsed from the gills and mantle. After killing them with formalin they were shaken in a measured quantity of water and exactly determined samples placed in a flat-bottom dish and counts made by means of a counting plate. Specimens of various sizes were used, though most of them were of market size. Counts were made of the separate broods of 13 oysters, and on the mixed broods of 2 groups of 6 oysters. Table 12 gives the results and includes measurements of the shells of the maternal parents and the stage of development of the larvae in those broods which were separately counted.

The average of all 25 broods is 214,642 larvae per oyster, although single broods varied from about 70,000 for the smallest specimen to 355,000 for one of the larger ones. These specimens were in general considerably smaller than those used in the two series of mixed broods, which represent more fairly the number of larvae produced by the standard market-size oyster. The average of the Oyster Bay series is 283,273 and of the Mud Bay series, consisting of somewhat smaller specimens, 247,199. The number of larvae produced obviously depends upon the size of the maternal individual and upon the degree of "fatness", or amount of stored nourishment, which is required for the maturation of the eggs. The data here described indicate that the ordinary marketable native oyster produces a brood of from 250,000 to 300,000 larvae.

TABLE 12.—*Number and stage of development of larvae in broods of 13 oysters, and number of larvae in 2 groups of 6 broods each*

Oyster specimen no.	Length	Width	Number of larvae	Stage
	mm	*mm*		
121	32.7	23.5	130,628	Morulae.
125	30.3	24.0	113,142	Straight-hinge 160μ–170μ.
126	28.0	23.5	95,667	Do.
127	29.5	27.5	150,600	Morulae.
128	29.0	23.0	156,875	Do.
129	29.7	21.2	184,114	Late morulae.
130	31.0	25.8	355,500	Morulae.
131	23.5	19.2	69,490	Straight-hinge 160μ–170μ.
132	28.2	24.4	126,174	Do.
139	36.2	26.2	293,473	Early gastrulae.
140	29.2	27.0	213,781	Gastrulae.
141	28.5	23.3	136,666	Do.
142	36.8	26.2	171,818	Do.
Oyster Bay				
1	38.1	33.0		
2	40.6	30.5		
3	45.7	30.5		
4	38.1	30.5		
5	40.6	33.0		
6	45.7	35.5		
Average			283,273	
Mud Bay				
1	38.1	30.5		
2	38.1	30.5		
3	38.1	33.0		
4	38.1	25.4		
5	43.2	25.4		
6	35.5	27.9		
Average			247,199	

It has been observed that most specimens carrying larvae appear to have discharged almost all of the eggs from the gonad, for the meats are generally transparent and watery. This is in contrast to Galtsoff's (1930a) observation on *Ostrea virginica* that at a single spawning only a relatively small proportion of the eggs are discharged. The difference may be related to the fact that the native spawns alternately as male and female (Coe, 1931a, b).

Stafford (1914) stated that the presence both in the parent and in the bay of all swimming stages shows "that the young do not all swarm out from the brood chamber of the mother at the same time, age, or size, but filter out gradually, perhaps during the gaping condition of the shell while respiration is going on in the parent." In table 12 the stage of development of the larvae of 13 broods is given. In proportion to the size of the parent there does not appear to be a significant difference in the number of larvae per brood with respect to stage of development, although it is true that the largest broods consist of embryos. While this evidence neither confirms nor refutes Stafford's idea of the gradual release of the larvae, it is probable that many of the free-swimming larvae of small size found in plankton samples may be the result of abortions. Disturbing the parent oysters appears to cause them to discharge broods of "white larvae" or those which have not developed valves. In many cases oysters have been taken up from the beds and placed in dishes of clean running seawater in the laboratory, and those specimens bearing young larvae observed to discharge them by opening and closing the valves. That such abortions occur in nature is shown by statistical sampling of the oysters on certain beds.

RELATION OF TEMPERATURE TO SPAWNING

The development and discharge of germ cells are well known to be functions of the water temperature. As was shown in table 1 and figure 7 the average temperature of the water in southern Puget Sound begins to rise in early spring from the winter minimum of about 6° to 9° C., reaching a level of 18° to 20° C. in August. During the early months of spring the gonads begin active development and the stored nourishment of the bodies is used in the maturation of the eggs and sperms. The extensive researches of Stafford (1913), Churchill (1920), Gutsell (1924), Nelson (1928a, b, c), Prytherch (1929), Galtsoff (1930b, 1932), and others have demonstrated that there is a certain minimum, or critical temperature below which little or no spawning occurs. In *Ostrea virginica* this minimum is 20° C. for spawning by the female, although the male is able to spawn at a lower temperature. Galtsoff's observations are particularly significant, for he was able to show by laboratory experimentation that at a temperature of 20° C. or above, the sexually mature female may be induced to spawn by adding either sperms or sperm extract to the water. Below 20° C. sperms would not stimulate spawning. It is of importance to note that Galtsoff's work confirmed the conclusion of previous investigators based upon ecological observations. In the same manner he was able to induce spawning in the Japanese oyster, *O. gigas*, by addition of sperms when the temperature was 25° C. or higher, although more recently Elsey (1933) wrote that spawning could be stimulated at 22° C.

Orton (1920) stated that the European oyster, *Ostrea edulis*, spawns when the water temperature reaches about 60° F. (15° to 16° C.). In *O. lurida* Coe (1931a) found specimens bearing larvae whenever the water temperature was as high as 16° C., while Hori (1933) set the minimum at 14° and the maximum at 20° C. The exactness of such observations is not always clear, however, for it is questionable whether the temperatures given are actually averages or merely approximations, and maxima and minima are not stated.

Prytherch (1929), in his thorough study of various phases of the spawning and setting behavior of *Ostrea virginica* near Milford, Conn., concluded that spawning begins when the temperature at high tide reaches 20° C. He considered that the lower pH (7.2) of the water at low tide, when the temperature was much higher, was the factor preventing spawning. At high tide, on the other hand, when the water reached about 20° C. and the pH was about 8.2 the oysters spawned. It is obvious that some factor in addition to temperature is necessary to stimulate spawning, and the suggestion that a high pH is required appears, from his results, to be well founded. Judging from these investigations, it is to be concluded that it is not the maximum temperature on any particular day which must be up to the critical level, but the minimum, or high-tide temperature.

It is clear, also, that the gonads must be at the required state of maturity before spawning will take place, regardless of temperature, for it was noted (Hopkins, 1931b) near Galveston, Tex., that the oysters were not ready to spawn during spring until the water temperature, after a rapid rise, reached about 25° C. At the same time, it has been well demonstrated that, with other factors favorable, spawning in *O. virginica* begins when the high-tide temperature reaches the critical minimum of 20° C. It is important to know what conditions of temperature influence *O. lurida* in this respect. (Hopkins, 1936.)

A thermograph was placed on a frame in Oyster Bay so that the sensitive bulb was at the level of the oysters in the dike below. The records, therefore, represent with a high degree of accuracy the conditions of temperature of the water surrounding the oysters. The variation in water temperature on the oyster grounds during winter and summer and at different stages of tide has been described in table 1 and figures 5 and 6.

Although he appeared to be uncertain of the specific factor involved in stimulating the beginning of spawning, Orton (1926) concluded that spawning of *O. edulis* takes place primarily during the full-moon tidal period. Prytherch's (1929) work indicated that the rise in water temperature, due to warming of the tide lands during the extreme low tides, was responsible for stimulating reproductive activity. He stated that in Milford Harbor, Conn., "the majority of the oysters spawned at the end of the July full-moon tidal period, when the water was brought to a favorable spawning temperature." Nelson (1928 a, b) concluded that there is a definite relationship between the rapidity of the rise in temperature after the high-tide temperature reaches 20° C. and the time required for the initiation of spawning in *O. virginica*. He found during several seasons that spawning started from 52 to 94 hours after the temperature of 20° was reached, depending upon the rapidity of the subsequent rise. His observation is in accord with Galtsoff's (1930b, 1932) experimental finding that a sharp rise in temperature will induce discharge of germ cells.

In the case of Olympia oysters, however, the grounds are diked and are all between low- and high-tide levels. The variation in salinity and pH at different stages of the tide is usually not very great (fig. 12) but the temperature is subject to wide fluctuations. When the tide is low the oysters are covered by only a few inches of water which quickly responds to weather conditions. During the day low tides in March, when the weather is favorable, the temperature may rise to 20° or 25° C., probably causing the maturation of eggs and sperms. Actual spawning does not usually begin until late in April or some time thereafter.

During each season oysters were opened systematically on representative grounds in both Oyster Bay and Mud Bay to determine when spawning started and the number of adults bearing larvae throughout the season. Sampling was begun well in advance of the spawning period and consisted in the opening of 100 oysters on each of the test beds, 2 or 3 times a week. When a gravid individual was found the larvae were placed in a vial and preserved with formalin for examination in the laboratory. The method is described in greater detail with reference to the rate of larval development, and it is necessary here only to state that graphs of the results were made showing the percentage of oysters bearing larvae throughout each season. From these results and the thermograph records it is possible to correlate spawning activity and water temperature.

Four graphs (figs. 15–18) are reproduced showing the percentage of gravid oysters on different days and the daily average and minimum temperature. Three of the figures refer to Oyster Bay, one to Mud Bay, but all agree with respect to the influence of temperature upon spawning. In 1932 (fig. 15) no specimens bearing larvae were found until May 17, when 12 out of 100 bore very young embryos. The temperature record shows a sudden rise at this time. For some days the average temperature had varied from 13° to 15° C., but the minimum, or high-tide temperature had been relatively stable. On the 16th the minimum temperature rose from about 12° to over 13° C., and was followed by the sudden onset of spawning. For several weeks afterward, while both minimum and average temperature steadily increased, spawning was quite prolific. On the same graph the daily range of tide is plotted to indicate possible correlation with tidal periods, as described by Orton (1926). This is discussed below.

149604—37——4

In Oyster Bay in 1933 (fig. 16) the graph has a somewhat different appearance because spawning was relatively light. On May 18, 2 percent of the oysters bore newly spawned eggs, though the minimum water temperature was only about 12° C. On the 24th or 25th, however, spawning started at a considerable rate and continued thereafter. At this time the minimum temperature was about 13° C. and the average about 14° C. It is remarkable that the few oysters which spawned early did not retain the larvae, for it may be noted on the graph that the first conchiferous larvae, of about 5 days development, were not found until the 31st. It is probable that a few oysters were able to discharge eggs but subsequent low temperature caused abortions. Though this record is not as clear as could be desired, it indicates definitely that the first successful spawning took place when the minimum temperature reached approximately 13° C.

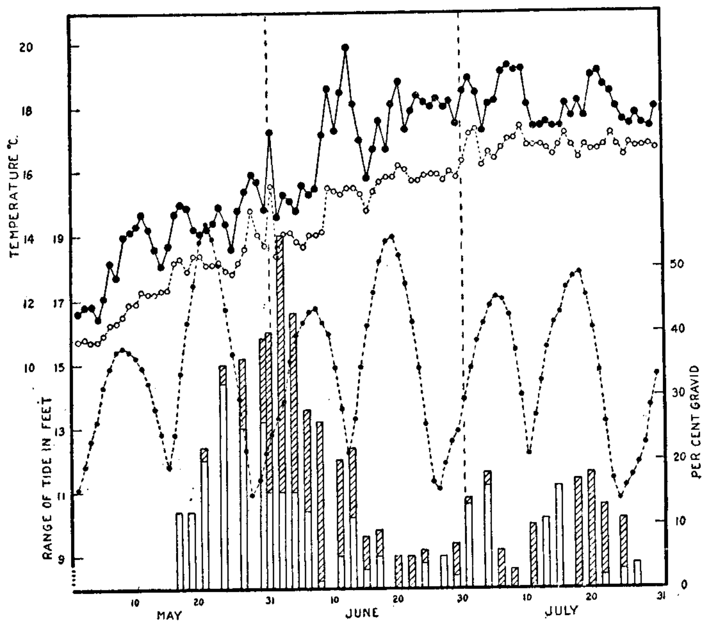

FIGURE 15.—Daily average and minimum temperature in Oyster Bay during summer of 1932 as related to the frequency of spawning and range of tide. Open portions of columns refer to white larvae or embryos, shaded portions to conchiferous larvae.

During the same year, in Mud Bay, the beginning of spawning may be more closely correlated with a rise in minimum temperature from about 12° to over 13° C. (see fig. 17). The average temperature, at the same time, was about 14° C. The spring rise in temperature in Mud Bay is characteristically late in comparison with Oyster Bay and the entire breeding season is therefore later. In 1935, in Oyster Bay (fig. 18), spawning started just after the minimum temperature reached a level of 13° C., although the average was between 15° and 16° C.

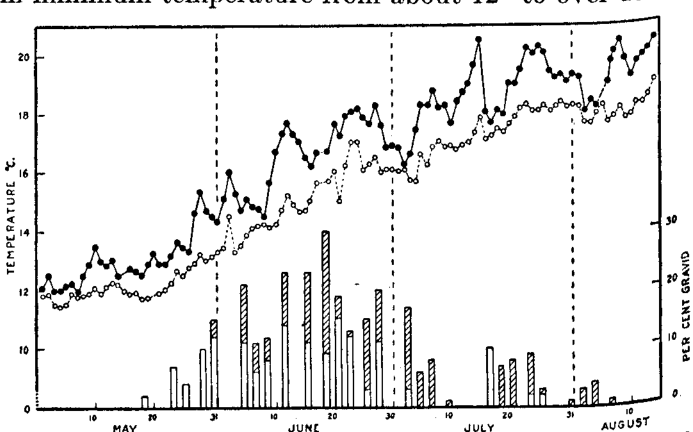

FIGURE 16.—Daily average and minimum temperature in Oyster Bay during summer of 1933 as related to frequency of spawning. Compare figures 15 and 18.

These four series are selected for reproduction because they represent the most complete data at hand referring to specific localities. It is certain that it is not the low-tide temperature which initiates spawning in spring, for on many days preceding the time of beginning of spawning the water in the dikes would warm to 20° or 25° C. and remain so for several hours. It may be noted that, in the four cases presented, the average temperature varied over a wide range at the critical time. The minimum temperature occurs commonly during the higher high tide and this shows a striking relationship to the onset of spawning. Prytherch's (1929) conclusion that the high-tide temperature must be adequate before spawning will begin appears to apply equally well to this species. Judging from these data, the critical temperature for spawning may be placed at about 13° C., possibly from 12.5° to 13° C.

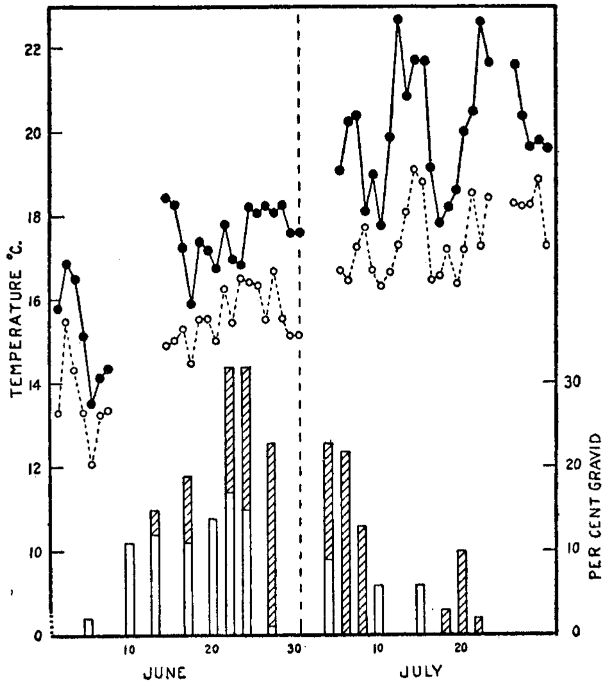

FIGURE 17.—Daily average and minimum temperature in Mud Bay during summer of 1933 as related to frequency of spawning. Compare figures 16 and 18.

It has frequently been noted that spawning is most likely to begin during or shortly after a period of neap tides. In spring and early summer, as shown in figure 15, at such times the minimum temperature is at a relatively high level. During a period of spring, or extreme tides, the tide flats warm in the sunshine and raise the temperature of the water coming in with the flood tides. The great range of tide in this place, 18 to 19 feet during a spring tide period, causes the colder water of the deep channels down the bays to reach the oyster grounds at high tide, while the warmer water is forced toward the head of the bay. During the neap tides a week later, however, the range may be only 11 or 12 feet, permitting the relatively warm water, resulting from the preceding low tide period, to remain over the oyster grounds. While the highest temperature is to be found in the dikes at low tide during a period of spring tides, the highest high-tide temperature may frequently occur in the neap-tide period, thereby inducing spawning.

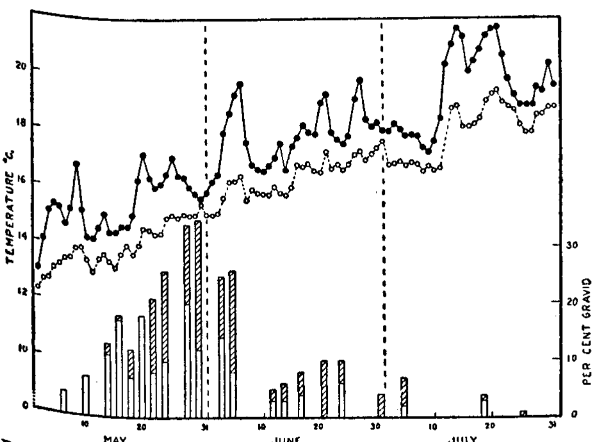

FIGURE 18.—Daily average and minimum temperature in Oyster Bay during summer of 1935 as related to frequency of spawning.

It is probable that this estimate of the critical temperature for spawning is not out of harmony with the results of Hori (1933) and Coe (1931a), who stated that the water temperature during spawning was at least 14° and 16°, respectively. Their measurements appear to refer either to the average temperature or to that indicated by more or less frequent readings. As shown above, the average temperature at the time of the initial spawning is generally 14° to 16°.

SPAWNING SEASON

The spawning period of the Olympia oyster appears to be quite different from that of *O. virginica* in Long Island Sound, as described by Prytherch (1929). In that place the oysters spawned prolifically on a particular day, when water conditions were favorable, so that the time of setting of the larvae could be exactly determined with reference to the time of discharge of the eggs. During several years, according to Prytherch, the first spawning was relatively light, and was followed about 2 weeks later, during the next period of spring tides when the water was warmer, by more general spawning.

The native oyster, as described by Stafford (1914), spawns during a period of about 2½ months. According to this author, in 1913, in British Columbia waters, spawning occurred from about May 20 until the end of July, with the maximum spawning activity at the middle of June. On the coast of southern California Coe (1931a–1932b) found that spawning in this species continues for a period of about 7 months of the year. In the same manner, *O. virginica* on the Gulf coast spawns during many months (Hopkins, 1931b).

TABLE 13.—*Percentage of oysters bearing larvae in Oyster Bay*

Date	Number opened	Number gravid	Number not gravid	Percent gravid	Date	Number opened	Number gravid	Number not gravid	Percent gravid
1931					1931				
May 25	15	7	8	47	July 2	30	4	26	13
May 27	15	6	9	40	July 8	37	3	34	8
May 29	10	2	8	20	July 9	64	3	61	5
June 12	27	4	23	15	July 10	28	3	25	11
June 19	34	8	26	24	July 15	53	0	53	0
June 21	20	3	17	15	July 24	30	0	30	0
June 22	11	1	10	9	July 27	21	3	18	14
June 27	29	2	27	7	Aug. 8	20	0	20	0

TABLE 14.—*Percentage of adult oysters bearing embryos (E) and conchiferous larvae (C) in dikes 5 and S (Oyster Bay) and dike B (Mud Bay) during 1932*

Date	Dike 5		Dike S		Dike B		Date	Dike 5		Dike S		Dike B	
	E	C	E	C	E	C		E	C	E	C	E	C
May 17	12						July 1	13	1	4	6		1
19	12						2					5	
21	20	3					4	13	4	8	4		5
24	32	3					5						
27	25	11					6		6		10		
30	26	13					8		3	6	12		2
31	15	25					9					9	
June 2	15	40					11		10		8		1
3					14	[2] 13	12					6	
4	15	28					13	11			8		10
6	12	16					14						
8	1	25					15	16			6		5
10					7	30	16						
11	5	15					18	17		4	8		7
13	11	12	4	[1] 12			19						
14					7	19	20		18	4			2
15	3	5	2	8			21					5	
16					2	11	22	2	11		4		
17	5	4		4			25	3	8	4	6		6
18					4	10	26						
20		5	12	4			27		4		6		8
21						5	28						6
22		5					30						
23					5	4	Aug. 1				2		10
24	4	2	4	2			2						
27		5		12			4					1	
28						5	5		1	4			
29	2	5					8	2					
							31		1				

[1] No oysters opened before June 13.
[2] No oysters opened before June 3.

TABLE 15.—*Percentage of adult oysters bearing embryos (E) and conchiferous larvae (C) in dikes 5 and S (Oyster Bay) and dike B (Mud Bay)*

Date	Dike 5		Dike S		Dike B		Date	Dike 5		Dike S		Dike B	
	E	C	E	C	E	C		E	C	E	C	E	C
1933							1933						
May 19	2						June 27					1	22
24	7		6				28	11	9	2	12		
26	4		6				July 3	3	14		12		
29	10		10	2			4					9	14
31	10	4	10	8			5		6		4		
June 5	10	11	22	6			6						22
6					2		7		8	4	6		
7	6	4	8	14			8						13
9	8	4	4	20			10		1	2	4	6	
10					11		15					6	
12	14	10	4	22			17	10			4		
13					12	3	18						3
16	11	13					19			6			
17					11	8	20						10
19	9	21		32			21		8	12			
20						14	22						2
21	15	4	8	20			24	2	7		6		
22					17	15	26	2	1	2			
23	12	1		20			31		1				
24					15	17	Aug. 2		3		4		9
26	3	12		10									

TABLE 16.—*Percentage of adult oysters bearing embryos (E) and conchiferous larvae (C) in dikes 5 and T (Oyster Bay) and dike B (Mud Bay) during 1934*

Date	Dike 5		Dike T		Dike B		Date	Dike 5		Dike T		Dike B	
	E	C	E	C	E	C		E	C	E	C	E	C
Apr. 19			7				June 1	5	6	6	2		
27			6	5			7					3	8
28					3	[2] 1	8		6		4		
May 1					8	7	9						8
2	14	[1] 20	19	6			11	1	2		5		
9					18	3	12					3	6
10	2	17	9	17			13		3	5	1		
11			16	29			14					3	8
12					10	3	15	9	1		7		
14	9	18	13	18			16					6	
17					14	15	22		2		4		
18	10	23	5	18			25	1	6		3		
19					11	24	29		4	4	2		
25	1	10	1	20			July 6				1		
26						18	9		1	4	3		
28		6	7	9			10					3	
29					1	17	13	1	1		2		
30		7	4	6			21						1
31						15	25			1			

[1] No oysters opened until May 2.

[2] No oysters opened until Apr. 28.

TABLE 17.—*Percentage of adult oysters bearing embryos (E) and conchiferous larvae (C) in dikes 5 and T (Oyster Bay) and dike A (Mud Bay) during 1935*

Date	Dike 5		Dike T		Dike A		Date	Dike 5		Dike T		Dike A	
	E	C	E	C	E	C		E	C	E	C	E	C
May 6	4						June 1					14	12
10	7						3	14	11	27	21		
14	11	2					4					1	24
15					8		5	8	14	11	22		
16	17	1	[1] 4				6					8	14
17					12		12	3	2			1	[2] 18
18	7	5	4				14	3	3				
20	18		10	1			17	4	4	4	3		
21					18	10	21		10				
22	8	13	6	8			24	6	4	3	4		
24	10	16	10	6			July 1		4	3	2		
28	20	14					5	2	5	7	2		
29					17	24	19	3	1				
30	12	23	10	26			26			1			

[1] No oysters opened until May 16.

[2] Sampling discontinued.

TABLE 18.—*Number of spat caught on plane glass surfaces as determined by the angle of the surfaces: 0°, under horizontal; 90°, vertical; 180°, upper horizontal*

Angle of surface	Area square inches	Number of spat	Average number of spat per 2,400 square inches
0°	2,400	1,195	1,195
[1]45°	1,200	42	181
[2]45°	1,200	139	
[1]90°	2,400	6	11
[2]90°	2,400	16	
[1]135°	1,200	1	3
[2]135°	1,200	2	
180°	2,400	1	1

[1] Perpendicular. [2] Parallel to general direction of current.

A correct estimate of spawning activity of functional females was obtained by opening 100 adults two or three times weekly throughout the season on selected typical beds. This mode of sampling has been carried on in two bays during 4 consecutive years. In 1931, the work was not begun in time to permit exact determination of the entire duration of the spawning season, but in table 13 the results of miscellaneous samples are given for comparison with later years. The table indicates, however, that after the end of May the proportion of adults bearing larvae became continuously less, until in July and August gravid specimens were only occasionally found.

More complete data were obtained during the years 1932 to 1935 in both Oyster Bay and Mud Bay. Tables 14 to 17 summarize the results. In Oyster Bay two grounds were employed for sampling, one well up the bay, the other some distance below, or one high ground (dike 5) and one low ground (dike T). In Mud Bay samples were taken from dike B, a ground which is closely similar in all respects to most of those in the bay. The oysters were opened at the beds to eliminate the possibility of confusion due to the occurrence of spawning or abortion during transportation. In the tables the gravid specimens are divided into two groups, according to whether they bear unshelled embryos (E) or conchiferous larvae (C), in order to indicate more exactly the rate of spawning. While the complete data are given in the tables, a more significant picture of spawning activity may be obtained from figures 15 to 18, in which the percentage of gravid specimens on each day is shown as a column, the shaded portion of which represents conchiferous larvae, the open portion the embryos up through the trochophore stage. The tables and figures are not quite complete in that they do not include the very occasional gravid specimens that may be found as late as October, but these are too few to warrant any attention.

In the tables it may be noted that the time when spawning begins varies over a period of about a month, depending upon climatic conditions which control the temperature of the water. While, in Oyster Bay, the first oysters bearing larvae were found at about the middle of May in 1932 and 1933, in 1934 spawning started a full month earlier. In Mud Bay the oysters generally start spawning some time later than in Oyster Bay, even early in June during some years.

Spawning goes on at a significant rate for a period of about 6 weeks, although larvae may be found in some adults for as long as 5 or 6 months. The reproductory activity is best shown in figures 15 to 18, which indicate that after it once begins, the frequency of spawning slowly increases to a maximum, then gradually diminishes until gravid individuals are found only occasionally. During most years, the rate of spawning may be represented with fair accuracy by a simple symmetrical distribution curve, though sometimes (fig. 15) there is a later, secondary wave of spawning. In 1932, in Oyster Bay this later spawning was considerable, though not as important as the original activity early in the season. In other years it was not apparent that there was any definite renewed spawning activity.

In his work on *O. edulis*, Moebius (1883) said that as many as 20.6 percent of the adults bore larvae at once, and estimated from frequent observations, that at least 44 percent of the oysters produced broods during the season. Stafford's (1914) results indicate a comparable proportion bearing larvae at the same time, though he did not estimate the proportion of the population which produced broods. The data obtained during the sampling described above provide a means of estimating with some degree of certainty the total spawning activity throughout several seasons.

Because of the frequency of the samples, it is possible to analyze the rate of development of the larvae, as is described below, and to detect the relative number of oysters bearing newly spawned eggs. From this one may reach an estimate of the total number of adults which bear broods. In 1932, as shown in table 14 and figure 15, the oysters spawned prolifically in Oyster Bay. At one time as many as 55 out of 100 carried broods. By referring each age group back to the date of spawning and then determining the total percentage of individuals spawning during the season it was possible to demonstrate that at least 1.5 broods per oyster were produced. That is, apparently all of the individuals bore one brood and at least half were gravid for the second time.

In 1933, however, at the same place only about 75 percent of the individuals became gravid (fig. 16). During most years it appears that approximately 100 percent of the adults bear larvae, but only in 1932 was much greater spawning activity noted. Judging from all data available, it is probable that the variation in number of broods produced during different seasons is between about 75 and 150 per 100 adult oysters. In addition, the specimens would also spawn as males, as described by Coe (1931a, b). A source of error in such estimates is the possibility of abortions of young embryos which would, therefore, not be counted. It would be difficult to determine how frequently abortion of a brood occurs, but it is clear that it sometimes happens.

DEVELOPMENT OF LARVAE

Although Stafford (1914) reached the conclusion that the larvae develop normally for a period of 16½ days within the maternal brood chamber it is probable that the method he employed was unsatisfactory. He would periodically pry the valves of a gravid specimen partly open and take a sample of the larvae. Such handling of the specimen might readily result in a disturbance of normal function and interfere with larval development. A strictly biological method, therefore, would not appear to be adequate to solve the problems related to rate of development under natural conditions.

It was necessary to use a system of sampling the oyster population and determining at frequent intervals the stage of development of larvae in the various broods. On each of two typical grounds in Oyster Bay 100 adults were opened 3 times weekly. Larvae from gravid specimens were separately preserved in vials for later laboratory examination to determine their size or stage of development. By taking samples at frequent intervals throughout the season it was possible to organize the results so that gravid specimens bearing broods of the same stage of development could be grouped and followed through the various stages. If on 1 day 10 percent of the oysters bore newly spawned eggs, 2 days later about the same number would be found with embryos of a certain stage. In subsequent samples the group would continue to recur until the larvae reached the size at which they are discharged. A single brood was found to consist of larvae of approximately the same stage, within relatively narrow limits. In no case were larvae of widely different stages found in a brood, and it may be concluded that an individual seldom, if ever, spawns as a female while carrying a brood of larvae.

Records of the larvae taken in such collections were arranged in tabular form (fig. 19) to show the percentage of adults bearing larvae of different stages of development. By connecting the values from date to date and stage to stage, the age of each group is made clear. Division of the developmental process into 10 stages is largely arbitrary but at the same time convenient. While the embryonic stages, up through the trochophore, are well defined, the only significant difference between straight-hinge larvae of different ages is in size. Measurements with an ocular micrometer were made of the larvae in each sample and while there is necessarily some uncertainty as to exact size, because of the variation among the larvae themselves, this is not great enough to be confusing.

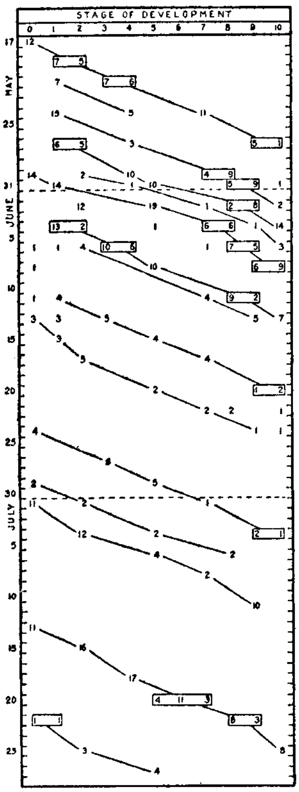

FIGURE 19.—Graph showing percentage of adult oysters bearing broods of larvae of each of 10 stages, as follows: 0, eggs, or early segmentation; 1, blastulae; 2, gastrulae; 3, trochophores; 4, first conchiferous larvae with incomplete valves; 5 to 10, straight μ-hinge veliger larvae classified according to approximate length of valves: 5, 110–120μ; 6, 120–130μ; 7, 130–140μ; 8, 140–155μ; 9, 155–170μ; 10, 170–185μ. The percentage values of larvae of definite size groups are connected to indicate rate of development. See text.

The example reproduced (fig. 19) is only one of many which are at hand but there is little difference between them. In the first place it will be noted that a total period of 9 to 11 days is required for development from eggs to the largest straight-hinge larvae. The general embryology has been well described by Stafford (1914) and is essentially the same as in *O. virginica*, so that it is not necessary to describe it here. To illustrate some of the important stages there is reproduced in figure 20 a series of drawings from Hori (1933), an original copy of which Professor Hori kindly prepared for the writer. The figures are drawn accurately to scale so that they may be employed for the identification of larvae of the species.

When they are discharged from the gonad the eggs are 100 to 105μ in diameter, as stated by Stafford (1914) and Hori (1933). Development proceeds much more slowly than in the case of oviparous species. On the day after the eggs are discharged into the brood chamber they have become blastulae. At the age of 2 days they are usually in the gastrula stage, and 1 day later they have developed the swimming organ, or prototroch, and are actively swimming trochopore larvae. Usually on the fourth day the small valves may be seen developing on the dorso-lateral surfaces as a pair of clearly defined structures about 30 to 40μ long. This may be called the first conchiferous stage, and in figures 15 to 18 they are considered as such and included in the shaded portions of the columns. On the fifth day the valves have become complete and enclose the larvae entirely except when they are swimming with the velum protruding. In *O. virginica*, as stated by Stafford (1913), "The age at which swimming begins may be considered to be about 5 hours, reckoned from fertilization * * *." As indicated above, the early embryology proceeds much more slowly in the viviparous *O. lurida*, requiring between 3 and 4 days to reach the swimming stage.

Larvae carried in the brood chamber are commonly spoken of as being either white or black. The expressions, "white-sick" and "black-sick" are frequently used in this respect. It is true, in general, that the young embryos show as pure white in the branchial chamber adjacent to the gills, and that older larvae in the well-advanced straight-hinge stage appear as a dark-gray or bluish-black mass. Yet one may not judge accurately the stage of development by estimating the depth of color. The

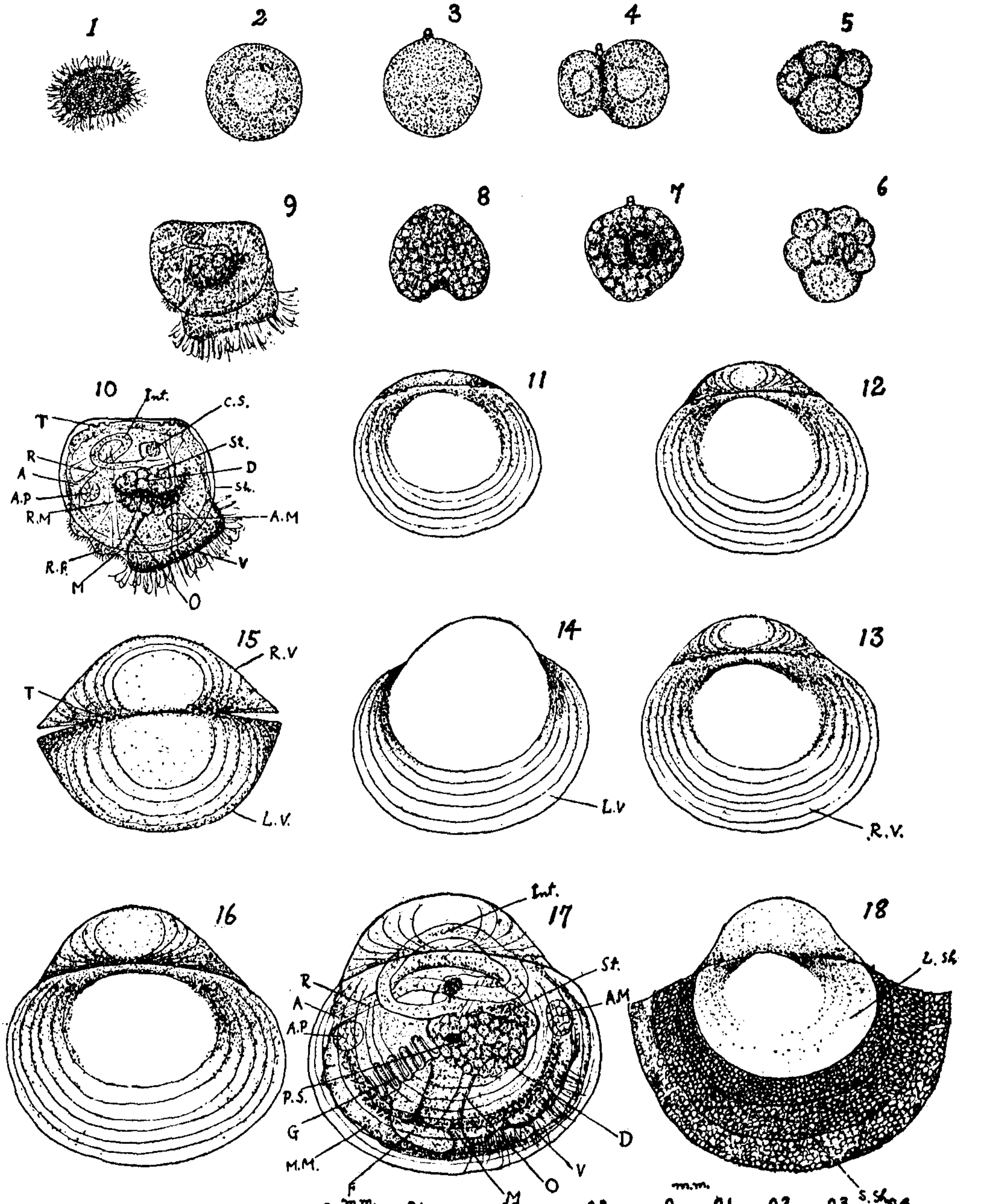

FIGURE 20.—Developmental stages of larvae of *Ostrea lurida*. From Hori (1933). 1, sperm ball; 2, ovum; 3, ovum with polar body; 4, first cell division; 5, second cell division; 6, morula; 7, blastula; 8, gastrula; 9, early straight-hinge veliger; 10, veliger larva at time of discharge from brood chamber; 10–15, shells of free-swimming larvae of various sizes; 16, full grown larva of setting size; 17, young spat with growth of new shell. A, anus; A. M., anterior adductor muscle; A. P., posterior adductor muscle; C. S., crystalline style; D, digestive diverticula; F, foot; G, gill; Int., intestine; L. sh., larval shell; L. V., left valve; M, mouth; O, oesophagus; P. S., pigment spot; R, rectum; R. F., rudiment of foot; R. M., retractor muscle; R. V., right valve; Sh., shell; S. Sh., spat shell; St., stomach; T, teeth; V, velum.

149604—37——5

pure whiteness of the eggs and young embryos slowly changes toward the gray after development of the valves. As the larvae grow older the mass becomes darker and darker, while the valves develop and pigment forms in the tissues. Frequently the largest larvae appear as black with a somewhat bluish tint, but it often happens that larvae of the largest size ever found in the brood chamber are only a medium gray.

After 5 days of development in the brood chamber the larval valves become complete and the larvae are in the straight-hinge stage, so called because the dorsal border of the valves is straight, in contrast with the later pronounced umbo in the hinge region. The further developmental stages are arbitrarily arranged according to length of the larval valves, as measured under the microscope.

These results appear not to be out of harmony with those of Stafford (1914) save that in the present case development is somewhat more rapid. His estimate of a period as long as 16½ days may be correct for the locality in which he worked, or it may be due to his method of analysis. His data on water temperature, though incomplete, appear not to differ greatly from those taken in the present instance. Coe's (1931a) estimate of a period of about 10 to 12 days required for development within the branchial chamber is more in accord with the records described above, which indicate a period of about 10 days, on the average.

In his work on *O. edulis* Orton (1926) estimated the gestation period, and stated (p. 219):

> An analysis of the spawning oysters into those with young embyros and those with mainly shelled larvae brings out the fact statistically that oyster larvae under natural conditions are retained in the mantle cavity a period of only 1 to 1½ weeks from the date of their extrusion as fertilized eggs from the parent.

In a later paper (1936) he wrote:

> The white-sick stage is thus normally of about 3 to 3½ days duration, the grey-shelled stage about 1½ to 2 days or less, and the black-sick stage of variable duration, probably 4 days or less. It seems probable that the oyster larva becomes fully developed normally in the sea in a period of 6 or 7 days and is expelled at an age between 7 and 10 days.

Apparently his samples were not taken with sufficient frequency to permit analysis in the manner described above. Nevertheless it is probable that the period of larval development within the maternal brood chambers is not greatly different in the two species.

Stafford used the word "swarming" to designate the final release of larvae from the maternal brood chamber, in contrast to the original spawning whereby the eggs are released from the gonad. It may be considered, in viviparous species, that swarming is the delayed completion of the spawning process which in oviparous oysters, as described by Nelson (1928c) and Galtsoff (1930b–1932), is accomplished at once by means of rhythmic contractions of the adductor muscle. Whether discharge of the larvae is accomplished in the same manner is not known, but it has been observed that during abortions the embryos are forcibly ejected by means of shell movements.

After discharge the larvae live and grow as free-swimming organisms for a period of approximately 1 month. The largest larvae found in the brood chambers are 180 to 185μ long, as described by Stafford (1914) and Hori (1933). The smallest straight-hinge larvae, 5 days after fertilization of the eggs, are about 110 to 120μ long. Growth in length of the valves within the brood chamber proceeds at a rate of about 12μ per day. At the time of setting the larvae are almost constant in size, of a length very close to 320μ. As is described in the following section, at least 30 days elapse between the time of discharge of the first larvae and the time when the first spat are found. During this period the larvae grow in length from 180μ to 320μ, or an average rate of about 5μ per day.

Quantitative observations were not made on the abundance of larvae in the water, though plankton samples were frequently taken. In the case of this species it is not necessary to estimate the frequency and intensity of spawning from the age and abundance of larvae in the plankton, for this was more readily and accurately accomplished by opening oysters periodically, as has already been described. Correlation between time of spawning and setting is considered below.

Stafford (1914) wrote that the largest larvae found in plankton samples, and the smallest spat found on shells soon after attachment, had a length of 255μ. Hori (1933), in a series of experiments on the artificial propagation of the species, stated that the length of newly-set spat is 320μ. He worked with oysters imported into Japan from Puget Sound, and was able to grow the larvae to maturity in dishes by feeding them ground sea lettuce (*Ulva*). Setting under the artificial conditions was successfully accomplished and his measurements of the spat are identical with those of the writer. A great many spat have been measured during these experiments and in no case has an attached spat been seen which was significantly less than 320μ long. It is of interest also that Stafford's (1913) measurements of larvae of *O. virginica* at setting size are different from those of other observers. While he stated that newly-set spat are 380μ long, Prytherch (1934) measured them as 330μ "across the shell at its greatest diameter."

Whether these differences are due to error in measurement or to actual differences in the size of the setting larvae may not be determined from Stafford's works. It is certainly not impossible that under other environmental conditions the larvae of *O. lurida* may be ready to attach at a smaller size. Stafford's (1914) figures of older larvae and of newly-set spat do not show the umbo of the left valve to be as prominent as those of Hori (1933), which are in exact accord with observations of the writer. It is a possibility, also, that differentiation may proceed, under some circumstances, more rapidly than growth, with the result that the organs of the larvae reach the stage of maturity at a size smaller than that observed during the present work. There is, in addition, the possibility that the oysters studied by Stafford are of a distinct variety, having different characteristics from those of the Olympia oyster, though such is hardly likely. However, the fact remains that the measurements of Hori and the writer agree perfectly for both larvae and spat. Stafford's measurements are exactly the same only up to the time of swarming.

SETTING

As was described in the preceding section, spawning is a long-continued process, and not as in some places an occurrence confined to a period of a day or two. It would therefore be expected that setting of larvae would also continue during a considerable period of time. It is important to know the frequency of attachment of larvae throughout the season and the relation of this to the rate of spawning.

However, before describing the methods employed to analyze the results of setting during the different seasons it is necessary to consider the matter of cultch. Various questions have frequently arisen as to what constitutes the most favorable cultch and why oyster larvae attach as they do to certain surfaces. This phase of the investigation is of importance in throwing light upon the results described later.

EFFECT OF ANGLE OF SURFACE

Practical oyster growers have often noticed that most of the spat are to be found on the under surfaces of shells or other objects in the water. The question therefore arose as to whether this was due to some specific reaction of the mature larvae or merely to the fact that sedimentation and growth of algae and other organisms on the upper surfaces ordinarily prevent attachment of larvae. The opinion is frequently encountered that larvae seek the shadows and migrate to the relatively dark under surfaces. In order to determine, in the first place, whether larvae actually attach more abundantly to lower surfaces even when upper surfaces are equally clean an experiment was performed which provided various angles for comparison. Some of these results have already been published (Hopkins, 1935).

Wire frames were made of galvanized hardware cloth of ½-inch mesh, each frame holding three 8- by 10-inch panes of clear glass 1 inch apart and parallel. Some of the frames were designed to hold the panes in either a vertical or a horizontal position, others were so constructed that the panes were held at an angle of 45°. Thirty plates were used in each of the three positions, horizontal, vertical, and at the 45° angle. These were placed in the water of a dike at low tide on one day and removed the following day when the dike was exposed. They were in the water only 24½ hours and may be considered as all equally clean since the time was too short for any considerable amount of fouling. Half of the vertical and 45° plates were placed perpendicular to the general direction of tidal flow, the other half parallel, in order to indicate the effect of current.

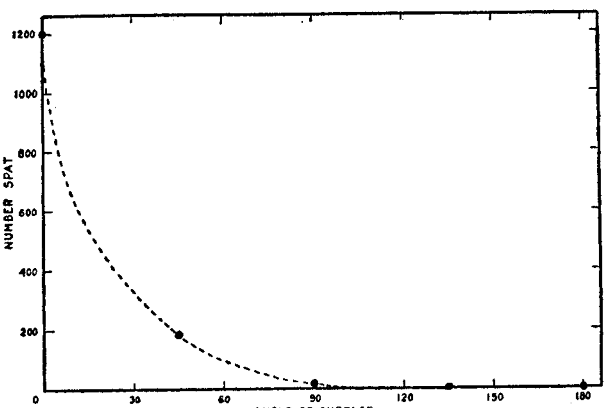

FIGURE 21.—Number of spat caught per 2,400 square inches of glass surface at different angles: 0°, under horizontal; 180°, upper horizontal; 90°, vertical.

After removal from the water the plates were allowed to dry, removed from the frames, and the number of spat caught on all surfaces carefully counted with a binocular microscope. In the analysis of the results the different angles are referred to as follows: 0°, under horizontal; 180°, upper horizontal; 45°, under, and 135°, upper, surfaces of the 45° panes; and 90°, vertical. In table 18 the results are presented in detail. The effect of the angle of the surface on its efficiency as a collector of spat is further illustrated in figure 21, in which the average values in table 18 are plotted graphically. The correlation between angle and number of spat caught is remarkably close, when it is considered that in each case, except for the vertical plates, the area of surface was only 2,400 square inches.

It may be noted in the table that the panes which were parallel to the direction of flow of tide caught definitely more spat than those perpendicular to the current. This would appear to indicate that setting may be proportional to the rate of current. Prytherch (1929) noted that larvae of *Ostrea virginica* set most abundantly on the leeward side of objects in the water, where the current is reduced to a minimum, and concluded that the heaviest setting takes place when the current is least. The above results suggest that the larvae of the native oyster react differently.

The values represented in the graph (fig. 21) are the totals, including plates which were both perpendicular and parallel to the current. It might possibly be a more exact picture of setting behavior if only the results obtained with the parallel series were plotted. However, to do so would hardly alter the curve, since the difference in efficiency of the various angles is tremendously greater than that between plates of the same angle but in different positions with reference to tide. Also, in its present form, the curve is more typical of natural conditions, considered from an ecological point of view.

The results of these experiments have an obvious practical application, for they point out the desirability of furnishing cultch which has a large amount of the ideal under horizontal surface. It is also of practical importance to know that the more freely the current flows along the surfaces the more spat will be caught, presumably because more water, bearing larvae, comes into contact with the surfaces. A comparison of the efficiency of two types of manufactured spat collectors serves to illustrate well the commercial application of the results described above.

Prytherch, in 1929, used the egg crate filler, coated thinly with concrete, as a collector of seed oysters on the Atlantic coast. (See Bureau of Fisheries Document 1076, Improved Methods for the Collection of Seed Oysters.) These fillers, made of cardboard, provide a large amount of surface for the attachment of larvae, and the rough concrete surface is particularly favorable for setting. Such spat collectors are spread on the seed grounds at the correct time and have proven to be highly effective. The method is in use on some of the Olympia oyster beds where the fillers remain covered at low tide because of the dikes (see fig. 2).

However, the experiments described above show that the best surface for the catching of spat of the Olympia oyster is the under-horizontal, and the egg crate filler lies on the bed with all partitions in the vertical position. Also, the filler, lying on the oyster ground, does not permit the free flow of water over the surfaces and the individual cells contain relatively still water, frequently resulting in their filling with silt. In order to develop an efficient collector for Olympia oysters it was, therefore, necessary to design a modification of the egg crate filler which would provide a large amount of under-horizontal surface and also permit the water to flow freely over all the surfaces.

This special collector was made like the egg crate filler, but the individual partitions are twice as wide, and consists of two rows of six cells each. The cells are 2 inches square by 4 inches long (see fig. 22). It lies naturally on the ground in a position which is at an angle of 90° to that of the egg crate filler. Both vertical and horizontal surfaces are present, and the water flows freely through the cells. As they are now used they consist of two rows of seven cells, making the total area almost the same as that of the egg crate filler, but the counts of spat which were made for comparison refer to the original type.

TABLE 19.—*Comparison of efficiency of 2 types of manufactured spat collectors*

	Number of spat per 1,000 cm^2			Total area (cm^2)	Total number of spat	Average number of spat per 1,000 cm^2
	Under-horizontal	Vertical	Upper-horizontal			
Egg crate filler	----------	427	----------	4,724	2,064	427
Special collector	3,235	1,066	28	3,464	4,775	1,378

Table 19 gives the results of counts of spat caught on egg crate fillers and special collectors which were put on the same grounds at the same time and removed together 3 months later. Each series is the average obtained by analysis of three collectors.

The table shows that the average number of spat caught on 1,000 square centimeters of the egg crate filler is 427, while on the special collector the average is 1,378. This value refers to all surfaces, which in the egg crate filler are vertical, and in the special collector both vertical and horizontal. It was conclusively demonstrated that the special design is more than three times as effective as the standard filler.

It is to be expected that the difference between the numbers of spat caught on horizontal and vertical surfaces would not be as great for concrete-coated paper as for plane glass, as described above, since the roughness of the concrete provides a large amount of surface which may be at all angles. The vertical concrete wall has a large horizontal component in the projecting grains of sand which are large in proportion to the oyster larvae. Therefore, the values in table 19 do not exactly fit the curve obtained with plane glass (fig. 21), but the points fall along a more gently sloping curve. The significance of the observation cited above, that flow of water along surfaces is necessary for most efficient setting, is well demonstrated by the difference between the numbers of spat caught per 1,000 square centimeters of vertical surface on the two types of collectors. The special collector is about two and one-half times as effective, considering only the vertical walls.

On most grounds egg crate fillers collect large quantities of silt which fills the cells and kills the spat. Frequently only those caught on the upper edges survive. In the case of the special collector, however, the water is able to flow through the cells and prevent deposition of silt. Even on soft ground only the bottom layer suffers a loss as the collector settles into the surface. Such an example is shown in the upper photograph of figure 22, while the lower surface of a collector placed on firm ground shows little mortality.

It would appear that the habit of attaching primarily to an under surface has the function of protecting the delicate young spat from various unfavorable conditions, such as hot sunshine, and deposition of silt. Immediately suggested by the results is the possibility that the larvae are photosensitive and react negatively, causing them to collect in the shadows where they set. Such a view would imply that setting takes place almost entirely during the day, and that at night the larvae would not concentrate on under surfaces.

To determine whether light is a factor in the setting behavior of larvae, two sets of wire frames, each containing 15 glass plates, were placed on an oyster ground so that the plates were horizontal and allowed to remain for about 24 hours. The plates of one set were painted black on the upper surfaces, the others left clear. Both surfaces of each pane of glass were carefully examined with a binocular miscroscope and all spat counted. On the lower surfaces of the black glass 435 spat had caught, while on similar surfaces of the clear glass 616 were counted. Not one was found on the upper surfaces of either group. It is not considered significant that the clear glass caught more spat than the black, but it is important that the shadow under the latter did not result in any increase in the catch.

In other expèriments, which are described in a later section, it was demonstrated that larvae set as well at night as during the day, and that in all cases the lower surfaces of horizontal panes receive almost all of the spat. It is therefore obvious that light is not an orienting factor in the setting behavior of larvae of this species. The pigment spots of mature larvae have often been looked upon as possibly sensitive to light, but Prytherch (1934) concluded that larvae are not photosensitive, and that the pigment spots have an entirely different function. The present results confirm his conclusion.

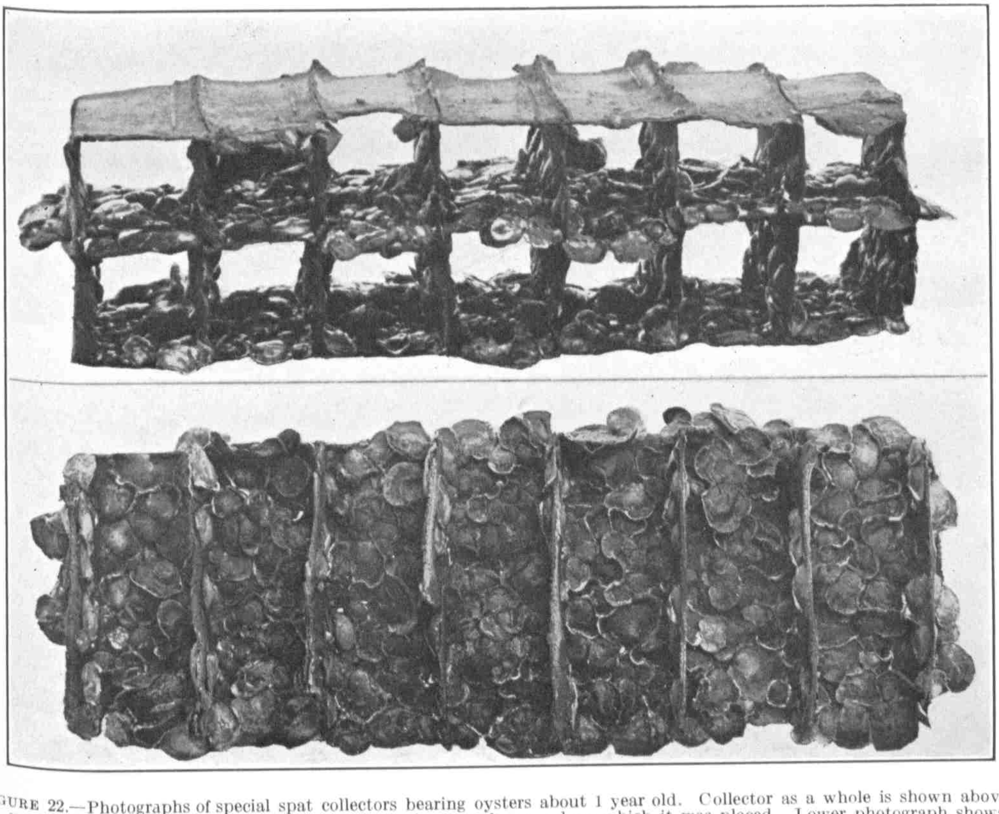

FIGURE 22.—Photographs of special spat collectors bearing oysters about 1 year old. Collector as a whole is shown above in upside-down position. Lack of spat on bottom due to soft ground on which it was placed. Lower photograph shows an under horizontal surface. Total length about 12 inches.

The graph (fig. 21) suggests that the effect of angle of surface on the number of spat caught is purely mechanical and not due to any definitely biological reactions of the larvae. Hori (1933) stated that swimming larvae commonly are in an inverted position, with the velum uppermost. This has been observed also by the writer and is well illustrated in Prytherch's (1934) work on larvae of *Ostrea virginica*. The velum projects through the valves as a flattened, ciliated swimming organ, while the heavier shell hangs downward. The foot with which the larvae must adhere is beside the velum and projects more or less upward, although it is extensible in all directions. It is most likely that the swimming larva, as it comes into contact with a surface from below, is able to hold on with the foot, while on coming down upon a surface it is the hinge portion of the shell that touches. In this manner, as the angle of the surface departs more and more from the under horizontal there is constantly less chance of the foot touching. This interpretation, in effect, is that the observed results are due to accidental contact of the foot with the surface as the larvae is swimming and being washed about by tidal currents. Prytherch's descriptions of setting, as directly observed with the microscope, suggest that larvae of *O. virginica* may react differently in this respect.

If the above-described interpretation is correct it would be expected that in places where the water is highly turbulent the larvae would frequently be turned over so that they might also catch on upper surfaces. It has frequently been observed on oyster grounds near Olympia, in places where the water flows over dikes, that the rocks and shells close to the dikes bear spat also on upper surfaces.

METHOD OF DETERMINING FREQUENCY OF SETTING

It is of considerable importance to know the duration of the setting season and the times when maxima are reached. For this purpose it was necessary to plant cultch periodically during the entire season. The system finally adopted, after the first year, was to plant a wire bag of shells on each experimental ground and allow it to remain for 7 days. It was then removed and brought to the laboratory. As one bag was taken from the ground a new one was planted and allowed to remain for the following 7 days. It was found necessary, however, to carry on at each place two such 7-day series so that one overlapped the other. In one series, for example, the bags would be in the water from Monday until the following Monday; in the other series, from Friday until the next Friday. A clean lot of shells was therefore put into the water every 3 or 4 days.

After being brought from the grounds the shells were allowed to dry and counts made of the number of spat caught. Bags were made of 1-inch mesh galvanized wire netting and were about 30 inches long by about 8 inches in diameter. Each held something over three-quarters of a bushel of Japanese oyster shells. These shells were preferable because of their large size, generally 4 to 6 inches long, and the white color of the inside surfaces. In the bags the shells were held at all possible angles, eliminating any error that might be traceable to the angle of the surfaces.

Counts were made only of the spat on the inside surfaces, because of their color and smoothness and because the outside surfaces are too rough, and often lamellate, so that all spat are not readily seen. This is not difficult to understand when it is realized that the shells were in the water only 7 days and the oldest spat a millimeter or less in diameter. Two bags of shells were left in the water for a month and a half to allow the spat to grow to a large enough size to permit accurate counts of the number on inside and outside surfaces. The results are summarized in table 20. In one case 33 percent were on inside surfaces, and in the other, 36.1 percent. The larger number on the outside surfaces is probably due to roughness as well as to greater area. The two series average 34.6 percent inside and 65.4 percent outside. In calculating the number of spat caught in a bag the counts made on inside surfaces are considered as 35 percent of the total. This proportion would not be correct if the shells were spread directly upon the grounds, for most of them, because of curvature, fall with the outer surfaces down.

TABLE 20.—*Number of spat caught on inside and outside surfaces of shells in wire bags*

Bag no.	Date planted	Date removed	Number of spat on inside surfaces (25 shells)	Number of spat on outside surfaces (25 shells)
Dike 1				
2810	June 16	July 30	237	352
			163	268
			85	260
			100	287
			66	200
			127	196
			80	200
			129	237
Total (200 shells)			987	2,000
Percentage			33.0	67.0
Dike 5				
2966	June 16	July 30	144	344
			178	258
			118	250
			115	289
			189	246
			172	274
			178	254
			196	372
Total (200 shells)			1,290	2,287
Percentage			36.1	63.9
Average percentage			34.6	65.4

Records were kept on the basis of a standard-size bag of shells, and at the time of counting the shells were carefully measured in a box of definite dimensions. Although some bags were fuller than others, the remeasurement eliminated any error from this source. It is true, of course, that it is impossible to obtain exactly uniform shells, and that at times they might be relatively smaller or larger than the average. It was noted, however, that this had little to do with the results. Generally, a standard bag contained 125 to 150 shells, though some held as many as 200 or as few as 100. When the shells are small they provide more surface per unit of volume, but impede the free circulation of water. When extra large, the water flows freely among them, though the area of surface is not so great. These factors appear to offset one another, in the case of bags of small diameter such as were used, and the resultant averages are relatively consistent.

To standardize the system of counting and calculating the total number of spat caught by this method, 100 unselected shells from each bag were examined carefully, on their inside surfaces, with a binocular miscroscope, and every spat counted. To avoid error, circles were drawn around the spat as they were counted, for in some cases as many as 600 or 700 spat were found on the inside surface of a shell. The number of spat on the inside surfaces of 100 shells was used as a basis for calculating the number on both surfaces of all shells as described above. The variation between the different shells, with respect to the number of spat caught on the inside surfaces, was tremendous. In one typical case the extremes were 0 and 730. This was obviously due to differences in the angles at which the shells are held as well as to their size and their position in the bag. On the shells in this particular bag, which was selected for description because it was in the water during a period of abundant setting, an average of 358 spat per shell were caught.

During the first season the method employed was somewhat different. Bags of shells were left in the water for various lengths of time, the spat counted, and a great many of them measured for the purpose of determining from their size distribution the time at which setting took place. The method of measurement was discarded because of the large error, due chiefly to differences in rate of growth during periods of spring and neap tides, which affect the low-tide temperature, and also probably to specific peculiarities of the different spat. The records for 1931 are therefore not as exact as those for the following years.

Experimental series of this kind were carried on in the two principle oyster-producing bays near Olympia during five consecutive seasons. In addition, two other bays were studied for one season. The results of the analyses are given in detail in the following section. The time of beginning of setting was determined by daily examination of shells on the grounds until spat were found.

SETTING SEASONS, OYSTER BAY

SEASON OF 1931

Observations were not begun in 1931 in time to permit obtaining of complete data on spawning, though it is evident (table 13) that most of the larvae were discharged during May and early June, for after this time few gravid specimens were to be found. Bags of shells, however, were left in the water for various periods throughout the season. The first spat were found on June 12, and they were of the size of mature larvae, with no new growth, so that this date may be considered as the time when larvae began to attach.

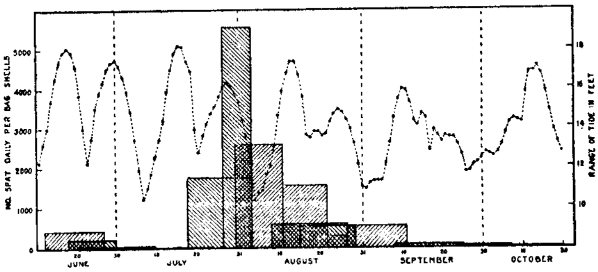

FIGURE 23.—Average number of spat caught daily on bags of shells left in dike 5 (Oyster Bay) for different periods during 1931. Daily range of tide is also shown.

The results of counts of spat on the shells are given in table 21. Only two grounds were studied in detail, and the samples from only one of these (dike 5) were thoroughly analyzed. The other series was checked sufficiently to show that the course of the setting season was identical on the two grounds. Figure 23 gives a better picture of the abundance of larvae setting during different portions of the season. After setting had started on June 12, it continued for a period of about two weeks. Comparison of the graph (fig. 23) with table 21 is necessary for reaching an understanding of the season as a whole. The first bag of shells which caught spat was in the water for 15 days, from June 12 to 27, and caught a total of 6,065 spat, or an average of 404 per day. The bag which was in the water from June 30 to July 24 caught a negligible total of only 35 spat, and none at all was caught between July 10 and 18. The actual significant period of setting, therefore, was between June 12 and 30, and during the last 10 days of this time the average daily catch was very slight.

After this period, during which almost no larvae attached, a very profuse set began to take place. The table shows that the beginning of the second setting period was probably just after July 24, since the shells removed on that date bore a few spat. Between this date and August 3, when shells were brought in again, a great amount of setting occurred. The bags which were in the water from July 30 to August 11 caught fewer spat than those in between, indicating that the peak of frequency of setting was probably between July 24 and 30. During the remainder of the season the rate of setting became gradually slower.

TABLE 21.—*Number of spat caught on bags of shells on two grounds in Oyster Bay, 1931*

Date planted	Date removed	Number of days	Dike 1		Dike 5	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
June 12	June 27	15	7,286	485	6,065	404
June 18	June 30	12	1,900	158	2,480	207
June 20	July 10	20			697	35
June 30	July 24	24			35	1
July 10	July 18	8			0	0
July 15	July 24	9			30	3
July 18	Aug. 3	16	22,320	1,395	28,071	1,754
July 27	do	7	40,520	5,789	39,040	5,577
July 30	Aug. 11	12	35,980	2,998	31,063	2,588
Aug. 8	Aug. 27	19			10,863	571
Aug. 11	Aug. 22	11	14,277	1,298	16,866	1,533
Aug. 15	Aug. 29	14	6,957	497	7,240	517
Aug. 22	Aug. 27	5			1,340	68
Aug. 27	Sept. 11	15			7,769	518
Sept. 8	Sept. 25	17	2,691	150	1,474	87
Sept. 24	Oct. 7	13	1,163	89	817	63
Oct. 7	Oct. 20	13			10	0.77

TABLE 22.—*Number of spat caught on bags of shells on 3 grounds in Oyster Bay throughout the season of 1932*

[Counts were made on only a few of the dike 5 series for comparison]

Date planted	Date removed	Number of days	Dike 1		Dike 5		Dike S	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
June 24	June 27	3	4,286	1,429			527	176
June 27	July 1	4	21,694	5,423			3,913	978
June 29	July 4	5	30,083	6,016			3,463	693
July 1	July 8	7	42,037	6,005	42,040	6,006	5,342	763
July 4	July 11	7	38,156	5,451			16,263	2,323
July 8	July 15	7	36,657	5,237			3,494	499
July 11	July 18	7	19,981	2,854	19,963	2,852	4,756	679
July 15	July 22	7	9,577	1,368			1,888	269
July 18	July 25	7	2,654	379	2,960	423	281	54
July 22	July 29	7	2,614	373			1,220	174
July 25	Aug. 1	7	3,352	479			1,474	210
July 29	Aug. 5	7	4,981	712	4,043	577	1,986	284
Aug. 1	Aug. 8	7	7,146	1,021	4,206	601	1,820	260
Aug. 5	Aug. 12	7	13,132	1,876	10,951	1,564	2,665	381
Aug. 8	Aug. 15	7	11,229	1,604			2,214	216
Aug. 12	Aug. 19	7	25,618	3,659	18,420	2,631	2,086	298
Aug. 15	Aug. 22	7	31,406	4,486	31,694	4,528	3,315	473
Aug. 19	Aug. 26	7	31,824	4,546			6,891	984
Aug. 22	Aug. 29	7	51,877	7,411	37,023	5,289	4,894	699
Aug. 26	Sept. 2	7	15,591	2,227			1,521	217
Aug. 29	Sept. 5	7	6,419	917			1,389	198
Sept. 2	Sept. 9	7	10,694	1,528			333	48
Sept. 5	Sept. 12	7	4,441	634			803	115
Sept. 9	Sept. 16	7	2,029	289			423	60
Sept. 12	Sept. 19	7	563	80	1,374	196	843	120
Sept. 16	Sept. 23	7	983	140			311	44
Sept. 19	Sept. 26	7	1,468	209	1,802	257	651	93
Sept. 23	Sept. 30	7	1,466	209			655	93
Sept. 26	Oct. 3	7	211	30			307	44
Sept. 30	Oct. 7	7	534	76			141	20
Oct. 3	Oct. 11	8	471	59			374	47
Oct. 7	Oct. 14	7	160	23			360	51
Oct. 11	Oct. 17	6	69	11				

Although not as complete as the results for later years, these records proved that two well-defined periods of setting occurred with their maxima about 6 weeks apart. The finding was particularly significant since the later setting was so much more profuse than the earlier, although the oyster growers had planted cultch only early in the season. It appears to have been a common idea that only by planting cultch in time for the initial setting could a good catch be obtained. In 1931 this was certainly not the case. The larvae continued to set in small numbers up until about the middle of October.

Either dike 5 or dike 1 (Olympia Oyster Co.) was used for experimentation during all five seasons. The former is at a level of about 1.5 feet above the zero tide, while the latter has a height of about 3.5 feet. Both grounds are considered as excellent seed-catching areas. According to the results obtained in these experiments the 2 grounds are almost equally favorable. As may be seen in table 21 the number of spat caught on bags of shells which were in the water at the same time is almost identical for the two dikes. Considering only those bags which were in the dikes during the same periods, the total number of spat caught was 137,074 in dike 5, and 136,581 in dike 1.

SEASON OF 1932

In 1932 the system of carrying on two overlapping series of bags of shells for each ground was put into effect. Although involving the counting of spat on a great many more shells the results well justify the effort because of the increased accuracy obtained, permitting more exact determination of the times of maximum and minimum frequency of setting. Complete counts were made of two series and on sample bags of another (table 22). No spat were found until June 26, although daily observations were made. After this date setting continued until the middle of October, a total period of over 3½ months.

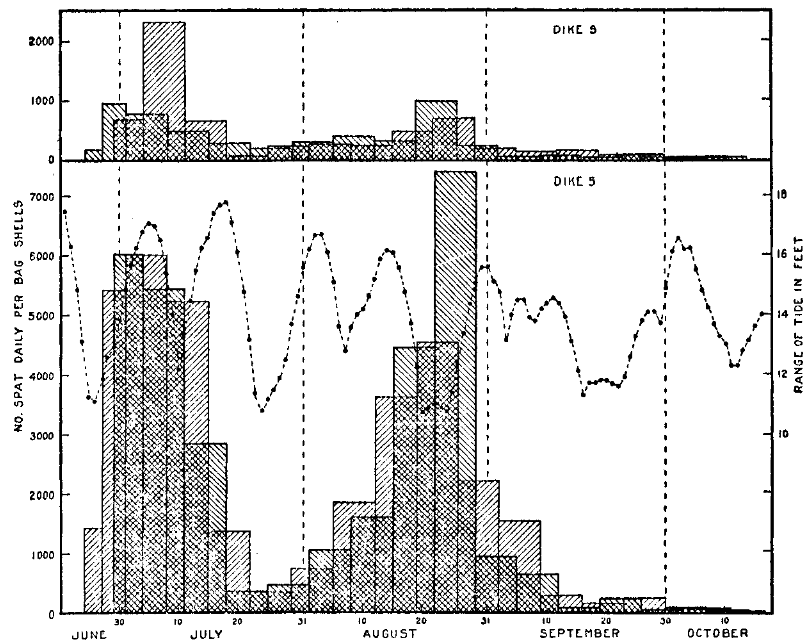

FIGURE 24.—Average number of spat caught daily per bag of shells on two grounds in Oyster Bay, 1932. Each bag was in the water for 7 days. Range of tide is also shown.

Represented graphically (fig. 24) the more numerous samples make an excellent picture of setting activity. Dike S (Steele ground) is about 2 miles down the bay from dike 1 and is removed from the larger area in which most of the beds are located. The total number of larvae caught is therefore considerably less than on grounds up the bay. There are two distinct major periods of setting having their maxima during the first few days of July and near the end of August respectively. The graphs representing the two grounds are substantially alike with respect to the times of the maxima and minima and differ only in the total number of spat caught at any time. As was found in the previous year the season consists of two distinct setting periods, with the maxima in the present case approximately 8 weeks apart.

TABLE 23.—*Number of spat caught on bags of shells on two grounds in Oyster Bay during the season of 1933*

Date planted	Date removed	Number of days	Dike 5		Dike S	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
June 26	July 3	[1] 7(1)	951	951	196	196
June 30	July 7	[1] 7(5)	16, 200	3, 240	1, 815	363
July 3	July 10	7	27, 566	3, 978	9, 416	1, 345
July 7	July 14	7	23, 248	3, 321	5, 455	779
July 10	July 17	7	9, 900	1, 414	2, 450	350
July 14	July 21	7	11, 480	1, 640	2, 225	318
July 17	July 24	7	14, 483	2, 069	1, 060	151
July 21	July 28	7	20, 082	2, 869	3, 144	449
July 24	July 31	7	16, 302	2, 329	4, 745	678
July 28	Aug. 4	7	8, 320	1, 189	4, 196	599
July 31	Aug. 7	7	9, 551	1, 364	6, 619	945
Aug. 4	Aug. 11	7	8, 167	1, 167	1, 297	185
Aug. 7	Aug. 14	7	7, 277	1, 039	2, 838	405
Aug. 11	Aug. 18	7	23, 040	3, 291	16, 872	2, 410
Aug. 14	Aug. 21	7	16, 766	2, 395	12, 954	1, 850
Aug. 18	Aug. 25	7	16, 778	2, 397	5, 928	847
Aug. 21	Aug. 28	7	15, 784	2, 255	2, 040	291
Aug. 25	Sept. 1	7	6, 003	858	823	117
Aug. 28	Sept. 4	7	3, 602	514	343	49
Sept. 1	Sept. 8	7	573	82	----------	----------
Sept. 4	Sept. 11	7	467	67	----------	----------
Sept. 8	Sept. 15	7	120	17	----------	----------
Sept. 11	Sept. 18	7	100	14	----------	----------

[1] Bags in water for 7 days, but setting started some time after they were planted.

TABLE 24.—*Number of spat caught on bags of shells on grounds in Oakland Bay and Little Skookum in the season of 1933*

Date planted	Date removed	Number of days	Oakland Bay		Little Skookum	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
June 30	July 7	7	240	34	----------	----------
July 3	July 10	[1] 7	1, 640	234	480	80
July 7	July 14	7	982	140	577	82
July 10	July 17	7	920	131	246	35
July 14	July 21	7	1, 630	233	428	61
July 17	July 24	7	4, 731	676	243	35
July 21	July 28	7	10, 620	1, 517	791	113
July 24	July 31	7	5, 650	807	440	63
July 28	Aug. 4	7	1, 340	191	403	58
July 31	Aug. 7	7	680	97	157	22
Aug. 4	Aug. 11	7	297	42	----------	----------
Aug. 4	Aug. 18	14	----------	----------	1, 560	112
Aug. 7	Aug. 14	7	0	0	----------	----------
Aug. 7	Aug. 21	14	----------	----------	3, 563	255
Aug. 11	Aug. 18	7	200	28	----------	----------
Aug. 14	Aug. 21	7	2, 591	370	----------	----------
Aug. 18	Aug. 25	7	2, 614	373	709	101
Aug. 21	Aug. 28	7	1, 131	161	----------	----------
Aug. 21	Sept. 21	31	----------	----------	86	3
Aug. 25	Sept. 1	7	0	0	----------	----------
Aug. 28	Sept. 5	8	185	23	----------	----------

[1] In Little Skookum 6 days.

SEASON OF 1933

In 1933 complete counts were made on shells planted in the same periodic manner in dikes 5 and S, and in addition two other adjacent bays were included (see tables 23 and 24). The three bays are treated together because of the similarity of the setting periods. Little Skookum (Skookum Inlet) is a small bay which branches off from Oyster Bay about half way between the mouth and the upper end, and well down from most of the oyster grounds (see chart, fig. 4). The mouth of Oakland Bay is very near to that of Oyster Bay and it would therefore not seem improbable that the water entering the two bodies of water is almost identical. As a result of pollution of the water in this region by waste liquor from a pulp mill several years before, the oyster beds in Oakland Bay and Little Skookum had been seriously depleted and the supply of spawning oysters reduced to a low level. For this reason the catch of seeds could not be expected to be as great as in the upper end of Oyster Bay, which retained more spawners.

The results obtained on two grounds in Oyster Bay (dikes 5 and S) and on one typical ground each in Oakland Bay and Little Skookum are presented graphically in figure 25. On all of the grounds there were three periods during which setting was especially profuse. The graphs show the three maxima as occurring early in July, at the end of July, and at the middle of August. The last maximum was somewhat later in Oakland Bay than in the other areas, but the first two were in all cases at almost the same time. The total length of the setting season was only about 2½ months, from the beginning of July until the middle of September, a full month shorter than in 1932. The first spat were found in Oyster Bay on July 3, and in Little Skookum the next day. In Oakland Bay the exact date was not noted, but the first bag of shells to bear spat was in the water from June 30 until July 7, indicating that setting began at almost the same time as in Oyster Bay.

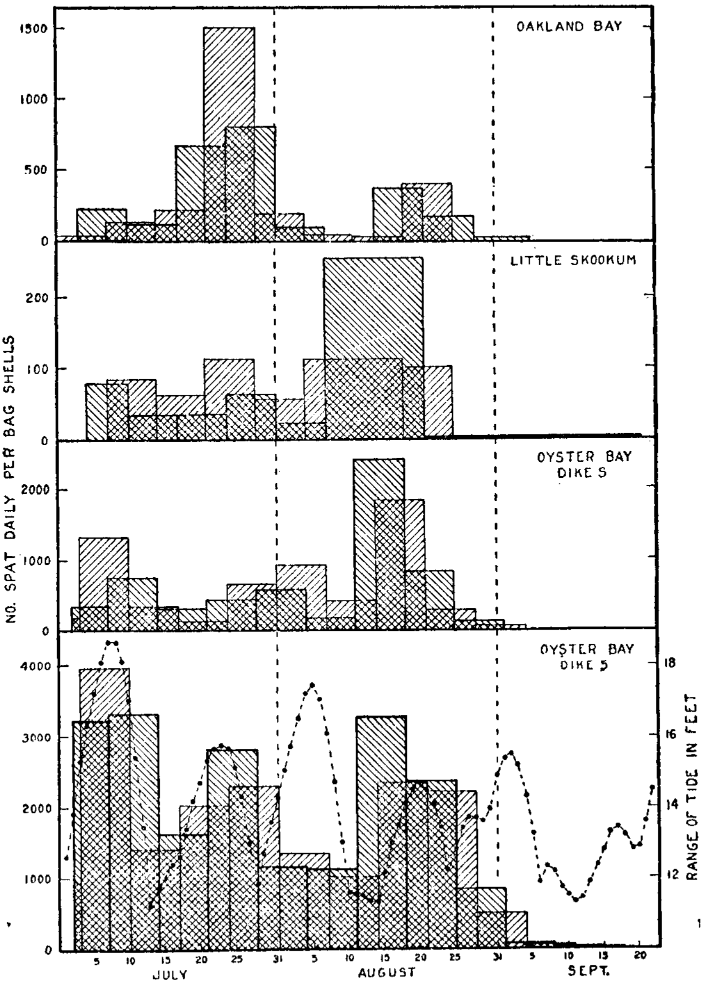

FIGURE 25.—Average number of spat caught daily per bag of shells on two grounds in Oyster Bay and one each in Skookum Inlet and Oakland Bay, 1933. Range of tide is also indicated.

In the season of 1933 setting started later and stopped earlier than during any of the other years. The reason for this short season may be seen in the records of water temperatures (see table 1, fig. 7). The water warmed to the spawning temperature much later in the spring, and did not reach as high a level by the end of the summer as during other years, thus reducing the length of the spawning season. Also, as was pointed out in the section on spawning, fewer adults bore broods of larvae.

SEASON OF 1934

In the summer of 1934 setting started on June 4, a month earlier than in the preceding year, and continued until the end of September (see table 25, fig. 26). In both dikes (5 and S) there were again two distinct periods of setting, during June and early August, respectively. However, each period was of considerable duration and consisted of two minor maxima. In each instance the two submaxima are approximately 2 weeks apart, while the two peaks of the second period are about 6 weeks later than those of the first period. While in some seasons the second setting period is the greater, as in 1931, during 1934 the first was by far the more important. In 1932, however, the two were roughly equal. The results obtained in dike S are similar, but the submaxima do not show so clearly, possibly because the number of spat was too small to indicate such details. At the middle of July there was a period of about 2 weeks during which only an occasional larva attached. The figure shows that between July 9 and July 23 the number of spat caught was insignificant. A similar cessation of setting was also noted in 1931 for an even longer time in between the two major divisions of the setting season. As will be discussed later, this does not appear to be directly correlated with a similar variation in the frequency of spawning.

TABLE 25.—*Number of spat caught on bags of shells of 2 grounds in Oyster Bay during the season of 1934*

Date planted	Date removed	Number of days	Dike 5		Dike S	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
May 28	June 4	[1] 7(1)	218	218	(2)	----------
June 1	June 8	[1] 7(5)	2,267	453	(2)	----------
June 4	June 11	7	3,569	510	549	78
June 8	June 15	7	47,229	6,761	3,430	490
June 11	June 18	7	44,825	6,403	8,510	1,216
June 15	June 22	7	39,053	5,579	8,610	1,230
June 18	June 25	7	34,051	4,864	10,487	1,498
June 22	June 29	7	48,309	6,901	8,000	1,143
June 25	July 2	7	48,600	6,943	6,855	979
June 29	July 6	7	28,671	4,096	5,407	772
July 2	July 9	7	16,448	2,349	4,307	615
July 6	July 13	7	4,386	626	936	133
July 9	July 16	7	398	57	79	11
July 13	July 20	7	55	8	(2)	----------
July 16	July 23	7	100	14	(2)	----------
July 20	July 27	[1] 7 (4)	2,132	533	160	40
July 23	July 30	7	6,193	885	892	127
July 27	Aug. 3	7	20,785	2,969	2,204	315
July 30	Aug. 6	7	13,728	1,961	1,360	194
Aug. 3	Aug. 10	7	14,694	2,099	2,453	350
Aug. 6	Aug. 13	7	24,823	3,546	1,737	248
Aug. 10	Aug. 17	7	8,200	1,171	526	75
Aug. 13	Aug. 20	7	6,634	948	377	54
Aug. 17	Aug. 24	7	2,731	390	503	72
Aug. 20	Aug. 27	7	1,047	149	417	59
Aug. 24	Aug. 31	7	3,528	504	31	4
Aug. 27	Sept. 3	7	2,497	357	192	27
Aug. 31	Sept. 7	7	1,480	211	69	10
Sept. 3	Sept. 10	7	1,303	186	130	18
Sept. 7	Sept. 14	7	1,471	210	178	25
Sept. 10	Sept. 17	7	1,403	200	351	50
Sept. 14	Sept. 21	7	123	17	34	5
Sept. 17	Sept. 24	7	257	37	34	5
Sept. 21	Sept. 28	7	----------	----------	62	9

[1] Bags in water for 7 days, but setting started some time after they were planted.
[2] Only occasional spat; too few to warrant counting.

TABLE 26.—*Number of spat caught on bags of shells in dike 5 in Oyster Bay during the season of 1935*

Date planted	Date removed	Number of days	Total number of spat	Number of spat daily	Date planted	Date removed	Number of days	Total number of spat	Number of spat daily
June 14	June 21	[1] 7(3)	7,991	2,664	Aug. 9	Aug. 16	7	22,751	3,250
June 17	June 24	[1] 7(6)	20,451	3,408	Aug. 12	Aug. 19	7	52,810	7,544
June 21	June 28	7	48,848	6,979	Aug. 16	Aug. 23	7	62,110	8,872
June 24	July 1	7	86,034	12,291	Aug. 19	Aug. 26	7	33,628	4,808
June 28	July 5	7	25,114	3,587	Aug. 23	Aug. 30	7	19,008	2,715
July 1	July 8	7	44,311	6,330	Aug. 26	Sept. 2	7	18,672	2,667
July 5	July 12	7	17,890	2,555	Aug. 30	Sept. 6	7	15,800	2,257
July 8	July 15	7	9,506	1,358	Sept. 2	Sept. 9	7	5,942	848
July 12	July 19	7	16,505	2,357	Sept. 6	Sept. 14	8	694	87
July 15	July 22	7	27,751	3,964	Sept. 9	Sept. 16	7	171	24
July 19	July 26	7	28,097	4,013	Sept. 14	Sept. 20	6	380	76
July 22	July 29	7	16,157	2,308	Sept. 16	Sept. 27	11	514	46
July 26	Aug. 2	7	3,791	540	Sept. 20	...do....	7	122	17
July 29	Aug. 5	7	274	39	Sept. 27	Oct. 5	8	108	13
Aug. 2	Aug. 9	7	817	116	Oct. 5	Oct. 12	7	211	30
Aug. 5	Aug. 12	7	2,394	342					

[1] Bags in water for 7 days, but setting started some time after they were planted.

SEASON OF 1935

Records for this year were analyzed completely only in dike 5, since it had already been well demonstrated that different portions of the bay differ only in the number of spat setting, while the time is the same. The results are given in table 26, and figure 27, and they show a marked similarity to those of previous years in that there are two major divisions of the setting season. After starting on June 17 setting increased in frequency, reaching the first maximum at the end of the month. A second, smaller maximum centered about July 20. From July 29 until August 9 there was a time when almost no larvae attached, and then the second major setting period started, reaching a peak soon after the middle of August. Although the season was practically over early in September a few spat were caught up until mid-October, making a total setting season of nearly 4 months.

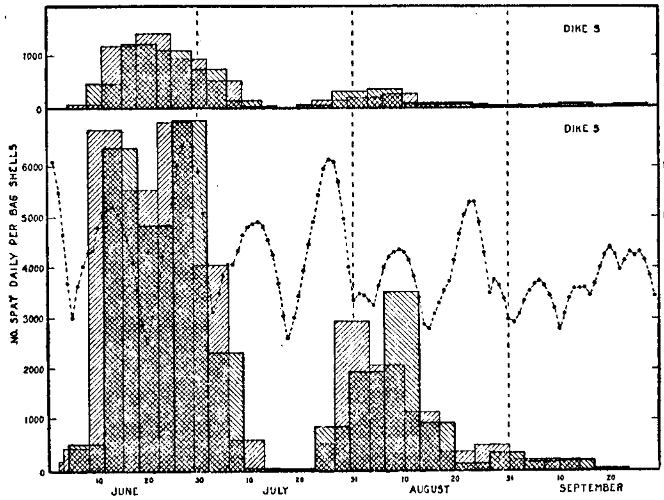

FIGURE 26.—Average number of spat caught daily per bag of shells on two grounds in Oyster Bay, 1934. Range of tide is indicated also.

Other bags of shells were planted in the same dikes at more frequent intervals, in order to give more exactly the times of the maxima. This series will be considered below with respect to the analysis of the significance of the results.

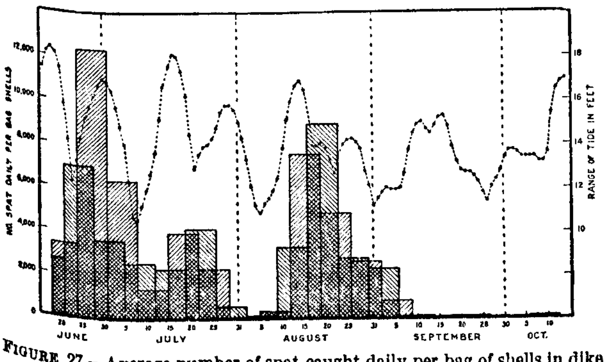

FIGURE 27.—Average number of spat caught daily per bag of shells in dike 5 (Oyster Bay) in 1935. See also figure 33 for results with more frequently planted cultch.

SETTING SEASONS, MUD BAY

Although parallel to Oyster Bay and separated from it by only a few miles, Mud Bay is somewhat different hydrographically, as was indicated above. Also, the spawning and setting activities of the oysters are so different in the two bodies of water that they must be treated separately. It was shown in tables 14 to 17 that spawning does not begin until relatively late in Mud Bay, sometimes as much as 3 weeks later than in Oyster Bay. Setting is therefore similarly later.

TABLE 27.—*Number of spat caught per bag of shells on two grounds in Mud Bay, 1931*

Date planted	Date removed	Number of days	Dike B: Total number of spat	Dike B: Number of spat daily	Dike D: Total number of spat	Dike D: Number of spat daily	Date planted	Date removed	Number of days	Dike B: Total number of spat	Dike B: Number of spat daily	Dike D: Total number of spat	Dike D: Number of spat daily
June 17	June 29	12	6,626	552	6,240	520	June 29	Aug. 7	9	0	0	0	0
June 25	July 1	6	7,390	1,231	3,120	520	Aug. 7	Aug. 21	14	120	8	414	30
June 29	July 9	10	6,949	695	10,037	1,003	Aug. 21	Aug. 26	5	60	12	323	65
July 9	July 17	8	3,021	377	3,709	463	Aug. 26	Sept. 10	15	331	22	628	42
July 13	July 25	12	331	27	228	19	Sept. 5	Sept. 26	21	871	41	1,988	95
July 20	Aug. 7	18	0	0	0	0	Sept. 26	Oct. 8	12	0	0	103	8

SEASON OF 1931

Bags of shells were planted and removed periodically for spat counting on two grounds. Dike *B* is near the shore and dike *D* is next to the small channel which remains at low tide (see chart, fig. 4). As in Oyster Bay during this year a system of planting shells for regular intervals was not employed and the results are not as accurate as in later seasons. Setting began on the 16th of June and the maximum was reached at the end of the month, after which it diminished gradually in intensity (see table 27, fig. 28). From soon after the middle of July until early in August no spat were caught, but after this time a few were found on every bag of shells until the end of September. The total number of seeds caught was small as compared with Oyster Bay during the same season. The first setting period was by far the more important, as shown in the figure, while in Oyster Bay the later period of setting was more significant. All tests in Mud Bay were made in dikes *A*, *B*, *C*, *D* (J. J. Brenner Oyster Co.) and *E* (Charles Brenner).

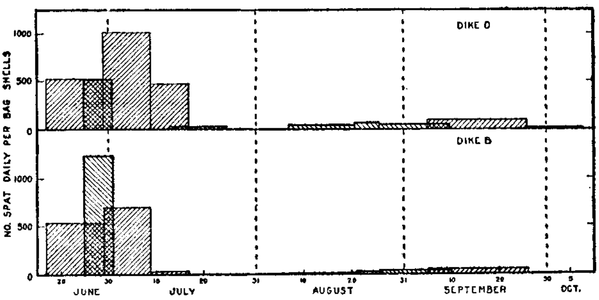

FIGURE 28.—Average number of spat caught daily per bag of shells left in dikes B and D (Mud Bay) for different periods during 1931.

SEASON OF 1932

During this year the improved method of sampling was employed and complete counts were made on the shells tested in dike *B*. For comparison, some counts were made on shells planted in dikes *D* and *E*. The latter is across the channel from dike *D*. The original results are given in table 28, and the dike *B* values are represented graphically in figure 29. The picture is in some respects different from that obtained during 1931, but the 2 years are alike in that there were two separate setting periods. In the graph the first period falls into two maxima. The late setting, though not as intense, was sufficient to be of commercial importance, although it continued only until early in September.

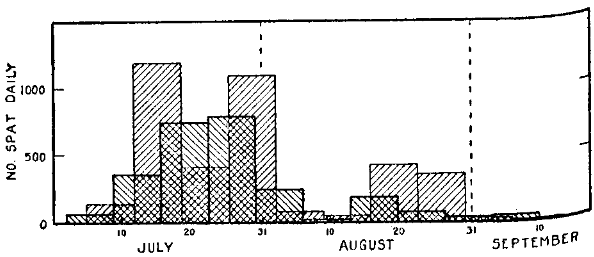

FIGURE 29.—Average number of spat caught daily per bag of shells in dike B, Mud Bay, 1932.

SEASON OF 1933

The results for this year are given in table 29 and figure 30, and consist of complete counts on two series of bags of shells. The graphs are very similar save that the number of spat caught in dike *E* is only a small fraction of that obtained in dike *B*. It was necessary to double the scale in plotting the results in the former case in order to make the values distinct. It has generally been found that the catch of seeds in dike *E* and grounds nearby is much less than in other places a short distance away.

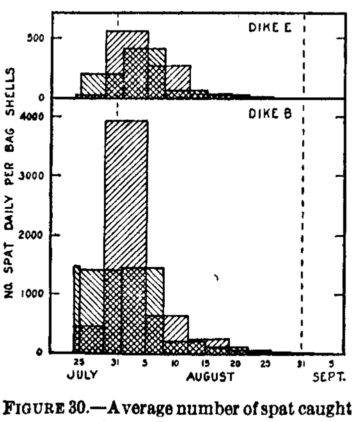

FIGURE 30.—Average number of spat caught daily per bag of shells in dikes B and E, Mud Bay, 1933.

TABLE 28.—*Number of spat caught on bags of shells planted periodically in Mud Bay during 1932*

[Counts were completed on the dike B series, and representative samples from dikes D and E were studied for comparison]

Date planted	Date removed	Number of days	Dike B		Dike D		Dike E	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
July 2	July 9	7	441	63			466	66
July 5	July 12	7	935	134			609	87
July 9	July 16	7	2,521	360			3,663	523
July 12	July 19	7	8,350	1,193	7,626	1,089	3,469	496
July 16	July 23	7	5,153	736			4,034	576
July 19	July 26	7	2,843	403	2,275	325		
July 23	July 30	7	5,590	798				
July 26	Aug. 2	7	7,692	1,099	5,520	789	6,047	864
July 30	Aug. 6	7	1,705	243	2,126	304		
Aug. 2	Aug. 9	7	442	63			354	51
Aug. 6	Aug. 13	7	50	7				
Aug. 9	Aug. 16	7	269	38				
Aug. 13	Aug. 20	7	1,238	177			1,391	199
Aug. 16	Aug. 23	7	2,902	427	4,057	579	4,271	610
Aug. 20	Aug. 27	7	530	76			1,395	140
Aug. 23	Aug. 30	7	2,463	352	5,177	739		
Aug. 27	Sept. 3	7	220	31				
Aug. 30	Sept. 6	7	175	25				
Sept. 3	Sept. 10	7	320	46	860	123		
Sept. 6	Sept. 13	7	45	6				

TABLE 29.—*Number of spat caught on bags of shells on 2 grounds in Mud Bay, 1933*

[Dike B is more favorable seed ground, although the time of most profuse setting is the same on both beds]

Date planted	Date removed	Number of days	Dike B		Dike E		Date planted	Date removed	Number of days	Dike B		Dike E	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily				Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
July 18	July 25	[1]7(1)	1,494	1,494			Aug. 12	Aug. 19	7	1,836	262	234	33
22	29	[1]7(5)	2,318	464	157	31	15	22	7	913	130	163	23
25	Aug. 1	7	9,933	1,419	1,417	202	19	26	7	530	76	55	8
29	5	7	27,678	3,954	3,877	554	22	29	7	226	32	(2)	
Aug. 1	8	7	10,011	1,430	2,951	421	26	Sept. 2	7	183	26	(2)	
5	12	7	8,154	1,165	1,892	270	29	5	7	61	9	(2)	
8	15	7	1,565	223	463	66							

[1] Bags in water for 7 days, but setting started some time after they were planted.
[2] Only occasional spat; too few to warrant counting.

TABLE 30.—*Number of spat caught on bags of shells on 2 grounds in Mud Bay, 1934*

Date planted	Date removed	Number of days	Dike B		Dike E		Date planted	Date removed	Number of days	Dike B		Dike E	
			Total number of spat	Number of spat daily	Total number of spat	Number of spat daily				Total number of spat	Number of spat daily	Total number of spat	Number of spat daily
June 9	June 16	[1]7(1)	39	39	7	7	June 26	July 3	7	729	104	137	19
June 12	June 19	[1]7(4)	377	94	123	31	June 30	July 7	7	1,360	194	355	50
June 16	June 23	7	2,134	305	248	35	July 3	July 10	7	788	112	85	12
June 19	June 26	7	1,998	285	343	49	July 7	July 14	7	401	57		
June 23	June 30	7	1,562	223	266	38	July 10	July 17	[2]7(4)	66	17		

[1] Bags in water for 7 days, but setting started some time after they were planted.
[2] Setting stopped 4 days after planting.

The figure shows only one period of setting, which started between July 24 and 25, reached a maximum about a week later, then gradually declined until early in September when it reached the zero level. The entire length of the setting season was only about 1½ months. Nevertheless, oyster growers obtained a highly satisfactory catch of seeds, for during a short time the frequency of attachment was greater than was found in this bay during any of the other years.

SEASON OF 1934

This was a relatively poor seed year in this bay, as may be seen in table 30 and figure 31. Even for the dike *B* results it was necessary to employ a scale 10 times as great as that used in most of the figures in order to obtain a satisfactory graph. After starting to set on about June 16 the larvae never attached in great numbers, so that at the time of the maximum the bags of shells caught an average of only about 300 spat per day in dike *B* and only about 50 per day in dike *E*. The entire setting period

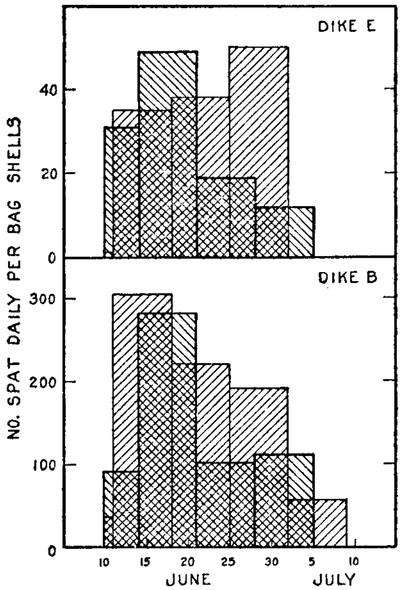

FIGURE 31.—Average number of spat caught daily per bag of shells in dikes B and E, Mud Bay, 1934.

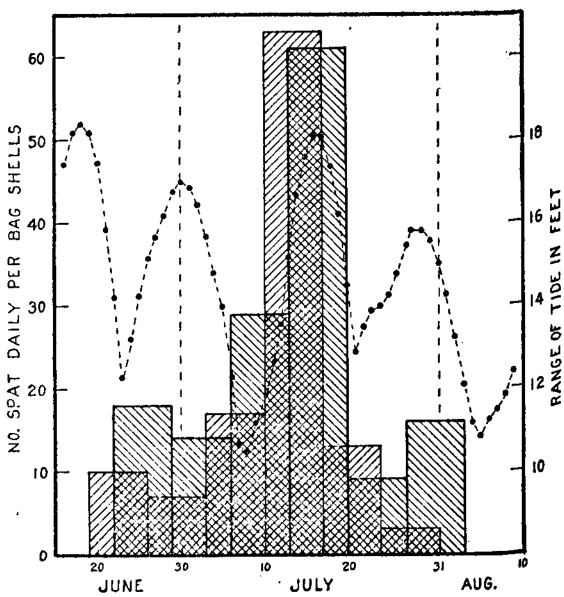

FIGURE 32.—Average number of spat caught daily per bag of shells in dike E, Mud Bay, 1935.

occupied only about 1 month, and no larvae became attached after the middle of July, although bags of clean shells were planted twice weekly until the end of September.

TABLE 31.—*Number of spat caught on bags of shells in dike E in Mud Bay during the season of 1935*

Date planted	Date removed	Number of days	Total number of spat	Number of spat daily	Date planted	Date removed	Number of days	Total number of spat	Number of spat daily
June 19	June 26	7	74	10	July 13	July 20	7	428	61
June 22	June 29	7	128	18	July 17	July 24	7	94	13
June 26	July 3	7	54	7	July 20	July 27	7	68	9
June 29	July 6	7	102	14	July 24	July 31	7	22	3
July 3	July 10	7	122	17	July 27	Aug. 3	7	115	16
July 6	July 13	7	203	29	July 31	Aug. 7	7	0	0
July 10	July 17	7	445	63					

SEASON OF 1935

Because of more concentrated investigations in Oyster Bay little attention was paid in 1935 to Mud Bay. One series of bags of shells was completed in dike *E*, which is not good seed ground. The catch in dike *B*, judging from records of previous years, was probably at least five times as great. The trend of the setting season is shown in table 31 and figure 32. Setting started at the last of June, reached a maximum at the middle of July, and stopped at the first of August. Even during the time of most abundant setting the bags of shells caught an average of only about 50 spat per day. There was some later set after the middle of August, but it was of small significance and samples taken are not complete enough to be included in the table and graph.

Mud Bay is different from Oyster Bay in time of spawning, time of beginning of setting, time of maximum intensity of setting, and duration of the setting season. While Oyster Bay, Little Skookum, and Oakland Bay are closely similar with respect to setting seasons, Mud Bay is entirely different, and the results have to be presented separately.

PERIODICITY OF SETTING

In the foregoing account it was described, particularly with reference to Oyster Bay, that several periods of setting may occur during each season. Attempts to correlate these periods with conditions of salinity, pH, or temperature have resulted in no significant relationship. Local weather conditions appear to have little or no influence upon the setting of larvae, save in their effect upon water temperature which controls spawning and rate of larval development. A period of setting occurs generally as a matter of many days duration, seldom less than 2 weeks. In this locality it is not concentrated within a few days, as described by Prytherch (1929) for Long Island Sound. Ordinarily, only a few spat are found when a setting period begins, but during the following days the larvae attach more and more abundantly.

The oyster growers have the problem of deciding when to plant cultch so that it will not be silted over or covered with organic growth before the larvae are able to attach. The system has always been in use to plant the cultch in advance of the time of setting, after it is known that spawning has started, so as to be certain that the cultch is in the water when setting begins. Naturally, it frequently occurred that cultch was planted far too early and the maximum catch of seeds was not obtained. During 1931, an opportunity was afforded to test roughly the depreciation in efficiency of cultch after being in the water for some time.

TABLE 32.—*Loss in percentage of efficiency of cultch after 9 days*

Bag number	Date planted	Date removed	Number of spat	Difference
Dike 1				*Percent*
3578	July 18	Aug. 3	22,320	44.91
3515	July 27	Aug. 3	40,520	
Dike 5				
3577	July 18	Aug. 3	28,071	28.09
3516	July 27	Aug. 3	39,040	
Average percent difference				36.50

During the middle of the summer the water is typically relatively free of silt and organic growth, as compared with spring and early summer. In 1931 the second major period of setting began between the 25th and the 28th of July. Two bags of shells had been planted on July 18 and two on the 27th. All were removed on August 3. The counts of spat on the two groups are given in table 32. It is assumed, for convenience, that the bags planted July 27 were placed in the water just at the correct time to obtain the maximum catch, though they may have been a little too late to get all of it. The other bags were planted 9 days earlier. When all bags were removed at the same time and the number of spat counted there was found to be a remarkable difference. One bag planted in dike 1 on July 18 caught a total of 22,320 spat, while the bag planted beside it on the 27 caught 40,520 spat. Similarly, in dike 5 the earlier bag caught 28,071 spat, and the later, 39,040. The average difference between the two groups is 36.5 percent, indicating that the earlier shells had lost one-third of their efficiency as spat collectors in 9 days, even during the time when the bay water was most free from fouling materials and organisms. The shells in wire bags are less subject to fouling than those thrown directly upon the grounds, for they are well supported above the silt of the bottom and tidal flow serves to keep them clean. The depreciation in effectiveness of shells thrown on the grounds is probably very rapid, particularly during early summer when there is still considerable silt. An understanding of the setting periods should serve to make it possible to eliminate much of the loss due to fouling of cultch.

It was noted that setting periods appeared to be approximately 2, 4, or 6 weeks apart, rather definitely spaced, suggesting that tidal periodicity might be concerned. By plotting the daily range of tide throughout each setting season (fig. 23 to 27) this suggestion was shown to be well founded. In almost every case the time of maximum frequency of setting is near to the time of greatest tidal range; and in many cases it may be observed that during neap tides, when the range of tide is small, the frequency of setting is also low. In some of the series in which 7-day bags were used it is difficult to decide from the graphs the exact dates of maximum frequency of setting. To throw more light upon the nature of the periodicity and the possible relation to tidal conditions a series of bags of shells was tested in one dike in 1935 in such a manner that each bag generally remained in the water only 2 or 3 days.

TABLE 33.—*Number of spat caught on bags of shells planted at frequent intervals in Oyster Bay, dike 5, 1935*

Date planted	Date removed	Number of days	Total number of spat	Number of spat daily	Date planted	Date removed	Number of days	Total number of spat	Number of spat daily
June 18	June 20	2	1,120	554	July 23	July 25	2	4,786	2,393
June 19	June 21	2	1,840	920	July 24	July 26	2	2,788	1,394
June 20	June 22	2	4,123	2,061	July 25	July 27	2	2,851	1,425
June 21	June 24	3	6,909	2,303	July 26	July 29	3	3,231	1,077
June 24	June 25	1	5,471	5,471	July 27	do	2	883	441
June 22	June 24	2	3,226	1,613	Do	July 30	3	1,220	407
June 25	June 26	1	1,186	1,186	July 29	July 31	2	177	88
June 26	June 27	1	4,131	4,131	July 30	Aug. 1	2	88	44
June 27	June 28	1	8,703	8,703	July 31	Aug. 2	2	37	18
June 28	July 1	3	8,211	2,737	Aug. 1	Aug. 3	2	83	41
June 29	do	2	37,704	18,852	Aug. 2	Aug. 5	3	122	41
Do	July 2	3	10,157	3,386	Aug. 3	Aug. 6	3	191	64
July 1	July 3	2	24,120	12,060	Do	Aug. 5	2	57	28
July 2	July 4	2	29,149	14,574	Aug. 5	Aug. 7	2	60	30
July 3	July 5	2	31,043	15,021	Aug. 6	Aug. 8	2	34	17
July 4	July 6	2	20,360	10,180	Aug. 7	Aug. 9	2	57	28
July 5	July 8	3	16,640	5,547	Aug. 8	Aug. 10	2	191	95
July 6	do	2	7,500	3,750	Aug. 9	Aug. 12	3	1,200	400
Do	July 9	3	8,805	2,935	Aug. 10	do	2	360	180
July 8	July 10	2	2,914	1,457	Do	Aug. 17	7	45,314	6,473
July 10	July 12	2	1,080	540	Aug. 12	do	5	47,968	9,593
July 11	July 13	2	622	311	Aug. 17	Aug. 19	2	17,126	8,563
July 12	July 15	3	3,162	1,054	Do	Aug. 20	3	19,571	6,524
July 13	do	2	4,520	2,260	Aug. 19	Aug. 21	2	9,694	4,847
Do	July 16	3	6,168	2,056	Aug. 22	Aug. 24	2	4,351	2,175
July 15	July 17	2	4,617	2,308	Aug. 23	Aug. 26	3	4,783	1,594
July 16	July 18	2	4,445	2,222	Aug. 24	Aug. 27	3	9,434	3,145
July 17	July 19	2	4,200	2,100	Aug. 26	Aug. 28	2	4,662	2,331
July 18	July 20	2	4,831	2,415	Aug. 27	Aug. 29	2	6,225	3,112
July 19	July 22	3	10,460	3,487	Aug. 28	Aug. 30	2	3,663	1,831
July 20	July 23	3	5,723	1,908	Aug. 29	Aug. 31	2	2,757	1,378
Do	July 22	2	3,448	1,724	Aug. 30	Sept. 2	3	5,794	1,931
July 22	July 24	2	2,843	1,421	Aug. 31	Sept. 3	3	6,791	2,263

Smaller units make the graph (fig. 33) more complete and permit a more certain statement of the correlation between frequency of setting and tidal periods. The results of the counts are given in detail in table 33. On the graph the daily range of tide is also plotted, and it may readily be seen that the maximum of the first setting period is centered almost exactly during a period of extreme, or spring, tides. Setting started on June 17, at the time of maximum range of the preceding tidal period, and reached a peak 2 weeks later. The first wave of setting may be considered as having ended about July 10, during neap tides, and a new set started immediately afterward, not reaching a definite sharp peak. It is to be noted that while this setting period continued until the end of the month, for a total time of about 3 weeks, the intervening neap tides had a high minimum range of 13 feet. The difference between spring and neap tides in this case was small, and little difference in rate of setting is to be observed.

The next major setting cycle is concentrated during the extreme spring tides, having started at the time of the preceding neap tides. The following neap tides were not markedly different in range, and the effect is slight, though obvious. During the prominent neap tide period at the beginning of August almost no spat were caught.

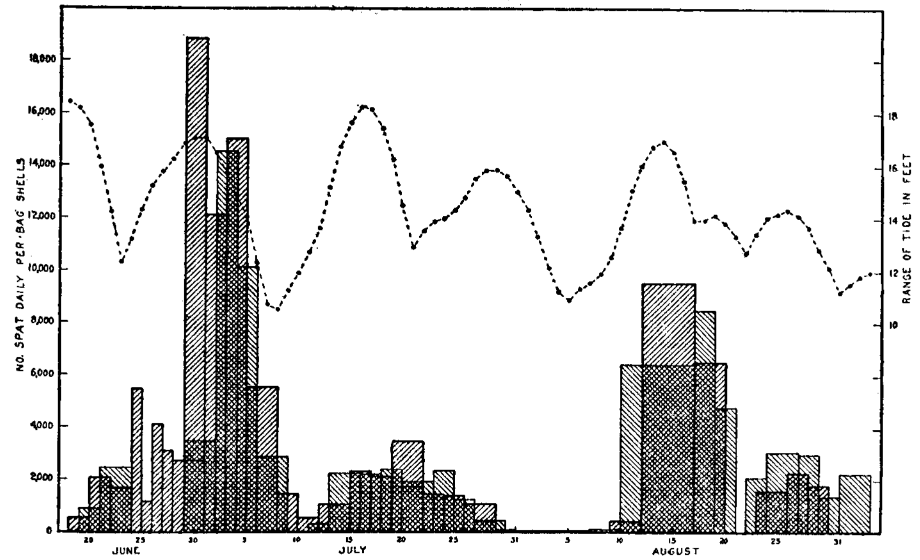

FIGURE 33.—Average number of spat caught daily per bag of shells left in water (dike 5, Oyster Bay) for periods of usually 2 or 3 days, 1935. Tidal range is also shown to illustrate correlation. Compare with figure 27.

This series shows on a more exact basis that the previous interpretation of results obtained with weekly bags is generally correct.

An important source of possible error in reaching an understanding of the significance of counts of spat on the shells in bags is the fact that the shells are clean and thoroughly efficient as spat collectors only at the time they are put into the water. During the next 7 days they become increasingly less efficient. The error is overcome to some degree by using overlapping series. It is to be noted, for example, in figures 27 and 33 that the average number of spat caught daily during any time is greater on the shells that were in the water 2 or 3 days than on those kept for 7 days. In interpreting weekly series it is necessary to take the factor of fouling into consideration, for it would not be correct to say that the exact center of the highest column in any case represents the day of most abundant setting.

STAGES OF TIDE AND SETTING

Since periods of spring tides were shown above to provide most favorable conditions for the attachment of larvae it is of interest to determine the effect of different stages of tide. In Milford Harbor, Conn., Prytherch (1929) found for *Ostrea virginica* that—

"Heaviest setting occurs in the surface layer during the period of low slack water, which is the zone in which the oyster larvae were found to be most abundant. Setting continues as the tide begins to run flood, gradually becoming less intense as the velocity of the current increases, and finally ceasing altogether when the current attains a velocity of 10 centimeters, or one-third foot, per second."

Where this investigator worked the range of tide is less than half of that in southern Puget Sound and it is hardly to be expected that setting habits of larvae would be identical in the two places.

When experiments on this subject were begun it was desired to determine at what stages of tide setting is most intense and the possible effect of such factors as daylight and darkness, salinity, temperature, and pH. Glass plates, supported in wire frames as previously described, were arranged in units of fifteen 8- by 10-inch plates, making a total area of under surface of 1,200 square inches, almost 1 square yard. At low tide the frames were just covered by the water retained in the dikes. A set of frames was placed upon the ground and allowed to remain for a definite interval, then removed, allowed to dry and the number of spat counted.

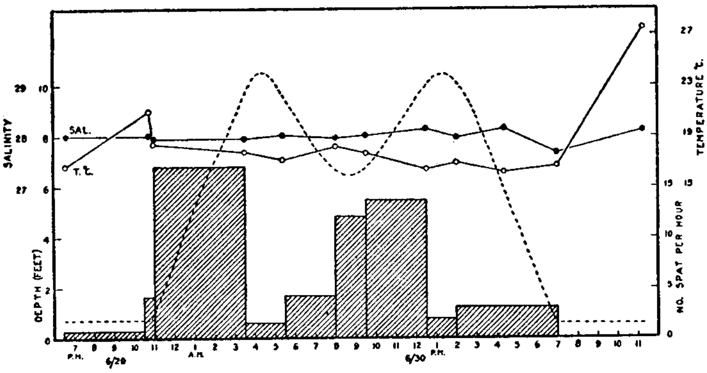

FIGURE 34.—Number of spat caught hourly per unit of cultch with relation to stage of tide, temperature, and salinity. (Oyster Bay, dike 5, June 29 and 30, 1932.)

In the first series, plates were planted in the dike soon after it was exposed by the receding tide, at 6:30 a. m., and allowed to remain until just before the flood-tide water came over the dike (fig. 34). During this time the plates caught but 3 spat. The next set was in the water for a total time of 30 minutes, from near the end of the exposed period until the water was about 1 foot deep over the dike. Throughout the rest of the tidal cycle it was arranged to have a set of plates in the water during each major tide except for about 1½ or 2 hours at the times of high and low tides, which were separately tested.

In figure 34 the results are given as number of spat caught hourly on each of the sets of plates. Shown also are depth of water throughout the period and values of temperature and salinity obtained each time samples were changed. The fewest spat were caught at low tide when the dike was exposed, the most on the two flood tides, although at, or near, the time of the higher low tide spat were also caught. During ebb tide few larvae set, in proportion to the activity at flood tide. It is of interest that salinity and temperature were quite uniform during the experimental period, save that the exposed dike permitted warming of the water at low tide. It is also clear that attachment of larvae is not markedly influenced by daylight or

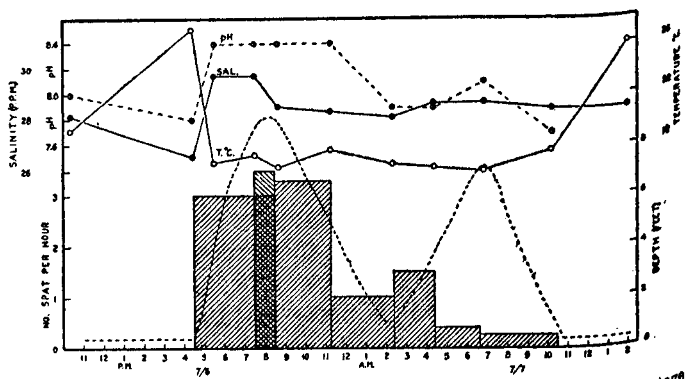

FIGURE 35.—Number of spat caught hourly per unit of cultch with relation to stage of tide, temperature, salinity, and pH. (Oyster Bay, dike S, July 6 and 7, 1932.)

darkness. The two high tides in this case were almost identical and setting was almost equally heavy on the two floods, one day, the other night.

In the next experiment, about 2 weeks later, made on a different ground, the first high tide was more than 4 feet higher than the second. Whether the different picture obtained (fig. 35) is due to the large difference between the two tides is uncertain though it would not seem unlikely that the greater flow of water in the former may account for the heavier set. On neither day was a single spat caught when the dike was exposed. Setting was about equally profuse on flood and ebb of the first tide, and it is suggested that the very low tide after midnight, which almost left the ground exposed, caused rate of current or other factors on the ebb and flood tides to be similar. The following secondary high tide produced few spat, most of which set during the flood.

Except when the ground was exposed the temperature varied only slightly. It is of interest that the most prolific setting took place when both pH and salinity were quite high. The water in the dike at the end of the period of exposure had a pH of 7.8, while about an hour later it was 8.4. At the same time the salinity rose from a little over 26 to more than 29 parts per mille.

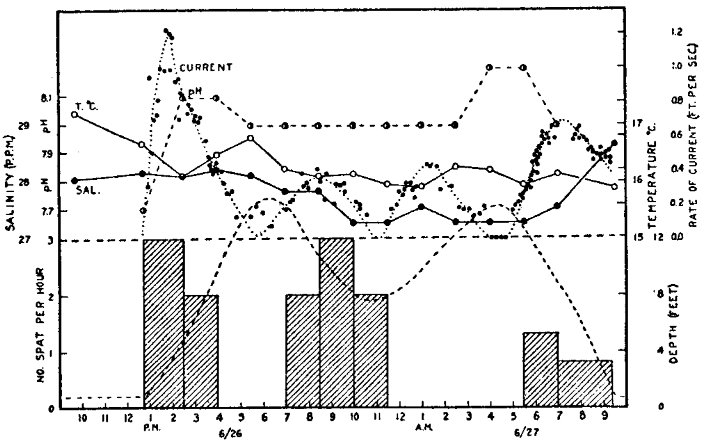

FIGURE 36.—Number of spat caught hourly per unit of cultch with relation to stage of tide, rate of current, temperature, salinity, and pH. (Oyster Bay, Made Ground, June 26 and 27, 1934.)

In an attempt to reach a more definite conclusion a similar experiment was made in a later year with the additional help of an electric current meter. The boat was anchored in the channel near the oyster ground and the current meter suspended from a framework directly in the dike. The meter hung just above the oysters, at the level of the panes of glass, and the transmission line was led to the boat where counts of revolutions were made. The results are shown in figure 36. Spat were caught only at three well separated times: During the first flood and the following small ebb, and during the major ebb of the next day. The first and the last coincide definitely with the times of swift current. In the second case the current was not particularly rapid, but it is true that the heaviest setting took place about half way between high and low tide, when the current during this ebb was swiftest. Why no spat were caught on the second flood is not known, though it must be realized that in an experiment of this kind, necessarily carried on over a limited area and with a relatively small amount of cultch, chance is a large factor in determining whether the water in the particular place happens to contain larvae. For this reason the error involved in the tests is considerable. Nevertheless, the results are, within certain limits, of great interest.

The final series to be described here is shown in figure 37. The experiment consisted of two parts. One set of plates was in the water for an entire tide, from high to low or low to high. In the other group two overlapping series of plates were used, each set being left in the water 3 hours. The lower portion of the graph represents the first group. Although spat were caught during all four tides, only during the two floods did very many larvae set. By far the most were caught during the major flood tide following the extreme low of the first day.

The sets of plates which were in the water for 3 hours each gave generally similar results. Those which caught most spat were exposed during the time when the flood tide was most rapid, from 1½ hours after the water came over the dike, in the first case, until 1½ hours before high tide. During the first, or small, ebb fewer spat were caught than on the major ebb the next morning. The current records are incomplete in two places, because seaweed became entangled in the current meter. The pH was remarkably constant throughout the period, save that at low tide it dropped from 8.4 to 7.8, due to respiratory activity of the oysters in the shallow, warm water. Salinity and temperature also varied but slightly.

Prytherch (1934) made the important finding that larvae of *Ostrea virginica* may vary over a wide range in the time required for completion of the setting process, and stated that:

> The most rapid setting was observed at salinities of 16 to 18.6 per mille and was completed in from 12 to 19 minutes.

He also determined that:

> In solutions that were above or below this salt concentration, the time for setting increased and reached a maximum of 140 and 144 minutes in salinities of 5.6 and 32.2 per mille respectively.

It is of great significance that the time required for a larva to complete the process of setting may vary from 12 to 144 minutes, for it would therefore appear that a number of environmental conditions might become limiting factors.

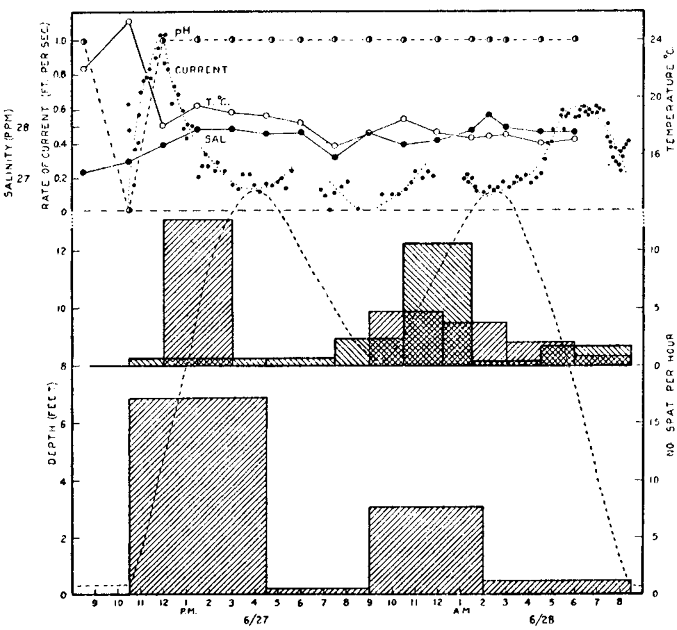

FIGURE 37.—Number of spat caught hourly per unit of cultch with relation to stage of tide, rate of current, temperature, salinity, and pH. (Oyster Bay, Gale Ground, June 27 and 28, 1935.)

That the matter of rate of setting may have influenced the results of the experiments just described appears to be certain. In one case a set of plates was left in the water for only 15 minutes, yet it bore spat. In other cases the plates which were in the water for a longer period caught fewer spat than expected. In the last series described (fig. 37) the plates which were exposed during the major flood tide for a period of 6 hours caught a total of 103 spat. The three sets shown in the upper graph, covering the same period of time, caught a total of only 42 spat. It is suggested that those larvae which had not completed the setting process released their hold when the plates were withdrawn from the water, so that possibly only those that began to set soon after the plates were immersed were able to attach permanently. More clearly to illustrate the point it may be stated that a set of plates, left in the water during the entire 24 hours caught a total of 199 spat, while the four sets of the lower graph caught 151, and all of the double series of 3-hour plates caught but 129 spat.

This information is of assistance in interpreting the results of the four experiments for it indicates that the first portion of the time that the plates are in the water must be given most weight. In such an instance as that shown in the upper graph of figure 37 the first 3-hour set of plates caught few spat; the next one, planted 1½ hours later caught many; the third, still 1½ hours later caught few. It would seem safe to assume that most of this set occurred between 12 and 1:30 o'clock, or the third set would have caught a larger number.

Summarizing these experiments it may be said that almost no spat are caught when the tide is low and the water in the dike is still. At this time the water is warmest, the salinity lowest, though only 1 to 2 per mille below that of the maximum, and the pH lowest, especially after the ground has been exposed for some time. As the tide comes in setting increases in intensity, most of it occurring when the water is 6 to 8 feet deep over the beds on which the tests were made. At this time the pH and salinity are relatively high and the temperature low. In some cases there appears to be a correlation between rate of current and frequency of setting. There seems to be no obvious parallel with conditions observed by Prytherch (1929) in Connecticut.

DEPTH OF SETTING

Most of the favorable grounds for the collection of spat are relatively high, at a level of 3 to 8 feet above the average lower low tide. While usually not so good as producers of the best oysters for market the higher grounds are used almost entirely for the collection of seeds. To the practical oystermen, who have always believed that most of the larvae set when the tide is low and the water on the grounds clear and warm, the highest grounds offered the warmest water at low tide and for this reason were especially favorable for catching seeds. However, as was shown in a preceding section, setting takes place at a lower frequency at low tide than at any other time.

Only when the tide is as much as half high are some of the best seed beds completely covered, except for the few inches of water held by the dikes. Because they are covered by deep water so much less of the time and are closer to the warmer surface water the seed beds are best for obtaining rapid growth of the spat, while on lower grounds, where growth is slower, the oysters fatten better but not so many spat are caught. It is probably true that cultch becomes fouled with organic growth more quickly on the lower grounds, thus preventing a heavy set of spat, but it appeared possible that some other factor might be concerned in determining that higher grounds are so much more effective.

TABLE 34.—*Number of spat caught on shells in four series of wire baskets suspended at fixed distances from surface of water*

[A basket covered a depth of 5 inches]

Depth (inches)	Series 1 number of spat	Series 2 number of spat	Series 3		Series 4	
			Depth (inches)	Number of spat	Depth (inches)	Number of spat
0-5	402	228	0-5	338	0-5	182
6-11	1,029	517	6-11	612	8-13	696
14-19	1,393	640	14-19	662	16-21	664
24-29	779	392	24-29	723	24-29	654
39-44	757	417	42-47	624	32-37	544
64-69	718	447	71-76	591		
99-104	530	495				

Several series of experiments were performed for the purpose of finding at what depths the larvae set most profusely. Wire baskets were constructed 12 by 12 inches wide and 5 inches deep, filled with clam shells, suspended in series one above the other, and the entire series hung from a float which was anchored in the channel. The baskets were supported so that each was in a horizontal position, occupying 5 inches of depth. They were placed so as to be well separated in the series and to maintain a constant distance from the surface for periods of from 2 weeks to 2 months, and the spat then counted.

The results of four series are given in table 34. In two series the baskets were at depths ranging from the surface down to 104 inches. The others reached only to 37 and 76 inches, respectively. In each basket 30 unselected shells were gone over carefully and every spat counted. The results are relatively uniform, considering the impossibility of measuring the exact area of individual shells, and when the results of the two longer series are averaged and plotted as number of spat per unit of cultch at different depths it becomes evident that the most spat were caught within the first 20 to 30 inches from the surface. In all cases the sample at the surface (0 to 5 inches) caught fewest spat, possibly because of the scouring action of waves, partly, perhaps, because larvae do not set as profusely within that area as they do a short distance below. On the bags suspended below this level of maximum setting fewer and fewer spat were caught. About twice as many spat were taken on the shells at a depth of 14 to 19 inches as on those at 99 to 104 inches.

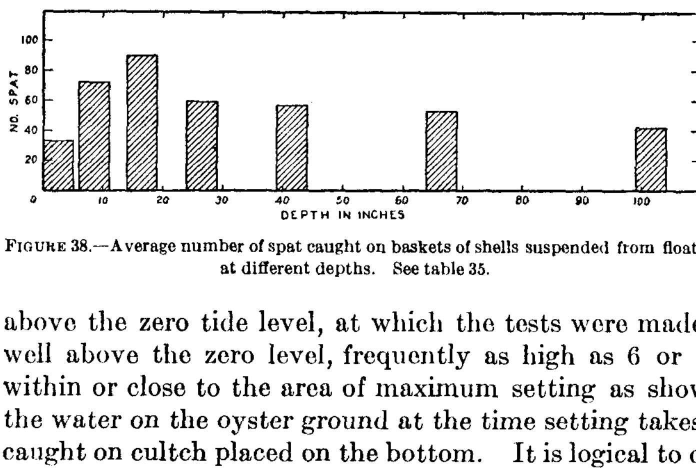

FIGURE 38.—Average number of spat caught on baskets of shells suspended from floats at different depths. See table 35.

It was shown above that most of the larvae set when the water has a depth of about 6 to 10 feet or more above the zero tide level, at which the tests were made. The best seed grounds are well above the zero level, frequently as high as 6 or 8 feet, thereby placing them within or close to the area of maximum setting as shown in figure 38. The deeper the water on the oyster ground at the time setting takes place the fewer spat will be caught on cultch placed on the bottom. It is logical to conclude that this is one of the reasons why the higher grounds are best adapted to the catching of spat.

Difficult to understand in view of these results is the fact that all natural beds in the region are located between low- and high-tide levels, or in shallow channels which are almost dry at low tide. The graph shows that the number of spat caught diminishes gradually with increasing distance from the surface. Tests were made only down to about 8.5 feet and the results suggest that larvae would set to some extent at much greater depths. It appeared likely that beds of oysters might be found in the deep channels well down the bay but extensive dredging in such places failed to disclose a single oyster. It may be that there is little clean cultch to which the larvae might attach, but clam shells were found abundantly in some places. The factor responsible for this localization of natural oyster beds is not clear, but in Yaquina Bay, Oreg., oysters of the same species occur almost exclusively in the deeper waters.

These experiments have served a more immediately practical purpose. Following the original observations in 1931, which demonstrated that a very heavy set of spat could be obtained by employing floats, it was suggested to oyster growers that they try the method on a commercial scale. One of them tried it with a float made of two logs and a wire bottom, filled with Japanese oyster shells, in 1932. He was quite successful and during the following years others have started catching seeds in

FIGURE 39.—Photograph showing float with removable compartments filled with cultch for catching spat.

this manner. In 1935 and 1936 the method has been put into practice on a large commercial scale, with floats filled with shells or manufactured collectors. Some of the growers have worked out a system of dividing the floats into a series of removable compartments, in which the cultch is placed, thus facilitating handling and minimizing possible storm damage. (See fig. 39.) Counts made on typical egg crate fillers or special-type collectors in 1935 showed that they caught an average of 5,000 to 10,000 spat each.

These floats may be anchored in the channels or pot holes of Oyster Bay, where they get a swift current of water. The manufactured collectors are always placed so that water will flow through the cells bringing abundant larvae and washing out silt. Most of the growers using the method at the present time are those who have satisfactory growing ground but lack adequate seed beds. Formerly these growers purchased what seeds they were able to get, but in recent years, since almost complete destruction of oysters on the State-owned seed beds of Oakland Bay following the beginning of operations of a nearby pulp mill, almost no seeds have been purchasable. The float method now makes it possible for anyone with growing ground to obtain abundant seeds at a cost considerably less than would be required to maintain seed ground for the purpose.

CORRELATION BETWEEN SPAWNING AND SETTING

In the foregoing account detailed descriptions have been given of observations of spawning activities and on setting of larvae throughout the several seasons under different conditions. It is of interest to consider reproductory activities in their entirety in order to correlate the initial spawning with the somewhat later setting and metamorphosis of the larvae. Coe (1932 a, b) stated that spawning in this species continues during at least 7 months of the year on the coast of southern California, while in British Columbia waters, according to Stafford (1914), "The spawning season appeared to extend from about May 20 to about the last of July, and to have reached its maximum about the middle of June." This is a total spawning period of about 2½ months, and he observed a setting period of about the same length, from early July until nearly the middle of September. The investigations described above indicate a total spawning period of 3 to 4 months, although the most intense spawning activity is confined to a much shorter time.

Stafford estimated that at least a month is required between spawning and setting, while Coe (1932a) stated:

> Shortly after they have been spawned into the water these young bivalves attach themselves to almost any kind of solid objects. The free-swimming stage is thus very short and the opportunities for dispersal are limited.

In a similar manner Galtsoff (1929) wrote:

> It is noteworthy that, although the whole development of the Pacific oyster is about twice as long as that of the eastern oyster, the duration of the free-swimming stage, when the organism is subjected to the vicissitudes of life in the open water and is not protected by the mother's body, in both cases lasts for about a fortnight. Thus, the fact that *Ostrea lurida* spends half of the period of its development within the brood chamber of its mother is of no particular advantage, and the free swimming larvae of both species have an equal chance to become prey to plankton-feeding organisms or to be carried away by the tides.

Because of the fact that the free swimming larval period lasts for a month or more, as was noted above, it is obvious that there is great opportunity for dispersal; and in view of the fact that the maternal individuals protect their larvae until they have developed to an advanced bivalve stage at which they are presumably able to protect themselves from many of the unfavorable environmental factors it must be considered that the chances of survival are greater than in the case of oviparous species, which cast the unprotected eggs into the open water.

TABLE 35.—*Dates on which first spawning and first setting occurred*

Date	Oyster Bay			Mud Bay		
	Spawn	Spat	Number of days	Spawn	Spat	Number of days
1931		June 12			June 16	43
1932	May 17	June 26	40	May 25	July 7	51
1933	do	July 3	47	June 4	July 25	53
1934	Apr. 17	June 4	48	Apr. 24	June 16	47
1935	May 5	June 17	44	May 13	June 29	

The only accurate estimate available of the duration of the free swimming period of larval life is that obtained by Hori (1933) who grew the larvae in the laboratory by feeding them macerated sea lettuce (*Ulva*). He removed black larvae from the brood chambers and kept them in dishes of seawater at a temperature of about 20° C. and found that they reached full size and attached after 22 days. The temperature of the water in Puget Sound is generally considerably lower and it is to be expected that development of larvae would proceed more slowly.

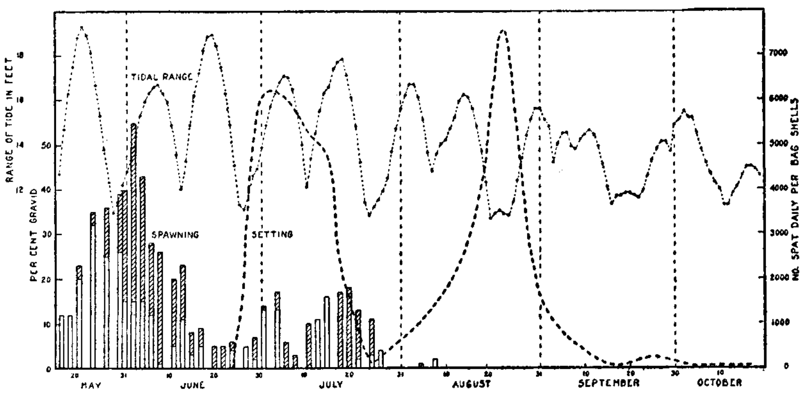

FIGURE 40.—Frequency of spawning and setting during season of 1932 in Oyster Bay. Setting is indicated by a trend line derived from values given in figure 24. Tidal range is also shown.

Field observations on the time when the first larvae and the first spat were found each season are summarized in table 36. In Oyster Bay the interval varied during 4 years from 40 to 48 days, while in Mud Bay the extremes were 43 and 53 days, or about 4 days longer each year. Available data do not permit an exact statement of the total time from spawning until setting, for it is most probable that natural conditions may cause it to vary from year to year. Water temperature necessarily is concerned in determining rate of growth and it is probable that development may be affected by the abundance of food material. Hori (1933) was able to grow larvae of *Ostrea gigas* by feeding them *Chlorella pacifica*, but larvae of *O. lurida* did not thrive on this alga. The experiments of Amemiya (1926) indicated that salinity, also, is an important factor in the development of larvae of several species. It has been described that during the first 10 days larval development takes place within the maternal brood chamber and the free swimming period in Oyster Bay is therefore some 30 or more days in length.

Although tables and graphs of both spawning and setting activities have already been described, a complete picture of the season of propagation is better presented, as in figures 40 and 41, by including measurements of both spawning and setting on the same graph. In figure 40, referring to Oyster Bay in 1932, the frequency of occurrence of gravid adults is shown as a histogram while the time and abundance of larvae setting is indicated by a trend line derived from the results obtained by sampling with bags of shells as previously described. Range of tide is also given. During this year most of the spawning took place from the middle of May until the middle of June, and during July there was some further active spawning. In some respects the record of setting resembles that of spawning, though the break between the two setting periods may not readily be correlated with a comparable cessation of spawning. If the second setting period is traceable to larvae resulting from July spawning the mortality of larvae produced during the first spawning period was tremendously larger, for the later period of setting was very intense.

In the graph referring to the year 1934 (fig. 41) the picture is somewhat similar, though one can hardly consider that there was a second distinct period of spawning. In this figure the correlation between tidal periods and setting is strikingly shown, while in figure 40 the second setting period appears to be correlated with the neap tides. However, in the latter case it is not quite correct to plot tides in this manner, for at the time of the second major set there were very low tides, but the high tides were not great, so that the total range shown is small. In both years, which were selected for presentation because they represent marked differences in time of spawning and setting, the seasons of reproduction cover about 5 months.

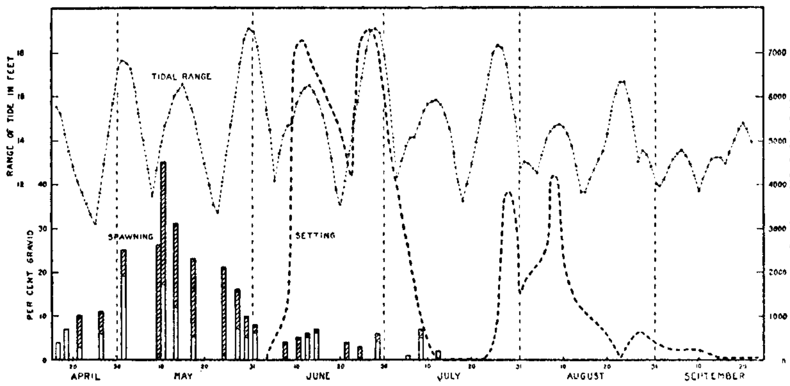

FIGURE 41.—Frequency of spawning and setting during season of 1934 in Oyster Bay. Setting is indicated by a trend line derived from values given in figure 26. Tidal range is also shown.

It may be noted that setting begins during the third period of tides following the beginning of spawning, and also that for 5 seasons, the second major setting period takes place during the third and fourth spring tide periods following that when the first set occurs. The time intervals seem to be predetermined, either by the spawning activity or by cyclic changes in the water which are correlated with tidal periodicity.

DISCUSSION

In the foregoing account various phases of the spawning and setting activities of the Olympia oyster have been described with particular reference to their application to commercial cultivation. Larvae of this viviparous species develop slowly within the maternal brood chamber, or that portion of the mantle chamber which contains the palps and the anterior ends of the gills, and require an average time of about 10 days before they reach the size at which they are normally discharged into the open water. While eggs spawned by the female of *O. virginica* and other viviparous species develop to the trochophore, or earliest swimming stage, within a few hours, in the case of *O. lurida* the same stage is not reached for about 4 days. Rapid early development is characteristic of those species which discharge the eggs directly into the open water, in contrast with the viviparous Olympia oyster which protects the embryos.

Oyster culture in Puget Sound is somewhat different from that in other parts of the United States in that the range of tides is greater, with a maximum range of 20 feet. The oyster grounds are above the extreme low-tide level and are surrounded by dikes which hold enough water to protect the oysters from freezing and drying, while at high tide they may be covered by as much as 16 or 18 feet of water. Such tides involve the movement of great quantities of water and swift currents, but most of the beds are located in the upper ends of the bays where currents are not so rapid. The interchange of cold water from the very deep portions of the Sound with that in the upper ends of the oyster-producing bays prevents the temperature from rising to a high level even during an exceptionally warm season. For this reason eastern oysters, transplanted to Puget Sound, were never able to spawn, since the high-tide temperature on the oyster beds does not reach the critical level of 20° C.

The spawning season is of several months duration and, although in no case has a sudden burst of spawning been observed in which a great number of oysters were involved, as occurs frequently with oviparous species, it has been found that smaller numbers of individuals often bear embryos or larvae of the same age, indicating that favorable conditions may cause spawning to take place in a considerable portion of the population at the same time. Alternation of sexual phases (Coe, 1931a, b; 1932a) probably is responsible for the rather slowly developed wave of spawning, for different individuals are at any time in different stages of maturity. Sometimes as many as 12 to 15 percent of the adults bear larvae of the same age, so that a system of statistical sampling serves to show the rate of growth. Whether sperms or sperm extract will stimulate discharge of eggs by functional females (Galtsoff, 1930b, 1932) has not been demonstrated in this species, but it is considered probable.

It is hardly to be expected that the small native oyster would discharge as many eggs as the larger oviparous species (Galtsoff, 1930), not only because of difference in size but also because the eggs are held within the mantle chamber where they grow into larvae almost twice the diameter of the eggs, and space alone probably acts as a limit. Although an individual produces in one brood only about 250,000 to 300,000 larvae, all individuals are capable of bearing at least one brood each season, while the eastern oyster is generally functional as only of one sex during a single season (Coe, 1932c, d). In some years as many as 150 broods are produced per 100 oysters, indicating that a large number bear second broods, while in other seasons as few as 75 broods per 100 individuals are produced. The degree of success of a spawning season depends upon the number of larvae per brood and the total number of broods produced.

A problem which has never before been attacked is that of the relationship between angle of surface and frequency of attachment of larvae, although Prytherch (1934) observed that larvae in a dish set more abundantly on the vertical sides than on the bottom. It was shown in preceding pages that most larvae attach to under horizontal surfaces and that as the angle departs from this the larvae set in smaller numbers. It was demonstrated that this behavior of the larvae is not due to the effect of light, but the suggestion was put forward that in the normal swimming position of the larva the foot is projecting upward and therefore is able to take hold most readily to the under horizontal surface. Actual setting, according to Prytherch, is a specific process, and larvae may crawl for some time before definitely attaching themselves, but the foot must take hold before final attachment. It would seem probable, from considerations of structure, that the larvae of other species may also attach most abundantly to under horizontal surfaces. Various factors, however, may influence the reaction, and it would be of interest to determine the activities of other species in this respect. Incidentally, Prytherch's (1934) observation that the pigment spots are not light-sensitive organs but have another function is in accord with the present results in that no evidence of a directive influence of light was noted.

By planting cultch periodically throughout each season and allowing each unit to remain in the water for only a few days it was possible to obtain a picture of the frequency of setting at all times. The results, of course, represent the potential catch at any time, rather than the number of larvae setting on the commercial beds, for in the experimental work new shells were planted twice weekly to provide clean cultch at all times, while the older shells on the grounds are usually fouled and unfavorable. In this manner it was shown that in most oyster-producing bays the setting season is not limited to a short period early in the summer, as thought by many oyster growers, but is of several months duration. This information has resulted favorably for the growers for they no longer plant cultch well in advance of the beginning of setting, as was the previous practice. The fact that after setting starts there is still a week or more before the time of maximum setting gives them sufficient time for the planting of cultch.

The setting season consists of several distinct periods which in certain bays are remarkably uniform from year to year. The first period of the season is followed by a second major setting period 6 to 8 weeks later. There is a marked parallel between tidal periodicity and periodicity in the setting of larvae. The peak of a setting period coincides generally with the maximum tidal range of a run of spring tides. Therefore, after setting begins, one may determine from the tide tables the time of the following extreme tides when the rate of setting will be at a maximum. It is probable that the total tidal range is not so much the important factor, but the incidence of extreme low tides without regard to the height of the following high tides. Of practical importance is the very prolific late setting period, which follows the first on the next third and fourth spring tide periods; for oyster growers are able to plant cultch at this time, also, thereby improving their chance of obtaining a satisfactory catch of seeds.

The exact reason for the control of setting by tidal periods is not now definitely known. The beginning of spawning, however, is associated with the tides, for the water warms more rapidly during spring tides. After the minimum water temperature reaches the critical level for spawning there appears to be no connection between further spawning and tides. Orton's (1926) observation that a maximum of spawning occurred at about the time of full moon may in some instances apply also to the Olympia oyster, but analysis of data on spawning during several years indicates that maxima of spawning, as judged from the findings of newly spawned eggs or young embryos, occur during neap tides as well as during full-moon and new-moon tidal periods. The relation between setting of larvae and tidal periods appears not to be traceable to a similar correlation between spawning and tidal periods.

It appears most likely that Prytherch's (1934) work on the effect of copper brought into the bays with land drainage may be applicable to the Olympia oyster, also. He reached the conclusion, from both laboratory experimentation and field observation, that precipitation of copper from solution in the inflowing river water permits the mature larvae to absorb this substance which is required for setting and metamorphosis. For this reason natural oyster beds are always found in relatively enclosed bodies of water which receive a considerable inflow of land drainage. A period of extreme low tides permits a more effective mixing of the fresh water with the sea water, providing the required mineral for the larvae. He found that most larvae attached during low and early flood tides in the surface layer of the water when the salinity was lowest and the rate of current very slow.

In the present work it was found that the best set of spat was caught, on floating cultch, within about 2 feet of the surface of the water, and that with increasing depth the frequency of attachment became less and less. Although during summer there is very little salinity difference from surface to bottom it may be sufficient to account for the results on the basis of Prytherch's conclusion. More difficult to understand, however, is the fact that on the oyster grounds most spat are caught at relatively high tide, when the water is deep and of the maximum salinity, while at low tide, when the salinity is lowest and the amount of mineral from land drainage presumably in highest concentration, almost no larvae set. At this time other factors, such as low pH, may inhibit setting. It is clear, also, that during a period of extreme tides the fresher water entering the upper end of a bay goes farther down the bay and is most thoroughly mixed with the sea water.

These results appear to permit interpretation in the light of Prytherch's conclusion, though the specific factor involved is not definitely known. Although copper may be the controlling factor in the bays studied it is not difficult to conceive that other substances may act in a similar manner. That is, copper may be only one of a number of factors which may control the setting process. As a result of field observations near Galveston, Tex., (Hopkins, 1931b), it was concluded that setting occurred only when the salinity was relatively high, in the neighborhood of 20 p.p.m., for in that place the salinity was frequently very low. Prytherch (1934) disagreed with this conclusion, although he demonstrated experimentally that the setting process proceeds most rapidly at a salinity of 15 to 25 p.p.m. Very slow completion of attachment may be of considerable disadvantage to the larvae and thereby constitute the reason for the writer's observation that spat were caught chiefly when the salinity was high. In addition to salinity and copper there may be other factors which determine the time and frequency of setting under different conditions.

It is not possible to give an exact statement of the number of days required for larvae to reach the setting stage, though it was demonstrated that they develop for about 10 days within the maternal branchial chamber before being discharged. The free-swimming period appears to be 30 to 40 or more days, depending largely, perhaps, on water temperature, so that the total larval life is at least 40 days. This is about three times as long as that of *Ostrea virginica* (Prytherch, 1929). The long larval life permits wide dispersal but also subjects the larvae to various plankton-feeding organisms as well as to the effects of tides and storms.

Mortality of larvae is necessarily large in any species. It may be estimated that oyster growers catch and grow not more than about one out of a million larvae produced, when it is considered that the 4-year-old oysters discharge about 300,000 eggs and all of the younger individuals also propagate on a smaller scale. Mortality of spat is also tremendous. It was shown that during a period of profuse setting as many as 12,000 spat per day might be caught on the shells in one bag. Since there were generally only about 125 shells in a bag, each shell caught several hundred spat within a few days. Yet, after 1 year it is remarkable to find a shell with as many as 50 spat. Most of the mortality appears to take place within the first few weeks after setting, and while some of it is due to overcrowding it cannot all be traced to this cause.

SUMMARY

1. Grounds on which Olympia oysters are grown are surrounded by dikes to retain a few inches of water over the oysters at low tide. The maximum range of tide at this place is about 20 feet, the average about 14 feet, and most grounds are located between the minus 2 foot and plus 4 foot tide levels.

2. Average water temperature varies between a winter low of 6° to 9° C. and a summer high of 18° to 20° C. In summer the temperature is highest when the tide is

low, and the shallow water often reaches 30° C., while during winter low tides occur at night and a temperature as low as about −2° C. has been recorded.

3. Salinity of the water on the oyster beds at high tide varies, in Oyster Bay, between about 26 p. p. m. in winter and about 29 p. p. m. in summer; in Mud Bay the range is about 27 to 29.5 p. p. m. Salinity of the surface water, however, is subject to greater variation.

4. Hydrogen-ion concentration varies throughout the year from a pH of 7.7 to 7.8 in midwinter to about 8.4 in late spring. It is probable that prolific growth of algae in spring, in the presence of fertilizing substances brought in by the winter rains, accounts for the high pH at this time.

5. Market-size oysters bear broods of 250,000 to 300,000 larvae. The number of larvae per brood depends generally upon the size of the maternal oyster.

6. Generally each oyster produces one brood per season, but in some years as many as 50 percent bear second broods while in other seasons as few as 75 percent of the individuals spawn as females. Abortions of embryos frequently occur, however.

7. Spawning of functional females begins in the spring when the minimum, or high tide, temperature reaches 12.5° to 13° C.

8. Most broods of larvae are produced during a period of about 6 weeks at the beginning of the spawning season, though an occasional gravid individual may be found as late as October.

9. An average period of 10 days is required for development within the branchial chamber from the time the eggs (diameter, 100μ to 105μ) are extruded from the gonad until straight-hinge veliger larvae (length of valves, 180μ) are discharged.

10. As compared with oviparous species, development of the larvae of *O. lurida* is very slow, and the age of the various stages may be stated approximately as follows: 1 day, blastulae; 2 days, gastrulae; 3 days, trochophores; 4 days, first conchiferous larvae with incomplete valves; 5 days, straight-hinge veliger larvae completely enclosed by valves 110μ–120μ long; 10 day, veliger larvae with valves 180μ-185μ long.

11. The free-swimming period is 30 or more days in length and varies from year to year, probably according to water temperature.

12. Larvae set most frequently on an under horizontal surface, while fewest catch on upper horizontal surfaces. A definite relationship exists between angle of surface and number of spat caught.

13. This setting behavior of larvae is not due to a directive influence of light but to the swimming position whereby the larval foot projects upward.

14. A special type of manufactured spat collector, designed to take advantage of these habits, is now in use commercially.

15. In Oyster Bay the setting season consists of two distinct periods, 6 to 8 weeks apart. Secondary periods of setting may occur between these two or after the second.

16. Setting seasons in Oakland Bay and Skookum Inlet are similar to those in Oyster Bay. In Mud Bay seasons are shorter and maxima occur at different times.

17. Times of maximum frequency of setting fall within periods of spring tides when tidal range is greatest.

18. On cultch suspended from floats most spat are caught at a distance of 1 to 2 feet from the surface. This appears to be one reason why high grounds catch the most seeds. Floats filled with cultch are now being employed commercially to take advantage of these results.

19. Few spat are caught at low tide, most when the tide is about half high. Frequency of setting appears to be associated with swiftness of current.

20. Setting of larvae begins in the third tidal period following that during which spawning starts. Setting later in the season appears to depend upon larvae remaining in the water from earlier spawning as well as upon larvae resulting from late spawning.

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FURTHER NOTES ON THE DEVELOPMENT AND LIFE HISTORY OF SOME TELEOSTS AT BEAUFORT, N. C.

By SAMUEL F. HILDEBRAND and LOUELLA E. CABLE

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FURTHER NOTES ON THE DEVELOPMENT AND LIFE HISTORY OF SOME TELEOSTS AT BEAUFORT, N. C.[1]

By SAMUEL F. HILDEBRAND and LOUELLA E. CABLE, *United States Bureau of Fisheries*

CONTENTS

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INTRODUCTION

The following accounts of the development and life history of a miscellaneous group of teleostean fishes is a continuation of earlier studies by the same authors, published in the Bulletin of the United States Bureau of Fisheries, volume XLVI, 1930, pages 383 to 488, and volume XLVIII, 1934, pages 41 to 117 (see Bibliography).

Most of the specimens and data used were collected at Beaufort, N. C. However, some of the specimens and data were secured elsewhere, principally by Dr. Lewis Radcliffe and the late William W. Welsh, working aboard the Fisheries vessels *Albatross*, *Fish Hawk*, and *Grampus*.

The authors were very materially assisted in the field work, carried on from 1925 to 1932, by the various members of the staff of the United States Fisheries Biological Station at Beaufort, N. C., especially by Dr. James S. Gutsell and Capt. Charles Hatsel, who accompanied one or both of the writers on many trips, and also collected independently.

The drawings presented herewith were prepared by the junior author, unless otherwise stated in the legends. The junior author, also, did much of the tedious work of sorting the young fishes from other forms and the general debris usually taken in towings, and made some of the preliminary identifications. The senior author, under whose direction the work was carried on, is responsible for final identifications, the interpretation of the data, and for the preparation of the manuscript.

The principal collecting stations are indicated with small circles on the map (fig. 1). One-meter tow nets, one at the surface and one on the bottom, hauled simultaneously, were the only nets used at the farthest offshore stations. At the stations near shore, and at those in the partly enclosed waters, otter trawls and beam trawls also were used. Furthermore, collecting seines, particularly small ones made of bobbinet, were employed along the shores both in the inside waters and along the outside beaches.

An otter trawl having the cod-end surrounded by bobbinet, built as a modified 1-meter tow net, with the collar laced to the meshes of the trawl, was found very useful for collecting young fish. The fish taken in the bobbinet generally were past the larval stage and too active to catch with an ordinary 1-meter tow net, yet small enough to pass through the one-fourth inch square mesh of the collecting trawl. This apparatus proved very satisfactory at Beaufort, where there is little or no rough or rocky bottom.

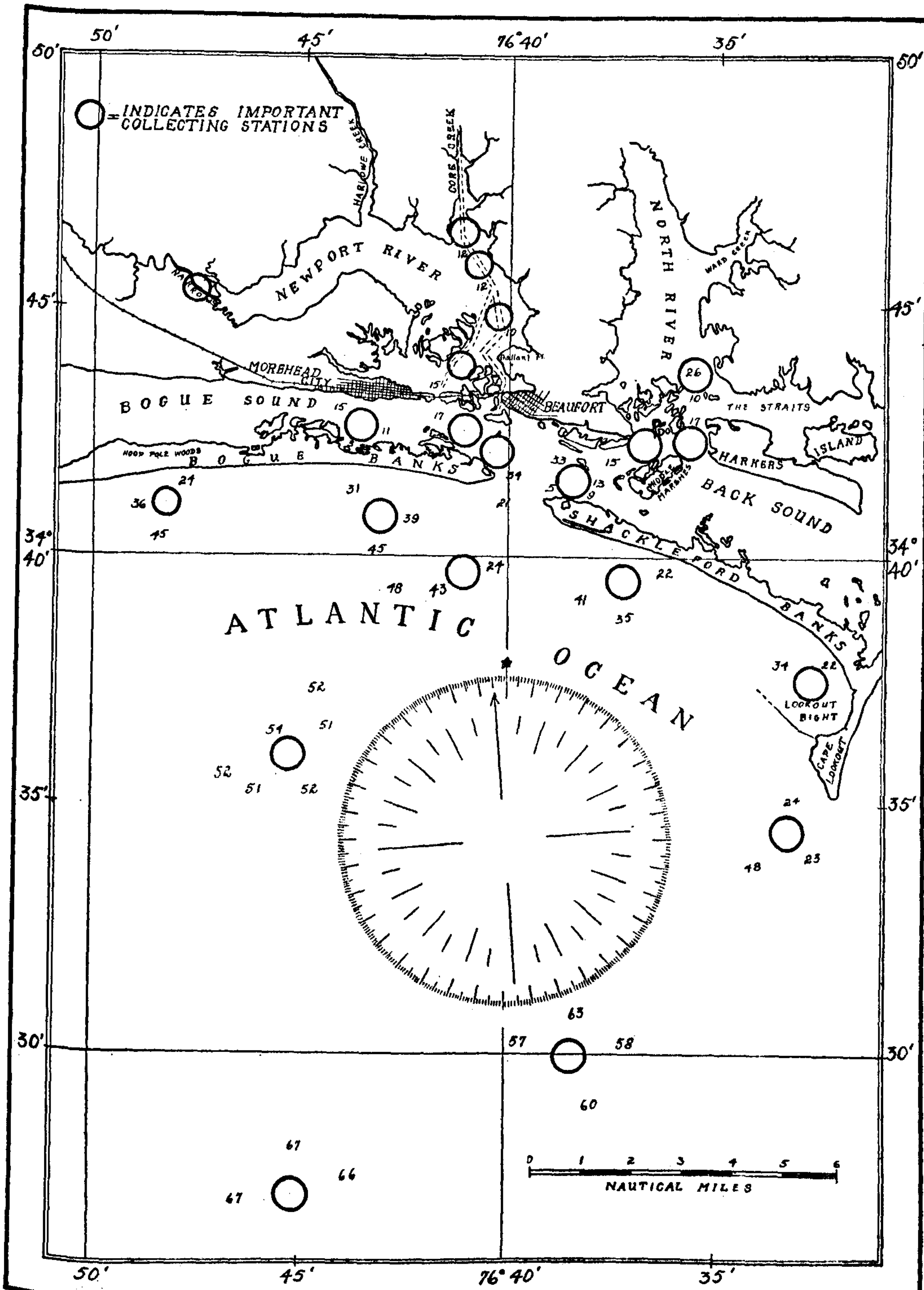

FIGURE 1.—Map of Beaufort Harbor and neighboring waters. Numbers on the map show the depth of the water in feet at the principal collecting stations.

It will be seen from the following accounts that generally many gaps remain in the series of developmental stages of the various species treated. However, in every case enough new information is presented to make publication seem quite worth while.

It has been possible, at least for some of the species discussed, to determine from the time and place of collection of the eggs or early young or both, the approximate duration of the spawning season and also the place of spawning, even though ripe fish were not seen. The movements or migrations of the young, too, were determined for some of the species from the places of collection of immature fish. Considerable information relative to the rate of growth during the first several months of life also was gained for several species, and is shown in tables and graphs presented.

All the species discussed in this paper, exclusive of the pinfish and the hakes, spawn during the summer, and either are scarce or absent in the local shallow water during the winter. The pinfish and the hakes, however, spawn during autumn and winter, and the young sometimes were taken in large numbers during the winter in company with young spots and croakers, the last named species also being winter spawners, as shown in an earlier paper by the writers (1930, pp. 417 and 433).

The drawings of the eggs and newly hatched fish are based on living material. All the rest of the illustrations were prepared from preserved specimens.

SCOMBEROMORUS MACULATUS (MITCHILL). SPANISH MACKEREL, WITH NOTES ON RELATED SPECIES

The development of the eggs and the early larvae, up to 6 days of age, of the Spanish mackerel was described and figured by John A. Ryder (1882, pp. 135–172). It is now possible to describe and figure some older stages of Scomberomorus.

The eggs used in Professor Ryder's study were secured directly from ripe fish at several different points in Chesapeake Bay. The eggs, according to Ryder, float in sea water and vary in size from "one-twenty-fifth to one-twentieth of an inch in diameter." They generally hatched in 24 hours. Segmentation proceeded quite regularly, as usual in teleostean eggs. The newly hatched fish was scarcely 2 mm long. When 3 days old the larvae had absorbed the contents of the yolksac, and the mouth was wide open. On the sixth day after hatching (length not stated), according to Ryder's figure 17, the mouth had grown very large and wide with a sharp angle at the joints of the lower jaw. Prominent teeth already were present. This is the most advanced larva described and figured (anterior part of body only) by Ryder, and it seems to be identifiable with the smallest larvae now at hand.

The specimens upon which the present study is based were caught in nets, mostly on the coast of North Carolina in the vicinity of Beaufort. However, among the larger young, specimens from Massachusetts, South Carolina, Georgia, Florida, Louisiana, Cuba, St. Lucia, and Panama also have been studied. All the larvae under 14 mm in length were taken at sea and mostly several miles offshore along the coast of North Carolina. Neither the larvae nor the older young were found numerous during the extensive collecting done in the vicinity of Beaufort. Nevertheless, adult Spanish mackerel occur there in season (spring and fall) in sufficient abundance to be of considerable commercial value. However, comparatively few seem to remain during the spawning season.

The ceros (locally pronounced "zero") or kingfish, *S. cavalla* and *S. regalis*, are too scarce (especially the last named one) on the coast of North Carolina to be of much commercial importance. They are sought, however, by sportsmen, who prefer them to Spanish mackerel because they run larger in size. *S. cavalla* sometimes attains a weight of 50 to 75 pounds, and *S. regalis* 25 to 35 pounds, whereas *S. maculatus* attains a maximum weight of only 20 to 25 pounds. The average run in weight of these species respectively in the order named, however, is only about 7, 5, and 2 pounds.

The Spanish mackerel and the ceros or kingfishes are all of wide distribution. The spanish mackerel (*S. maculatus*) ranges from Cape Cod, Mass., (sometimes as far north as Maine) south to Brazil on the Atlantic coast and from San Diego, Calif., to the Galapagos Islands on the Pacific. The ceros (*S. cavalla* and *S. regalis*) are about equally as widely distributed on the Atlantic, though they do not occur on the Pacific coast. *S. cavalla* and *S. maculatus* are recorded also from the Atlantic coast of Africa. All the species seem to be chiefly of southern distribution, large quantities being taken in southern Florida, on the Gulf coast, and southward.

The Spanish mackerel, like the other species of the genus, is migratory. It appears on the coast off Beaufort, N. C., in the spring, generally arriving in April, and it returns again in the fall, comparatively few remaining during the summer. According to local fishermen and fish dealers the fish of the spring run are poor and contain green roe. This statement is affirmed by our limited observations. In the fall the fish are fat and without roe. Spawning takes place during the summer, as shown subsequently, at a time when the fish locally are scarce. Therefore, the vicinity of Beaufort evidently is not an important spawning area.

The ceros occur off Beaufort chiefly in the fall, and are scarce or absent the rest of the year. All three species of Scomberomorus discussed are taken in large numbers in southern Florida and on the Gulf coast during the winter, when they are absent in North Carolina and northward.

CHARACTERS OF THE ADULT

Adult Scomberomorus are recognized by the elongate, little-compressed body; long pointed snout; large mouth with strong teeth; and by a keel of skin on the sides of the tail posteriorly. The dorsal fin is long, composed of 14 to 18 feeble spines, 14 to 18 soft rays, followed by 7 to 10 separate finlets. The anal fin similarly is followed by about an equal number of finlets and the caudal fin is deeply forked. The general color is silvery, generally with spots and markings that differ among the species.

The three species of Scomberomorus herein considered are rather closely related. However, *S. cavalla* is distinguishable by the more slender body and the abruptly decurved lateral line under the second dorsal. Furthermore, the origin of the anal usually is under the middle of the dorsal, whereas in the related species it is a little farther forward. Large individuals of *S. cavalla* are plain bluish above and silvery below, without spots, though young ones are described as having bronze spots.

S. regalis differs from the other species in having scales on the pectoral fins and in having one or two continuous black lines along the side. In addition to the black lines it retains elliptical bronze spots throughout life.

S. maculatus, as stated elsewhere, runs smaller in size than the related species. It has no scales on the pectoral fins, and no black line on the side, though it has bronze spots. The lateral line, as in *S. regalis*, is more gently decurved under the second dorsal than in *S. cavalla*. In *S. maculatus* the anterior part of the first dorsal, back to about the fifth spine, is wholly black, whereas in the limited number of specimens of *S. regalis* examined only the outer two-thirds of that part of the fin are black, the base being white.

SPAWNING

A fairly full report on the spawning season of the Spanish mackerel, *S. maculatus*, was given by R. Edward Earll (1882, pp. 395–426). This writer made a special investigation and stated (p. 404) that this fish begins to spawn in the Carolinas in April, in Chesapeake Bay in June, and in the vicinity of Long Island not until the last of August. Mr. Earll stated, furthermore (p. 405):

> * * * The spawning season on our coast continues throughout the summer, and, in any particular locality, it lasts from 6 to upward of 10 weeks. * * * Again, a single individual is a number of weeks depositing its eggs, as shown by the fact that when the first are excluded a large percentage are still small and immature.

It seems to us from the evidence obtained during the investigation upon which this report is based that Mr. Earll set the beginning of the spawning season ("in April") too early for North Carolina. It has been stated already (p. 509) that the Spanish mackerel arriving off Beaufort in April and May contain green roe. Furthermore, no larvae were collected there prior to June 28 (1927).

Other young of sizes stated were taken in the vicinity of Beaufort as follows: Larvae 4.0 mm and less in length, June 28 (1927), August 17 (1927), and August 26 (1929); larger larvae up to 8.0 mm in length, July 12 (1915), and September 1 and 2 (1914); young 14 to 20 mm long, July 7 (1913), July 9 (1915),[2] and September 2 (1914); and specimens up to 80 mm long, August 15 (1913), and October 7 (1930).

The larger young, that is, fish 14 mm and upward in length are capable of swimming and may have traveled some distance from the spawning ground. In fact, some of these larger young were taken in inside waters, whereas the smaller ones were caught only in outside waters. Larvae 8 mm and less in length, as already shown, have no fins and are quite helpless. Except as wafted about by currents and tides, they no doubt remain where they were hatched.

It may be concluded, then, that a limited amount of spawning (for the young, as stated elsewhere, are not numerous) takes place in the open waters off Beaufort Inlet, and apparently none in the inside waters. Furthermore, larvae under 8.0 mm in length quite certainly are only several days old. As these small larvae appeared in the collection from June 28 (1927) to September 2 (1914), it may be concluded also that spawning takes place off Beaufort at least from the latter part of June to near the end of August. It cannot be stated definitely that the earliest larvae of any one season were taken, yet the absence of young in our collections prior to the end of June does in a measure confirm the statement of local fishermen and fish dealers, as well as our observations, that the fish of the spring run (April and May) at Beaufort are not ripe, and that spawning very probably does not take place in the vicinity of Beaufort until sometime in June.

So far as we are aware nothing is known definitely about the spawning habits of *S. cavalla* and *S. regalis*. The limited number of fish examined, taken in the fall of the year, contained no roe. No evidence indicating that they spawn on the coast of North Carolina has been found.

DESCRIPTIONS OF THE YOUNG

It cannot be stated positively that the young fish herein described are all Spanish mackerel, for even the adults of the species of Scomberomorus are rather closely

[2] Some of the small specimens used in the preparation of this report were collected as early as 1913 to 1915 by Dr. Lewis Radcliffe, formerly of the Bureau of Fisheries, who already had identified some of them provisionally when they fell into our hands. Therefore, we wish to credit Dr. Radcliffe with laying the foundation that made this report on Scomberomorus possible.

related, and the young may not be separable. Nevertheless, it seems highly probable that we are dealing with Spanish mackerel only, as shown subsequently.

The descriptions that follow are all based on preserved specimens. Considerable shrinkage takes place during the hardening process. Consequently the smallest larvae herein described, though shorter than the largest ones described by Ryder (1882) in the fresh state, are more advanced in development.

Specimens about 2.5 mm long.—The body is robust, but the tail is long and slender, being notably longer than the head and trunk. The greatest depth is contained in the total length about 3.25 times. The mouth is very large and broad and strongly oblique; the gape reaches under the eye; and the lower jaw projects slightly and is straight and broad. Teeth already are plainly visible. The myomeres are indistinct anteriorly and posteriorly and therefore cannot all be enumerated. They appear to be rather numerous. Slight indications of rays are present above and below the tip of the tail. Pectoral fin membranes are prominent, with indications of rays.

The general color of the preserved specimens is brownish. A dark spot just behind the symphysis of the lower jaw is at least sometimes present, and another one appears on the abdominal wall a short distance in advance of the vent (fig. 2).

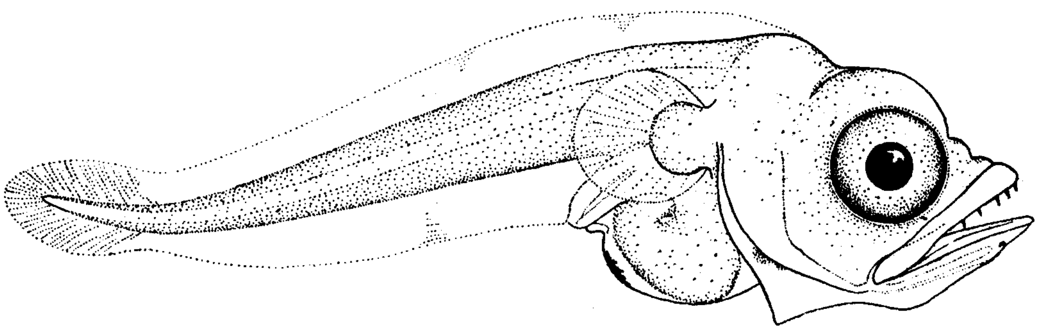

FIGURE 2.—*Scomberomorus maculatus.* From a specimen 2.75 mm long.

The chief distinguishing character, and the one that seems to "link" these larvae with the smaller and larger ones, is the large broad oblique mouth with well developed teeth.

Specimens 3.0 to 3.5 mm long.—The caudal portion of the body has grown proportionately much shorter and deeper, the vent now being situated near midbody length, and the greatest depth is equal to the head, and is contained about 3.0 times in the length. The mouth remains large and wide, and has become more strongly oblique. Two depressions, one over the snout and another at the nape, are present and rather more prominent than in the smaller fish already described. Several prominent spines are present on the preopercular margin (which disappear in the adult). Three slender spines are developed in the anterior part of the dorsal finfold, though no soft rays are developed, a sequence contrary to that found in other species studied, and apparently contrary to the general rule in spiny-rayed fishes, in which the soft rays most usually are developed before the spines appear. A variation in the relative length of the dorsal spines seems to exist among individuals of about this size and larger ones, as in some specimens the first spine is longest and in others the second one.

A few dark spots are present along the ventral surface of the caudal portion of the body, and generally some dark markings appear on the dorsal wall of the abdominal cavity (figs. 3 and 4).

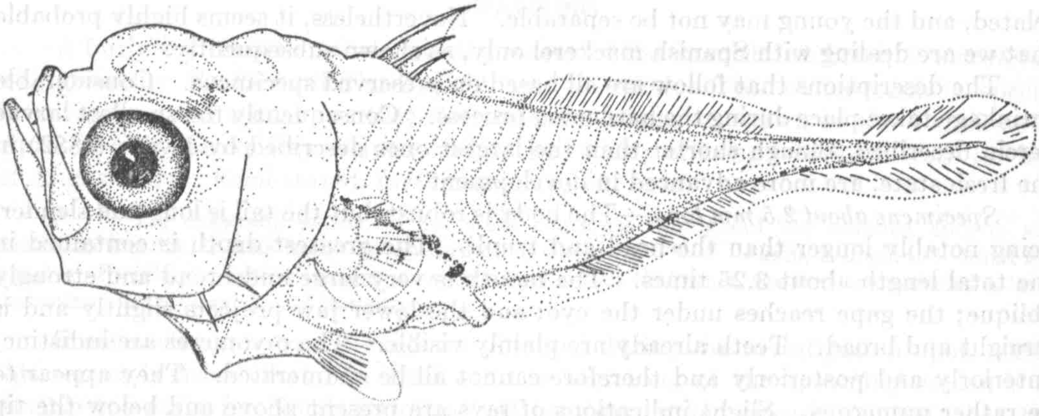

FIGURE 3.—*Scomberomorus maculatus*. From a specimen 3 mm long.

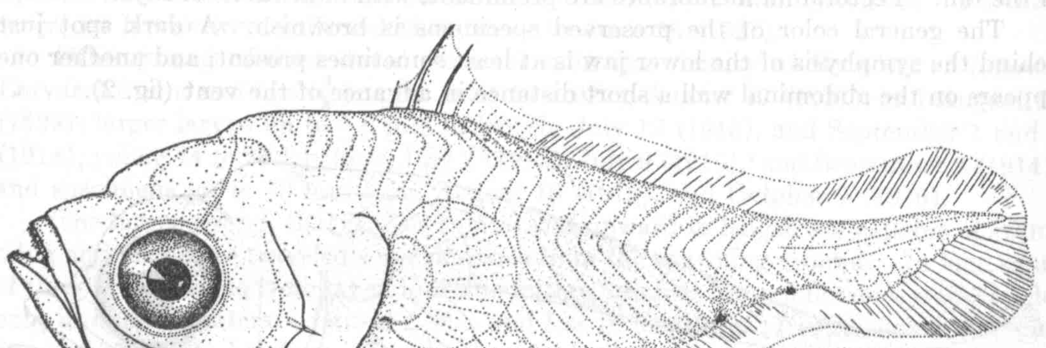

FIGURE 4.—*Scomberomorus maculatus*. From a specimen 3.25 mm long.

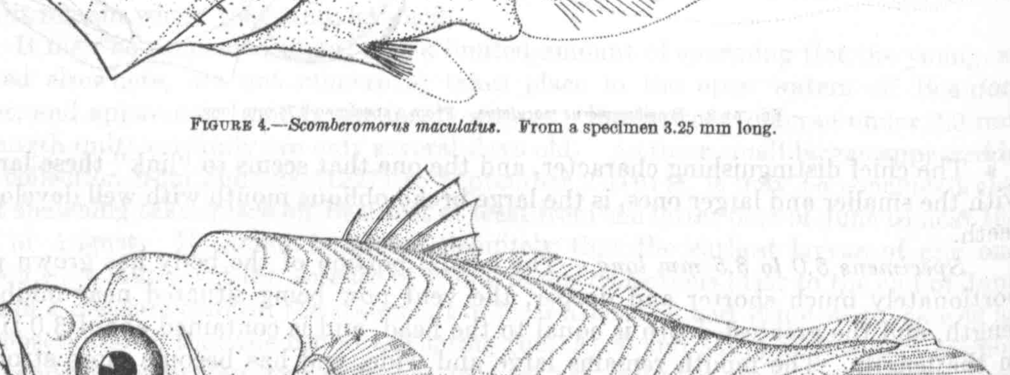

FIGURE 5.—*Scomberomorus maculatus*. From a specimen 4 mm long.

Specimens 4.0 to 4.25 mm long.—Two specimens of this range in size are at hand. They are very similar to specimens 3.5 mm long, differing principally in the development of two additional spines in the dorsal fin, five spines now being present (fig. 5).

Specimens about 6.0 mm long.—The large mouth has become much less strongly oblique, the gape anteriorly being below the level of the middle of the eye, whereas in specimens about 4.0 mm long it is at or above the upper margin of the eye. The maxillary has become narrower, and now reaches well beyond the middle of the eye. Teeth are very prominent. The snout has become much more pointed, and there is a sharp demarcation and depression where the premaxillaries apparently articulate with the skull bones. In advance of this depression or groove there is a pronounced hump in some specimens, which has a tendency to form a backwardly directed hook over the groove. This depression is distinct in the smaller fish described, though the premaxillaries are not definitely outlined. A second depression present at the nape in smaller fish has now disappeared. Dorsal spines have increased to seven in number, and are relatively high, the longest one being a little longer than the snout. There is variation in the relative length of the dorsal spines, the first spine particularly being shorter in some specimens than in others. Soft rays still are imperfectly developed. The notochord is directed upward sharply, as usual at this stage in fishes destined to have homocercal tails. Myomeres are numerous, but cannot be counted accurately. Four spines, though reduced in size, remain present on the preopercular margin as in younger fish.

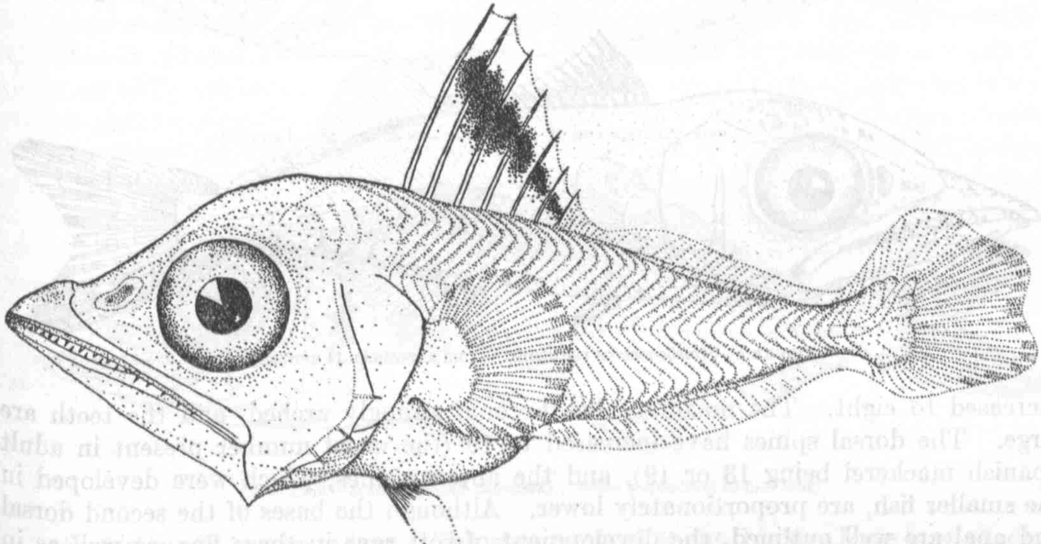

FIGURE 6.—*Scomberomorus maculatus* (?). From a specimen 5.75 mm long.

The general color of the long-preserved specimens at hand is brownish. The only color marking is a broad black band on the dorsal spines (fig. 6).

No specimens between a length of 4.0 and 5.0 mm are at hand. Unfortunately the 5.0-mm specimen is imperfect, especially in having the dorsal spines broken. The next smallest specimen in good condition is 5.25 mm long. Considerable advancement in development took place, if the larvae actually are all of one species, while the fish grew in length from 4.0 to 5.0 mm. The chief connecting "links" between the smaller specimens and the present group are: The very large mouth with prominent teeth; the preopercular spines, four in number in each stage; the retention of the depression over the snout, marking the articulation of the premaxillaries; and the prominent dorsal spines. The great increase in length of the dorsal spines is somewhat disturbing in the absence of intermediate specimens. There can be no doubt, however, that these fish, if not of the same species as the smaller and larger ones herein described, at least are of a related species.

Specimens 7.0 to 8.0 mm long.—Three specimens of this size are at hand. They differ little from the somewhat smaller ones described in the preceding section. The upper jaw is now slightly arched as in larger fish; dorsal spines have increased to eight, and remain high as in the smaller fish; soft rays are fairly definite in all the fins, though no articulations are evident; the caudal fin shows a tendency to fork; and the color apparently remains unchanged.

Specimen 14 mm long.—Only one specimen of this size is at hand, and none intermediate of this one and those described in the immediately preceding section. Therefore, a considerable gap remains. However, several similar and identical characters "link" this fish with the smaller ones, showing that if not identical they at least are representatives of related species.

The 14-mm specimen is much more elongate than the smaller ones described, the greatest depth being contained about four times in the standard length. The snout has become still longer and more pointed, being contained 2.1 times in the head, and it projects well beyond the lower jaw. The groove at the articulation of the premaxillaries remains prominent. Spines on the preopercular margin have

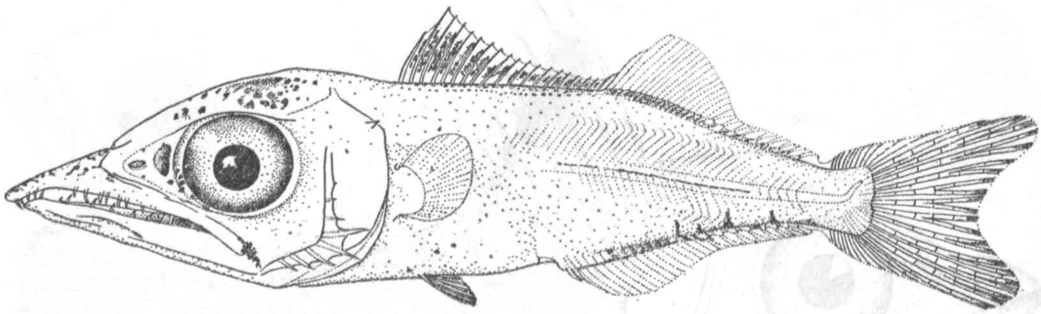

FIGURE 7.—*Scomberomorus maculatus.* From a specimen 14 mm long.

increased to eight. The maxillary has become strongly arched, and the teeth are large. The dorsal spines have increased to 19 (the usual number present in adult Spanish mackerel being 18 or 19), and the anterior ones, which were developed in the smaller fish, are proportionately lower. Although the bases of the second dorsal and anal are well outlined, the development of soft rays in these fins, as well as in the pectorals, is still retarded, whereas those of the caudal and ventrals are rather better developed. The origin of the anal is somewhat in advance of the second dorsal, whereas in adults its origin generally is under or behind that of the second dorsal. Dorsal and anal finlets are not yet definitely developed but thickenings in the fin membranes that will constitute the bases of the finlets are evident. The primitive fin membrane, however, remains continuous in each fin. The caudal fin now is distinctly concave.

The general color of the preserved specimen is brownish, with some black pigment at the posterior end of the maxillary, and scattered black specks on the head and snout. The black band on the spinous dorsal present in smaller specimens remains, but is somewhat broken up into spots in the 14-mm fish. Blackish specks also are visible along the base of the second dorsal and anal fins (fig. 7).

Except for the comparatively great change in the height of the anterior dorsal spines, the 14-mm fish connects up well with the 8.0-mm ones. Additional specimens will be required to determine positively the identity of this fish and the smaller specimens mentioned.

Specimens about 17 mm long.—Five specimens of about this size are at hand. Development is much further advanced than in the 14-mm fish already described. The finlets of the dorsal and anal, eight or nine in number in each fin, are more distinctly outlined, yet remain connected by the primitive membrane. The caudal fin is now definitely forked. The origin of the anal remains slightly in advance of the origin of the second dorsal.

Pigmentation has increased somewhat. Some specimens are partly silvery in color. The black band on the spinous dorsal, very pronounced in younger fish, is now broken up into spots (fig. 8).

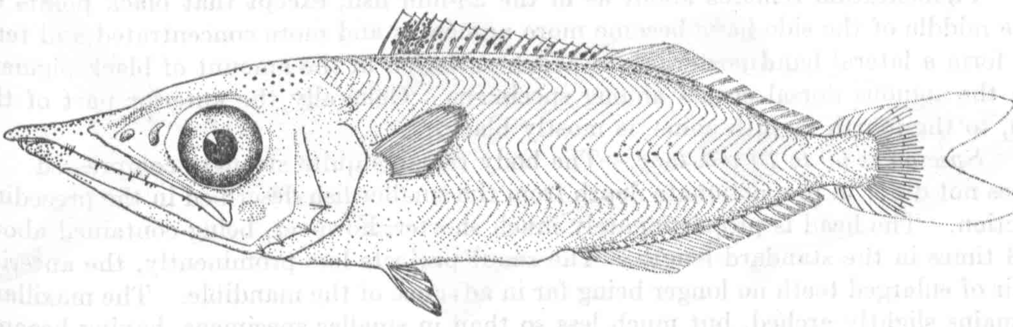

FIGURE 8.—*Scomberomorus maculatus.* From a specimen about 17 mm long.

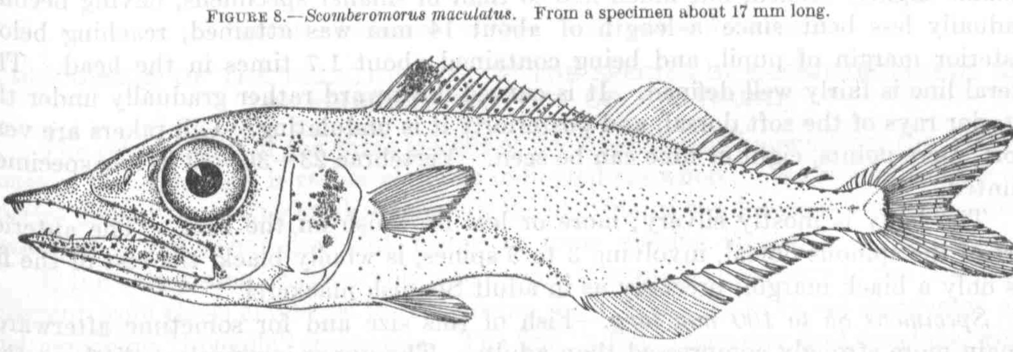

FIGURE 9.—*Scomberomorus maculatus.* From a specimen 22 mm long.

Specimens 22 to 25 mm long.—Ten specimens of about this size have been studied. The body has become rather more slender, the depth now being contained about 4.5 times in the standard length, and it remains rather strongly compressed. The head is long, about 2.5 times in the standard length; the snout is sharply pointed and projects strongly beyond the lower jaw, as in younger fish, its length being contained about 2.2 times in head. The groove at the articulation of the premaxillaries remains evident. The mouth is very large and the teeth are strong, a pair of large canines in the upper jaw being on the part projecting beyond the lower jaw. The maxillary reaches somewhat past the middle of the eye and is contained about 1.4 times in the head. Only two preopercular spines remain. The origin of the anal is now only slightly in advance of that of the second dorsal. The rays of these fins remain imperfectly developed, though those of the other fins are well formed. The finlets are all well developed and separate. The caudal fin is well forked, but not as broadly as in the adults.

Pigmentation has progressed fairly rapidly. The general color is silvery, though the back has a brownish cast. The black markings are shown in figure 9.

Specimens 35 to 40 mm long.—Six specimens of about this size are at hand. The advancement over the 25-mm fish is not great. The upper jaw projects less prominently, and the articulation of the premaxillaries no longer is marked by a definite groove. The preopercular spines have been almost completely absorbed. In some specimens of this size a slight indication of a lateral line is present. The second dorsal and anal now have attained more nearly the relative position occupied in adult fish, as the origins are about opposite each other. (In adult *S. maculatus* and *S. regalis* the origin of the anal generally is slightly behind that of the second dorsal, whereas in *S. cavalla* it often is nearly under the middle of the second dorsal). The rays of these fins now are quite fully developed. The following counts are based on one specimen: D. XIX–17–VII; A. II, 17–VIII; vertebrae 22+31=53.

Pigmentation remains about as in the 25-mm fish, except that black points on the middle of the side have become more numerous and more concentrated and tend to form a lateral band posteriorly. Much variation in the amount of black pigment on the spinous dorsal occurs among specimens. Generally the anterior part of the fin, to the fourth or fifth spine, is mostly black.

Specimens 60 to 70 mm long.—The body remains quite strongly compressed. It does not differ in proportionate depth from the smaller fish described in the preceding section. The head is proportionately much shorter, however, being contained about 3.3 times in the standard length. The snout projects less prominently, the anterior pair of enlarged teeth no longer being far in advance of the mandible. The maxillary remains slightly arched, but much less so than in smaller specimens, having become gradually less bent since a length of about 14 mm was attained, reaching below posterior margin of pupil, and being contained about 1.7 times in the head. The lateral line is fairly well defined. It is curved downward rather gradually under the anterior rays of the soft dorsal, and posteriorly it is undulating. Gill rakers are very short, mere points, eight or nine can be seen. Vertebrae 23+30=53 in one specimen counted.

The body is mostly silvery; more or less brownish on the back. The anterior part of the spinous dorsal, involving 3 to 5 spines, is wholly black, the rest of the fin has only a black margin, precisely as in adult Spanish mackerel.

Specimens 85 to 100 mm long.—Fish of this size and for sometime afterwards remain more strongly compressed than adults. The upper jaw projects little at this size, the teeth remain strong, but less so than in younger fish; and the caudal fin is now broadly forked, about as in the adult. No dermal keel is as yet evident in the lateral line on the caudal peduncle. The following counts and proportions are based on a specimen 97 mm long: Head 3.8; depth 4.6 in standard length; snout 2.8, maxillary 1.8 in head; D. XVII–16–VIII; A. II, 14–IX; gill rakers minute, 9; vertebrae 22+31=53.

The color is bright silvery, rather bluish silvery above. No spots or lines are discernible in the preserved specimens at hand (fig. 10).

Specimen 160 mm long.—A single fish of this length (and none intermediate of this one and one 115 mm long) is at hand. The 160-mm fish does not differ greatly from the smaller group described in the preceding section. The proportions given for the smaller fish have not changed.

No change in color appears to have taken place. No indications of spots or other markings are present on the body in the old preserved specimen studied.

Specimens 210 to 225 mm long.—One specimen of each length given is at hand. These fish were recently preserved. The larger one has dark spots (yellow in life) on the sides as in the adults. The smaller one has none, which seems to show that the spots are not always developed at a length of 210 mm. In structure these fish do not differ essentially from the 160-mm fish already described. These specimens still remain rather more compressed than large fish. The maxillary remains gently arched, and the snout sharply pointed, projecting slightly, just as in the smaller fish described in the foregoing section. The lateral line remains unchanged, being rather gently decurved under the anterior part of the soft dorsal, precisely as in adult Spanish mackerel. The gill rakers have increased somewhat in length, though they do not yet exceed a fourth the length of the pupil. Scales now are present on the soft dorsal and on the anal, though none can be seen on the pectorals. The dermal keel on the caudal peduncle is quite evident.

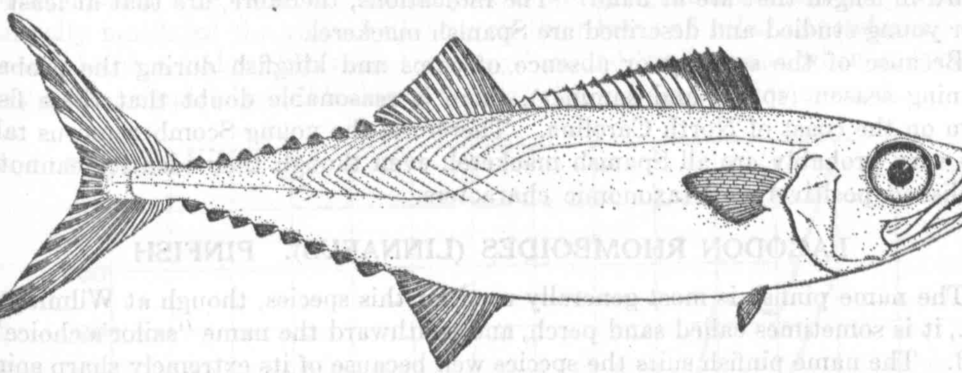

FIGURE 10.—*Scomberomorus maculatus.* From a specimen 97 mm long.

A DISCUSSION OF THE RELATIONSHIP OF THE SPECIES OF SCOMBEROMORUS AND THE PROBABLE IDENTITY OF THE YOUNG

The relationship of the three species of Scomberomorus known from the Atlantic coast of the Americas, is rather close, as indicated elsewhere. We recognize only one species among the young studied, though the identity of the 6.0- to 8.0-mm specimens described is somewhat doubtful, owing to some missing stages.

If the very young are separable into species it would be necessary to use characters different from those employed in recognizing the adults. We have not discovered any distinguishing "juvenile" characters. The first "adult" character that develops, which apparently is of some value in distinguishing the kingfish, *S. cavalla*, from the other local species of the genus, is the relative position of the soft dorsal and the anal. In the kingfish the origin of the anal is well behind the origin of the soft dorsal, often nearly under the middle of the soft dorsal, whereas in the other two species the origin of the anal is under or more usually slightly posterior to the origin of the soft dorsal. The soft dorsal and anal are not well developed until the fish reach a length of about 14 mm, and it is not until the fish reach a length of about 35 mm that the relative position occupied in adults is attained, as the origin of the anal is in advance of the second dorsal in smaller fish. The relative position of these fins remains unchanged in all the larger young (35 mm and upward in length) studied, the origin of the anal being slightly posterior to that of the second dorsal. Therefore, the specimens in our collection probably cannot be identified as *S. cavalla.*

The next distinctive character that develops is the lateral line, which is abruptly decurved under the second dorsal in the kingfish, *S. cavalla*, and rather gradually in the other species. The lateral line sometimes is evident in specimens 70 mm long, but often not until later. Judging from the course of the lateral lines the kingfish again seems to be missing among the specimens that could be checked for this character.

The Spanish mackerel, *S. maculatus*, and the spotted cero, *S. regalis*, are closely related, apparently distinguishable by the presence of scales on the pectoral fins, and by the presence of one or two longitudinal black streaks along the side of the latter. It is not known at what size these distinguishing characters develop. It can only be stated now that no scales are present on the pectoral fins in any of the young at hand. Neither are dark stripes present. In two adult *S. regalis* examined the anterior part of the spinous dorsal is not wholly black, the lower third or so being white. This is shown also in an often reproduced drawing. Adult Spanish mackerel, *S. maculatus*, examined have the anterior part of the fin, involving from three to five spines, wholly black. This is true of young Scomberomorus of about 60 mm and upward in length that are at hand. The indications, therefore, are that at least the larger young studied and described are Spanish mackerel.

Because of the scarcity or absence of ceros and kingfish during the probable spawning season (spring and summer), there is reasonable doubt that these fishes spawn on the coast of North Carolina. Therefore, the young Scomberomorus taken there very probably are all Spanish mackerel, even though their identity cannot be established positively by taxonomic characters.

LAGODON RHOMBOIDES (LINNAEUS). PINFISH

The name pinfish is most generally used for this species, though at Wilmington, N. C., it is sometimes called sand perch, and southward the name "sailor's choice" is heard. The name pinfish suits the species well because of its extremely sharp spines.

The pinfish is known from Cape Cod, Mass., to Texas, and is also reported from Bermuda and Cuba. On our coast it is common from Virginia southward. Its commercial value is not great, however, because of the small size attained. The maximum length reported is 13 inches, but the average length probably does not exceed 6 inches. In the statistical report of the Bureau of Fisheries for 1935, for example, it is listed only from North Carolina (180,000 pounds) and Florida (31,000 pounds). It is marketed in limited quantities in other States, mostly with other species as "mixed fish." Therefore, the exact amount marketed is not obtainable.

The pinfish is of good flavor, and no doubt the demand would be greater if the fish attained a larger size. Occasionally when large catches, running small in size, are made at Beaufort they are taken to the menhaden reduction plants and made into fish meal or fish scrap and oil. The pinfish is said to yield a very high grade of oil.

The pinfish is one of the comparatively few species that is a year-round resident in the shallow water of the estuaries, bays, and sounds at Beaufort. It seems to withstand cold rather better than most of the other species that winter locally. For example, on January 7, 1926, and again January 4, 1928, during rather continued abnormally cold weather many individuals of such species as the speckled trout (*Cynoscion nebulosus*), the spot (*Leiostomus xanthurus*), and the croaker (*Micropogon undulatus*), became numb and floated at the surface. No pinfish were seen among them. However, on December 28, 1925, a large number of this species (5 gallons), mostly rather large ones, were frozen to death in a "fish pool" from which they could not escape and which contained only about a foot of water at low tide. The temperature of the water at the time the fish perished is not known, but the air temperature dropped to 12° F., which is unusually low for Beaufort. It is of interest that some small mullets (*Mugil cephalus*) about 6 inches in length, that had been confined in the pool with the pinfish survived, indicating that this mullet can stand even more cold than the pinfish.

The pinfish is a nuisance in some respects to anglers because of its ability to cut the bait off the hook without itself getting caught, and to net fishermen because when "gilled" it is hard to remove. The sharp spines make the fish difficult to grasp without injury to the hands. Furthermore, a small sharp spine, directed forward, precedes the dorsal fin. This procumbent spine prevents the fish from being forced through the mesh (the usual procedure in removing gilled fish) without lifting the thread over the spine. The fish taken in this way generally are too small to be of much value. Therefore, fishermen often have to labor long at the disagreeable task of removing the fish from the nets without receiving anything in return.

The pinfish also was a most annoying pest to an investigator who had confined crabs in floating wire cages for the purpose of studying their life history. The fish continually mutilated the crabs by biting off their legs and other appendages. The fish could be observed readily while "working" around the float and when underneath it they swam completely upside-down, that is, with the ventral side upward.

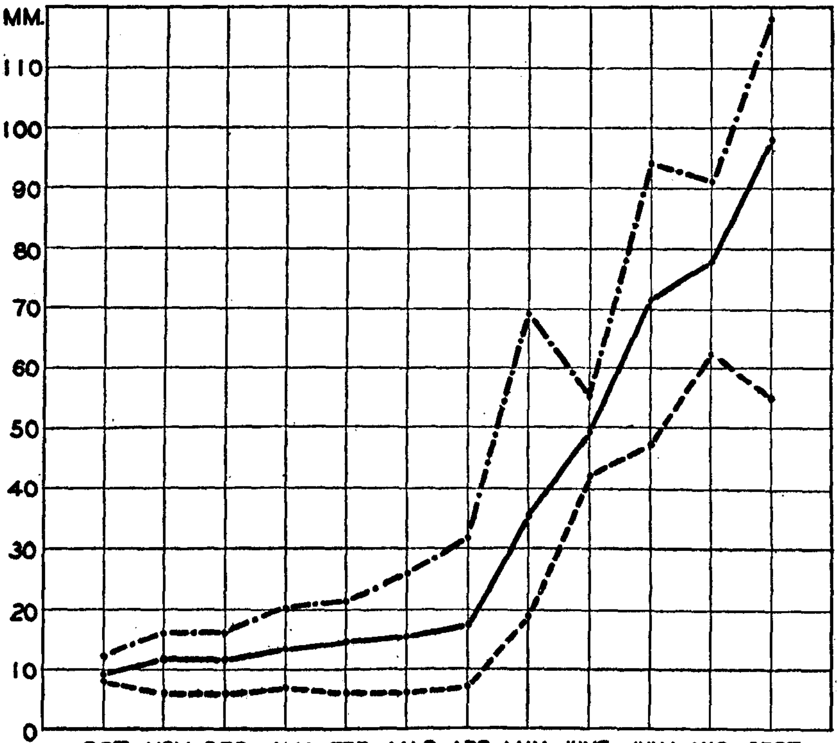

FIGURE 11.—Growth curve based on length measurements of 3,348 *Lagodon rhomboides* of the 0-class. Solid line, average length for each month of all fish measured; dot and dash (upper) line, largest fish; dot and several dashes (lower) line, smallest fish.

CHARACTERS OF THE ADULT

The pinfish (*Lagodon rhomboides*) belongs to the family Sparidae with the sheepshead (*Archosargus probatocephalus*), discussed elsewhere in this publication.

The adult pinfish is most readily recognized by its rather deep, compressed body, crossed by four to seven dark bars, and by its prominent deeply notched incisor teeth. The depth of the body is quite variable among specimens, being contained 2.2 to 2.9 times in the length to the base of the caudal. The head is rather long, and the snout is moderately pointed, being notably longer than the eye. The mouth is small and horizontal, with the maxillary reaching only to the eye. D. XI or XII, 10 to 12; A. III, 10 to 12; scales 62 to 68; vertebrae 9+15.

SPAWNING

Many adult fish were examined in the vicinity of Beaufort, from 1914 to 1917 and from 1925 to 1931, as to the state of development of the gonads. However, no ripe fish, nor even fish with developing roe, was found, notwithstanding that Smith (1907, p. 300) reported that a ripening female was seen at Beaufort on August 6 (1903), and a ripe male on November 20 (1903). The virtual absence of ripe, or ripening, fish in the local inshore waters suggests strongly that the fish go elsewhere to spawn. The collection of small young near the inlet and at offshore stations, only, as shown subsequently, seems to indicate that spawning takes place at sea, probably a considerable distance offshore. The presence of rather early young in the local waters over a long period of time, as shown in the following paragraph, indicates a long spawning season.

Young, 10 mm and less in length, first appeared in the tow toward the end of October, and continued to be taken each succeeding month until toward the end of April. However, they were most numerous in December and January. The presence of such small fish over this long period of time seems to show that spawning begins in October and that it continues until the following March.

All the smaller young, consisting of 242 fish of 10 mm and less in length, either were taken at offshore stations or in or near Beaufort Inlet, some of the stations being as much as 12 or 13 miles offshore, beyond which no collecting was done. However, as the eggs and early larvae, or fry under 5.0 mm in length, were not found, it seems probable that spawning takes place beyond the most distant stations made. Therefore, the young taken at sea presumably were migrating from the spawning grounds to the inshore waters where the larger young, of 12 to 15 mm and upward in length, and the adults are numerous.

DESCRIPTIONS OF THE YOUNG

The early larvae were not taken, and therefore remain unknown, as already stated.

Specimens about 5.0 to 5.5 mm long.—Two specimens with damaged caudal fins are at hand. The body is decidedly elongate and compressed, the depth being contained 3.6 to 3.9 times in the length without the caudal fin. The dorsal outline is concave just in advance of the eyes and also at the nape, or just posterior to the brain, which is visible through the thin walls of the skull. The head is rather low, compressed 2.9 to 3.0 in length. The snout is moderately pointed, as long as the eye, 3.0 to 3.5 in head; the maxillary reaches nearly opposite the anterior margin of the pupil; and the gape anteriorly is very slightly below the level of the middle of the eye. Teeth are not evident. About 22 myomeres may be counted. The vent is situated slightly nearer the base of caudal than tip of snout. The primitive dorsal fin membrane in the 5.0-mm fish has suggestions of rays in the region of the anterior part of the soft dorsal of the older fish. These rays are considerably further developed in the 5.5-mm specimen. Rays are rather more definitely developed in the anal fin than in the dorsal. The notochord is bent upward posteriorly, and well-developed caudal fin rays appear below it, which are broken distally. Therefore, the exact shape of the fin cannot be determined. However, as somewhat larger specimens have a rounded caudal, it may be assumed that the fin also was more or less rounded in the small specimens. Pectoral fins are quite well developed and rather long, but the ventrals are minute.

The general color is pale. On the median ventral line are three dark spots, one near the isthmus, another on the chest, and a third one just in advance of the vent. A row of black dots occurs along the ventral outline from the origin of the anal to the base of the caudal. A dark area, apparently internal, is visible on the side above and slightly posterior to the vent (fig. 12).

Specimens 6.0 to 7.0 mm long.—The advancement over the 5.0-mm fish, already described, is not great. The body apparently has become slightly more elongate, the depth in three specimens measured is contained 3.8 to 4.0 times in the length to the base of the caudal fin. The concavities in the dorsal outline (in advance of the eyes and at the nape) remain, but are less pronounced. No change, worthy of note, has

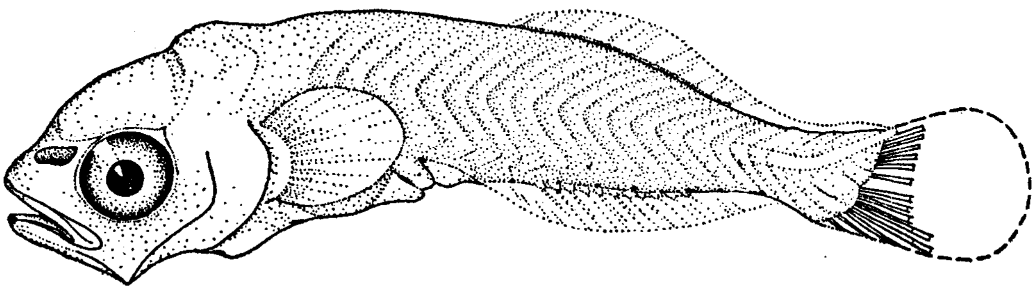

FIGURE 12.—*Lagodon rhomboides.* From a specimen 5 mm long.

taken place in the shape of the head, snout, eyes, or mouth. The principal advancement is the development of more definite soft rays in the dorsal and anal fins, of which about 12 can be counted in each fin. The spines, however, are not yet well differentiated. The caudal fin is quite long and round. The pectoral fins are long and reach to the vent, but the ventral fins are scarcely differentiated.

The black dots, present in the smaller fish described, persist and are more definite. In addition a few to several black dots now are present on the base of the caudal, two or more on the upper surface of the caudal peduncle, one at the nape, and generally an elongate blackish one above the base of the pectoral (fig. 13).

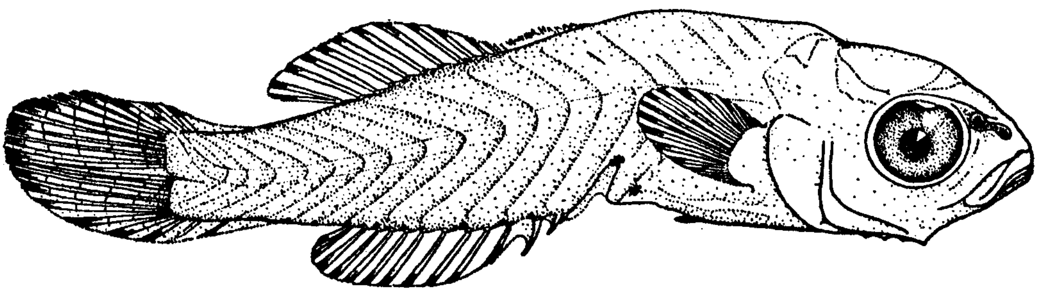

FIGURE 13.—*Lagodon rhomboides.* From a specimen 7 mm long.

Specimens 8.0 to 10 mm long.—Development has progressed rather slowly. The body has become somewhat more slender, but it remains about equally compressed, the depth now being contained 4.3 to 4.6 times in the length to the base of the caudal. The dorsal outline remains as in the smaller fish, except that depressions in advance of the eyes and at the nape have disappeared, but the brain remains visible. The head now is contained 3.5 to 3.6 in head; eye 2.9 to 3.1 in head; and the snout 3.0 to 3.3. The mouth remains oblique, with the maxillary reaching nearly opposite anterior margin of pupil. Jaw teeth now are evident, but contrary to most spiny rayed fishes studied, no spines are visible at this size on the preopercular margin. The vent now is situated at midbody length, without caudal. The development of the fins has progressed rather rapidly. The spines in the dorsal and anal are well differentiated; the caudal fin is long and round, being nearly as long as the head; the pectoral fins, too, are long, reaching the vent; but the ventral fins are minute, being scarcely longer than the pupil.

The only change in color, worthy of note, is the development of additional dark dots along the ventral outline of the chest and abdomen, which vary in number among individuals. Some specimens also have developed a few extra chromatophores on the dorsal surface of the head.

Specimens 13 to 15 mm long.—No measureable changes in the proportions of the body have taken place. However, the snout has decreased in proportionate length and is definitely shorter than the eye, 3.6 to 4.0 in the head, whereas the eye is contained 2.8 to 3.0 times in the head. The mouth remains oblique, the gape anteriorly being only slightly below the level of the middle of the eye; the maxillary reaches only slightly beyond the anterior margin of the eye; and the teeth remain minute. The skull remains transparent, leaving the brain plainly visible from above. The rays in the dorsal and anal are all developed as the usual number present in adults may be counted, but the spines remain proportionately much shorter than in the

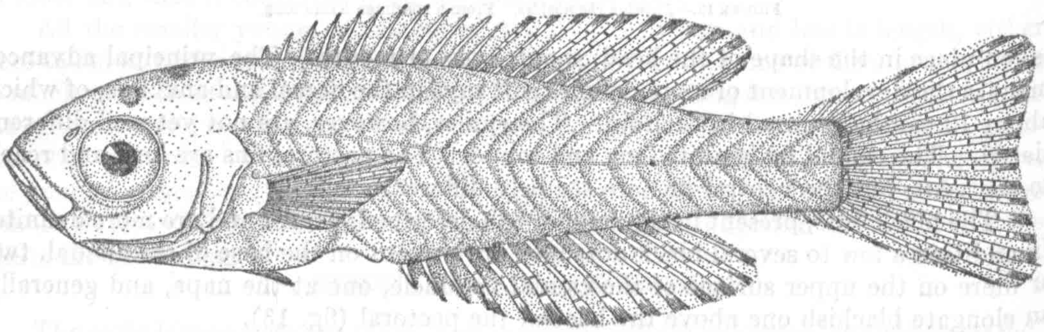

FIGURE 14.—*Lagodon rhomboides*. From a specimen 13 mm long.

adult. The caudal fin becomes square when the fish attains a length of about 12 mm and is definitely concave at a length of about 14 mm. The pectoral fins remain long, reaching nearly to origin of the anal; and the ventral fins have increased greatly in size, being nearly as long as the eye in 15-mm fish, but the spine is not yet well differentiated.

No changes in color markings worthy of note have taken place since a length of about 10 mm was attained (fig. 14).

Specimens 18 to 20 mm long.—Specimens of this length are variable in shape and color. Some specimens up to 20 mm in length remain quite as slender as 15-mm fish, whereas others are notably deeper. The slender specimens of this size are as void of pigmentation as 15-mm fish, whereas the deeper bodied specimens are profusely pigmented and have dark cross bars as in the adult. A few specimens only 16 to 17 mm long already have increased considerably in depth and have evident cross bars, whereas others up to 20 mm in length remain slender and pale. It is evident, therefore, that pigmentation and the deepening of the body take place simultaneously and that these changes occur at varying lengths. These changes apparently are associated with a change in habitat, as shown subsequently.

The depth is contained in the length to the base of the caudal 4.3 to 4.5 times in three unpigmented specimens measured, whereas in three pigmented fish of the same size it is contained 3.5 to 3.9 times. Other proportions do not differ measurably in the two groups, the head in six specimens (three of each group) measured being contained 3.3 to 3.6 times in the length without the caudal fin, eye 2.8 to 3.2 in the head, and the snout 3.3 to 3.8 in head. The teeth remain small and equally developed in the pigmented and unpigmented specimens. Pigmented specimens about 20 mm in length are at least partly covered with scales but smaller pigmented fish and unpigmented ones, up to 20 mm in length, have none. The ctenoid character of the scales is evident as soon as the scales are developed. The fins are longer and more fully developed in the pigmented fish, though the ventral spine is differentiated in each group. The pigmented specimens, however, have the first soft ray of the ventral produced into a short filament, which is not present in unpigmented fish. The caudal fin is deeply concave in all specimens.

The specimens referred to in the foregoing paragraph as unpigmented retain a few dark markings, essentially as in much smaller fish. The pigmented ones already

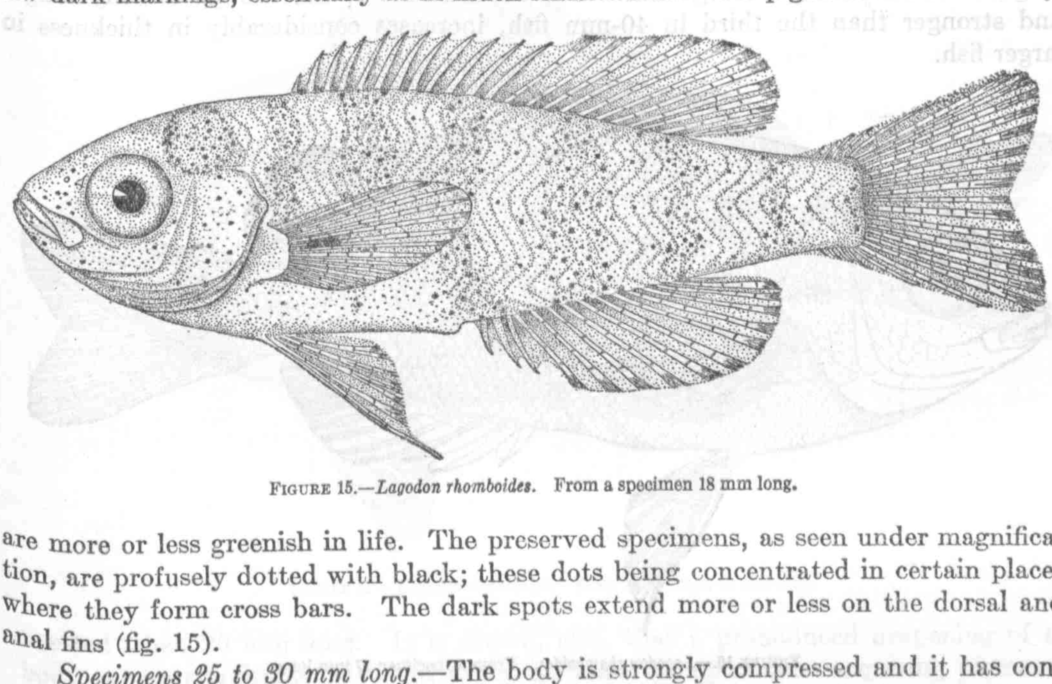

FIGURE 15.—*Lagodon rhomboides.* From a specimen 18 mm long.

are more or less greenish in life. The preserved specimens, as seen under magnification, are profusely dotted with black; these dots being concentrated in certain places where they form cross bars. The dark spots extend more or less on the dorsal and anal fins (fig. 15).

Specimens 25 to 30 mm long.—The body is strongly compressed and it has continued to increase in depth, which now is contained 2.5 to 3.0 in the length without the caudal fin, proportions found also in adults. The dorsal profile is strongly elevated and round, being much more strongly curved than the ventral outline. The head is rather short and deep, being contained 2.8 to 3.1 times in the length without the caudal fin; the snout remains blunter and proportionately shorter than in the adult, 3.5 to 3.8 in head; eye 3.1 to 3.5. The mouth has become almost horizontal, the gape being wholly below the eye; the maxillary reaches slightly past the anterior margin of the eye; and the anterior teeth are somewhat enlarged. The exposed tips of the anterior teeth are pointed, and under magnification it is evident that these tips arise in pairs from a common base. The body is fully scaled; the pectoral and ventral fins remain shorter than in adults; the first soft ray of the ventral retains a short filament, which reaches the origin of the anal; and the second anal spine already is stronger than the third one, though not as much so as in the adult.

In the general color pattern specimens 30 mm long do not differ greatly from larger fish (fig. 16).

Specimens 40 mm and upward in length.—The body is quite variable in depth among individuals, and it may be deeper in rather smaller fish than in much larger ones. For example, the depth is contained 2.3 times in the length to the base of the caudal in a 40-mm specimen, whereas in a 125-mm one it is contained 2.6 times. The snout continues to become more pointed and proportionately longer with age, being contained 3.1 times in the head in a 40-mm fish and 2.5 times in 165-mm ones. The mouth has become horizontal and much below the eye, and the teeth already are broad and well notched in fish 40 mm long. The caudal fin becomes more deeply forked with age, and the lobes become more sharply pointed. The pectoral and ventral fins increase in length and become pointed with age. The pectoral fins reach the vertical from the vent in specimens about 40 mm long, whereas in large specimens they reach beyond the origin of the anal. Specimens up to about 100 mm in length retain the filament on the first soft ray of the ventral which thereafter decreases in length and is missing in large fish. The second anal spine, though already longer and stronger than the third in 40-mm fish, increases considerably in thickness in larger fish.

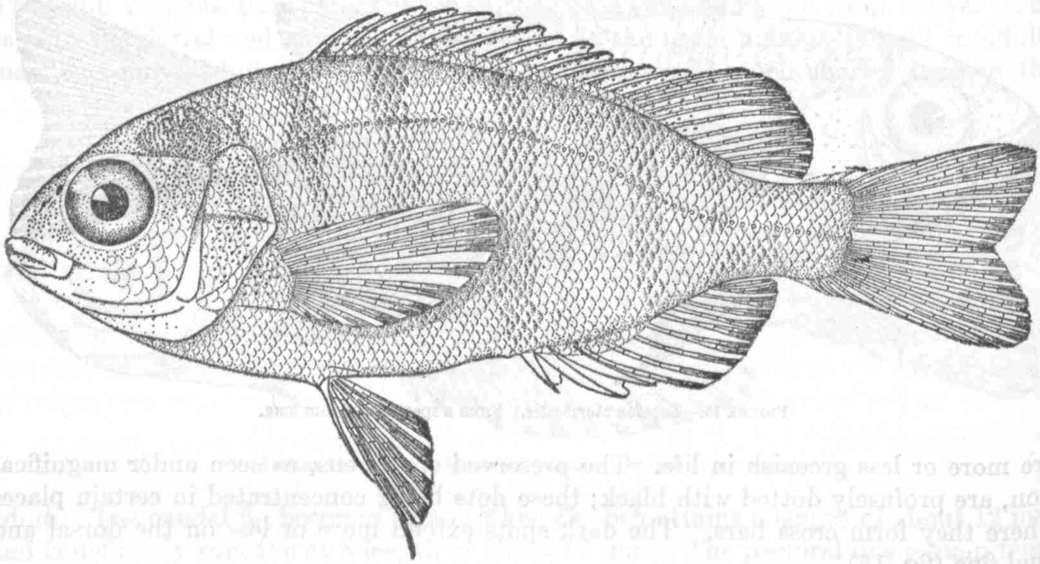

FIGURE 16.—*Lagodon rhomboides*. From a specimen 27 mm long.

The color is extremely variable. Dark cross bars are present in all specimens at hand, though variable in intensity. Furthermore, some specimens have prominent alternating bluish- and yellowish-green longitudinal lines which are indistinct or wanting in others (fig. 17).

DISTRIBUTION OF THE YOUNG

The smallest young (5.0 to 10 mm in length) secured were all collected offshore or in or near Beaufort Inlet. These young presumably were en route from the spawning grounds to inshore waters. Exactly where spawning takes place is not known. However, the indications are that it occurs a considerable distance offshore. The early larvae (under 5.0 mm in length), missing in the collections, which were made within 12 or 13 miles from the shore, would be expected to occur near the spawning grounds, as such small fish, lacking self-directive powers, could not have drifted far. The discovery of the habitat of these early young therefore remains for future investigation, but apparently should be sought a considerable distance offshore.

The smallest fry collected, ranging from 5.0 to 10 mm in length, were nearly all taken with 1-meter tow nets, and mostly at the surface. Young ranging upward of 10 mm in length enter the sounds and bays and estuaries freely, though some remain in the open outside waters until a length of about 20 mm or more is attained. After the fish enter the inshore waters they tend to settle more or less on the bottom.

Many of the young after entering the inshore waters occupy areas overgrown with eelgrass or other bottom growths, a habitat also occupied by their relatives, the young sheepshead.

It is interesting that the fish occupying the weedy areas become pigmented much earlier than those remaining in open water. In the description of young 18 to 20 mm in length it is shown that some specimens are well pigmented at a length of 18 mm and a few at even a smaller size, whereas others still are virtually unpigmented when 20 mm long. It is shown, also, that a pronounced deepening of the body occurs simultaneously. In every instance the specimens acquiring pigmentation, as well as the deeper body early, were collected in weedy areas, whereas the large (up to 20 mm in length) unpigmented ones were taken in open water.

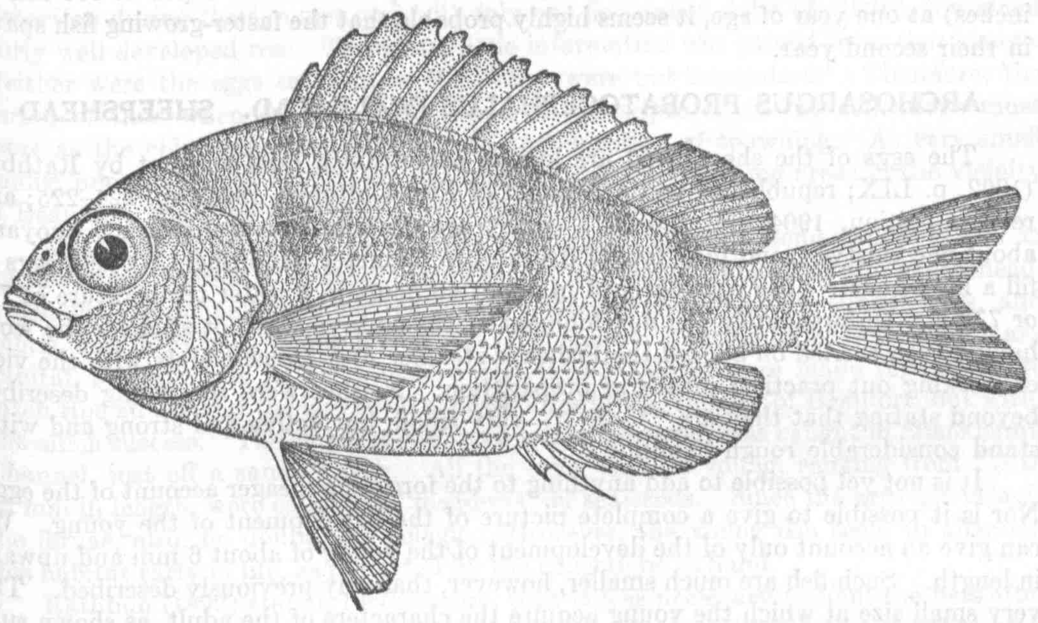

FIGURE 17.—*Lagodon rhomboides*. From a specimen 63 mm long.

During the winter (December to February) young ranging from about 12 to 16 mm in length are often numerous in the deeper channels, in the sounds and estuaries, in company with young croakers and spots of about the same size. At this season of the year large schools of young pinfish, and spots, were frequently seen in quiet coves of the breakwater and jetties along the eastern shore of Pivers Island. When winter is over young pinfish are not abundant in the deeper channels, as they then chiefly occupy the shallow weeded areas; and they are seen also around piers, breakwaters, jetties, wrecks, etc., where presumably they find the food they need, which seems to be virtually identical with that of the sheepshead (see p. 532).

GROWTH

The rate of growth of the pinfish during the first several months of life, as shown in figure 11, is very slow, owing no doubt to the cold weather of winter. Other common fall- and winter-spawned fish, such as the spot and the croaker, also grow slowly at first (Hildebrand and Cable, 1930, pp. 426 and 443). However, in May when the water became warmer, and food probably became more plentiful, the fish began to grow rather rapidly, and this rate of growth apparently was maintained for several months, not slowing down again until after September.

According to measurements taken the fish ranged from 50 to more than 100 mm in length when a year old. Since the average length of the usual catch of adult pinfish at Beaufort probably does not exceed 150 mm (6 inches) early maturity is probable. As some of the fast-growing fish already exceeded a length of 100 mm (4 inches) at one year of age, it seems highly probable that the faster-growing fish spawn in their second year.

ARCHOSARGUS PROBATOCEPHALUS (WALBAUM). SHEEPSHEAD

The eggs of the sheepshead are known only from a brief account by Rathbun (1892, p. LIX; republished in "A Manual of Fish Culture", 1898, pp. 224–225; and revised edition, 1904, pp. 226–227). They are described as transparent, buoyant, about one thirty-second inch (about 0.8 mm) in diameter, requiring 1,600,000 eggs to fill a fluid quart. The eggs hatched in about 40 hours in a water temperature of 76° or 77° F. Unfortunately the development of the embryo was not studied, the work having been carried on aboard the Fisheries steamer *Fish Hawk* merely with the view of working out practical means of propagation. Neither were the young described beyond stating that they are "* * * very small, but active and strong and withstand considerable rough handling."

It is not yet possible to add anything to the foregoing meager account of the eggs. Nor is it possible to give a complete picture of the development of the young. We can give an account only of the development of the young of about 6 mm and upward in length. Such fish are much smaller, however, than any previously described. The very small size at which the young acquire the characters of the adult, as shown subsequently, is quite remarkable.

The salt water sheepshead is of wide distribution, ranging from Cape Cod, Mass. (rarely to the Bay of Fundy), south to Tampico, Mexico. At Beaufort, N. C., it is a year-round resident, though more numerous in the summer than winter.

The sheepshead is sought not only by commercial fishermen, but also extensively by anglers, as it is one of the gamest of salt-water fishes. It is a food fish of excellent flavor and brings a good price in the market. It attains a maximum weight of 30 pounds according to published reports. However, the largest one which we saw at Beaufort, during 10 years of intermittent angling, collecting, and observation of fishermen's catches, was a female weighing 12 pounds (length not recorded). This fish was taken in a seine on Shackleford Banks (inside) by commercial fishermen. Fish weighing from 1 to 2 pounds (11 to 15 inches long) make up the principal catch of the angler locally, though individuals up to 5 pounds (20 inches in length) are not rare.

CHARACTERS OF THE ADULT

Adult sheepshead are characterized by the oblong, deep, compressed body, crossed by about seven black bars on a greenish-yellow background. The mouth is rather small, nearly horizontal, and is provided in front with incisor teeth, which are entirely or only slightly notched (not deeply notched as in some related species). The posterior teeth are composed of strong molars, which are used for crushing crustaceans and mollusks. The dorsal fin is long and continuous, being composed of 11 or 12 strong spines and 11 to 13 soft rays, and it is preceded by a short spine directed forward (more or less imbedded in large specimens). The caudal fin is forked; the anal consists of 3 sharp spines (the second one the largest) and 10 or 11 soft rays; and the pectoral fins are long, reaching to or beyond the origin of the anal. Vertebrae 9+15.

SPAWNING

No opportunity was found to examine a large number of sheepshead as to the development of the gonads. Of the comparatively few fish examined in the spring, when spawning evidentally takes place (many more specimens became available for dissection during the summer and fall) only one fish, taken June 16 (1926), contained fairly well developed roe. Therefore, little information was gained from that source. Neither were the eggs secured, or if so they were not recognized.[3] Therefore, the period of time when comparatively small young appeared in the collections must serve as the chief indication of the time and duration of spawning. As very small young, under 6 mm in length, are not represented, the spawning areas in the vicinity of Beaufort cannot be determined from the collections.

According to Rathbun (1892) the sheepshead spawns along sandy shores in southwestern Florida. A sandy shore is not the usual habitat of the sheepshead, which lives principally among rocks, piers, breakwaters, wrecks, sunken logs, and debris, and in Florida among mangroves. Therefore, it seems to leave its customary habitat to carry out its reproductive activities. Efforts were made repeatedly to catch ripe adults and the larvae on sandy shores in the vicinity of Beaufort, but without much success. The smallest specimen taken, however, was caught in Shackleford Channel, just off a sandy beach. All the other smaller young, ranging from 7.5 to 65 mm in length, were caught in "meadows" of seaweeds. Since the eggs are pelagic the larvae, also, no doubt, are pelagic. However, the young fish seem to abandon this habitat early in life, as indicated by the collections at hand.

Rathbun (1892) stated, furthermore, that it was necessary to haul the nets after 4 o'clock in the afternoon to catch ripe females, the best time being about sunset. Late evening spawning seems to be quite general among marine fishes producing pelagic eggs.

The smallest young secured at Beaufort was taken on May 20 (1930), in a tow net hauled at the surface in Shackleford Channel. This fish apparently was still living in its larval habitat, though already well past the larval stage. Why only this single specimen was taken in the pelagic stage cannot be explained, as great effort was made to secure others, many hauls with tow nets having been made in the same general vicinity from 1927 to 1931. Apparently the fish simply were not there. The next smallest young, ranging from 7.5 to 18 mm in length, were caught June 21 (1926), with a bobbinet seine hauled in eelgrass along the shores of Pivers Island. Small young, 11 to 21 mm in length, were taken as late as July 8 (1931). Thereafter they ran larger in size. However, a few specimens of 19 to 21 mm in length, and one 25 mm long, were taken as early as June 14 (1929). The range in length of the young collected each month, arranged in 5-mm groups, is shown in figure 23.

[3] The several years of experience gained in endeavoring to identify marine-fish eggs taken in tow taught us that the task is very difficult. Aside from the many that obviously were unknown, we never could be quite certain that we recognized all the species included among the supposedly known ones. To gain an idea of the great similarity of the eggs of some of the common marine species the reader is referred to earlier papers (1930 and 1934) by the writers.

Fish 6 to 8 mm long probably are not over 2 weeks old, but individuals 19 to 25 mm long, judging from the rate of growth of other species for which more data are at hand, may be 4 to 6 weeks old. It may be concluded, then, from the dates when young fish were caught, given in the preceding paragraph, supported by the single female with developing roe caught on June 16 (1926), that the sheepshead spawns from sometime in April to perhaps the latter part of June in the vicinity of Beaufort.

DESCRIPTIONS OF THE YOUNG

Specimens under 6 mm in length have not been taken. Therefore, the larvae, as already stated, remain unknown. The small size at which young sheepshead acquire the characters of the adults is remarkable.

Specimen 6.0 mm long.—A single specimen with a damaged caudal fin of about 6.0 mm (5.2 mm to base of caudal) in length is at hand. This fish already is well past the larval stage, as will be brought out in the following description.

Body elongate, compressed, its depth 3.4 times in length to base of caudal; head rather short, compressed, 3.0 in length to base of caudal; snout short, blunt, with rounded profile, 4.2 in head; eye wholly lateral, rather small for such a young fish, 3.1 in head; mouth small, oblique, almost terminal; maxillary reaching about to pupil;

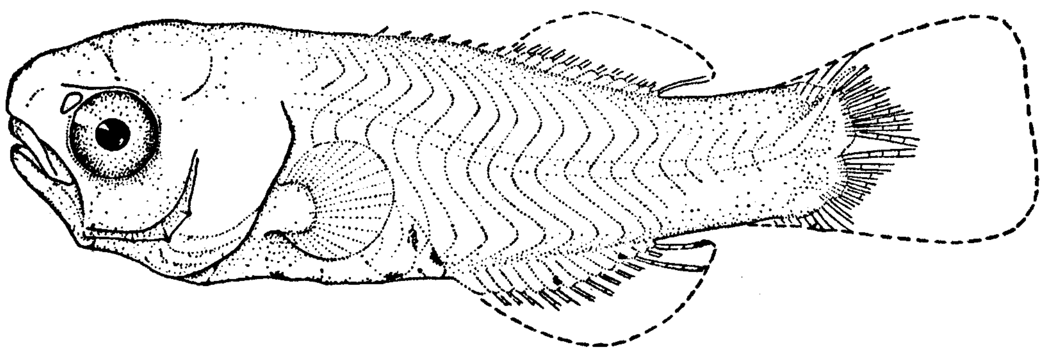

FIGURE 18.—*Archosargus probatocephalus.* From a specimen about 6 mm long.

preopercular spines present, but very short; vent a little behind midbody length; notochord bent upward posteriorly as usual in young teleosts having homocercal tails; myomeres about 27 (vertebrae in adults 9+15=24). The fins are remarkably well developed for such a small fish. Dorsal spines very short, about 7 discernible at this size (adults with 11 or 12); soft rays 12 (11 to 13 in adults); caudal fin with well developed rays (broken); anal fin with 13 rays, the spines not well differentiated (adults with 3 spines and 10 or 11 soft rays); ventral fins not yet discernible; pectoral fins broad, damaged, apparently rather short.

The general color of this preserved specimen is brownish, without very definite markings. Median ventral line with three obscure dark spots, one slightly behind isthmus, another below vertical from base of pectorals and the third one a very short distance in front of vent. A slight dark coloration is evident on side just posterior to vent, and two dark specks are present on the base of the anal fin (fig. 18).

Specimen 7.5 mm long.—A single specimen with a damaged caudal fin of about 7.5 mm (6.25 mm to base of caudal) in length is at hand. A fairly complete description of this specimen when fresh, was prepared. It was then about 8 mm long, having shrunken somewhat during preservation.

The differences between this specimen and the smaller one already described are not pronounced, except in color. The body has become somewhat more slender, the depth now being contained 3.9 times in the length to base of caudal, and the head remains short, compressed, 3.7 times in length to base of caudal. The snout also remains short, blunt, with a steep profile, only a little shorter than the eye, and is contained 3.0 times in the head. The mouth is slightly less oblique than in the smaller specimen.. The dorsal spines remain short and feeble, though 13, the full number (11 to 13) present in the adult, may be counted. The three anal spines now are differentiated. However, the spines are more retarded in development than the soft rays. The caudal fin (broken now) was described as "slightly concave" in the field notes. The ventral fins are quite evident, though minute, being scarcely longer than pupil, and are inserted very slightly behind the base of the rather broad well-developed pectorals.

The color of a fresh specimen is described in the field notes in part as, "pale, without cross bars, though small dark chromatophores are present along the side of body, but not yet forming cross bars." However, the preserved specimen does show an arrangement of chromatophores which suggest a bar between the anterior part of the soft dorsal and anal, and another just posterior to these fins (see fig. 19), precisely where bars are present in larger fish. The upper margin of the eye in the fresh

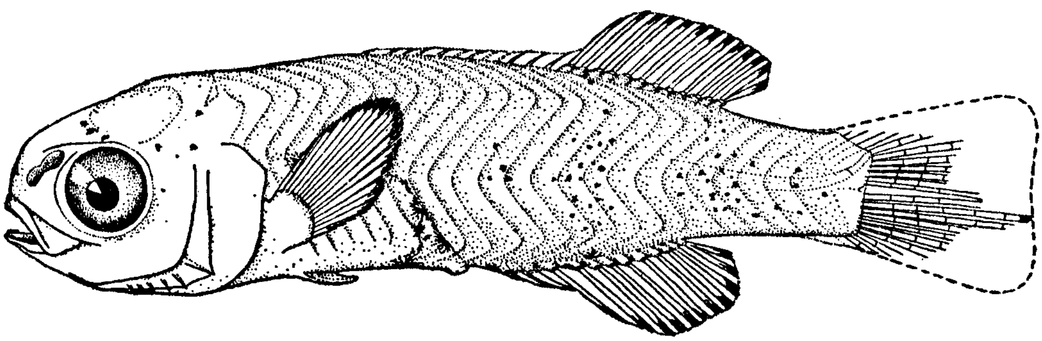

FIGURE 19.—*Archosargus probatocephalus*. From a specimen 7.5 mm long.

specimen was dark, and black chromatophores were present on the interorbital and also along the chest, abdomen, and base of anal. The three obscure dark spots along the median vental line in the smaller fish described persist in the larger one, the posterior one situated somewhat in advance of the vent having become rather more prominent (fig. 19).

Specimens 10 to 12 mm long.—Several specimens ranging from about 10 to 12 mm in length were collected. These fish already resemble the adults so much that they are not difficult to identify.

The body has become deeper, and it is much more robust, the depth being contained about 3.0 to 3.2 times in the length to base of caudal. The head has become notably broader and is now contained 3.0 to 3.25 in the length. The snout remains short, rounded, with a steep profile, and much shorter than the eye, its length 4.3 to 4.7 in head; eye 3.0 in head. The mouth remains small, slightly oblique, and nearly terminal, the maxillary reaching about to pupil. The lateral line has made its appearance, being represented by a few pores anteriorly. The body is almost fully covered with scales at a length of 12 mm, though not so indicated in figure 20. The dorsal and anal spines are much better developed, but still proportionately much shorter than in adults. The caudal fin is distinctly concave, and the ventral fins have increased greatly in length, being longer than eye and reaching nearly to vent.

Pigmentation has progressed rapidly, though it is not complete. Individual chromatophores are present everywhere and are concentrated in definite areas to form bars which are not developed equally early in all specimens. Usually, however, they are more or less definite in specimens 10 mm long, quite distinct in 12-mm fish, and generally 7 in number, as in the adult (fig. 20).

Specimens 15 to 18 mm long.—The body has become somewhat deeper, the depth now being contained about 2.9 in the length to base of caudal. The head remains short and deep, about 3.0 in length. The snout is a little less blunt and slightly longer, about 4.1 in head; eye longer than snout, about 3.0 in head. The mouth

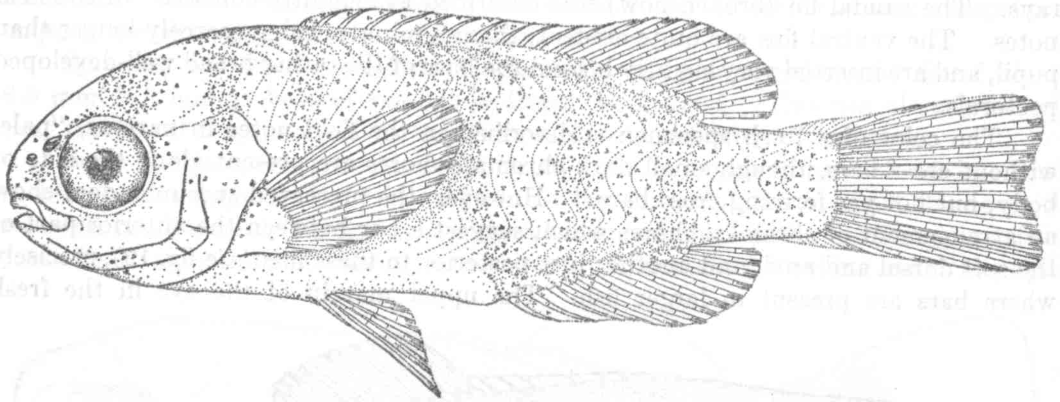

FIGURE 20.—*Archosargus probatocephalus.* From a specimen 12 mm long.

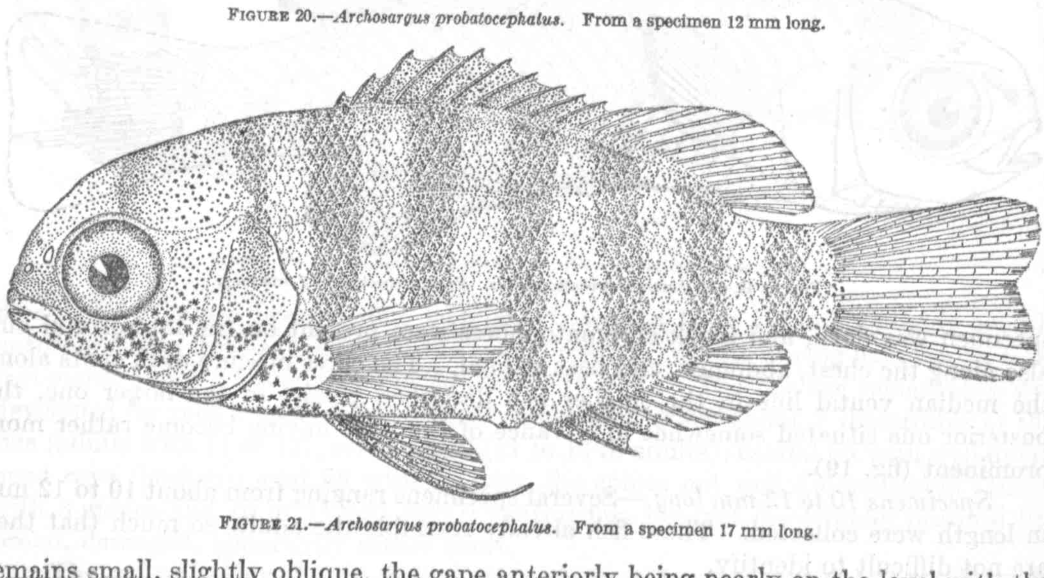

FIGURE 21.—*Archosargus probatocephalus.* From a specimen 17 mm long.

remains small, slightly oblique, the gape anteriorly being nearly on the level with the lower margin of the eye; maxillary reaching slightly past anterior margin of eye. Preopercular spines, present in smaller fish, no longer are evident. The lateral line generally is rather fully developed in specimens 18 mm long, and the body is covered with scales. The dorsal spines have increased in proportionate length, but remain notably shorter than the soft rays. The anal spines are well developed, the second one already being the strongest as in the adult. The outer unbranched ray of the ventral is not yet fully developed as a spine; the second ray with a free filament distally, frequently reaching origin of anal.

Specimens 18 mm long, in the fresh state, have the general color of the adult, including the characteristic black cross bars (fig. 21).

Specimens 25 to 30 mm long.—The body has increased still further in depth, which is now contained about 2.3 to 2.5 in the length to the base of the caudal. The head has become longer, 2.8 to 2.9 in length. The snout is longer and more pointed, 3.4 to 3.7 in head; eye longer than snout, 2.6 to 2.9 in head. The mouth is nearly horizontal, and wholly below the lower margin of the eye; maxillary scarcely reaching past anterior margin of eye. The lateral line is fully developed. The dorsal spines are strong and proportionately about as high as in adults; those of the anal also as in adults, the second one notably longer and stronger than the others. The caudal fin is slightly forked as in large individuals. The filament on next to the outermost ray of the ventral persists, reaching about to the origin of the anal, the outermost ray now being developed quite definitely as a spine. The pectoral fin has increased somewhat in length, its distal margin, instead of being round as in the smaller fish is now oblique, the longest rays being in the upper half of the fin, reaching nearly to origin of anal.

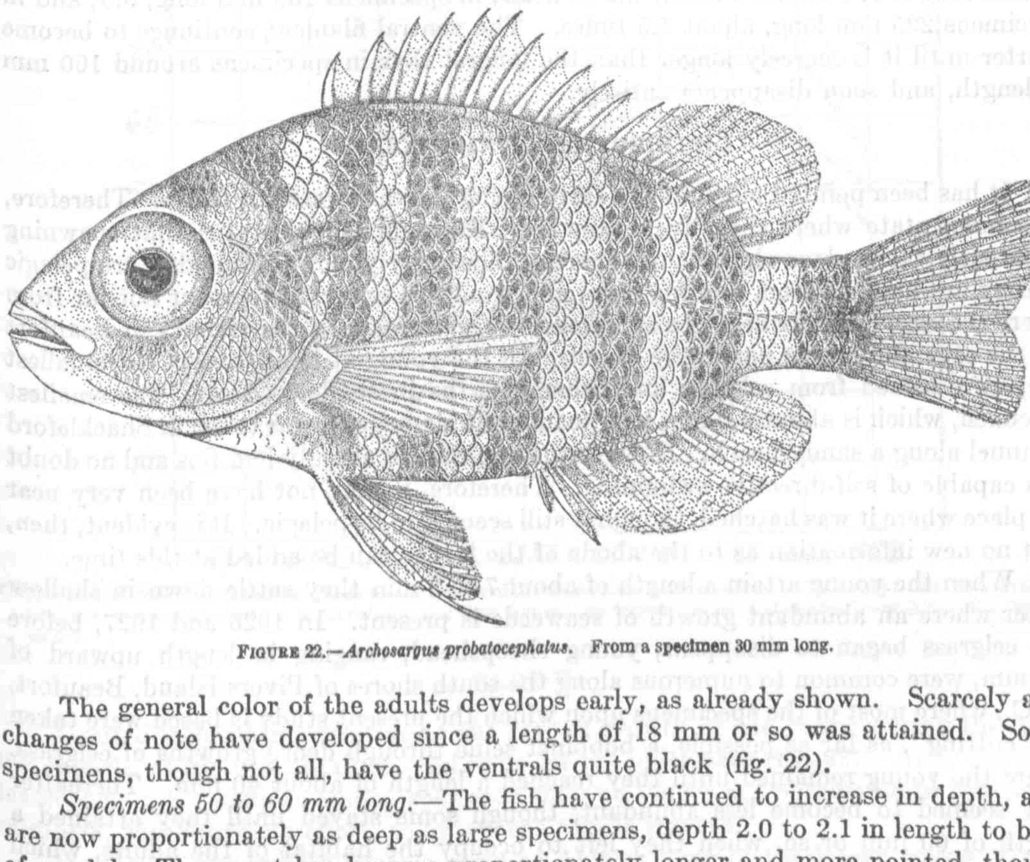

FIGURE 22.—*Archosargus probatocephalus.* From a specimen 30 mm long.

The general color of the adults develops early, as already shown. Scarcely any changes of note have developed since a length of 18 mm or so was attained. Some specimens, though not all, have the ventrals quite black (fig. 22).

Specimens 50 to 60 mm long.—The fish have continued to increase in depth, and are now proportionately as deep as large specimens, depth 2.0 to 2.1 in length to base of caudal. The snout has become proportionately longer and more pointed, though still notably shorter than in large individuals, equal to or a little longer than the eye, 2.8 to 3.1 in head; eye 2.8 to 3.3. The incisor teeth now are prominent, and the posterior molarial teeth are strong. The pectoral fin has acquired the shape it will retain, the fourth ray being longest with the rays below becoming shorter gradually, making the lower posterior margin straight and oblique. The ventral filament has become proportionately shorter, reaching vent in some specimens and to origin of anal in others.

The color, though somewhat variable, does not differ from that of somewhat smaller and larger fish. Some specimens have two dark spots on the base of the caudal fin which are missing in others. Many specimens have the ventral fins mostly black, and most individuals have a definite dark shoulder spot near the beginning of the lateral line, partly in and partly in advance of the second cross bar.

Specimens 75 mm and upward in length.—Although the proportionate depth of large specimens is attained when the fish reach a length of 50 to 60 mm, a pronounced change in the shape of the head and snout takes place as the fish continues to grow. The upper profile becomes notably more gently elevated, and the snout proportionately much longer and more pointed. In specimens about 75 mm long the snout (measured from anterior margin of eye to tip of upper jaw) is contained about 2.6 times in the head; in specimens about 100 mm in length, 2.3; and in specimens about 225 mm long, 2.1 times. The eye, as usual, becomes proportionately smaller as the fish grows, but the difference in the present species is unusually great. In fish about 75 mm long it is contained about 3.2 in head; in specimens 100 mm long, 3.5; and in specimens 225 mm long, about 4.5 times. The ventral filament continues to become shorter until it is scarcely longer than the longest rays in specimens around 100 mm in length, and soon disappears entirely.

DISTRIBUTION OF THE YOUNG

It has been pointed out that the early young (larvae) were not taken. Therefore, we cannot state where they live. However, Rathbun (1892) stated that spawning apparently takes place along sandy shores. The early young presumably are pelagic as they are hatched from floating eggs, and would be expected to occur not far from where the eggs are spawned. In an extensive search made in the vicinity of Beaufort for the eggs and larvae none were found. All the young at hand, except the smallest one, were seined from eelgrass and other growths in shallow water. The smallest specimen, which is about 6.0 mm long (caudal fin damaged), was taken in Shackleford Channel along a sandy beach. However, this specimen already had fins and no doubt was capable of self-directive swimming. Therefore, it may not have been very near the place where it was hatched, though it still seemed to be pelagic. It is evident, then, that no new information as to the abode of the larvae can be added at this time.

When the young attain a length of about 7 to 8 mm they settle down in shallow water where an abundant growth of seaweeds is present. In 1926 and 1927, before the eelgrass began to disappear, young sheepshead, ranging in length upward of 8.0 mm, were common to numerous along the south shores of Pivers Island, Beaufort, N. C., where most of the specimens upon which the present study is based were taken by "cutting", as far as possible, a bobbinet seine through dense growths of eelgrass. There the young remained until they reached a length of about 40 mm. Thereafter they seemed to become less abundant, though some stayed until they attained a length of 60 mm or so, when they left to occupy the habitat of the adults, which already has been described.

When the young sheepshead has attained a length of about 40 to 50 mm the teeth are developed essentially as in the adult and thereafter they may be observed along stone jetties, breakwaters, around piers, and wrecks where larger fish also live.

FOOD

The chief food of young sheepshead, ranging from 9.0 to 55 mm in length, while dwelling in shallow water in weeded areas, according to the contents of 111 stomachs, is copepods. Those under 30 mm in length utilized ostracods, which were rarely eaten by larger fish. Gammarus were sparingly eaten by the smaller fish, but abundantly by the larger ones. Small mollusks appeared early and continued to be eaten also by the larger fish. A few worms were eaten, and also some small decapod crustaceans, especially shrimp.

In addition to the animal foods named filamentous alga was present in such abundance in the stomachs of fish ranging from 25 to about 40 mm in length that it quite certainly was not taken by accident. Some stomachs, in fact, contained almost nothing else. It seems definitely to constitute a part of the food of fish of the size range mentioned. Larger fish ate of it more sparingly if at all.

The food of adults consists chiefly of mollusks and crustaceans which the fish find numerous along the breakwaters, piers, wrecks, etc., where the adult fish live. A favorite bait at Beaufort is the fiddlar crab. The teeth of the sheepshead, described elsewhere, are well adapted for seizing and crushing these common foods.

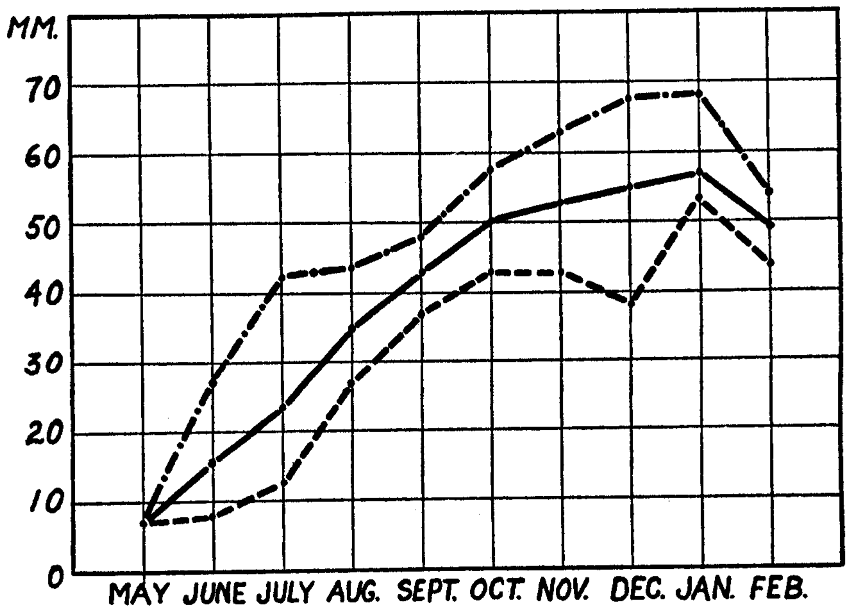

FIGURE 23.—Growth curve based on length measurements of 512 *Archosargus probatocephalus* of the 0-class. Solid line, average length for each month of all fish measured; dot and dash (upper) line, largest fish; dot and several dashes (lower) line, smallest fish.

GROWTH

Limited information relative to the rate of growth of the young during the first few months of life was obtained, and none for the older ones (fig. 23). After the fish leave their early habitat among seaweeds they no longer are obtainable in sufficient numbers, without much effort, to follow the rate of growth.

It seems quite certain that as early as August some of the larger young of the season already had deserted their habitat among seaweeds. Therefore, the range at the upper limit and consequently the average length, of those taken in the habitat of the juveniles no longer give correct information as to the rate of growth. In September many young definitely had moved away from their earlier habitat, as the fish had become comparatively scarce, though a few remained there nearly all winter.

The range in length of 46 young taken among seaweed in June from 1926 to 1931, is 7 to 25 mm. However, only one specimen, apparently a very fast growing one, exceeds a length of 21 mm. The average length of the 46 specimens is 12.8 mm.

The range in length of 311 young taken during July under the same general conditions and over the same number of seasons is 11 to 42 mm, the average length being 21.8 mm.

In August the range in length of 79 specimens, from the same localities and the same years, is 27 to 44 mm having an average length of 36.6 mm.

In September only 20 specimens, ranging in length from 38 to 47 mm, with an average length of 42.1 mm, were secured.

It seems probable that the measurements for July alone show fairly accurately the range in length, as well as the average size, of the young fish for that month. In June the smallest young of the season had not arrived in the weeded areas. Therefore, the lower limit of the range, and consequently the average length, are not correct. By August some of the larger young had left the weeded areas, and therefore the upper end of the range, as well as the average, is incorrect. In September the fish had gotten so scarce that with the same fishing effort put forth each month in 1926 only 20 specimens were secured, whereas in August 69 were taken, in July 299, and in June 36.

The data seem to justify the conclusion, however, that in June the largest young of the current season are around 20 to 25 mm long, the lower limit of the range and the average length being unknown. In July young range in length from about 11 to 42 mm, and the average length is close to 21.8 mm. In August the smallest young are about 27 mm long, and in September they are around 38 mm in length, the upper limit of the range and the average length being unknown for both months.

A fairly slow rate of growth seems to be indicated if the evidence produced elsewhere, showing that spawning at Beaufort begins sometime in April and ends near the end of June, is correct. A slow rate of growth and late maturity would explain, in part at least, why the sheepshead has diminished rapidly under heavy fishing, whereas other, presumably faster-growing, species have withstood it without a serious decline.

CHAETODIPTERUS FABER (BROUSSONET). SPADEFISH

The development of the eggs and recently hatched larvae of the spadefish was described and figured by Ryder (1887, pp. 521–523). It is possible now to describe and figure some more advanced stages, though the series is not yet as complete as desirable.

Professor Ryder did not state specifically that the eggs used in his study were taken directly from ripe fish caught in Chesapeake Bay, though this apparently may be assumed. He merely said, "This species spawns in the Chesapeake during the latter part of June and the early part of July. It is prodigiously fertile, the female probably discharging a million ova during a single season." It must be further stated, however, that the number of eggs deposited probably depends on the size of the female, because large fish generally, if not always, produce more eggs than smaller ones of the same species.

The eggs were not seen by us. Ryder states that they are pelagic, "somewhat over a millimeter in diameter", and have a single oil globule. Cleavage took place rapidly, as only an hour intervened between the first cleavage and the morula stage. Hatching took place in about 24 hours in a water temperature of 80° F.

The newly hatched fish were "about 2.5 mm in length." In 63 hours the yolk was nearly all absorbed, young fish had increased greatly in depth, and were nearly 4.0 mm long. The snout was very blunt, the mouth (according to the figure) was large and somewhat oblique, with the lower jaw projecting. An aggregation of pigment cells formed indications of a band above the base of the pectoral, and another at about midcaudal length.

The specimens forming the basis of the present study were collected mostly at Beaufort, N. C. Other young were taken on the coast of Georgia and on the Gulf coast of the United States. Unfortunately, stages in development connecting directly with the largest larvae described by Ryder are not at hand. The smallest specimen in the collections, identified as a spadefish, is only about 2.5 mm long in the preserved state. Although this larva is shorter than the oldest one described by Ryder, which was about 4.0 mm long when alive or fresh, it is much further advanced in development, showing apparently that much shrinkage took place during the hardening process. The characters connecting this larva with the younger ones described by Ryder are pointed out in the description of the specimen.

The spadefish is known in some localities as angel fish and also as moonfish. At Beaufort it is called porgee (or pogee), a name also heard in the lower Chesapeake. This species ranges from Cape Cod, Mass., at least as far south as Rio de Janeiro, Brazil. It is not common north of Chesapeake Bay. On the Atlantic coast of Panama it is one of the common food fishes, and is seen in the market almost daily. It is not caught in large quantities on the coast of the United States. Indeed, the statistical report of the Bureau of Fisheries for 1935 lists a catch of only 6,000 pounds, which was made in North Carolina. However, the fish is taken commercially all along the Atlantic and Gulf coasts from Chesapeake Bay southward. It is a fish of good flavor and always in demand. Consequently, much of the catch is consumed locally and it often does not enter the markets. Therefore, it fails to get into the records, which do not show its full importance as a food fish.

The spadefish is a summer resident at Beaufort, where it arrives in May and departs by about the beginning of October. At Key West, Fla., it is present the entire year, though most common during the summer. The species tends to congregate in small schools. It is caught chiefly with seines. However, it will take a hook baited with small bits of meat. Because of its small mouth, small hooks must be used. Furthermore, because of its tendency to nibble instead of swallowing the bait, considerable patience and skill must be exercised by the angler. If he is successful in hooking one, a good fight follows.

CHARACTERS OF THE ADULT

The spadefish belongs to the family Ephippidae, of which it is the only representative on the Atlantic coast of America. It is readily recognized by the very short, deep, compressed body which is only a little longer than deep. The teeth in the jaws are in brushlike bands, the outer series being slightly enlarged. In large individuals the anterior rays of the second dorsal and anal are considerably produced, and the caudal fin is deeply lunate. Fish under a foot or so in length bear four to six broad black cross bars, which tend to fade in large individuals. The ground color varies from brown to silvery green.

The maximum size of the spadefish is given as 20 pounds. However, fish weighing as much as 12 pounds are comparatively rare. The average weight of the fish seen in the Beaufort market probably did not exceed 1½ pounds, and those in the Colon, Panama, market were even smaller.

SPAWNING

According to Ryder (1887, p. 521) the spadefish spawns in Chesapeake Bay during the latter part of June and the early part of July. Hildebrand and Schroeder (1928, p. 307) stated, "Fish with well-developed roe were taken at Crisfield, Md., on May 26, 1916," and Smith (1907, p. 335) said "At Beaufort, ripe male and female fish have been found early in June." We can add to these observations only that we saw some females with developing roe at Beaufort on May 25, 1916.

The eggs either were not taken, or not recognized if taken, during the investigation at Beaufort. The scarcity of the young locally indicates that the vicinity of Beaufort is not an important spawning area.

The smallest larva caught, which is about 2.5 mm long, was taken July 11 (1929). The next smallest one, which is about 4.25 mm long, was caught July 12 (1915); another small one, 9 mm long, was taken July 9 (1930); and still another one, 17 mm long, August 16 (1916). Larger young were taken locally in 1930 as follows: 10, ranging in length from 49 to 62 mm, August 23; 21, varying in length from 57 to 86 mm, from September 4 to 16; and 1 each on October 18 and 21, respectively, 72 and 74 mm long. These young no doubt are all in their first summer. Their size, especially that of the smallest ones, suggests that at Beaufort spawning takes place at least during June, as indicated also by the few observations of ripe and ripening fish reported in a preceding paragraph. A definite determination of the duration of spawning, however, remains for future determination.

The 3 smallest young were all taken at sea, suggesting that the fish may spawn offshore. Offshore spawning is indicated, furthermore, by the absence of small fish under about 15 mm in length, in the extensive and thorough collecting done in the inside waters in the vicinity of Beaufort.

DESCRIPTIONS OF THE YOUNG

Specimen about 2.5 mm long.—A single specimen of this size is at hand. The body is deep anteriorly, decreasing greatly in depth just posterior to the vent, the greatest depth being contained 1.9 times in the length to the end of the notochord. The head is very deep, with a steep profile, which is slightly concave just above upper jaw. The snout is short and blunt, and not quite as long as the eye. The mouth is strongly oblique, the gape anteriorly being on a level with the middle of the eye, and the maxillary reaches opposite the posterior margin of the pupil. The preopercular margin is provided with a few prominent spines, and a sharp transparent dermal crest is present on the occiput. The notochord remains straight. The primitive vertical fin membranes persist and contain only slight indications of rays where the soft dorsal, caudal, and anal develop later in life. The ventral fins are not evident, but the pectorals are short and broad.

The general color of the preserved specimen is pale gray. Several dark chromatophores are present on the chest and the abdomen, and also a few on the gill covers (fig. 24).

This specimen resembles the largest larvae described by Ryder (1887, p. 522) in having a deep body, which seems to have grown much deeper in the older fish herein described. It, also, resembles the younger fish in the steep anterior profile and oblique mouth. The younger larvae had dark chromatophores on the abdomen, which have been retained by the older one at hand. However, no indications of dark chromatophores, suggesting bands (one above the base of the pectoral and another at midcaudal length), described and illustrated for the younger larvae by Ryder, are evident in the fish before us. Ryder does not mention nor illustrate a dermal ridge or crest at the occiput, present in the specimen herein described, and retained by somewhat larger fish. It may be assumed, therefore, that the ridge is not present in the early larvae. This ridge is suggestive of the crest bearing a spine in the young fool fishes (Monacanthus).

Specimen about 4.25 mm long.—Only one specimen of this length is at hand. The body remains deep anteriorly, but no longer decreases as abruptly in depth just posterior to the vent as in the smaller specimen already described. However, the body tapers sharply posteriorly. Its greatest depth is contained 1.7 times in the length to the end of the notochord. The head remains deep, with a somewhat more sloping anterior profile. Its length is contained 2.9 times in the length to the end of the notochord. The snout remains shorter than the eye, and the mouth is quite oblique, the gape anteriorly being about on a level with the lower margin of the pupil. The maxillary reaches below the middle of the eye. The crest or ridge on the head remains prominent, and slightly spinelike. The spines on the preopercular margin persist, but are less prominent. The notochord now is bent upward posteriorly, and

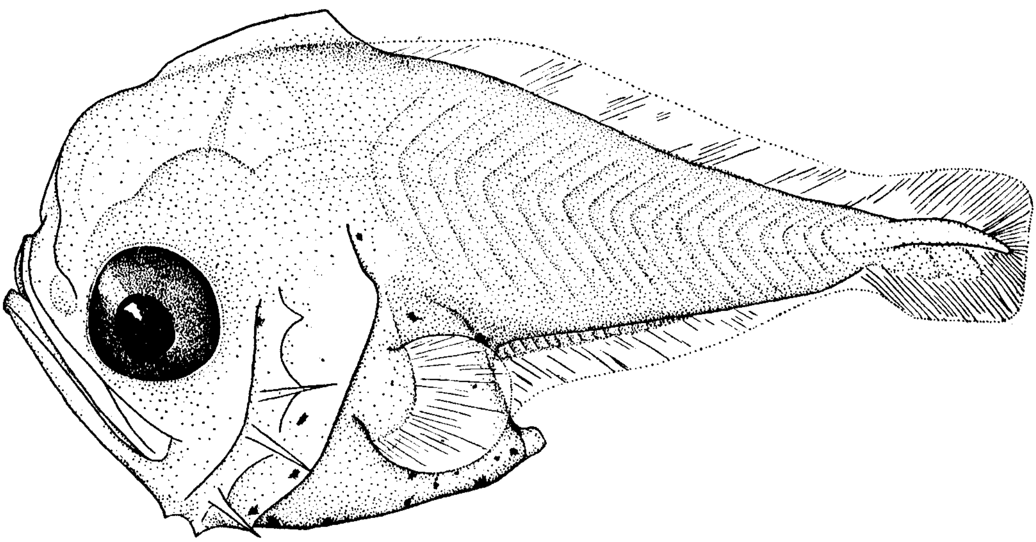

FIGURE 24.—*Chaetodipterus faber.* From a specimen 2.5 mm long.

below it are rather well developed rays, forming a moderately long caudal fin, the shape of which cannot be determined definitely because of the damaged condition of the fin, but it presumably had a round margin as in somewhat larger fish. The spines in the dorsal and anal fins are more retarded in development than the soft rays and cannot be enumerated definitely. About 23 soft rays may be counted in the dorsal and 20 in the anal. The pectoral fins are broken, and the ventral fins appear as mere tufts of dermis.

The preserved specimen at hand is very dark, apparently having become darkened by the action of a chemical in the denatured alcohol used. However, black chromatophores are visible along the side of the abdomen, on the head and back, and at midcaudal length. The last-mentioned ones are concentrated and slightly suggestive of a cross bar, shown by Ryder (1887, p. 522) for much younger fish, (fig. 25).

Specimen 9.0 mm long.—The body remains short and deep and has become somewhat more robust, the greatest depth being contained 1.8 times in the length without the caudal fin. The dorsal profile remains quite steep anteriorly, and rather more strongly curved than the ventral outline. The head has become broader. It is scarcely as deep as in smaller fish, and its length is contained 2.5 times in the length without the caudal fin. The snout remains blunt and shorter than the eye, being contained 4.2 times in the head, whereas the eye is contained 3.1 times. The mouth has become less strongly oblique, the gape being wholly below the eye, and the maxillary scarcely reaches beyond the anterior margin of the eye. Small pointed teeth now are evident in the jaws. Preopercular spines remain quite prominent. The dermal crest, or ridge, at the occiput has become proportionately shorter, and ends in a blunt spinelike point. The body now is covered with blunt spinelike plates, scarcely resembling scales (not shown in fig. 26), and the upper surface of the head (where the plates are missing) bears short hairlike spines. The fins are all developed and have the usual number of spines and soft rays present in adults. However, the spines still are somewhat retarded in development and proportionately shorter than in the adult. The margins of the vertical fins are all rounded. The ventral fins are quite large, and exceed the length of the pectorals.

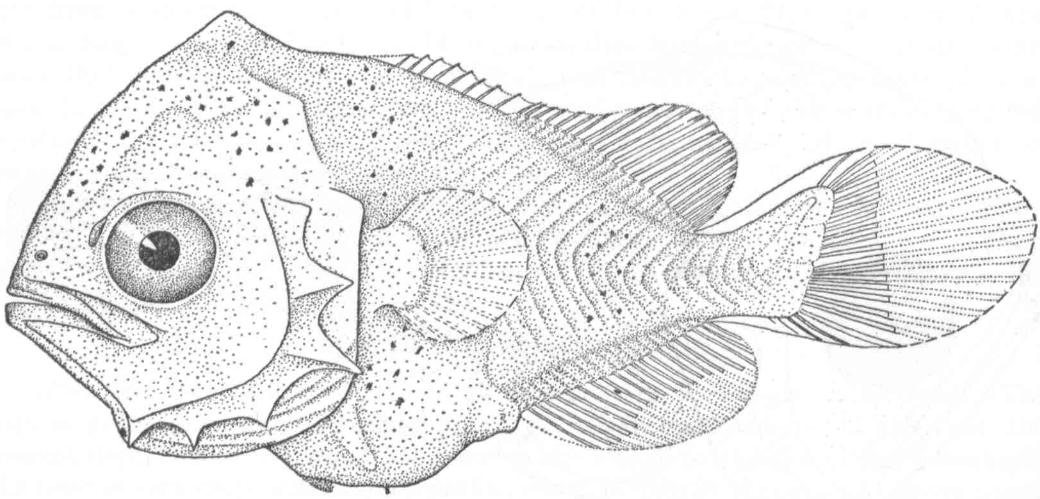

FIGURE 25.—*Chaetodipterus faber*. From a specimen 4.25 mm long.

The general color of the preserved specimen is dark brown. Dark chromatophores present in younger fish and in large specimens at hand are not visible in the 9.0 mm specimen. A few dusky markings are present at the shoulder. The soft dorsal, caudal and anal are colorless, but the ventrals are dark brown (fig. 26).

Specimen 11 mm long.—The body is proportionately a little deeper than in the 9.0-mm fish, the depth now being contained 1.5 times in the length without the caudal fin. The general shape of the head, and the proportions of the eye and snout have changed little. The preopercular spines have become rather shorter and blunter, and the occipital ridge of smaller fish now is represented by a small blunt projection. The lateral line is well developed. The scales no longer look like plates, and the spiny projections on them are smaller. The hairlike spines on the head, noted in the 9.0 mm specimen, have become minute. The dorsal spines have increased in length, but remain proportionately shorter than in larger fish. The ventral fins have continued to increase in length, and now reach the vent.

The general color is brownish, and the head and body nearly everywhere are dotted with black chromatophores. An indefinite pale crossbar on the back of the head extends down on the preopercle. The ventral fins are black, and spinous parts of the dorsal and anal are brownish and dotted with black, but the rest of these fins and the caudal and pectorals are entirely colorless (fig. 27).

Specimens 15 to 18 mm long.—The differences between these larger specimens and the 11 mm one are not great. The depth remains proportionately about the same, being contained 1.4 to 1.6 times in the length without the caudal fin. The snout,

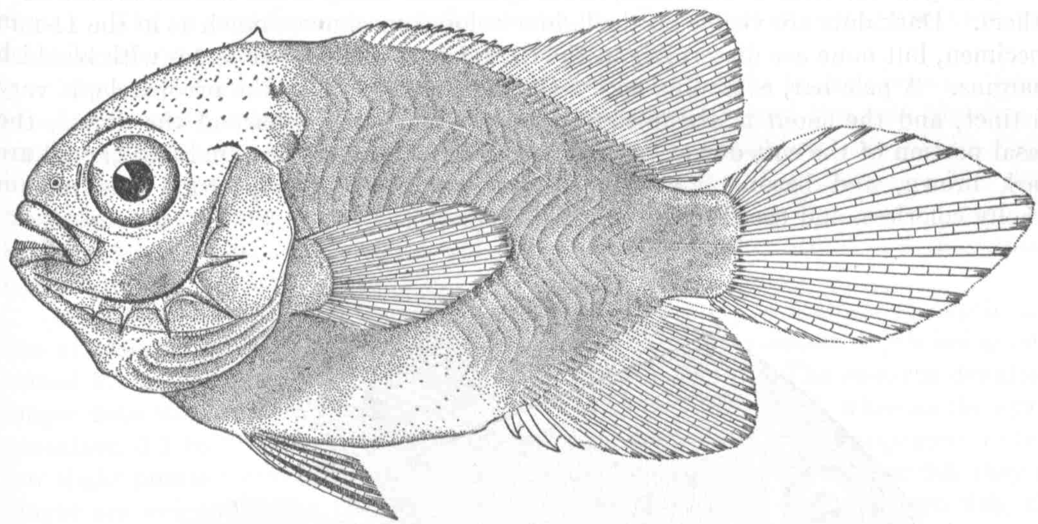

FIGURE 26.—*Chaetodipterus faber*. From a specimen 9 mm long.

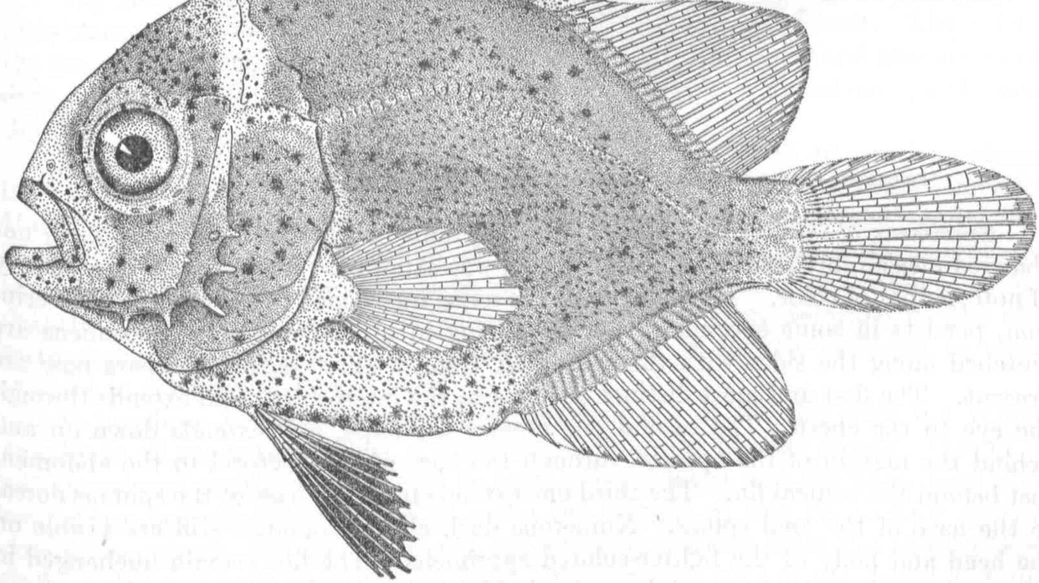

FIGURE 27.—*Chaetodipterus faber*. From a specimen 11.5 mm long.

which is shorter than the eye in younger fish, now is as long as the eye. The mouth is nearly horizontal and terminal, and the maxillary reaches scarcely to the eye. The preopercular spines have become quite small, and the occipital ridge is missing. Scales are well developed; they extend forward on the head to interorbital, and are strongly ctenoid. Very short hairlike spines remain visible on the head. The lobes of the soft dorsal and anal are high, and slightly pointed. The caudal fin, also, is somewhat pointed. The pectoral fins remain moderately short and rounded, whereas the ventral fins have increased still further in length, reaching fully to the origin of the anal.

The general color is brownish, some specimens being much darker brown than others. Dark dots are visible on the lighter-colored specimens, much as in the 11-mm specimen, but none are discernible in the darker ones which have scales with blackish margins. A pale bar, extending across the nape and down on the preopercle, is very distinct, and the snout is about equally pale. The spinous part of the dorsal, the basal portion of the soft dorsal, as well as the basal parts of the anal and caudal are dark brown, and become abruptly entirely colorless. The pectoral fins remain wholly colorless, and the ventrals are black (fig. 28).

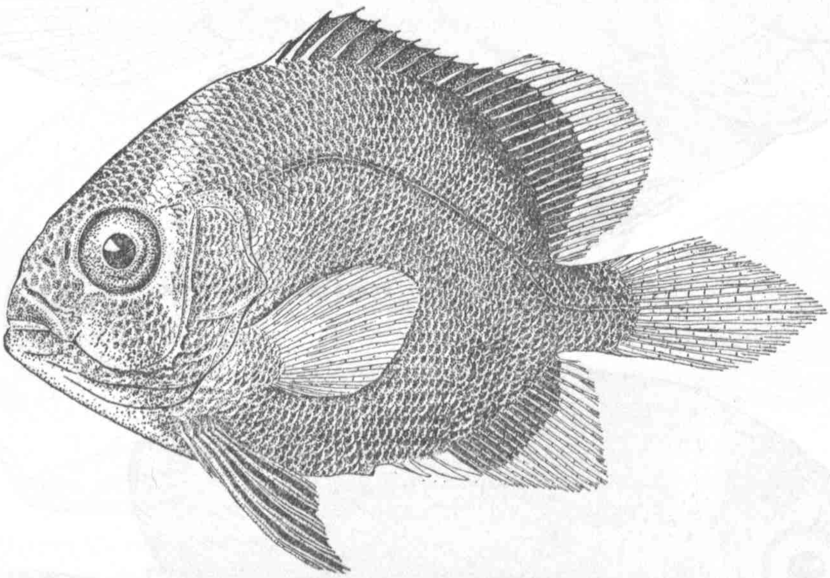

FIGURE 28.—*Chaetodipterus faber.* From a specimen 17 mm long. (Drawn by Mrs. E. B. Decker.)

Specimens about 20 mm long.—The proportions of the head and body have not changed measurably since a length of 18 mm was attained. The only change, worthy of note, is that of color. The pale bar at the nape, mentioned in the preceding description, persists in some specimens, but is missing in others, and some specimens are blotched along the sides with the same pale color. Three dark cross bars now are present. The first and most distinct one crosses the interorbital, and extends through the eye to the chest. The second one crosses the nape, and extends down on and behind the margin of the opercle, through the base of the pectoral to the abdomen, just behind the ventral fin. The third one extends from the base of the spinous dorsal to the base of the anal spines. Numerous dark chromatophores still are visible on the head and body of the lighter-colored specimens. The fins remain unchanged in color, except that the brown color extends higher on the dorsal and anal, involving fully the basal half of the soft rays.

Specimens 25 to 30 mm long.—The depth in proportion to the length of the body has increased still further since a length of about 15 to 18 mm was attained, being contained 1.25 times in the length without the caudal fin. The general shape of the body now is very similar to that of the adult. The head is proportionately shorter, as usual in larger fish, and is contained 2.75 in the length to the base of the caudal fin. The eye and snout are of equal length, being contained 3.2 to 3.5 in the head. The mouth is horizontal and terminal. The brushlike teeth are developed as in the adult. Preopercular spines remain present, but have become very small. Scales are fully developed, strongly ctenoid, and the hairlike spines present on the head in smaller fish have disappeared. The lobes of the dorsal, anal, and the caudal fins remain round. The ventral fins are long, the second ray (first soft ray) being produced and reaching about to the base of first soft ray of the anal.

The general color of preserved specimens varies from light to dark brown. Some specimens retain a trace of the pale bar crossing occiput, and the pale blotches of smaller specimens. A fourth dark cross bar, extending from about the middle of the base of soft dorsal to the base of the anal, now is more or less distinct. The dark brownish color of the dorsal and anal extends farther on the fins, leaving only the margins translucent. The caudal and pectorals remain translucent, and the ventral fins are mostly black.

Specimens 40 to 50 mm long.—The body has continued to increase in depth, and has attained about the proportions of full-grown fish, the greatest depth being contained 1.1 to 1.2 times in the length without the caudal fin. The snout is definitely longer than the eye, being contained 2.75 to 3.0 times in the head, whereas the eye is contained 3.3 to 3.7 times. Preopercular spines virtually have disappeared, only a few slight points remaining at and below the angle. In somewhat larger fish they no longer are evident. The dorsal spines are about as high as in full-grown fish, the third and largest one reaching the base of the last one if deflexed. Posterior to the longest spine is a black membrane, which reaches beyond the tip of the spine. The lobes of the soft dorsal and anal have become broadly rounded, and the caudal fin is broadly rounded to nearly square.

The general color is not much different from that of fish 25 to 30 mm long. A fifth black bar, situated on the caudal peduncle, however, is present. The color of the fins remains unchanged, except that the lobes of the soft dorsal and anal are wholly dark brown and the interradial membranes of the spinous dorsal are partly black (fig. 29).

Specimens 75 mm and upward in length.—Specimens 40 to 45 mm long already have acquired essentially the shape and proportions of the body of much larger fish. However, a notable change in the shape of the soft dorsal, anal and caudal takes place in larger fish. At a length of 75 mm the anterior soft rays of the anal in some specimens already are produced, as in large fish, making the margin straight or even slightly concave. The dorsal fin apparently is a little more retarded in this same forthcoming development. The caudal fin margin is slightly rounded to nearly straight in fish around 75 mm long.

It has been indicated already that development of the fins does not proceed equally in all spadefish. Thus, a specimen 90 mm long has the anterior rays of the soft dorsal and anal produced so as to form pointed lobes, and the outer rays of the caudal are sufficiently produced to make the margin of this fin slightly concave. Another specimen, 105 mm in length, by contrast, still has these fins shaped essentially as in specimens 40 to 45 mm long. The anterior rays of the dorsal and anal, as well as the outer rays of the caudal continue to increase in length, though unequally fast, as the fish grow, and become long and pointed in large individuals, often reaching beyond the midlength of the caudal fin. The membrane behind the third dorsal spine, already present in fish 40 to 45 mm long, which is at least somewhat longer than the spine, persists. This spine also develops, apparently reaching its maximum length in fish about 135 mm (5.5 inches) long, when it reaches to or sometimes beyond the base of the first soft ray of the dorsal, and thereafter it again becomes proportionately shorter. In a specimen 262 mm (10.5 inches) long it reaches only to the middle of the sixth spine if deflexed. The filament on the first soft ray of the ventral also persists in big fish, wherein it reaches to the origin of the anal.

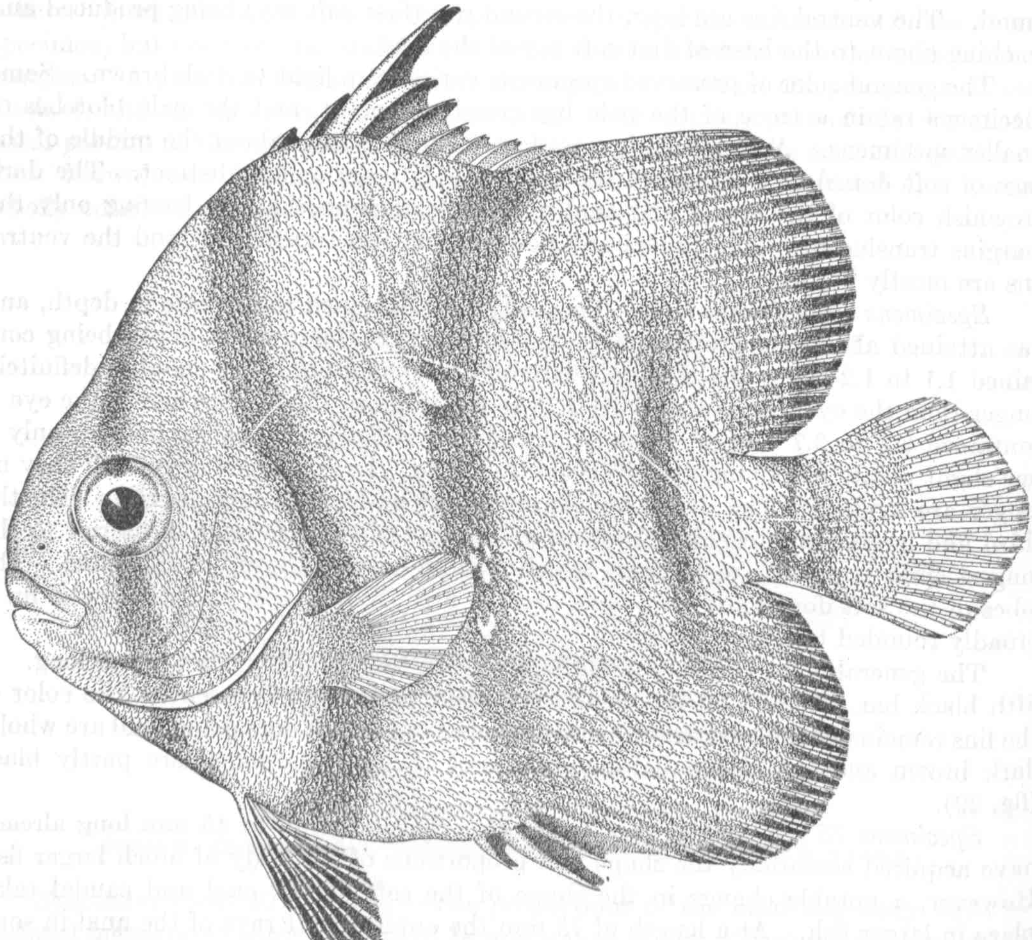

FIGURE 29.—*Chaetodipterus faber*. From a specimen 50 mm long.

The preserved specimens vary greatly in color, ranging from pale silvery to dark brown. Although the species is described as having four to six black bars, all the mature individuals at hand have five, except one old one (262 mm long) which has none. The caudal and pectorals are translucent except in fish upward of 110 mm in length wherein they are brownish. The ventrals remain black or at least dark throughout life.

DISTRIBUTION OF THE YOUNG

Too few early young were taken to cast much light on their distribution. The three smallest specimens at hand, having a length of 2.5, 4.25, and 9.0 mm were all taken at sea, the smallest one about 6 miles off Beaufort Inlet, the intermediate one somewhere off Southport (N. C.), and the largest a short distance west of Beaufort Inlet. It is not known whether the intermediate specimen was taken at the surface or bottom, but the other two were caught in bottom towings. The larger specimens were taken in inside waters in the immediate vicinity of Beaufort either with seines or with otter trawls. Other specimens, ranging upward of 11 mm in length, from the Gulf coast, principally from Louisiana and Texas, which have been studied, presumably were nearly all taken in shallow water with seines.

GROWTH

The literature contains little information on the rate of growth of the spadefish, and insufficient specimens were measured during the recent investigation at Beaufort for definite determination. Smith (1907, p. 335) stated, "In the latter part of August fish about 3 inches (75 mm) long may be seined in Beaufort Harbor." Hildebrand and Schroeder (1928, p. 307) reported the capture of small spadefish in Chesapeake Bay, which they believed were in their first summer, as follows: 1 fish, 55 mm long in September; and 35 fish, ranging in length from 65 to 100 mm in October.

Young spadefish evidently in their first summer were taken on the coast of North Carolina during the recent investigation as follows: 3 fish, respectively 2.5, 4.5, and 9.0 mm long, in July; 12 fish, ranging in length from 49 to 80 mm (average length 56.6 mm) in August; 21 fish, ranging in length from 57 to 86 mm (average length 72.1 mm) in September; and 2 fish, 72 and 74 mm long in October.

The data presented suggest that the young fish may reach a length of about 55 to 100 mm during their first summer on the coast of North Carolina and in Chesapeake Bay. As a fully mature, ripening female 135 mm (5.4 inches) long was seen, it seems probable that at least some of the fish reach that length during their second summer and that they may spawn when 2 years old.

FAMILY GOBIIDAE. GOBIES

Nine species of gobies with united ventral fins are recorded from the coast of North Carolina in this paper. These gobies are assigned to four genera, namely, Gobiosoma (two species), Microgobius (two species), Gobionellus (four species), and Gobius (one species). Three species of the genus Gobionellus appear to be new to the fauna of North Carolina, as stated elsewhere (p. 564). The single species of Gobius, namely, *glaucofraenum*, is known from North Carolina (Cape Lookout) from one specimen (Gudger, 1913, p. 165), which has not been seen by us. This species will receive no further mention in this paper. It appears to differ from all the other local species in having larger scales, about 23 transverse series on the side, and in the shorter second dorsal and anal fins, each fin having 10 rays.

In the present study we did not succeed in collecting eggs of gobies in their native environment. However, those of *Gobiosoma bosci* and *Gobionellus boleosoma* were secured through artificial means. The eggs of the other species dealt with in this paper remain unknown. Small larvae, usually under about 8 to 10 mm in length, were collected principally with 1-meter tow nets. The larger young, that is, fish from 8 to 10 mm and upward in length, were caught principally with especially adapted otter trawls, although some were taken with beam trawls and with bobbinet seines.

The comparative abundance at Beaufort of the young gobies discussed in this paper indicates that the adults are more numerous than the number taken in net collections suggests. It is probable that the adults adhere to the bottom or to objects on the bottom by means of the ventral disk, permitting nets to pass over them. Gobiosoma was able to escape nets quite successfully when confined in a large tank, as explained elsewhere. (See. p. 549). This propensity of escaping nets probably is exercised in nature by most species of gobies.

The original drawings of young and adult fish published in this paper are based upon preserved specimens. The illustrations showing the development of eggs are after Kuntz (1916) and were drawn from living material.

The main differences among the young of the three genera, with which this paper deals principally, are shown in a parallel comparison of characters appearing herewith. The adults of the local species differ from each other rather markedly. In Gobiosoma the body is naked, or at most only two scales are present on the base of the caudal. In Microgobius and Gobionellus, on the other hand, the body is nearly or quite fully covered with scales. Microgobius is distinguished from Gobionellus in having a deeper and more compressed body. Furthermore, the mouth is large and strongly oblique, the maxillary reaching nearly opposite the middle of eye in Microgobius, while in Gobionellus the mouth is scarcely oblique and the maxillary reaches only below the anterior margin of the eye. The dorsal spines are 7 in number and are about equally spaced in Microgobius, whereas Gobionellus has 6 dorsal spines, with the last 2 notably farther apart than the others; and Microgobius has a larger second dorsal and anal fin, each fin being composed of 16 or 17 rays, while Gobionellus has only 11 to about 15 rays in each fin.

The eggs of the gobies of North Carolina, as already indicated, have not been found in nature. Those of *Gobiosoma bosci* and *Gobionellus boleosoma* were secured by Kuntz (1916) by stripping the ripe fish. The eggs of the first-mentioned species also were secured recently by us. The eggs of all the other species remain unknown. Kuntz (loc. cit.) found that the eggs of *Gobiosoma bosci* and *Ctenogobius stigmaticus* (=*Gobionellus boleosoma*) each had a bundle of adhesive threads attached to the egg membrane. These threads no doubt serve the purpose in nature of attaching the eggs to submerged objects.

Ehrenbaum (1905), dealing with European species, stated that the eggs of *Gobius niger* are attached to plants, shells, ascidians, and stones; *G. flavescens* are attached to plants; and those of *G. minutus* to molluskan shells. Hefford (1910) found the eggs, with an adult fish (sex not stated), of *Gobius paganellus* "on a stone between tide marks on the shore" at Plymouth, England. It is not stated that the adult fish guarded the eggs. Clark (1913) stated that the eggs, with males, of *Crystallogobius nilssoni* were found in abundance in the waters at Plymouth, England, attached to the inside of empty tubes of Chaetopterus. Petersen (1917) figured the eggs of four species occurring on the coast of Denmark, namely, *Gobius niger*, *G. ruthensparri*, *G. minutus*, and *G. microps*, showing that the eggs of each species possess an adhesive foot. Lebour (1919) said of *Gobius paganellus:* "From early spring to late summer the males may be seen guarding their eggs, which are attached to the under surface of stones in masses." Lebour (1919) isolated several adults of *Gobius ruthensparri* in a tank and one deposited eggs on the inside of an empty oyster shell. It was not stated that the eggs were guarded by a male. Lebour (1920), who illustrated the eggs of *Gobius minutus*, *G. microps*, and *G. pictus* with adhesive organs, stated that those of the first-mentioned species were laid on an oyster shell, and those of the second one on the valve of a Pectan. The eggs of the last-named species apparently were not found in nature, but were deposited in the aquarium on a molluskan shell.

It would seem quite certain from the knowledge gained from the study of some American and European gobies, as shown in the preceding paragraphs, that these little fish generally, if indeed not always, attach their eggs to submerged objects, where they probably are guarded by the males. In these respects the spawning habits of the gobies agree in a large measure with the blennies, as shown in another part of this paper.

Gobiosoma bosci and *Gobionellus boleosoma* are landlocked, except during extremely high storm tides, in the Mullet Pond on Shackleford Banks near Beaufort. The water in this pond ranges from brackish to nearly fresh. In fact, it becomes fresh enough, at times, to support such fresh water plants as Potamogeton and filamentous fresh water algae. Here the two species named evidently carry out their reproductive processes, as ripe adults and young fish, less than 10 mm in length, have been collected. The bottom of the pond is quite muddy. In places luxurious growths of plants are present, and oyster shells, as well as live oysters, are found over some parts of the bottom. It would seem necessary for the gobies to attach their eggs either to plants or to oyster shells in this pond, as few other submerged objects are present.

DISTINGUISHING CHARACTERS OF THE YOUNG OF THE GENERA GOBIOSOMA, MICROGOBIUS, AND GOBIONELLUS.

The young of the three genera, Gobiosoma, Microgobius, and Gobionellus, discussed in the following pages are quite similar, especially when very small. The following comparison is offered with the hope that it may be found useful. Myomere and vertebrae counts in the three genera are almost identical, the range of vertebrae for the three genera (of Gobionellus only *boleosoma* was examined) being 11 or 12+15 to 17 and cannot be used in separating them and, therefore, are omitted.

Length 2.0 to 3.5 mm

GOBIOSOMA	MICROGOBIUS	GOBIONELLUS
Body rather deep; depth just posterior to vent about equal to head.	Body as in Gobiosoma.	Body extremely slender; depth of body posterior to vent notably less than length of head.
Vent typically well behind midbody length.	Vent typically at midbody length.	Vent notably behind midbody length.
Eye small.	Eye slightly larger.	Eye small, bulging.
Ventral outline of body usually with a few dark spots.	Ventral outline usually with more numerous black spots, and a double row behind vent.	Pigment spots as in Gobiosoma or more usually wanting.

Length 4.0 to 5.5 mm

Soft dorsal and anal bases short, the rays developed in some specimens, each fin with 11 to 14 rays.	Soft dorsal and anal bases long, longer than in Gobiosoma, the rays partly undeveloped.	Soft dorsal and anal bases short, the rays partly undeveloped.

The differences listed for smaller specimens, exclusive of the position of the vent which has changed, apply to fish 4.0 to 5.5 mm long. The two rows of dark spots behind the vent in Microgobius, now lying along the opposite sides of the anal base, have become very definite and serve as ready recognition marks.

Length 6.0 to 7.5 mm

Soft dorsal and anal each with 11 to 14 rays.	Soft dorsal and anal each with 16 or 17 rays.	Soft dorsal and anal each with 11 to 13 rays.
A dark sheath present above air bladder, not crescent-shaped.	A dark sheath over air bladder as in Gobiosoma.	A distinct crescent-shaped dark area over air bladder.

The differences listed in the shape of the body for smaller specimens apply to fish 6.0 to 7.5 mm long.

Length 8.0 to 12 mm

Body anteriorly rather robust somewhat rounded; head slightly depressed, as broad as deep.	Body and head compressed, rather deep.	Body more or less round and very slender.
Mouth rather small; maxillary reaching about opposite anterior margin of eye.	Mouth large, maxillary reaching opposite anterior margin of pupil.	Mouth small; maxillary scarcely reaching opposite anterior margin of eye.

The differential color markings mentioned for smaller fish remain as described in specimens 6.0 to 7.5 mm long.

Length 13 to 16 mm

Body anteriorly quite robust; head notably depressed.	Head and body compressed throughout.	Body extremely slender, remaining round.
Mouth only slightly oblique, terminal; maxillary reaching only slightly beyond anterior margin of eye.	Mouth large, strongly oblique, terminal to slightly superior; maxillary reaching nearly opposite middle of eye.	Mouth moderately oblique, small, terminal; maxillary scarcely reaching opposite anterior margin of eye.
Dorsal spines all about equally spaced.	Dorsal spines as in Gobiosoma.	Last two dorsal spines much farther apart than the others.

A COMPARISON OF THE EGGS AND THE YOUNG OF SOME AMERICAN AND EUROPEAN GOBIES

It has been shown in the preceding paragraphs that the eggs of all the American and European gobies that have been studied have adhesive threads or an adhesive foot by which the eggs become attached to submerged objects. A further comparison of the eggs, and the young, of the American and European species shows other similarities. The eggs of all the gobies, so far as they are known, are rather small. A dozen eggs of *Gobiosoma bosci* measured by us several hours after fertilization, when they had had time to expand, had a length of 1.2 to 1.37 mm, and their greatest width was 0.52 to 0.59 mm. The eggs of *Ctenogobius stigmaticus* (= *Gobionellus boleosoma*), according to Kuntz (1916), are extremely small, having an average diameter of only 0.3 mm. The eggs of European species, too, are rather small. Ehrenbaum (1905) gave the following lengths of the eggs for the European species named: *Gobius ruthensparri*, 0.7 mm; *G. paganellus*, 1.8 to 1.9 mm; *G. pictus*, 0.8 mm.; and *G. niger*, 1.5 mm. Lebour (1920) gave the length of the eggs of *G. microps* and *G. minutus* respectively as 0.85 to 1.0 and 1.08 to 1.4 mm.

The eggs of *Gobiosoma bosci* when first spawned, as stated by Kuntz (loc. cit.) and verified by us, are nearly spherical. After fertilization they expand and become eliptical, the greater axis becoming nearly twice as long as the lesser one. The adhesive foot, consisting of a bundle of threads, remains attached to one pole of the longer axis. The eggs of *Ctenogobius stigmaticus* (=*Gobionellus boleosoma*) according to Kuntz (loc. cit.) are more or less irregular or variable in shape, and they remain so throughout the incubation period.

All the eggs of the European gobies that have been described or figured, so far as the present writers are familiar with the literature, are more or less elongate. According to Petersen's figures (1917) the eggs of *Gobius niger* are very elongate, the greater axis being about four times as long as the lesser one, and one end of the egg is larger than the other one. The adhesive foot is attached to the smaller end. The eggs of *Gobius ruthensparri*, as figured by Petersen (loc. cit.) and by Lebour (1919), are more or less pear-shaped, and the greater axis is less than 2 times as long as the lesser one. The adhesive foot is attached to the larger end of the egg. The eggs of *Gobius microps* according to Petersen's figures (loc. cit.) are very similar to those of *G. ruthensparri*. However, the upper end of the egg is rather less pointed and the lower end has a slight pedicel to which the adhesive foot is attached. Lebour (1920) stated that the eggs of *Gobius pictus* are very similar to those of *G. microps*. The eggs of *Gobius minutus*, as figured by Petersen (loc. cit.) and also by Lebour (1920) are similar in shape to those of *G. microps*, being more elongate, however, as the greater axis is nearly two times as long as the lesser one. The adhesive foot is attached to a slight pedicel. The eggs of *Gobius paganellus*, as figured by Lebour (1919), are eliptical and very similar in shape to those of the American species, *Gobiosoma bosci*. The greater axis is rather more than two times as long as the lesser one, and the adhesive strands are attached to one pole of the longer axis.

A rather remarkable similarity exists among the young of the American and European gobies, that have been studied, as shown principally by the works of Kuntz (1916), Petersen (1917), and Lebour (1919 and 1920), and by the present paper. The newly hatched larvae are of a small to a moderate size. Kuntz (loc. cit.) gave the length of the newly hatched larvae of the American species, *Gobiosoma bosci* and *Gobionellus boleosoma*, respectively as 2.0 and 1.2 mm; Lebour (1919) stated that the newly hatched larvae of the European species, *Gobius paganellus* and *G. ruthensparri*, are respectively 4.0 and 3.1 mm long and (1920) that those of *G. microps* and *G. pictus* are respectively 3.0 and 2.7 to 3.0 millimeters in length; and Petersen (loc. cit.) gave the length of the newly hatched young of two other European species, *Gobius niger* and *G. minutus* as 2.6 millimeters each.

In general the body of the larvae is quite elongate and slender, varying somewhat among the species. The caudal portion is especially slender and tapers gradually to a point. The vent is placed somewhere near midbody length; generally, however, rather nearer the tip of the tail (without the finfold) than the end of the snout. At hatching the head is rather rounded and the mouth tends to be horizontal and inferior. Very soon the mouth becomes rather oblique. However, as the adult stage is reached the mouth, in at least several species, tends to assume again more nearly the position occupied at hatching. When the caudal fin is first developed it either has a straight or a slightly rounded margin. As development of the fish progresses this fin tends to become more or less concave. Even in *Gobionellus boleosoma*, which has a moderately long and more or less pointed caudal fin in the adult, this fin is concave in the young that are around 8 mm long. In some species as in those of Gobiosoma, reported upon in this paper, the caudal fin does not become round, as in mature fish, until virtually all the adult characters are developed at a length of about 15 mm. The spinous dorsal usually develops somewhat later than the other fins in teleosts. In the gobies this fin develops especially late, or not until all the other fins are quite fully formed.

The body in larval gobies generally is quite transparent and often the notochord or vertebrae are visible in part. The plainly visible air bladder, commonly with a crescent-shaped black area over it, is characteristic. Usually a few pigment spots are present at hatching and others soon appear. General pigmentation, however, takes place at a rather advanced stage, that is, after virtually all the adult characters are developed.

It is evident from the foregoing discussion that both American and European gobies generally have rather small eggs, which are variable in shape and somewhat in size among the species, and are equipped with an adhesive organ by which they become attached to submerged objects. The larvae as a rule are slender, quite transparent, and have at least a few pigment spots. Interesting phases in their development are the changes in the position of the mouth and in the shape of the caudal fin. In separating the species the myomere and vertebra counts sometimes are useful (although not in the American species discussed in this paper), the fin ray counts, as soon as they can be made, are extremely helpful, and the pigment spots are always important for identification purposes.

GOBIOSOMA BOSCI (LACÉPÈDE) AND GOBIOSOMA GINSBURGI, HILDEBRAND AND SCHROEDER. NAKED GOBIES

Two species of Gobiosoma, namely *bosci* and *ginsburgi*, occur in the waters at Beaufort. The last-mentioned species was described recently from Chesapeake Bay (Hildebrand and Schroeder, 1928, p. 324), Ginsburg (1933 p. 40) made a thorough study of the genus Gobiosoma, and found specimens of *G. ginsburgi* in collections from as far north as Cape Cod and southward to South Carolina, and of *G. bosci* from Long Island to Tampico, Mexico.

Specimens of adult *G. bosci* are much more numerous in the collection from Beaufort than those of *G. ginsburgi*. However, the reverse is true with respect to the young. In Chesapeake Bay (Hildebrand and Schroeder, 1928, p. 325) *bosci* was taken in shallow water only, whereas *ginsburgi* was taken principally in rather deep water and rarely in shallow water. A similar vertical distribution of the species is indicated for Beaufort, since all adult *bosci* from this vicinity were taken in very shallow water along the shores, whereas all specimens of adult *ginsburgi*, except one, were taken in water from a few to several fathoms in depth. The young that are recognizable as to species (10 mm and upward in length) have a vertical distribution identical with that of the adults.

KEY TO THE ADULTS OF THE LOCAL SPECIES

a. Body rather robust, its depth 3.95 to 4.8 in its length without caudal fin; second dorsal normally with 13 rays, infrequently with 12 or 14; ventral disk short, reaching about half the distance from its base to the vent; no scales on base of caudal ---------- *bosci.*

aa. Body more slender, its depth 6 to 7.15 in its length without caudal fin; second dorsal normally with 12 rays, infrequently with 11 or 13; ventral disk long, reaching two-thirds the distance from its base to the vent; two large scales on base of caudal, situated respectively on the base of the upper and lower rays of the fin ---------- *ginsburgi.*

Although the characters mentioned in the foregoing key readily separate the adults when two or more of the characters are taken into consideration, they cannot be used successfully in separating the young under about 10 mm in length, because the characters either are entirely undeveloped at that size or so imperfectly developed that they are useless. Neither have we succeeded in finding other distinguishing characters. Therefore, the young (under about 10 mm in length) cannot be discussed separately with respect to distribution, habitat, growth, etc. (figs. 30 and 31).

Young Gobiosoma are rather generally distributed throughout the local waters and are very abundant, as shown elsewhere (p. 558). Their relative abundance, in fact, suggests that the adults are more common than indicated by the number of grown fish generally secured in collecting nets. From the difficulty experienced in recapturing adult fish placed in a rather large tank table in the laboratory, it is evident that nets are not very efficient for capturing the fish, because they attach themselves, by means of the sucking disk, to the bottom or to objects in the water, or they hide under objects, thereby making it very easy for a net to slide over them. They no doubt escape the net in a similar way in nature. All of this is a further indication that the fish probably are more numerous than shown by the number of adults captured.

No evidence indicating that any one individual produces an excessively large number of eggs was secured. A female 25 mm long with a greatly distended abdomen, for example, contained only 249 eggs. Furthermore, the eggs in the ovaries in several specimens examined were all of uniform size, indicating that a single spawn-

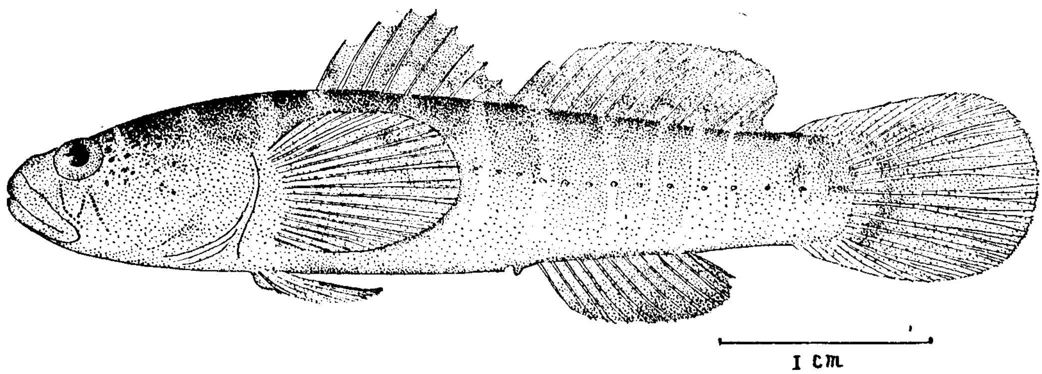

FIGURE 30.—*Gobiosoma bosci*. From adult 50 mm long. (Drawn by Louise Nash.)

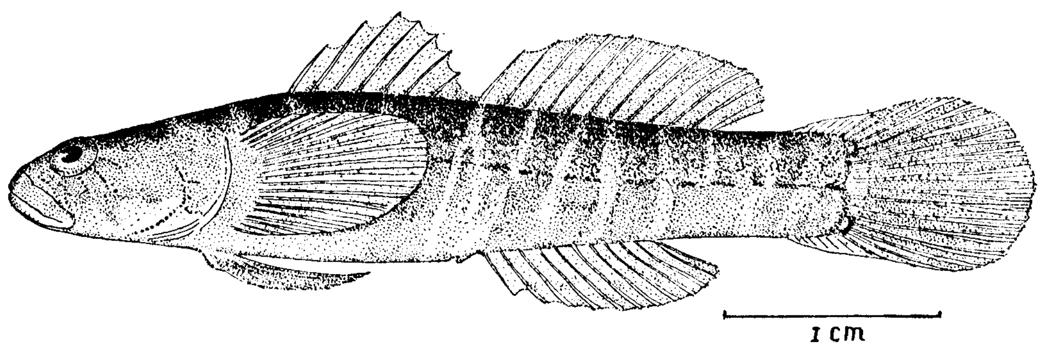

FIGURE 31.—*Gobiosoma ginsburgi*. From adult 45 mm long. (Drawn by Louise Nash.)

ing takes place during a season. The great abundance of the young—in several instances a hundred or more and in a few instances probably nearly a thousand specimens were taken in a single tow-net haul—then, would appear to be due to the presence of many adults.

The local species of Gobiosoma, which rarely exceeded a length of 2 inches, obviously are too small to be of direct commercial value, yet they probably are of some importance as forage for commercial species.

Nothing is known concerning the winter home of Gobiosoma. We have taken no specimens during the colder months of the year, or from early December to early May. It seems probable that these fish imbed themselves in mud during the winter. This probability is suggested by the abundance of gobies in seine hauls made in the Mullet Pond throughout the warmer months, in places where none were taken during the winter. This pond is connected with the adjacent sound only during exceptionally high tides, which occur generally only a few times during a year, and seldom near or in the winter months. It seems rather certain, therefore, that the gobies are present during cold weather but are not in open water where they can be caught with seines. Several species of Fundulus and *Cyprinodon varigatus* which also inhabit the Mullet Pond, are known to imbed themselves in mud during cold weather. Therefore, it seems probable that the gobies also enter the muddy bottom during the winter.

No external structural characters by means of which the sexes may be distinguished have been found. In general, the males range larger in size and are darker in color. However, specimens intermediate, both with respect to size and color, are nearly always present in collections, making a complete separation of the sexes from external characters impossible. In gravid fish the anal papilla, although present in both sexes, appears to be larger in the female than in the male.

SPAWNING

The information about spawning in Gobiosoma was derived mostly from the study of large collections of young. It has not been possible, however, as explained elsewhere, to separate definitely the young (less than about 10 mm in length) into two groups, representing the two local species, *bosci* and *ginsburgi*. Therefore, it is not known positively, although it is highly probable, that both species are represented among the fry. Neither is it known definitely whether much of the information derived from the study of the collections is applicable to one or both forms. The data based on the study of the collections of young give no evidence of two predominating spawning periods. Therefore, if two species are represented among the fry, the spawning seasons probably occur simultaneously or overlap so fully that no distinction may be made either from the size of the young nor from their abundance.

Collections of young Gobiosoma were made from 1927 to 1931. The larvae first appeared in the tow in May (the earliest date being May 11, 1929), and throughout the summer and fall until December (the latest date being Dec. 6, 1929). The larvae were common to abundant from June to September each year but most numerous during July and August. During October, November, and December only a few scattered ones were secured.

Among the females in the relatively large collections of adults made in the Mullet Pond during August (1930), principally small individuals were in spawning condition, the larger ones evidently having spawned out. This condition suggests that the principal spawning season was past, and is in general agreement with the situation suggested by the data based on the collections of young. Although the fry were abundant in the towings during August it may be assumed, that many of those taken, particularly the larger ones, were hatched during July. Furthermore, in September there occurred a pronounced drop in the number of young. The evidence, therefore, is that spawning begins early in May or possibly during the latter part of April, that it occurs most abundantly during July and ends except for an occasional late spawner, in September.

The larvae of Gobiosoma were taken over a wide variety of conditions and over a comparatively large area, as explained under that section of this paper dealing with distribution (p. 558). Since the eggs become attached and do not drift as already shown, spawning probably takes place over a large portion of this area and over a wide variety of conditions.

Nothing definite can be said concerning the spawning places of the two species of Gobiosoma represented locally, first, because the young under 10 mm in length could not be separated, and second, because ripe *G. ginsburgi* were not taken. Ripe *G. bosci* were taken only in the Mullet Pond where they no doubt spawn, as the larvae were present in the same places where the adults were taken. It seems probable, therefore, that spawning takes place in the general habitat of the adults. If that were the case, then it would follow that *G. bosci* would spawn only in shallow water along the shores, whereas *G. ginsburgi* would spawn principally in somewhat deeper water (see p. 548).

DESCRIPTIONS OF THE EGGS AND YOUNG

Eggs.—The eggs stripped from ripe fish taken in the Mullet Pond were first described by Kuntz (1916, p. 423). Since the present investigators have found only *G. bosci* in that pond, it seems probable that the eggs described were of this species. The eggs were secured again by the present investigators in August 1930 from fish taken in the Mullet Pond. The description of the eggs given by Kuntz is essentially correct. The ova when expressed from the female adhere in clumps unless immediately separated. The eggs when seen in a mass with the unaided eye are yellowish in color and quite opaque. Under the microscope a "bundle" of gelatinous threads with small branches are seen to be joined to the egg membrane at a certain point. These threads cause the eggs to adhere. Their function no doubt is that of attaching the eggs to vegetation or other objects in the water. The eggs are slightly heavier than sea water and when placed in a dish of water they sink gradually.

The mature unfertilized eggs, as observed by us, generally, are slightly elongate, but sometimes nearly spherical. The variation in the major axis of five selected eggs ranged from 0.637 to 0.675 mm and for the minor axis in the same eggs it was 0.52 to 0.6 mm. As soon as fertilization had taken place the eggs began to expand and became elliptical in shape. In the process of expansion the minor axis retained about its former length, for in 10 eggs measured during various cleavage stages it ranged from 0.573 to 0.592 mm. The major axis, however, becomes much longer, for its range in length in the same eggs ranged from 1.147 to 1.369 mm. Expansion appears to be fully completed by the time the first cleavage takes place and thereafter, according to our observations, the egg changes little or not at all in shape. According to Kuntz's figures, eggs with large embryos are more pronouncedly elliptical than those in the early cleavage stages (fig. 32).

When the egg is fully expanded a relatively large perivitelline space is present, for the yolk mass occupies somewhat less than half the space within the egg membrane. The position of the yolk varies greatly. Generally it lies toward one pole of the major axis of the egg and most frequently opposite the pole at which the gelatinous adhesive strands are attached. Occasionally, however, it is much nearer the opposite pole of the major axis, or it may occupy an intermediate position (fig. 33).

The yolk mass of the egg when seen under magnification has a greenish-yellow cast and it contains many minute oil globules. Due to the opaqueness of the yolk, many of the phases in the development either cannot be seen at all or are obscure. The processes in the development of the egg are well described and accurately figured by Kuntz (1916, pp. 423 to 426, figs. 43 to 50).

The cells in the early cleavage stages stand out very prominently as round elevations. As cleavage advances the fissures become less pronounced and gradually the blastoderm becomes circular in outline and sharply differentiated from the yolk (figs. 34 and 35).

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The development is rapid at first. Eggs fertilized at 10:30 o'clock in the morning and held at a temperature close to 27° C., for example, reached the 2-cell stage in

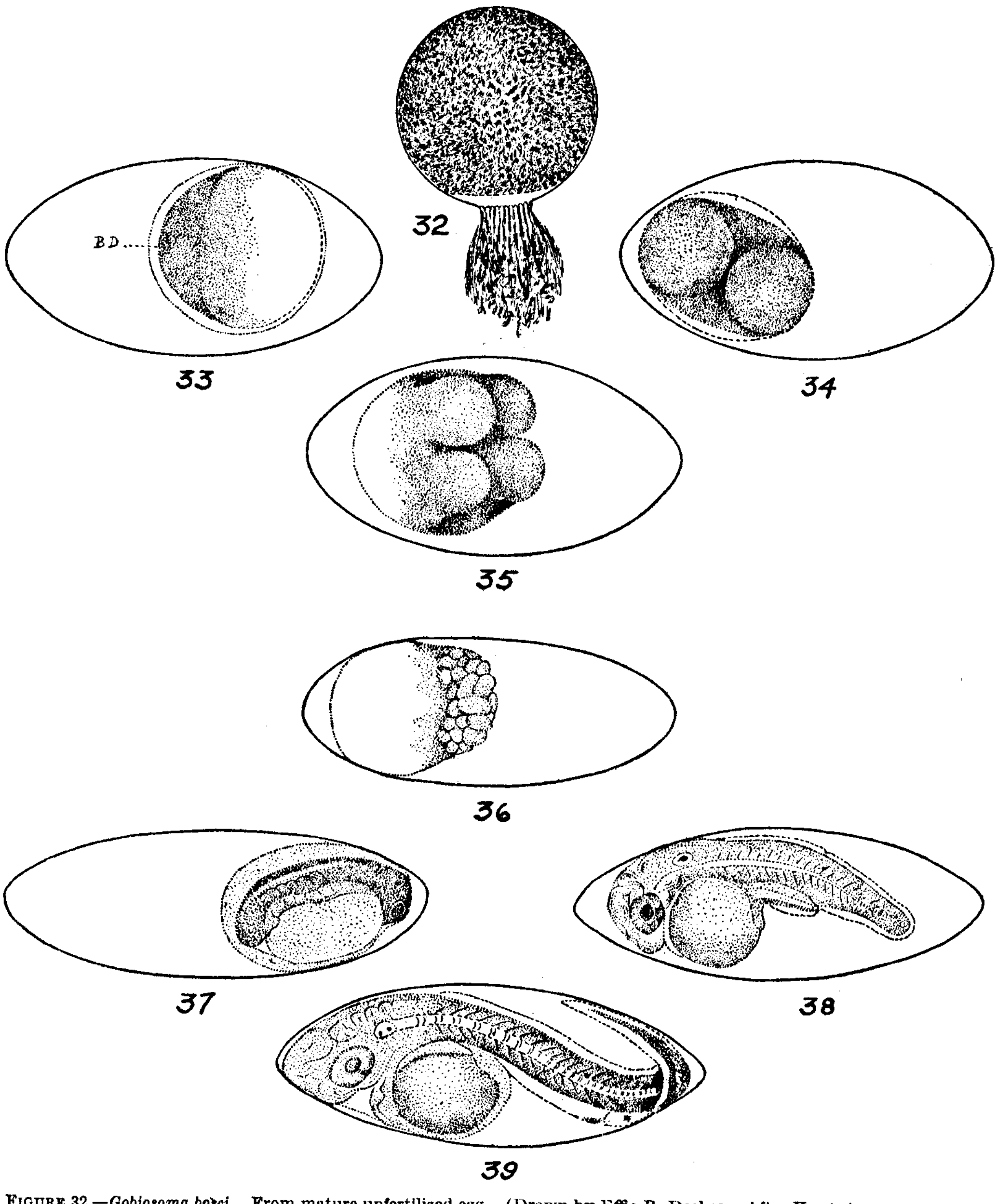

FIGURE 32.—*Gobiosoma bosci*. From mature unfertilized egg. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 33.—*Gobiosoma bosci*. From egg with fully developed blastodisc, BD. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 34.—*Gobiosoma bosci*. From egg with blastoderm of 2 cells. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 35.—*Gobiosoma bosci*. From egg with blastoderm of 4 cells. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 36.—*Gobiosoma bosci*. From egg with blastoderm of many cells. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 37.—*Gobiosoma bosci*. From egg with recently differentiated embryo. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 38.—*Gobiosoma bosci*. From egg with well-formed embryo. (Drawn by Effie B. Decker. After Kuntz.)
FIGURE 39.—*Gobiosoma bosci*. From egg with large embryo. (Drawn by Effie B. Decker. After Kuntz.)

1¼ hours, the 4-cell stage in 1¾ hours, and the 8- and 16-cell stages (for there were some eggs in each stage) were reached in about 2¾ hours. In about 22 hours, at a temperature varying from 26° to 27° C., the embryo had become well formed. Thereafter development progressed less rapidly, and hatching took place in about 4 days at a water temperature varying from about 26° to 28° C. (figs. 36, 37, and 38).

Although the yolk mass, after the expansion of the egg is completed, occupies less than half the area within the eggs, as stated elsewhere, nearly the entire space is utilized later by the advanced embryo which becomes bent back on itself, with the tail pointed in the general direction of the head. The position of the embryo within the egg is not always the same. In most instances the head is pointed toward the pole of the major axis at which the adhesive threads are inserted, but occasionally it is directed toward the opposite pole. This fact is not brought out by Kuntz (loc. cit.) (fig. 39).

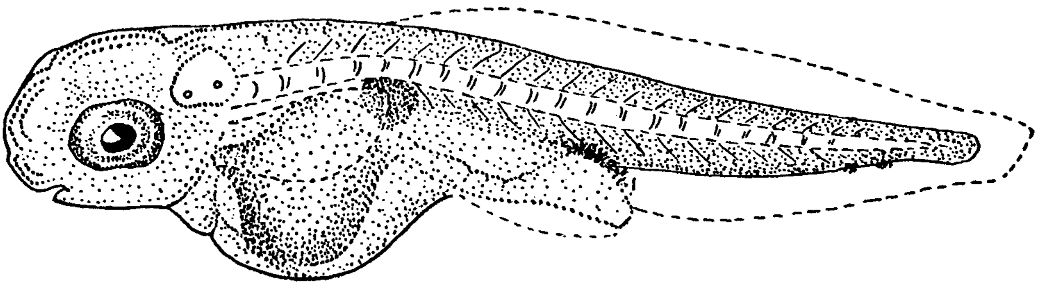

FIGURE 40.—*Gobiosoma bosci.* From a newly hatched fish about 2 mm long. (Drawn by Effie B. Decker. After Kuntz.)

Newly hatched young, 2.0 mm long.—The incubation period occupies about 5 days at the usual summer temperatures (around 24° to 27° C.) prevailing in the laboratory at Beaufort. The newly hatched fish is approximately 2.0 mm long and almost transparent. The air bladder is visible at the posteriodorsal aspect of the yolk mass. The vent is situated nearer the tip of the tail than the end of the snout. The mouth is inferior, although somewhat later it becomes strongly oblique, as shown subsequently. A few small pigment spots occur just over the vent and at the base of the ventral finfold posterior to the vent (fig. 40).

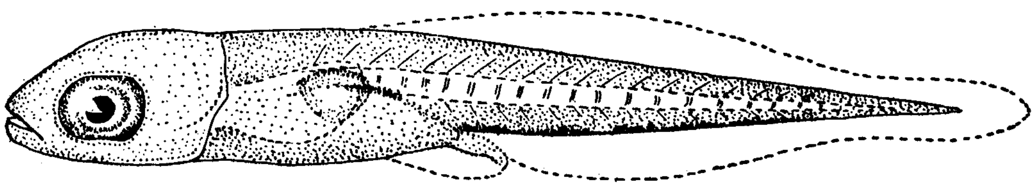

FIGURE 41.—*Gobiosoma bosci.* From a fish hatched in the laboratory, a few days old, and about 3 mm long. (Drawn by Effie B. Decker. After Kuntz.)

Kuntz (1916) was able to keep the fish hatched in the laboratory alive until a length of about 3.0 mm was attained. The mouth in the meantime, according to the illustration presented had moved forward and had become terminal and somewhat oblique. The line of pigment spots at the ventral outline of the tail had become somewhat more conspicuous than in the newly hatched fish (fig. 41).

The eggs and young hatched in the laboratory, upon which the foregoing descriptions are based, are known definitely to belong to *G. bosci.* The young up to 10 mm in length, upon which the descriptions that follow are based, were taken in the tow and probably include both local species, as already explained.

Kuntz did not have sufficient material for the preparation of descriptions and illustrations of all the stages in the development of the young. This information is supplied in the following pages.[4]

Specimens 1.8 mm long.—The smallest individuals in the collection of preserved specimens, which we assign with some doubt to this genus because of their similarity to Microgobius, are only about 1.8 mm in length. Such specimens are farther developed than a fresh or live larval fish 3.0 mm in length (fig. 13), which indicates that considerable contraction probably has taken place during preservation. The body is rather slender and somewhat compressed. The yolk is completely absorbed and the abdominal mass is quite small. The air bladder is plainly visible through the abdominal wall, lying dorsally of the abdominal mass. The intestine is free or at most loosely attached posteriorly and the vent is far behind midbody length. The finfold remains continuous but has slight indications of rays where it surrounds the pointed tail. The eye is excessively large, being equal to about three-fourths the depth of the head. The mouth is almost vertical and the snout is turned up slightly at the tip. The color consists of a few dark chromatophores on the median line of the abdomen and on the ventral surface of the tail, that is, at the base of the ventral finfold (fig. 42).

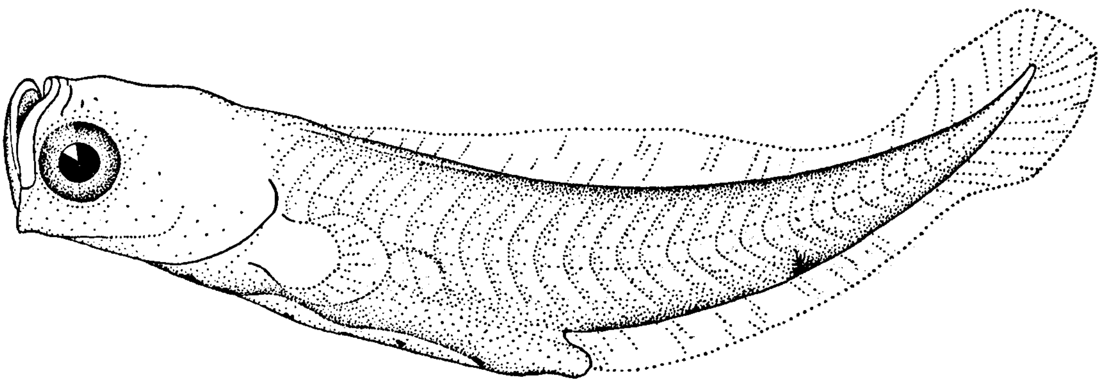

FIGURE 42.—*Gobiosoma sp.* From a specimen 1.8 mm long.

The position of the mouth in our specimens differs sharply from that shown in Kuntz's (loc. cit.) illustrations (figs. 40 and 41). Figure 40, based on a newly hatched fish, shows an inferior mouth, and figure 13, based on a fresh fish 3.0 mm long, represents the mouth as terminal and only slightly oblique, and shaped very much as in the adult. A sudden and a pronounced change in its position must take place since the specimens here described cannot be much older, as already indicated, than the 3.0 mm fish shown in figure 41. Illustrations, in various works, of the development of European gobies, too, show that the mouth in newly hatched larvae is inferior and that it tends to become oblique very early in life.

Specimens 4.0 mm long.—The body is moderately slender and notably compressed. The caudal portion of the body which is much more slender than the trunk in smaller individuals has become much deeper and at this size the depth just posterior to the vent is nearly as great as it is in advance of it. The air bladder remains visible, microscopically, through the abdominal walls, but the intestine which is partly free posteriorly in smaller specimens is now quite fully invaginated.

[4] Shropshire (1932, pp. 28 and 29, figs. 1 to 4) described four stages of young gobies under the name *Gobiosoma molestrum*, which is a synonym of *G. bosci* according to Ginsburgh (1933, p. 32). The two smaller stages are so different in the shape and position of the mouth from our series that they undoubtedly represent a different species. The two larger specimens figured could conceivably be identical with those of our series.

The finfold no longer remains continuous, as the caudal fin is fairly well developed and the bases of the dorsal and anal fins have become indefinitely outlined and some of the rays have become differentiated. Pectoral fins, too, are evident, but the ventrals remain undeveloped. The notochord is curved upward posteriorly, giving the tail a heterocercal appearance. The mouth remains nearly vertical as in younger fish. The body is unpigmented, except for a few dark chromatophores on the median ventral outline of the body and tail, the last one of these dark spots, situated near the end of the anal base, being the largest (fig. 43).

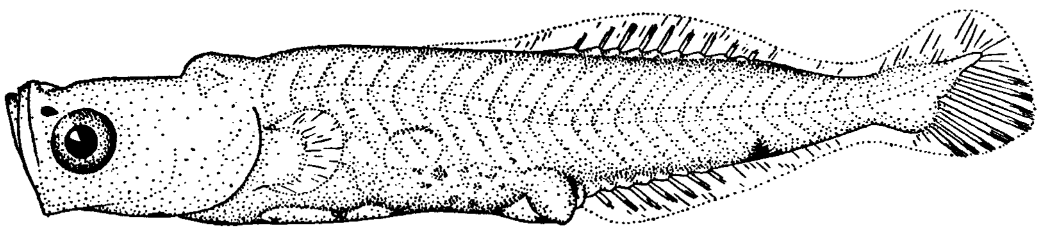

FIGURE 43.—*Gobiosoma sp.* From a specimen 4 mm long.

Specimens 5.0 mm long.—The shape of the body is essentially as in specimens 4.0 mm long. The mouth, however, is not quite as nearly vertical as in the smaller fish. The development of fins has progressed rather rapidly, the caudal, soft dorsal and anal being sufficiently developed to show the rays rather definitely and it is now possible to enumerate the rays of the second dorsal and the anal quite definitely which is a great help in identification. The first, or spinous dorsal, is partly developed in some specimens, but it is impossible to count the spines accurately. The pectoral fins are plainly evident but without distinct rays. The ventral fins, however, are still undeveloped. The air bladder remains slightly visible, microscopically, through the abdominal walls as an area which is slightly more transparent than the abdomen is elsewhere. The notochord is still turned upward posteriorly and pigmentation remains essentially as in 4.0 mm specimens (fig. 44).

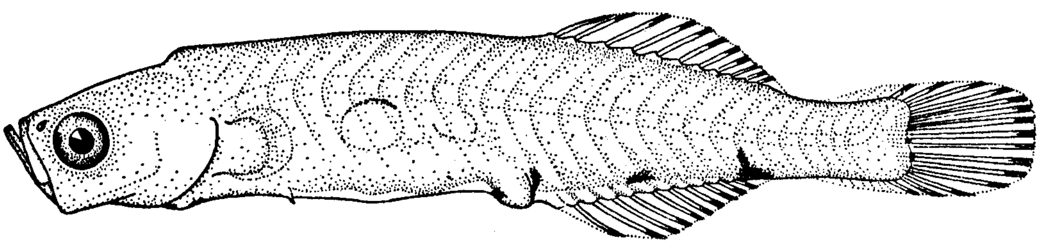

FIGURE 44.—*Gobiosoma sp.* From a specimen 5 mm long.

Specimens 7.5 mm long.—The body remains shaped essentially as in 5.0-mm specimens, that is, compressed and slender, the depth being contained in the length to base of caudal fin about 6.25 times. The fish has a somewhat different appearance, however, at this size, mainly because of the rather pointed snout; for the mouth, although still superior, has become rather oblique with a somewhat pointed projecting mandible, as seen in a lateral view. The muscular rings on the body remain rather distinct, but the heterocercal character of the tail generally has disappeared. The air bladder remains visible, microscopically, through the body wall as a somewhat lighter area. The development of the fins has progressed slowly. The spinous dorsal is not yet evident, but the ventrals now appear as a short tuft of membrane without evident rays. The caudal fin seems to have a nearly straight to a somewhat concave posterior margin. In life the body remains highly transparent and the fish are almost invisible when caught in a net, except for the dark eyes. Pigmentation on the body consists of two short dark lines situated on the median ventral line, the anterior one being under the posterior part of the head and the second one on the chest; a dark chromatophore appears just in advance of the vent; and usually a series of indefinite dark markings extends from the origin of the anal to the base of the caudal, the last spot of the series being on the base of the lower caudal rays and generally slightly vertically elongate. These markings are different from those in related species of gobies occurring locally and serve as a recognition mark (fig. 45).

Specimens 10 mm long.—The two local species of Gobiosoma are rather definitely separable at a length of 10 mm. In both species the body has become more robust since a length of about 7.5 mm was attained and generally it is somewhat rounded anteriorly. The greatest depth of the body in *bosci* is contained in the length to the base of the caudal about 5.3 times, whereas *ginsburgi* generally is more slender, the depth being contained in the length about 6 times. In *bosci* the head is nearly

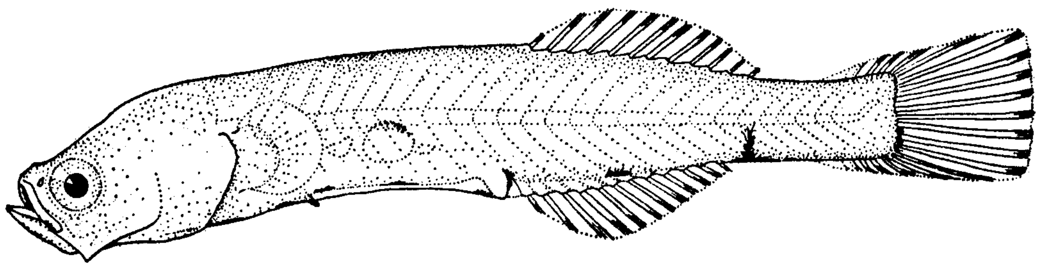

FIGURE 45.—*Gobiosoma sp.* From a specimen 7.5 mm long.

as broad as deep, the eyes have become slightly superior, the snout is comparatively round and blunt, and the mouth is moderately oblique and terminal. In *ginsburgi* the development in all these respects is rather less pronounced. The ventral fins are quite fully developed as a sucking disk in both species (reaching its greatest development in *bosci* at this size and becoming proportionately shorter later in life), and the first dorsal is present, although the spines are very weak and slender. The margin of the caudal fin remains straight to slightly concave. Variation in the progress of pigmentation is evident among specimens of the same species. However, the development generally is further advanced in *bosci* than in *ginsburgi*. In the latter no general pigmentation has taken place and the markings remain virtually as described for the 7.5-mm fish. The posterior one of the two short dark lines on the median line of the chest is now situated at the base of the ventral disk. The dark markings along the base of the anal and on the ventral outline behind the anal clearly are short hyphen-shaped lines when viewed ventrally and are rather more distinct than in smaller fish. In the most profusely pigmented individuals of *bosci* indefinite cross bars are present on the upper part of the sides and back. Also, an oblique bar reaches from the eye to the mouth and another bar occupies the base of the caudal fin (fig. 46; based on a rather unusually well developed specimen for its size).

A difference among specimens in the robustness of the body is present, as already shown. That the slender individuals generally are referable to *ginsburgi* is evident

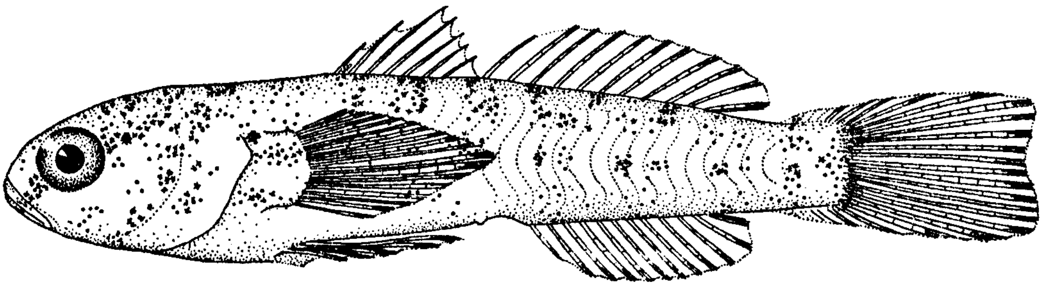

FIGURE 46.—*Gobiosoma bosci*.—From a specimen 10 mm long.

from the presence of two scales on the base of the caudal fin, previously described (p. 548), which *bosci* does not possess (fig. 47).

The development of adult characters at a larger size in *ginsburgi* than in *bosci* suggests that the first-mentioned species might reach a larger size. Judging from the adults taken this is not the case, for on the contrary the largest specimens in the collection are *bosci*.

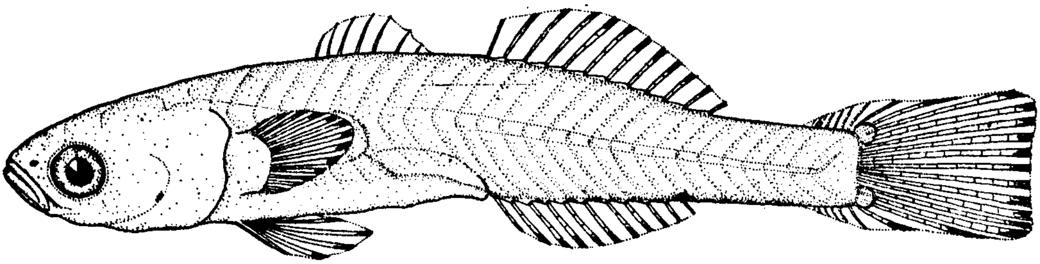

FIGURE 47.—*Gobiosoma ginsburgi*. From a specimen 11 mm long.

Specimens 15 mm long.—At this size *bosci* is robust anteriorly, the depth being contained about 5.3 times in the length to base of caudal fin; the head is depressed and quite as broad as deep; the snout is blunt; the eyes are directed slightly upward; the mouth is small, gently oblique, and terminal to slightly inferior; the maxillary reaches a little past anterior margin of eye; the fins are all fully developed, the margin of the caudal fin now being slightly rounded; and the body is fully pigmented. It is evident, therefore, that fish of this size have acquired nearly all the characters of the adult and are readily identifiable with the grown fish (fig. 48).

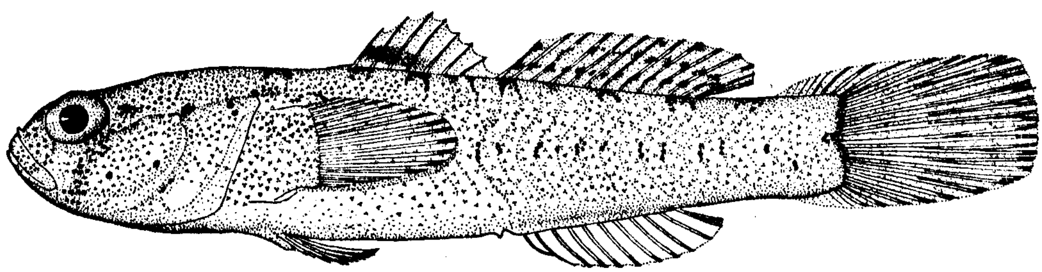

FIGURE 48.—*Gobiosoma bosci*. From a specimen 15 mm long.

It is possible to identify the young at a length of about 15 mm as to species with a reasonable degree of certainty. *G. ginsburgi*, at this size, is notably more slender, the depth being contained in the total length about 6.1 times. The greater length of the ventral disk, which (having attained its highest state of development at about this size, becoming proportionately shorter later in life) reaches nearly to or even past the vent in some specimens, also is evident. The interorbital space, too, is narrower, being equal to only about half the width of the pupil, whereas in *bosci* it is fully equal to the width of the pupil. Furthermore, *ginsburgi* has two scales on the base of the caudal fin which the other species does not possess. Pigmentation in *ginsburgi* in the specimens at hand has not progressed as far as in *bosci* of the same size. However, a considerable degree of variation in color development appears to exist among both species and the degree of pigmentation may be of no specific importance (fig. 49).

General characteristics of the young.—In general young Gobiosoma, even before fin rays are developed, may be recognized by the rather deep body, by the vertical mouth, by the air bladder which is visible as a clear area through the body wall, and, perhaps most important of all, by the pigment spots present, which remain about the same throughout the larval stages, or until pigmentation becomes general. These spots are black and consist of a single row occupying the median ventral line of the body. Two elongate spots (short lines) are situated under the head and chest, one or two immediately in advance of the vent and several behind the vent, or along the base

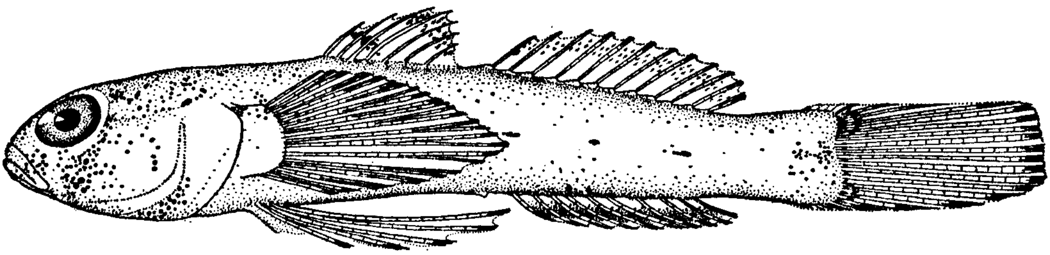

FIGURE 49.—*Gobiosoma ginsburgi.* From a specimen 15 mm long.

of the anal when that member becomes developed, the last spot of the series being at the base of the caudal when that fin becomes differentiated. When the dorsal and anal fins become developed, at a length of about 5.0 mm, the rather low number (generally 11 to 13) of rays in each fin is of much help in identification. At about this size the body becomes quite robust, the head rather broad, the caudal peduncle is short and deep, and the mouth is less nearly vertical than previously. Identification now is much simplified.

DISTRIBUTION OF THE YOUNG

Young Gobiosoma were taken in tow nets and seines in many places and over a wide variety of conditions, ranging from brackish water creeks and ponds, through salt and brackish estuaries, in Beaufort Harbor, along Bogue and Shackleford Banks (both shores) and at sea as far as approximately 15 miles offshore in 10 to 12 fathoms of water. The great majority of the hundreds of specimens collected were taken on the bottom, although occasionally a few appeared in the surface tow. The indications are, then, that the young, like the adults, dwell principally on the bottom. Since the larvae (under about 10 mm in length) could not be separated as to species, the distribution cannot be given separately for each species. Among the young fish that are recognizable, *bosci* was taken only in shallow water and only once at an outside station, that is, about 1 mile off Bogue Banks in a few fathoms of water. *G. ginsburgi*, on the other hand, was taken in both shallow and rather deep water and frequently at offshore stations.

As to time, the larvae are distributed over the entire summer, appearing first in May and a few stragglers as late as December, but they were common to abundant only from June to September.

GROWTH

Growth in Gobiosoma probably progresses moderately fast. It is not always an easy matter, however, to distinguish between those of the 0-class and the older ones, as the sizes intergrade during late summer. Specimens 18 mm long, taken in August, are recognizable as young of the current season and may be among the largest of their year class. Larger examples of the current year, if present, apparently could not be recognized, for they are as fully developed as the adults. Since the spawning season may be said to end, except for an occasional late spawner, by the end of August, it seems unlikely that the largest young become mature during their first summer. However, sexual maturity is reached at a very small size, for we have seen a few gravid females only 23 mm long and many gravid ones from 25 to 30 mm in length. Therefore, the authors are not prepared to state positively that none of the young become mature during their first summer, but they regard it as quite unlikely. It seems highly probable, however, that sexual maturity is reached during their second summer.

MICROGOBIUS HOLMESI SMITH. HOLMES GOBY

Two very closely related species of *Microgobius*, namely *eulepis* and *holmesi*, are recognized from North Carolina. As understood by us *eulepis* has a somewhat more slender and less strongly compressed body than *holmesi*, the depth in the former in the two specimens at hand is contained respectively 6.5 and 7.0 in the standard length, whereas in eight specimens of the latter the depth goes into the length 4.7 to 5.75 times. The mouth in *eulepis* appears to be rather more nearly vertical and the ventral disk is shorter, failing to reach the vent, whereas in *holmesi* the disk usually reaches to or beyond the vent. It is possible that *holmesi* may grow somewhat larger. However, it seems probable that a further study based on a larger number of specimens than is now available may show that the two nominal species intergrade, and in fact are identical. As now understood *eulepis* is very rare at Beaufort, whereas *holmesi* is moderately common. The known range of the two species is coterminous extending from Chesapeake Bay to North Carolina.[5]

The sexes are readily separable in *M. holmesi*, as the male has a row of prominent black spots on the interradial membranes of the anal just below the pale margin of the fin. These spots are entirely missing in the female, in which, as contrasted to the male, the membranes between the longest dorsal spines is jet black distally. In general, the males also have higher fins. The ventral disk, for example, usually reaches the origin of the anal in adult males, whereas it frequently reaches only to the vent in adult females. Furthermore, the females, at least during the breeding season, have a larger anal papilla. Whether similar sexual differences exist in *eulepis* cannot be stated at this time. The two specimens in the present collection in general agree in color with the females of *holmesi*.[6]

It is not surprising that the larval and young Microgobius do not appear to be separable into two species (if indeed more than one species is represented) since the adults of the local representatives are very closely related. Since *M. holmesi* is com-

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[5] Since the preparation of this manuscript Isaac Ginsburg, who has made a special study of the American gobies, concluded (Copeia, No. 1, 1934, p. 35) that *M. holmesi* and *M. eulepis* are identical and that both are synonyms of *M. thalassinus*.

[6] Smith (1907, p. 367) presents a very satisfactory illustration of an adult male *Microgobius holmesi*.

paratively common, whereas, *M. eulepis* is very rare, as previously stated, it seems logical to refer all the young, at least tentatively, to *holmesi*.

The locally represented species of Microgobius reach a length of only about 2 inches and they probably are of only slight economic value even as forage fish, because of their comparative scarcity. The rather large number of young taken suggests, however, that the fish may be somewhat more common than is indicated by the scarcity of adults in the collections.

Neither adults nor young were taken from December to February, inclusive. It seems probable, therefore, that these fish leave the local waters during the winter, or that they possibly seek shelter in the mud or sand like Fundulus and probably other minnows.

SPAWNING

The eggs of Microgobius have not been studied. *M. holmesi* with large roe were taken only during the first half of July. That the spawning period of this species is not limited to the month of July is evident, however, from the collection of larvae at hand, as shown subsequently. Smith (1907, p. 368) reported that a female *M. eulepis* distended with nearly ripe eggs was taken at Beaufort on May 18 (1905). No gravid fish of the last mentioned species were seen during the present investigation.

A few young Microgobius, only about 3.0 to 4.0 mm long, were taken as early as March 11 (1929), and a few equally as small were taken as late as November 21 (1927). The larvae were numerous, however, only during July, August, and September. The collection of young Microgobius indicates, therefore, that some spawning takes place as early as March, that it continues throughout the summer, probably extending into the month of November, and that the principal spawning season occurs during July, August, and September.

Larval Microgobius were taken over the entire area in which tow-net collections were made, including Beaufort Harbor, the adjacent sounds and estuaries, and off Beaufort Inlet to Cape Lookout and as far as 12 to 13 miles offshore. It seems reasonable to expect Microgobius to produce eggs which become attached like those of Gobiosoma and Gobionellus, and like those of the various European species that have been studied. If that be true the eggs do not drift and the recently hatched young should be expected to occur somewhere near the place where the eggs were spawned. It seems probable, therefore, that spawning takes place over much of the area in which the larvae were taken.

DESCRIPTIONS OF THE YOUNG

Specimens 1.6 to 4.0 mm long.—Specimens of Microgobius 4.0 mm and less in length generally are difficult to separate from Gobiosoma (figs. 50 and 51). A careful study has revealed no outstanding structural differences in these small larvae, and color marking in preserved specimens, except in rather rare instances, are not of much help until a length of about 4.0 mm is attained. In general, the vent in Microgobius is slightly more anterior in position than it is in Gobiosoma. This difference is evident only when specimens of even size are compared, and it is not readily shown in a table of measurements, because few specimens are straight enough for an accurate measurement and, furthermore, the position of the vent evidently changes with growth. The quotients derived from dividing the caudal portion of the body into the total length to the tip of the notochord, even in specimens varying less than a millimeter in length, do not show a constant difference. An average difference, however, is evident, for in 12 specimens measured of each genus, the caudal portion of the body averages 2.15

times in the length in Microgobius (with a range of 2.02 to 2.3) and 2.24 times in Gobiosoma (with a range of 2.13 to 2.33). Microgobius also has a slightly larger eye. However, the difference is so slight and the size of the eye changes so rapidly with growth that the difference cannot be shown easily in a table of measurements. Furthermore, the size of the eye in the delicate larvae of this size appears to have been affected by the strength of the preservative used which varied considerably with the different lots in the present collection.

The first concrete difference observed between specimens of Microgobius and Gobiosoma are color markings which generally are fairly well developed at a length of 4.0 mm, frequently at 3.0 mm, and occasionally at a somewhat smaller size. Gobiosoma, as explained elsewhere (p. 555), has only a few dark markings on the ventral outline, consisting generally of about two elongate spots on the median ventral line under the head and on the chest, a larger spot or blotch at the vent and a few posterior to the vent, including one (situated at the last rays of the anal fin when that member becomes developed) that is notably larger than the others. Microgobius, on the other hand, has more numerous dark spots on the ventral outline and a double row of rather

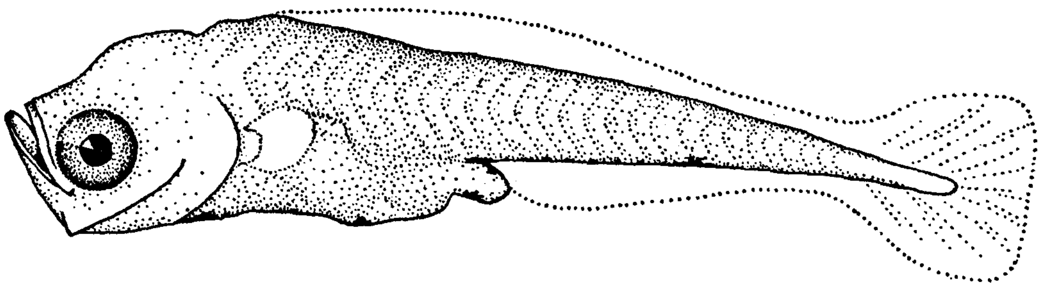

FIGURE 50.—*Microgobius sp.* From a specimen 1.68 mm long.

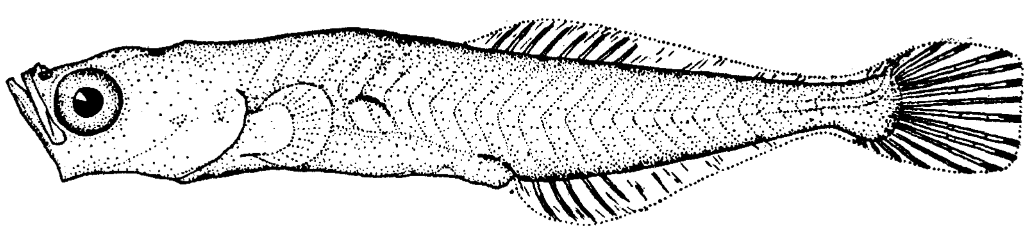

FIGURE 51.—*Microgobius sp.* From a specimen 4.5 mm long.

well outlined dots extending from the vent to near the end of the tail, or nearly to the base of the caudal fin when that member becomes developed. The dark spot at the vent typically forms a short black line lying parallel with the upper margin of the loosely attached hind gut. Occasionally the larvae of Microgobius, only a few millimeters long, have a few dark spots at the nape and two more or less definite rows of minute black dots on the dorsal surface of the caudal portion of the body (fig. 51). No markings of any kind have been noticed on the dorsal outline in the larvae of Gobiosoma.

Specimens 5.0 mm long.—At a length of about 5.0 mm the second dorsal and anal fins usually are sufficiently developed (although some of the posterior rays generally are undifferentiated) to admit of a count accurate enough to establish the fact that these fins are too long for Gobiosoma which has only 11 or 12 rays in each fin. The slightly larger eye in Microgobius remains equally as evident at this size as in the smaller individuals previously described. Differences in color markings between Microgobius and Gobiosoma which generally become established when the fish reach a length of about 4.0 mm, remain essentially as described in the preceding paragraph (fig. 51).

Specimens 7.5 mm long.—The general shape of the body, as well as the head and mouth remain very similar in Microgobius and Gobiosoma. The slightly larger eye in the first-mentioned genus, noticed in the very smallest larvae at hand, remains evident. The second dorsal and anal fins are quite fully developed and a fairly accurate fin-ray count is obtainable. In addition to the higher fin-ray count (second dorsal and anal each with about 16 or 17 rays) in Microgobius, it is evident now that the caudal peduncle also is shorter. The color markings in Microgobius remain largely as when they first appeared, except that no dark markings are present on the back in any of the specimens examined. The two rows of dark spots along either side of the base of the anal fin are more distinct and each spot is now horizontally slightly elongate (fig. 52).

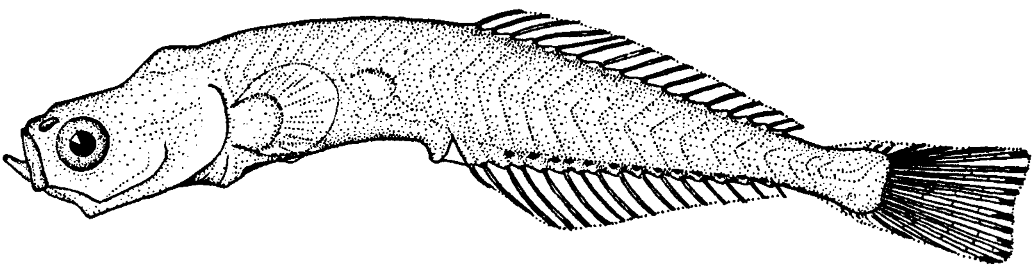

FIGURE 52.—*Microgobius sp.* From a specimen 7.6 mm long.

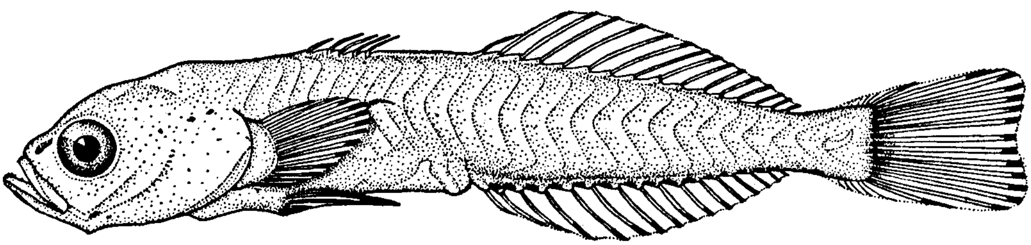

FIGURE 53.—*Microgobius sp.* From a specimen 10 mm long.

Specimens 10 mm long.—A difference in the shape of the body between specimens of Microgobius and Gobiosoma is plainly evident in examples about 10 mm long. In Microgobius the body remains nearly as strongly compressed as in smaller fry, but in Gobiosoma it has become notably more robust anteriorly and the head is broader with a wider interorbital space. Although the mouth remains about equally oblique in the representatives of each genus, it is evident now that the gape in Microgobius is somewhat larger, the maxillary reaching about below the anterior margin of the pupil, whereas it ends slightly in advance of this point in Gobiosoma. All the fins, exclusive of the first dorsal, are now quite fully developed. The ventral disk is long and slender. The caudal fin is shorter than the head and its margin remains straight to slightly concave. The spinous dorsal usually consists of four very slender spines, with two or three of the posterior ones still missing. Pigmentation has advanced only slightly. In addition to the pigment spots described in smaller fish, at least some specimens now have a few dark markings about the mouth, a few on the side of the head and an indication of a slight dark bar at the base of the caudal. Some specimens also have some black dots along the bases of the dorsal fins (fig. 53).

Specimens 15.0 mm long.—The body has become more robust but remains compressed throughout. The eyes are lateral in position; the mouth is large, terminal to slightly superior and nearly or quite as oblique as in 10-mm fish; and the maxillary reaches nearly opposite middle of eye. The fins, including the spinous dorsal, are all well developed. The caudal is strongly rounded to pointed and fully as long as the head; the long ventral disk usually reaches nearly to or even beyond the origin of the anal; the dorsal spines are rather long and slender, the longest ones being equal to or slightly longer than the eye and snout; and the posterior rays of the second dorsal and anal frequently reach the base of the caudal when deflected. Pigmentation has progressed considerably, for nearly the entire body is covered with minute dark points. The color markings along the ventral and dorsal outlines, described for smaller fish, in most specimens have become somewhat less pronounced (fig. 54).

It is evident from the foregoing description that nearly all the structural characters of the adult, exclusive of scales, are developed at a length of 15.0 mm and identification is comparatively easy. The scales first appear when the fish is about 18 mm long and they become evident on the caudal peduncle first, and from there squamation proceeds forward until it is virtually completed when the fish reaches a length of about 23 mm.

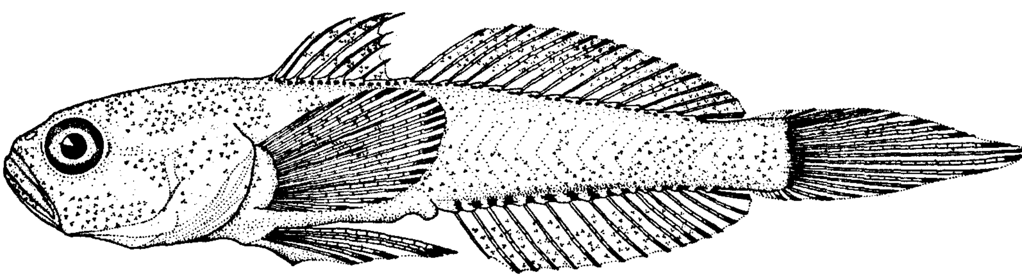

FIGURE 54.—*Microgobius sp.* From a specimen 15 mm long.

It is interesting that in specimens from about 16 to 25 mm long the ventral disk is proportionately longer than in larger fish, generally reaching to or a little beyond the origin of the anal at this size.

Microgobius and Gobiosoma, at a length of about 15 mm, differ strongly. Microgobius now has a more compressed body; a much narrower and deeper head with the eyes fully lateral; the mouth is much larger, more strongly oblique, and terminal to slightly, superior; and the fins are much higher than those in Gobiosoma.

DISTRIBUTION OF THE YOUNG

It already has been stated under the section of this paper dealing with spawning that the larvae of Microgobius were taken virtually over the entire area in which tow net collections were made. This area includes Beaufort Harbor, the adjacent sounds and estuaries, and at sea, 13 to 15 miles offshore. The variation in depth over this area ranges from a few feet to 12 fathoms.

The larvae were taken in inside waters 37 times and offshore 20 times. The inside catches, besides being more numerous, generally contained a larger number of fish per catch. A total of about 90 larvae was taken outside, whereas a total of about 760 larvae was taken inside. Although a somewhat greater number of hauls probably was made in the inside waters, that difference would not offset the great difference between the number of larvae taken in inside and outside waters. It may be concluded, therefore, that young Microgobius are decidedly more numerous in Beaufort Harbor and adjacent sounds and estuaries than they are off Beaufort Inlet.

In about an equal number of surface and bottom hauls Microgobius was taken at the surface 13 times and on the bottom 45 times. Young Microgobius, like the adults, therefore, are primarily bottom dwelling. With respect to distribution over time, a few young appeared in the catches in March, April, and May, they become rather numerous in June, and abundant in July, August, and September; only a few were taken in October and November, and none from December to February.

GROWTH

The largest young of the season were caught in September and had reached a length of 32 mm. It seems quite certain that such individuals will reach an adult size of 40 to 50 mm, and sexual maturity, during their second summer. However, some of the young taken with the large ones mentioned are only about 5.0 mm long. It seems doubtful that such individuals will attain an adult size and sexual maturity before their third summer. It may be concluded, therefore, that some of the larger and faster-growing individuals certainly reach an adult size and sexual maturity during their second summer when about a year old. Others almost certainly are not full grown, nor sexually mature, before their third summer.

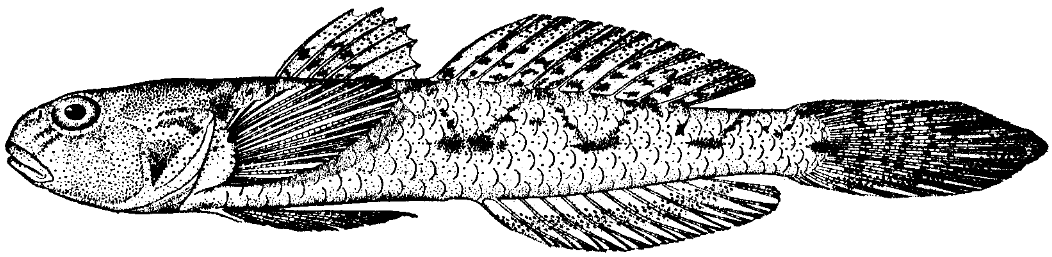

FIGURE 55.—*Gobionellus boleosoma.* From an adult 34 mm long.

LOCAL SPECIES OF GOBIONELLUS

A single species of Gobionellus, namely, *boleosoma,* heretofore has been recorded from the coast of North Carolina. This fish was assigned to *Ctenogobius stigmaticus* by Smith in "The Fishes of North Carolina" (1907, p. 365). However, Ginsburg (1932, p. 23) in an exhaustive study of extensive collections in the Bureau of Fisheries and the National Museum failed to find *stigmaticus* north of Florida This investigator assigned the common Atlantic coast species of scaled goby (which ranges from North Carolina at least as far south as Panama) to *boleosoma* and places it in the genus Gobionellus. Mr. Ginsburg's nomenclature has been adopted by the present writers. Attention is called to the fact that Smith's illustration (loc. cit., fig. 167) is not correct for *boleosoma.* The figure probably represents an entirely different species. Accordingly, a drawing of an adult based on a specimen from Beaufort has been prepared (fig. 55).

A few representatives of a second species of Gobionellus, namely, *shufeldti,* recently were taken in fresh water in Newport River. *G. shufeldti* according to Ginsburg (1932, p. 14) differs from *boleosoma:* (*a*) In having one or more rows of scales on the median line of the back in advance of the first dorsal (in one specimen from Beaufort, assigned to this species, however, the median line of the back is naked as in *boleosoma*); (*b*) in having a slightly higher average number of rays in the dorsal and anal fins, the typical number being dorsal 12, anal 13, as compared with dorsal 11, anal 12 in *boleosoma;* (*c*) in having no definite dark shoulder spot, nor V-shaped dark markings along the sides whereas these color markings generally are quite evident in *boleosoma;* (*d*) in reaching a larger size (according to the few specimens at hand from North Carolina the maximum size attained by *shufeldti* is about 70 mm, while the largest specimen of *boleosoma,* of which many specimens have been collected, is only 55 mm long); (*e*) in inhabiting fresh and slightly brackish water, whereas *boleosoma* ranges from salt to brackish water. If the young of *shufeldti* are present in the collection, they are confused with *boleosoma.*

Two other species of gobies which Mr. Ginsburg (loc. cit.) also places in the genus Gobionellus, not as yet recorded from Beaufort, have been taken there recently, namely, *oceanicus* and *hastatus.* These species both differ from the other local Gobionellus in the more numerous rays in the dorsal and anal fins, the usual number in the dorsal being 14 and in the anal 14 or 15. The two species differ from each other largely in the number of scales in a lateral series, *hastatus,* according to 10 specimens from Beaufort, has 81 to 89, and *oceanicus,* according to 3 specimens from Beaufort, has 61 to 68 scales. The counts agree with those made by Ginsburg (1932, p. 39) based on specimens from Panama, Puerto Rico, Cuba, Florida, and Louisiana. The young of at least one of these species apparently also are included in the present collection.

GOBIONELLUS BOLEOSOMA (JORDAN AND GILBERT). SCALLOP FISH

The young of Gobionellus are much less numerous in the collection than those of Gobiosoma and Microgobius, but they are not rare, as 177 larvae are at hand. Adults of *Gobionellus boleosoma* have been taken more frequently locally than those of Microgobius, but much less often than Gobiosoma. The local distribution of adult *G. boleosoma* seems to be rather general. They were taken most frequently with seines in shallow water and on muddy bottom, both in salt and slightly brackish water, including in one instance a small drainage ditch. In somewhat deeper water they were secured only twice, once in the channel of Newport River, a few miles north of the laboratory, and again at sea off Bogue Banks.

Many variations or differences have been noticed among adults from Beaufort. In some specimens the body is more slender than in others. Also, the size of the mouth, the teeth, and the eyes varies. The median portion of the abdomen is variously scaled or naked and in some specimens the caudal fin is much longer than in others. Most of these differences certainly are associated with sex. In general, large males are more slender than females, and they have larger eyes, more prominent teeth, and a longer and more pointed caudal fin.

The maximum size attained by this goby is about 55 mm. It no doubt is preyed upon by larger predatory fishes, but it evidently is not abundant enough to be of much importance as a forage fish. Therefore, its economic value must be very slight locally.

Gobionellus boleosoma is present in the vicinity of Beaufort throughout the year, as both adults and young have been taken occasionally during the winter months as well as during the summer. Therefore, it evidently does not migrate, and no evidence indicating that it seeks protection from the cold by burying itself in mud or sand has been secured.

SPAWNING

Ripe or nearly ripe fish have been taken locally during July and August. Very small larvae (2.5 to 5.0 mm long), however, were taken as early as May 15 (1929), and as late as November 3 (1928). The young were not abundant at any time. The largest number of specimens was secured during July and August, which may represent the principal spawning period.

It is not definitely known where this goby spawns. The eggs are demersal and bear adhesive threads, which suggests that spawning probably takes place where there are sufficient objects in the water for the attachment of the eggs. Small larvae, only a few to several millimeters long, were taken virtually over the entire area in which towings were made. This area includes Beaufort Harbor, and the neighboring sounds and estuaries, as well as the waters off Beaufort Inlet, extending 12 to 15 miles offshore. It seems probable, therefore, that spawning takes place both in the inside protected waters and along the outside shores.

DESCRIPTIONS OF THE EGGS AND YOUNG

Eggs.—The eggs were described by Kuntz (1916, pp. 426–428) on the basis of samples stripped from fish taken and identified by the present senior author as *Ctenogobius stigmaticus*, following Smith (1907, p. 365). The following descriptions of the eggs and their development is a condensed account, based on Kuntz's paper. The illustrations of the development of the egg and the figure of the newly hatched fish are also from Kuntz.

The eggs are yellow in color, highly translucent, somewhat irregular in shape and have a diameter of about 0.3 mm. Their specific gravity is only slightly greater than sea water. The egg membrane is thin and delicate and usually drawn out into a blunt apex at the insertion of the "peduncle", that is, at the insertion of the gelatinous threads. The egg contains a relatively enormous amount of protoplasm and very little yolk (fig. 56).

The fully developed blastodisc covers about half the area of the surface of the yolk. The first cleavage act, at ordinary summer laboratory temperature, takes place in about 30 minutes and the successive cleavages occur in rapid succession. The first cleavage plane cuts deep into the blastodisc and the first cells usually, although not always, are quite symmetrical. Until the 16-cell stage is reached the cells are in a single row. Thereafter they become heaped up on one side of the yolk (figs. 57, 58, and 59).

As cleavage advances the blastoderm becomes more distinctly dome-shaped and it soon becomes thickest at the periphery. The peripheral growth of the blastoderm advances and the yolk becomes entirely engulfed, the blastopore closing within 6 hours after fertilization (figs. 60 and 61).

Soon after the closing of the blastopore a distinct linear thickening of the blastoderm, representing the axis of the future embryo, grows anteriorly from the blastopore. As the differentiation of the embryonic axis advances the anterior region of the differentiated area of the blastoderm becomes distinctly broader than the posterior region. That is, the differentiation of the embryo begins in the anterior or head region and advances posteriorly (fig. 62).

The subsequent growth of the embryo advances rapidly. Within 11 hours after fertilization the embryo is well formed and it shows 10 to 12 somites. An hour later the embryo almost completely encircles the egg and the posterior region of the body is already free from the greatly reduced yolk mass. The embryo, although highly transparent, is marked by small areas of delicate pigment. It now more than encircles the periphery of the egg membrane, and the entire period of incubation at laboratory temperature occupies not over 18 hours (figs. 63 and 64).

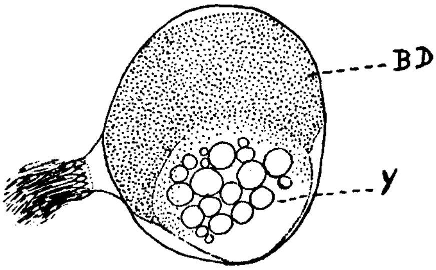

FIGURE 56.—*Gobionellus boleosoma.* From egg with undivided blastodisc, BD; yolk, Y. (Drawn by Effie B. Decker. After Kuntz.)

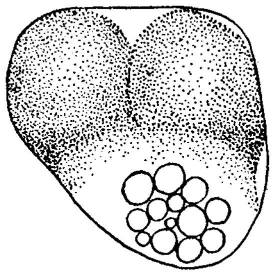
FIGURE 57.—*Gobionellus boleosoma.* From egg with 2-cell blastoderm. (Drawn by Effie B. Decker. After Kuntz.)

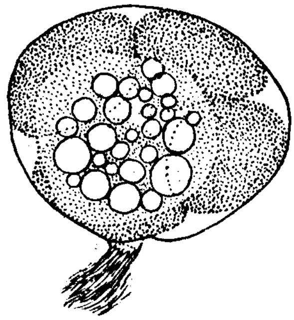
FIGURE 58.—*Gobionellus boleosoma.* From egg with a 4-cell blastoderm. (Drawn by Effie B. Decker. After Kuntz.)

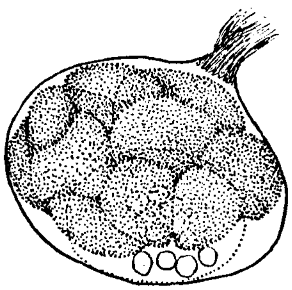
FIGURE 59.—*Gobionellus boleosoma.* From egg with a 16-cell blastoderm. (Drawn by Effie B. Decker. After Kuntz.)

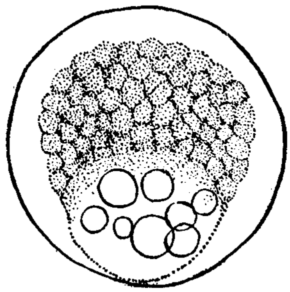
FIGURE 60.—*Gobionellus boleosoma.* From egg with blastoderm of many cells. (Drawn by Effie B. Decker. After Kuntz.)

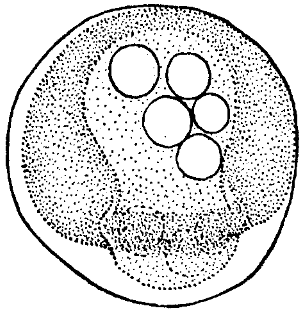
FIGURE 61.—*Gobionellus boleosoma.* From egg with blastoderm growing around yolk shortly before closing. (Drawn by Effie B. Decker. After Kuntz.)

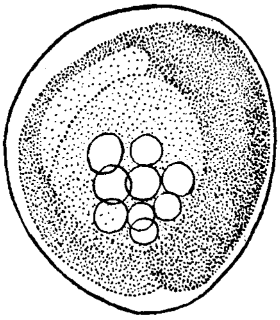
FIGURE 62.—*Gobionellus boleosoma.* From egg showing an early stage in the differentiation of the embryo. (Drawn by Effie B. Decker. After Kuntz.)

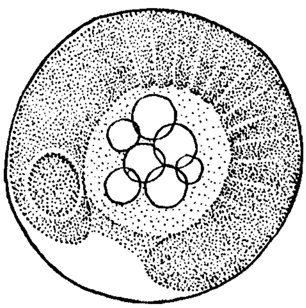
FIGURE 63.—*Gobionellus boleosoma.* From egg with well-differentiated embryo. (Drawn by Effie B. Decker. After Kuntz.)

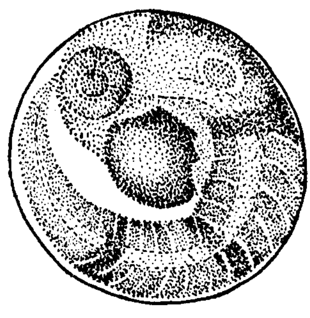
FIGURE 64.—*Gobionellus boleosoma.* From egg with large embryo, just before hatching. (Drawn by Effie B. Decker. After Kuntz.)

The newly hatched fish, 1.2 mm long.—The following account of the newly hatched fish has been compiled from Kuntz's description (loc. cit.) based on a fresh specimen: It is exceedingly delicate, and only about 1.2 mm long. It is highly transparent and marked by small areas of delicate yellow pigment on the dorsal surface of the head, over the vent and with a vertical band about half way from the vent to the tip of the tail. The vent is located slightly in advance of midbody length. The dorsal and ventral finfolds are continuous and the depth of each fold is equal to or greater than the depth of the body posterior to the vent (fig. 65).

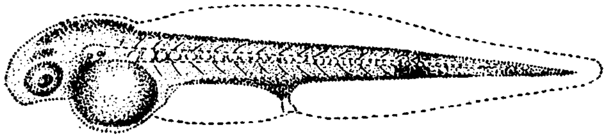

FIGURE 65.—*Gobionellus boleosoma.* From newly hatched fish, length 1.2 mm. (Drawn by Effie B. Decker. After Kuntz.)

Kuntz was able to keep the delicate larvae alive in the laboratory only a few hours, and he did not have any advanced larval stages. Descriptions and illustrations of the subsequent development of the young are based on preserved specimens contained in the collection studied by the present writers.

Specimens 2.5 mm long.—The larvae of this genus are extremely slender and this character generally distinguishes them from those of Gobiosoma and Microgobius. The caudal portion of the body is especially slender and at this size notably longer than the rest of the body. The head is rather broad, its width being nearly as great as its depth; the mouth is almost vertical and very close in front of the moderately large protruding eyes. The air bladder is plainly visible as a round or slightly elongate clear area within the abdominal cavity; dorsally of the air bladder the dark peritoneum is visible (and at a slightly larger size the black peritoneum at this point becomes very pronounced and forms a recognition mark). Fins are undeveloped, except for a slight indication of rays in the fin fold around the tip of the notochord (fig. 66).

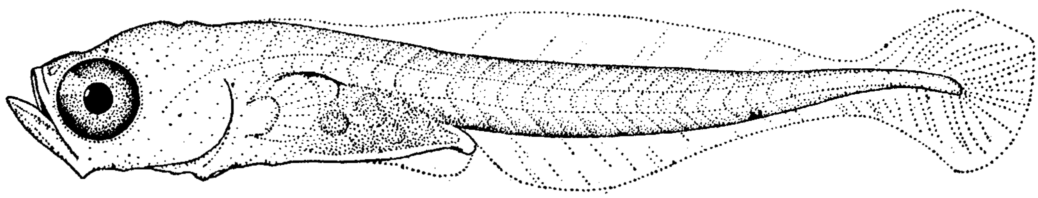

FIGURE 66.—*Gobionellus boleosoma.* From a specimen 2.5 mm long.

Specimens 3.5 mm long.—The fish has become only slightly more robust than it was at a length of 2.5 mm. The mouth remains very close to the eyes, but has become slightly less vertical. Pectoral fins have appeared as tufts of membrane without rays. The notochord remains straight, with indications of rays around its tip. The soft dorsal and anal bases are in part evident, but no definite rays have developed. On some specimens a few very small dark spots are present along the ventral outline of the body and tail. The black peritoneum over the air bladder is moderately distinct and has acquired a crescent shape which is characteristic of the young of this species (fig. 67).

Specimens 5.0 mm long.—Little change has taken place in the shape of the head and body since a length of 3.5 mm was attained. The mouth has become slightly less strongly oblique, but remains superior, and the gape is proportionately further removed from the eye. The notochord is bent upward sharply at the tip, giving the tail a heterocercal appearance. The caudal fin is fully formed, with definite rays, and has a nearly straight posterior margin. The soft dorsal and anal contain some well-developed rays, but a definite fin ray count is not yet obtainable. The pectorals remain as tufts of membrane, and the ventral fins (disk) are not yet evident. Pigmentation has made little progress. It now consists of two or three short, narrow, dark lines on the chest, a very small dark spot at the vent and a slightly larger one at or near the end of the anal base. The crescent-shaped dark area over the air bladder, visible through the abdominal wall, is prominent and serves as a ready recognition mark (fig. 68).

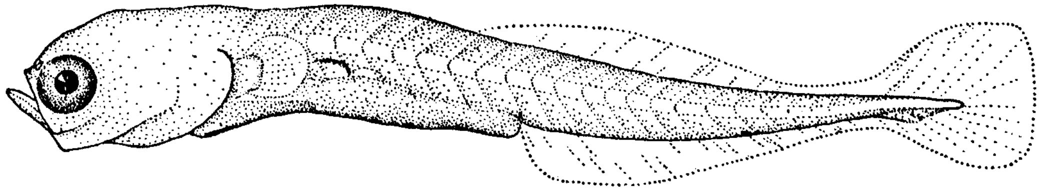

FIGURE 67.—*Gobionellus boleosoma.* From a specimen 3.7 mm long.

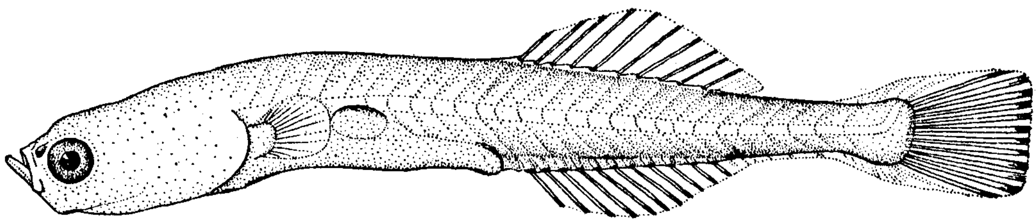

FIGURE 68.—*Gobionellus boleosoma.* From a specimen 5.1 mm long.

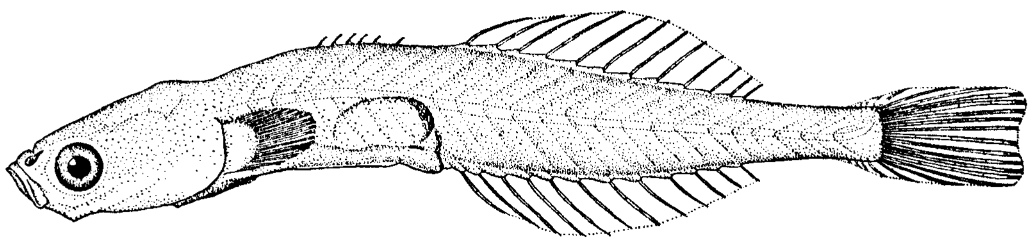

FIGURE 69.—*Gobionellus boleosoma.* From a specimen 7.5 mm long.

Specimens 7.5 mm long.—The body has increased somewhat in depth but remains comparatively very slender, the depth being contained in the length to the base of the caudal about 7.5 to 8.0 times. Some progress in the development of the fins has been made. It is now possible, in at least some specimens, to make a fairly accurate count of the soft dorsal and anal rays, each fin having 11 to 13 rays. The caudal fin is well developed and its margin is straight to slightly concave. The pectoral fins have indications of rays and the base of the ventral disk is just becoming evident. The spinous dorsal is undeveloped, or in some specimens just becoming evident. The notochord, sharply bent upward at its tip, remains visible. A crescent-shaped dark area over the air bladder is quite distinct. This dark area is visible with the unaided eye in somewhat larger specimens and is a definite aid in identification. Pigmentation on the body remains virtually as in 5.0 mm fish (fig. 69).

Specimens 10 mm long.—The body remains much more slender than in other local genera of gobies, and fully as slender as in 7.5-mm fish, the depth being contained in the length to base of caudal about 6.5 to 8.0 times. The mouth is still quite oblique, nearly terminal and small, the maxillary scarcely reaching opposite anterior margin of eye. The fins are all developed. However, the spines of the first dorsal usually remain short and slender. The ventral disk is fully developed and long, reaching about three-fourths of the distance from its base to the vent. The pectoral fins, too, are rather long but do not reach quite as far back as the ventral disk. The margin of the caudal fin is straight to rounded. The crescent-shaped dark area over the air bladder has become quite pronounced and in some specimens is clearly evident with the unaided eye. Pigmentation has made no definite advancement (fig. 70).

Specimens 13 mm long.—The body remains extremely slender, the depth being contained in the length to base of caudal about 10 times. The head has become slightly broader and somewhat depressed. The mouth is small, oblique, and terminal, and the maxillary scarcely reaches the vertical from the anterior margin of eye. The air bladder is visible microscopically, but the crescent-shaped black area above it (that is, the dark peritoneum), very evident in somewhat smaller fish, is quite indistinct and somewhat changed in shape. The spinous dorsal now is fully developed and it is plain that the last two spines are much further apart than the others, which appears to be characteristic of the local species of the genus. The pectorals and ventral disk are long, but do not extend as far back on the body as in somewhat smaller fish.

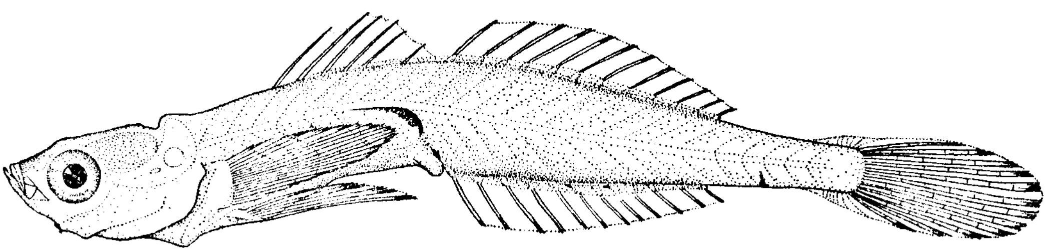

FIGURE 70.—*Gobionellus boleosoma.* From a specimen 10 mm long.

However, there appears to be some variation in this respect among individuals. The caudal fin is about as long as the head and its margin is slightly convex. Progress in pigmentation varies greatly. In a 13-mm specimen it has progressed little further than in the 10-mm fish, described in the foregoing paragraph. However, there is at hand one specimen 11 and another 12 mm long which have some dark markings on the head, including indications of a dark oblique bar between the eye and the mouth (characteristic of the adult); scattered dark dots on the back and along the ventral edge of the abdomen, a more definite series of black spots on the base of the anal, and with indications of wavy dusky bars on the caudal fin, as in the adult.

No perfect specimens from Beaufort suitable for drawing are at hand. Furthermore, the differences between fish 10 mm and 13 mm long are slight, as pointed out in the description. For these reasons no illustration of the size described in the foregoing paragraph is offered.

Unfortunately specimens between 13 and 22 mm in length (the latter being adults) are not at hand. The fish described in the foregoing paragraph are quite immature, yet sufficient adult characters are developed to make identification fairly easy and certain. The characters that are especially helpful in the identification of specimens of the size described in the foregoing paragraph are: (*a*) The fin-ray counts (dorsal and anal each having 11 to 13 rays), which may be made accurately, (*b*) the greater distance between the last two dorsal spines than between the others, (*c*) the long pectoral fins and ventral disk (reaching about two-thirds the distance from their bases to vent), (*d*) the general shape of the head and the small mouth (the maxillary scarcely reaching the eye). The head is still somewhat less strongly depressed than in the adult, the snout more pointed and the mouth more oblique, (*e*) the elongate body, which remains more slender than in the adult (depth in the length to base of caudal in the adult about 5.0 to 6.25 times, in 13 mm young about 10.0 times), and (*f*) the characteristic color developed on some specimens, especially the oblique bar between the eye and the mouth and the wavy dusky bars on the caudal fin. However, a series of about five slightly elongate dark spots along the middle of the side, the last one being situated on the base of the caudal, which are quite characteristic of the adult, are undeveloped in the 13 mm specimens at hand.

Gobionellus boleosoma, at about 13 mm in length, differs from *Gobiosoma bosci* and *ginsburgi*, and *Microgobius holmesi*, of similar length, very prominently in the much more slender body, as well as in the smaller mouth, and in the long space between the last two dorsal spines.

DISTRIBUTION OF THE YOUNG

The young were taken in tow nets over nearly the entire area in which collections were made, including Beaufort Harbor, the adjoining sounds and estuaries, and off Beaufort Inlet to Cape Lookout and at stations as far as 13 to 15 miles offshore. They were taken 22 times at offshore stations and 17 times in the inside waters. The young appeared in surface hauls only 6 times and in bottom hauls 33 times, indicating that the young, like the adults, dwell chiefly on the bottom. We also have many specimens taken by the United States Fisheries schooner *Grampus* in 1917 from Florida to Texas.

The distribution of the young as to time differs from that of the other common gobies at Beaufort in that some individuals, 13 mm and less in length, were taken throughout the year, while the other species are not present in collections made during the winter months. Very small larvae, under 5.0 mm in length, were taken from May to November.

GROWTH

The scarcity of the species and the long spawning season resulted in capturing comparatively few young, which vary widely in size. It is consequently impossible from the few specimens taken to determine definitely the rate of growth. The presence in the tow of larvae only about 8.0 mm in length during March and April, which evidently were hatched the previous summer or fall, suggests a slow rate of growth, at least during the winter months. Sexual maturity apparently is reached at a length of about 25 to 30 mm, but it is not known how old a fish is when it attains that length.

GOBIONELLUS OCEANICUS (PALLAS). OCEAN GOBY

In addition to the young of *G. boleosoma* described in the forgoing pages, at least one other species is represented. Most of the specimens of the second group are large enough to permit a fairly accurate count of the dorsal and anal rays which is about the same for each fin, namely, 14 or 15 (rarely 13). This number of rays suggests that the specimens either are *oceanicus* or *hastatus*. The adults of these species are separable by the difference in the number of scales in a lateral series (see p. 565). However, no scales are developed in the young at hand. Therefore, the specimens cannot be definitely identified at this time and are only tentatively referred to *oceanicus*.

The specimens of the second group of Gobionellus differ from the first one, furthermore, in having a more slender body and in the somewhat more retarded development. For example, in specimens of *boleosoma* 10 mm long the spinous dorsal is equally as well or even better developed than in specimens of *oceanicus* (?) 15 mm long. Specimens of this group of Gobionellus, with the very slender body, range in length from 9.0 to 18 mm. If smaller ones are contained in the collection they were not recognized as different from *boleosoma*. Only 15 specimens were collected in the vicinity of Beaufort. In addition 23 specimens, taken by the United States Fisheries schooner *Grampus* off the eastern coast of Florida and in the Gulf of Mexico, are at hand.

SPAWNING

The time and place of spawning remain largely undetermined, as the eggs and very small larvae have not been taken. Since two of the common local species of gobies (*Gobiosoma bosci* and *Gobionellus boleosoma*) are known to spawn in the usual habitat occupied by the adults, it seems reasonable to expect this species to do likewise. However, the number of adults taken locally is too small to admit of a definite statement in regard to their habitat. The examples at hand were taken on rather muddy bottom, two in Newport River and one along the shores of Pivers Island. The young were collected at Beaufort over such a long period of time that it is impossible to judge definitely when spawning takes place, the specimens having been taken in February, April, August, September, October, November, and December. Since these young generally were taken with those of *G. boleosoma*, a species known to spawn throughout the summer, it seems probable that the spawning period of *G. oceanicus* may extend over the same period of time.

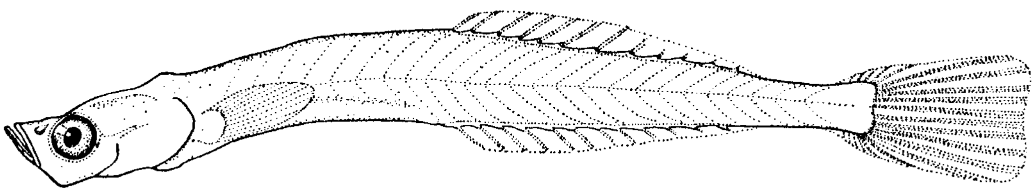

FIGURE 71.—*Gobionellus oceanicus*. From a specimen 9 mm long.

DESCRIPTIONS OF THE YOUNG

Specimen 9.0 mm long.—Only one specimen of this, the smallest size recognized, is at hand. It was taken by the *Grampus* at latitude 27°39′, longitude 83°36′ on January 24, 1917. This fish differs from *boleosoma* of the same size in the extremely slender body, the depth being contained in the standard length about 9.7 times (as compared with 7.3 times in *boleosoma*). The bases of the dorsal and anal rays are visible in part, but the rays themselves are almost wholly undeveloped. Twelve or 13 fulcra can be counted in each fin, the posterior ones being feebly and very probably in part undeveloped, whereas in *boleosoma* the rays are quite well formed at this size. Pectoral fins are evident, although without definitely formed rays. The ventral disk, already well formed in *boleosoma* of this size, is not evident (fig. 71).

Specimens 14 mm long.—The body remains very slender, the depth being contained in the standard length about 9.0 times. The soft rays of the dorsal and anal are now well developed and easily enumerated, each fin having 14 or 15 rays. However, generally only two or three spines have become visible in the first dorsal, this fin being scarcely as well developed at this size as it is in specimens of *boleosoma* only 10 mm long. The pectoral fins are well developed and have definite rays, but the ventral disk is rudimentary, whereas it is long and prominent in specimens of *boleosoma* when only 10 mm long (fig. 72).

Specimen 18 mm long.—Only one specimen of this size is at hand, which is the largest post larva in the collection. Development has progressed rather slowly and is about in the same stage as a *boleosoma* of a length of 10 to 12 mm. The body has become rather more robust, the depth being contained in the length to base of caudal about 8.0 times. The spinous dorsal is partly developed, five slender spines being present, whereas in the fully developed individuals the normal number is six. The ventral disk is quite well formed and reaches about half the distance from its base to the vent. This specimen, like the smaller ones, is void of color. The transparent air bladder with the dark membrane over it remains visible through the abdominal wall (fig. 73).

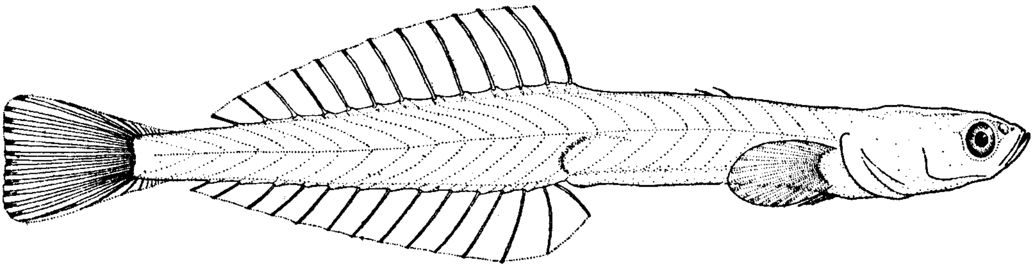

FIGURE 72.—*Gobionellus oceanicus.* From a specimen 14 mm long.

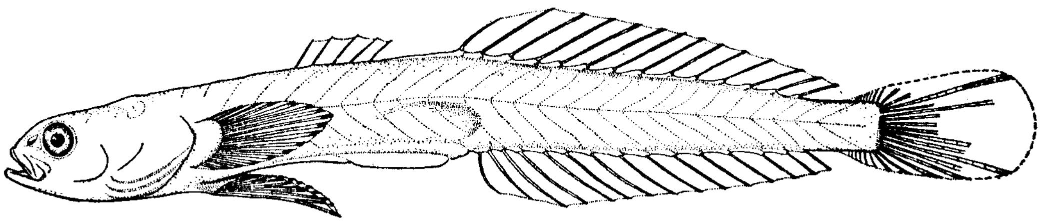

FIGURE 73.—*Gobionellus oceanicus.* From a specimen 18 mm long.

DISTRIBUTION OF THE YOUNG

The number of specimens taken is entirely too small to permit drawing a conclusion in regard to the distribution of the young of this species. Eight of the 14 specimens from Beaufort were collected off Beaufort Inlet, while the others were taken in the harbor and a neighboring estuary. The 23 specimens collected by the *Grampus* were all taken offshore. The young, therefore, may be expected along the outer shores, as well as in inside waters.

Only two specimens were taken in surface towings at Beaufort, all the others appearing in bottom hauls. Of the 23 specimens collected by the *Grampus* 21 were taken on the bottom. This information is missing for the other specimens. It seems probable, therefore, that the young may occur at any depth in the water inhabited, but that they are most commonly on the bottom. Nothing can be reported at this time concerning the rate of growth.

FAMILY BLENNIIDAE. THE BLENNIES

Three species of blenny, namely *Hypsoblennius hentz*, *Hypleurochilus geminatus*, and *Chasmodes bosquianus* are common on the coast of North Carolina. The development of the eggs of all these species has been studied, and also the development of the young of the first two named. The young of *C. bosquianus*, a species less common at Beaufort than the other two, remain unknown. A fourth species, *Blennius stearnsi*, was recorded from Beaufort by Radcliffe (1914) without comment. This species was not seen by us.

The adults are not especially difficult to identify, yet care is required as the species superficially are not strikingly different. This is true especially of young adults. Accordingly the following key, embodying characters thought to be readily usable and dependable, is offered.

KEY TO THE GENERA AND SPECIES

a. Head short, deep; *forehead very steep* (nearly vertical); snout scarcely projecting. Mouth small; maxillary scarcely reaching middle of eye. *Canine teeth wanting.* P. 14, rarely 13 or 15; D. XII, 14 or 15; A. II, 16 ---------- *Hypsoblennius hentz*

aa. Head somewhat longer, not quite as deep; forehead not very steep, strongly convex; snout projecting moderately. Mouth small; maxillary reaching only slightly past anterior margin of eye. *Each jaw with a strong canine tooth posteriorly, near angle of mouth.* P. 14; D. XI to XIII, 14 or 15; A. II, 16 or 17 ---------- *Hypleurochilus geminatus.*

aaa. Head notably longer and not as deep; forehead not steep, rather gently convex; snout strongly projecting, very pointed. *Mouth large; maxillary reaching to or past posterior margin of eye.* Canine teeth wanting. P. 12, rarely 11; D. XI or XII, 18; A. II, 17 or 18 ---------- *Chasmodes bosquianus.*

THE CHARACTERS OF THE EGGS AND NEWLY HATCHED YOUNG

The eggs of the three species of blennies discussed in this report are not difficult to recognize. That is not true for the young, however, which are very similar in appearance. The distinguishing characters of the eggs and newly hatched larvae are shown in the parallel comparison which follows. The distinguishing characters of young *Hypsoblennius hentz* and *Hypleurochilus geminatus* taken in the tow are described in the text. Since young *Chasmodes bosquianus* were not taken in collections made in nature, our present knowledge of its development ends with the newly hatched larvae.

DISTINGUISHING CHARACTERS

EGGS

Hypsoblennius hentz	*Hypleurochilus geminatus*	*Chasmodes bosquianus*
Moderately small, about 0.77 mm in diameter. Eggs with violet or old rose colored bodies (disappearing in advanced stage of development) and yellow oil globules in yolk.	Small, about 0.69 mm in diameter. Eggs with purple spots (disappearing in advanced stage of development) and bright golden yellow to orange oil globules in yolk.	Large, about 1.04 mm in diameter. Eggs with pale yellow oil globules, never with violet or purple bodies in yolk.

NEWLY HATCHED YOUNG

Hypsoblennius hentz	*Hypleurochilus geminatus*	*Chasmodes bosquianus*
Larvae moderately small, average length about 2.7 mm. Myomeres behind vent about 23.	Larvae small, average length about 2.4 mm. Myomeres behind vent about 24.	Larvae large, average length about 3.66 mm. Myomeres behind vent about 28.
Black markings on abdomen (yolksac) generally scattered, usually not especially concentrated at upper edge of abdominal mass.	Black markings mostly concentrated at upper margin of abdominal mass.	Black markings mostly concentrated at upper margin of abdominal mass.
Lower two-thirds or so of inner surface of pectoral fin membranes with black chromatophores.	Pectoral fin membranes at most with only a few black chromatophores at base.	Lower two-thirds or so of pectoral fin membranes with black chromatophores.
An elongate branching black spot under auditory vesicle.	An elongate branching black spot under auditory vesicle.	No black under auditory vesicle.

A COMPARISON OF THE EGGS AND YOUNG OF SOME AMERICAN AND EUROPEAN BLENNIES

The eggs of the three species of blennies from North Carolina, forming the basis for the present report, all have an adhesive disk or foot by which they become firmly attached to objects in the water at the time they are laid, remaining attached throughout the period of incubation. The eggs of the European blennies, *Blennius pholis*, *B. ocellaris*, and *B. gattorugine*, all have similar organs of attachment (Lebour, 1927). In all these species, both American and European, the eggs are laid in a single layer. The adhesive organs generally, if not always, have a greater diameter than the eggs and keep them from touching each other. In another European blenny, *B. montagui*, the eggs are described (Guitel, 1893) as having a number of glutinous threads which attach them to the under side of stones. The eggs are said to press against each other, although presumably laid in a single layer.

Such distantly related forms as *Pholis gunnellus* (Ehrenbaum, 1909), *Anoplarchus purpurescens* (Schultz and De Lacy, 1932) and *Heterostichus rostratus* (Barnhart, 1932), formerly assigned to the family Blenniidae, but now referred to separate and distinct families, also have eggs which adhere. The adhesive organ, if any, for the first mentioned species are not described, it merely being stated that the eggs adhere in clusters. The egg of the third species has a number of adhesive threads like the one of *Blennius galerita*. The eggs of the two last-mentioned species, therefore, resemble those of the silversides (Menidia) in the structure of their adhesive organs.

The eggs may be attached to mollusk shells, particularly to the inner surface of the valves of empty oyster shells, as in *Hypsoblennius hentz*, *Chasmodes bosquianus*, and *Blennius ocellaris*. Or they may be attached to rocks in crevices or to the under side of overhanging rocks, as in *B. pholis*, *B. gattorugine*, and *B. galerita*. Again, they may be laid in such places as the hollow of an ox bone or bottle, as in *B. ocellaris*, or in clusters loosely attached to stones, as in the distantly related *Anoplarchus purpurescens* of the Pacific coast. The eggs in one "nest", if laid in a single layer, often cover several square inches of surface. The male was observed guarding the nest in most of the species studied by various investigators, as in *H. hentz*, *C. bosquianus*, *B. pholis*, *B. ocellaris*, *B. sphinx*, *B. gattorugine*, *B. montagui*, and *Clinus argentus*. Gudger (1927) reported that both sexes guard the eggs of *Pholis gunnellus*. Finally Shultz and De Lacy (1932) reported that the female guards the eggs of the Pacific coast blenny *A. purpurescens*.

The eggs of the three species of blenny from North Carolina, constituting the subject of a part of this paper, are all slightly flattened at the place of attachment, as stated in the descriptions of the eggs in the text. The eggs of two European species, namely, *Blennius pholis* and *B. gattorugine*, are described as decidedly flattened, the egg of the first-mentioned species being a little more than three-fourths of a sphere, and that of the other one only slightly more than half a sphere. The eggs of another European species, *B. ocellaris*, having a smaller adhesive organ, is described as nearly spherical.

It is pointed out in the text (pp. 579 and 592) that the eggs of two species of blennies from North Carolina have yolk containing brightly colored bodies. The eggs of *Hypleurochilus geminatus* have yolk with purple bodies, and those of *Hypsoblennius hentz* violet to old-rose colored ones when first spawned. The colored bodies gradually lose their outline as development of the egg progresses, and the color becomes diffuse, generally disappearing before hatching. Bright colors in the yolk seem to be usual in the eggs of European blennies also. The egg of *Blennius ocellaris*, *B. gattorugine*, and *B. pholis* are all said to have pink, red, or purple yolk, though no definite spots or bodies are mentioned. *Chasmodes bosquiannus* seems to be the only true blenny (family Blenniidae according to Jordan 1923) studied to date which has eggs containing yolk without pink, red, or purple color.

The eggs of the North Carolina blennies all contain many oil globules. The oil spheres are yellow, being especially bright golden yellow in *Hypleurochilus geminatus*. In the European species oil globules are mentioned only in the eggs of *Blennius ocellaris*.

The newly hatched fish of the European species *Blennius ocellaris*, *B. gattorugine*, and *B. pholis* are respectively 4.4, 4.9, and 5.4 mm long, and therefore larger than those of the American species, *Hypsoblennius hentz*, *Hypleurochilus geminatus*, and *Chasmodes bosquianus*, which are respectively 2.7, 2.4, and 3.6 mm long. Somewhat larger young would be expected as the eggs of the European species are larger than those of the American ones. The greater axis of the eggs of the European species, in the order named, are 1.2, 1.6, and 2.0 mm, whereas those of the American species, respectively, are only 0.77, 0.69, and 1.04 mm. Furthermore, the European species grow larger than the American ones. The former, in the order named, reach a length of about 175, 225 and 150 mm, whereas the latter attain a length, respectively, of only about 100, 75, and 90 mm. It is understood, of course, that the size of a fish is no criterion relative to the size of the egg it produces. However, in this instance the larger European species evidently do produce larger eggs than the smaller American ones.

Although the newly hatched young of the European species are larger than those of the American ones, as pointed out in the preceding paragraph, they are all strikingly similar in general appearance throughout the larval stages. The newly hatched larvae are fairly stocky anteriorly and have rather long slender tails, the vent being situated far in advance of midbody length. The pectoral fin membranes are comparatively large and generally more or less spotted with black. Usually black is present also on the abdomen which most often is concentrated on the side of the fish along the upper edge of the abdominal mass. Short black cross lines on the ventral edge of the tail may be present on only a few to several myomeres or on all the caudal segments.

In the older larvae the tail becomes proportionately shorter and heavier and the black on the sides and on the pectorals tends to become more prominent. In the postlarval stages the pectoral fins generally are proportionately much longer than in adults, and the caudal fin, which is round in the adult, tends to be slightly concave. Such a development of the caudal fin must be considered rather unusual, though a similar evolution has been observed in the gobies. (For descriptions and figures of the eggs and the young of the European blennies, *Blennius ocellaris*, *B. gattorugine*, and *B. pholis*, see Cunningham, 1889; Ford, 1922; and Lebour, 1927.)

HYPSOBLENNIUS HENTZ (LeSUEUR). SPOTTED SEAWEED FISH

Hypsoblennius hentz is common, but not abundant at Beaufort, N. C., and is known to range from Chesapeake Bay to Florida. It is recognized chiefly by its very steep forehead; small, horizontal mouth, the maxillary scarcely reaching under the middle of the eye; by the absence of canine teeth; the small gill opening; the broad pectoral, with 14, rarely 13 or 15 rays; and the moderately long and low dorsal and anal fins, the former consisting of 12 spines and 14 or 15 soft rays and the latter of 2 spines and 16 soft rays.

The males appear to grow larger than the females (largest male at hand 104 and the largest female 84 mm long) and the males have a much longer tentacle over the eye. Although the tentacle is variable in length among individuals of the same sex, it is rarely as long as the eye in adult females, whereas it always exceeds the length of the eye in adult males. Males differ from the females in external structure, furthermore, in having fleshy expansions or hoods, opening forward, attached to the two anal spines, and the fin itself is preceded by a low elliptical membranous hood, opening backward. Females have a distinct genital papilla, at least during the breeding season, which is not evident in the males (fig. 74).

The shallow water areas with rather hard, often somewhat shelly, bottom supporting growths of plants, sponges, ascidians, hydroids, etc., are the common summer habitat of the adults. The shallow areas are deserted during the winter when specimens occasionally are taken in the deeper channels and in holes, where the species also occurs sparingly during the summer.

It is a game little fish and like its relative, *Chasmodes bosquianus*, it fights when handled. It will seize the skin (its mouth being too small to catch more than the skin) of a man's hand and hold on bulldog fashion, allowing itself to be lifted by its grasp. However, its jaws are not strong enough to inflict a wound.

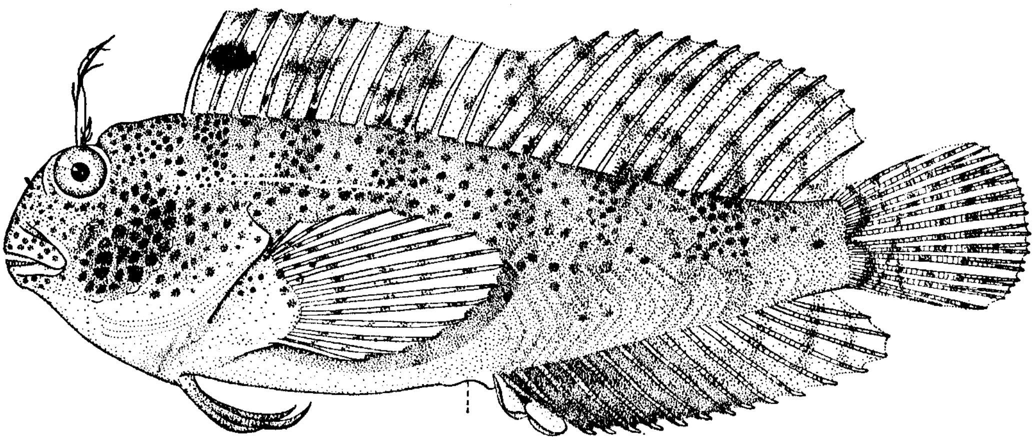

FIGURE 74.—*Hypsoblennius hentz.* Adult male 96 mm long. Note membranous expansions attached to the anal spines.

Color assimilation is well developed in this blenny. It is hardy, stands handling, and endures confinement in small aquaria very well and, therefore, it constitutes a fairly favorable subject for the study of its reactions to various color stimuli.

The species no doubt is preyed upon to a limited extent by various predatory fishes. It is not abundant enough locally to be of much importance even as a forage fish, and of course it is too small to be of direct commercial use, as 100 mm (4 inches) is near the maximum size attained.

The figures of the developing egg and the newly hatched larva are based on living material. The other illustrations were prepared from preserved specimens.

SPAWNING

Eggs of several sizes are present in the ovary at one time, just as in the other local species of blenny, suggesting a long spawning season, as well as repeated spawning. This expectation is substantiated by the presence of fry less than 5.0 mm in length in the tow from May 13 (1930) to September 13 (1927). The young of this species were never as abundant in collections as those of *Hypleurochilus geminatus*. They were taken in fair numbers, however, from about the middle of May to the end of August. It may be concluded, therefore, that the spawning period extends from May to August.

The eggs were seen first on August 25, 1927, when a female held in a battery jar spawned. Since no male was at hand the eggs could not be fertilized. Several "nests", each containing many eggs, were taken from May 31 to June 27, 1932. From this material it was possible to study the embryology in detail.

This blenny does not make a nest in the true sense of the word. However, it uses empty oyster shells (possibly also clam and scallop shells) with the hinge intact, from which the oysters probably have not been removed very long and which are still clean and white within. Therein the eggs are deposited, and they become firmly attached by means of an adhesive disk. In several instances, nearly the entire inner surface of both valves of the oyster shell was covered with eggs. Occasionally only a part of each valve was occupied by the eggs. It seems probable that in these last mentioned instances the nests were not completed, and that more eggs would have been deposited. Nests were found only on a natural oyster reef at the west end of Pivers Island, at or near the usual low tide line.

It is evident from the difference in the development of the eggs in a nest that they are not all spawned at the same time. The difference in development may range from an early cleavage stage to an advanced embryonic stage, suggesting that the eggs are laid over a period of several days. In general, the eggs near the hinge of the oyster shell are furtherest advanced, whereas those most distant from the hinge of each valve show the least development.

The eggs are in a single layer in the nest, not always in definite rows, and are well separated by the adhesive disks which have a greater diameter than the eggs. It is estimated that some of the larger nests found contained as many as 3,750 eggs. The eggs are so firmly attached that they can be removed without injury only by cutting the adhesive disk close to the oyster shell with a sharp instrument.

It is not known whether all the eggs in one nest are the product of one female, although this seems quite possible since all the eggs within an ovary evidentally do not mature at one time, as already stated. It is possible, therefore, that a female may go to the same nest several days in succession to spawn.[7]

The eggs probably always are guarded by a male. The foregoing statement is made notwithstanding the fact that a few nests were found with which no males were seen. On the other hand, a fish was seen to escape from a nest in a few instances, and several nests were taken with the male within the valves of the oyster shell constituting the nest. It is assumed in those instances when no males were seen that they escaped unnoticed.

The male stays within the oyster shell in taking care of the eggs. In case the shell is shorter than the fish it bends the tail forward to get within the shell, for it allows only the snout and eyes to protrude. A decided difference in the temperament of different males was noticed. It already has been shown that some males fled when someone approached. Others stayed with the nest and allowed themselves to be picked up (by hand) with the oyster shell containing the eggs. Only one male, upon being transferred from its native habitat to the aquarium, reoccupied his nest almost immediately, although others, after being in confinement for some time would even occupy empty shells. In a few instances males failed to return to their nests in

[7] Guitel (1893) has reported that among specimens of *Blennius montagui*=*B. galerita*, from the coasts of France, kept in a tank made of a small boat, in which their natural habitat was reproduced as nearly as possible, several females laid eggs in one nest situated on the under side of an overhanging stone. The eggs were all fertilized and guarded by the same male. It cannot be stated of course, that this procedure would obtain in nature.

nature after being disturbed. One male transferred to the aquarium devoured the eggs, instead of taking care of them. The single male which reoccupied his nest in the aquarium not only stayed in the oyster shell until the eggs were hatched (notwithstanding frequent disturbances during the incubation period for removing eggs for study), but also for several weeks afterwards or until removed from the tank. During the incubation period, as well as afterwards, he came out only to feed on bits of oyster and fish that were supplied, and even retreated between bites.

The male undoubtedly drives away intruders, for it was noticed that the eggs in nests deserted by the parent fish were destroyed very soon. The chief enemy noticed was the flat mud crab, *Eurypanopeus depressus* (Smith).[8] Specimens of this crab were taken with three deserted nests. The male, however, appears to have another function, namely that of keeping the eggs clean and in healthy condition. Just how this is accomplished is not evident. It was not noticed that he fanned the eggs especially, for he seemed to lie quietly within the oyster shell.[9] Yet, the eggs in a nest cared for by a male, and held in a tank with running water almost all hatched, whereas the eggs treated identically, but without a male attendant all died in advanced embyronic stages. A very small number of eggs in one deserted nest was hatched by providing special treatment. That is, in addition to keeping the nest in a tank with running water, the eggs were washed vigorously once or twice each day by playing a jet of water directly on the eggs, and by rushing the nest through water rapidly. A few eggs removed from a nest were hatched in standing water (changed twice daily) in a glass bowl. Eggs in deserted nests in tanks became infested with hydroids and copepods, which caused death before hatching. No infestations were noticed in eggs guarded by the male fish.

Spawning apparently takes place early in the morning. This conclusion is arrived at from the fact that eggs in early cell division stages were present only in nests taken before 9 o'clock in the morning. All eggs collected even as late as 11 o'clock in the morning already had passed the early cell division stages and those taken during the afternoon had progressed correspondingly further in development.

DESCRIPTIONS OF THE EGGS AND YOUNG

Description of the eggs.—The eggs of *Hypsoblennius hentz* are slightly flattened next to the adhesive disk or foot which attaches them to oyster shells, as already explained. The foot and the slight depression in the contour of the egg at the place of attachment are shown in only two of the accompanying drawings (figs. 77 and 83). The greater axis in 11 eggs measured varied from 0.72 to 0.8 mm, the average being 0.769 mm. The smaller axis which is difficult to measure accurately because the opaque foot obscures the outline of the egg, varied in four specimens from about 0.64 to 0.68 mm.

The eggs, as seen with the unaided eye, if still in rather early developmental stages, are pinkish in color. Under magnification it becomes evident that the color is within the yolk and in the form of spherical or more or less elongate bodies. The longest diameter of the latter apparently is always perpendicular to the plane to which the egg adheres. These bodies, as seen under magnification, are violet to old rose in color. They are variable in size within the same egg, as well as in shape and number in different eggs. They lie at various depths within the yolk, and therefore it is necessary to refocus the microscope to see all of them. The variation in number in different

[8] The writer is indebted to Dr. Mary J. Rathbun of the U. S. National Museum for the identification.

[9] Guitel (1893) stated that the male of *Blennius montagui*=*B. galerita*, a European species, does fan the eggs and that he will remove with his mouth any foreign object which may enter the nest.

eggs apparently ranges from about 12 to 24. During development these colored bodies become less and less definite in outline, and in advanced embryonic stages the color becomes paler and diffuse, often disappearing entirely several days before the egg hatches.

Golden yellow oil globules are also present. These spheres are equally as variable in size within an egg and in number in different eggs as the old-rose colored bodies. In general they are somewhat concentrated near the blastoderm. The oil globules persist in part at least until the egg hatches or even in the small yolksac attached to the newly hatched fish. In the accompanying drawings the old rose colored bodies are shaded, while the oil globules are unshaded. Some of the variations in the shape of the colored bodies are shown in the illustrations. The total number of colored bodies and oil globules is not shown. Those indicated are the ones which came into focus under the microscope at one level.

The egg, furthermore, has a large central body, apparently denser in texture than the rest of the egg, grayish in color like the adhesive disk, and quite opaque. This body disappears in the advanced embryonic stage. A similar central opaque body is present also in the eggs of the other two species of blenny discussed elsewhere in this paper.

The entire egg is moderately opaque, becoming more so as development proceeds. Fair perception is obtainable, however, in recently spawned eggs if viewed in a plane parallel with the surface to which they are attached. In the opposite direction the dirty-gray opaque adhesive foot, which cannot be detached without injury to the egg, and the opaque central body obscure vision. The yolk is granular in appearance. The egg membrane has deep lines and elevations, suggesting rugged eroded land. This sculpture on the egg case is not shown in the accompanying illustrations.

Segmentation and the development of the embryo.—The eggs forming the bases for the present account were taken in nature. The exact time of fertilization is not known. Therefore, the length of the period intervening between fertilization and the beginning of cell cleavage cannot be stated definitely. The earliest cell division stage found, namely four cells, occurred in two nests taken at 8:30 o'clock in the morning. These eggs probably had been laid 2 hours or so before the nests were found. This tentative conclusion is based on the results obtained with *Hypleurochilus geminatus* (p. 593). In that species segmentation started about 2 hours after fertilization. It seems reasonable to expect that the intervening time in these related species would be about equal at the nearly identical temperatures which prevailed (26° to 28° C.).

The blastodisc is apparently always situated next to the adhesive disk. This position of the blastodisc makes it difficult to observe cell division, as the opaque adhesive disk below and the opaque central body above it obscure vision. Fortunately, eggs in the early stages are more transparent than those in the more advanced stages. Consequently, it was possible to see the cells, even though dimly, through the mass of the egg (fig. 75). In a lateral view the cells could be seen more definitely. The first blastomeres apparently are about equal in size and the second cleavage cuts the blastodisc at right angles to the first. The perivitelline space is comparatively large at the positive pole and very small or wanting at the negative one (fig. 76).

Segmentation proceeds rapidly, the 8- and the 16-cell stages (figs. 76 and 77) following the 4-cell one at intervals of about 30 minutes each at a water temperature of about 26° C. As development proceeds the egg becomes more granular, and it becomes more and more difficult to see exactly what is taking place. While the blastoderm no doubt is dome-shaped, as usual in teleosts, it cannot be seen because of the opaqueness of the yolk (fig. 78). An advanced cleavage stage is reached in about

8 hours at a water temperature of 25° to 27° C. (fig. 79). In about 24 hours the germ ring becomes evident (fig. 80) and in 48 hours the embryo already is well differentiated. Generally only a part of it is visible from one viewpoint, as any part lying underneath

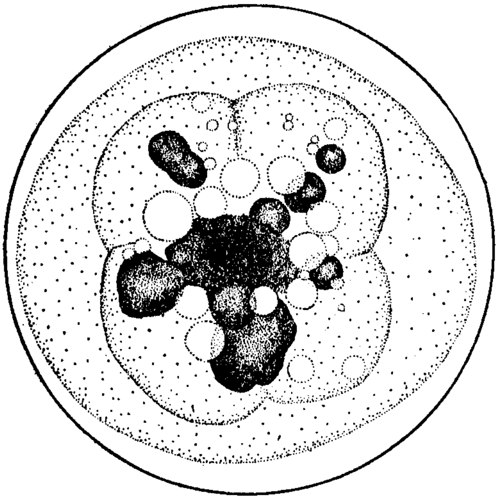

FIGURE 75.—*Hypsoblennius hentz.* From egg in 4-cell stage, about 2 to 3 hours after fertilization. (Drawn by Nell Henry.)

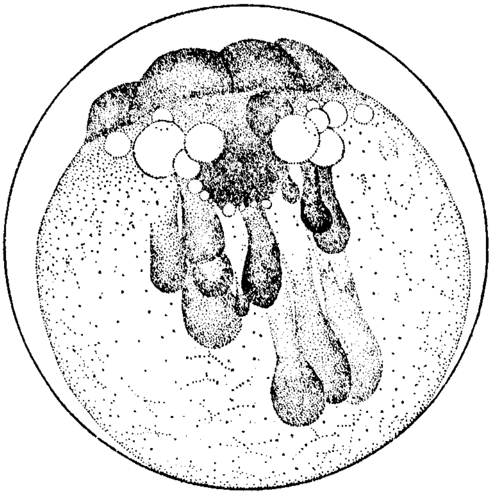

FIGURE 76.—*Hypsoblennius hentz.* From egg in 8-cell stage, lateral view about 3 hours after fertilization. A slight depression in the egg at place of attachment opposite the blastodisc is not shown. Note elongate shape of the shaded bodies. (Drawn by Nell Henry.)

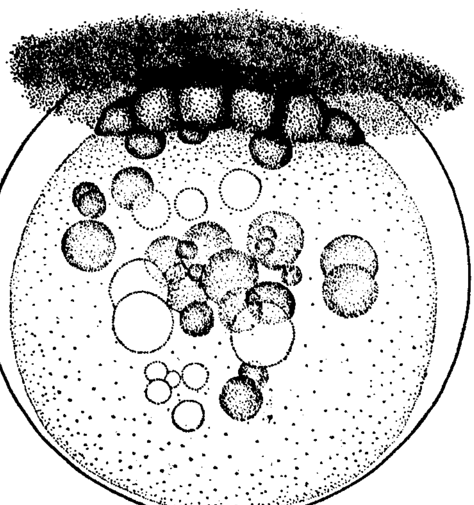

FIGURE 77.—*Hypsoblennius hentz.* From egg in about 16-cell stage, lateral view; about 3½ hours after fertilization. Adhesive disk shown at upper margin of egg. Note round form of shaded bodies in yolk. (Drawn by Nell Henry.)

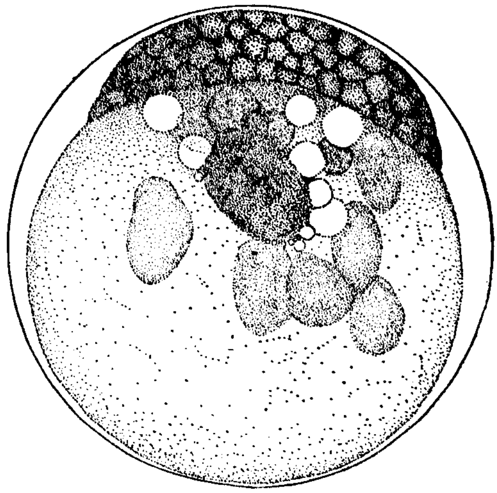

FIGURE 78.—*Hyposblennius hentz.* From egg in a moderately advanced cleavage stage; probably about 6 hours after fertilization. Only that part of the blastoderm projecting above the yolk is shown as the rest is obscured by the opaqueness of the egg. (Drawn by Nell Henry.)

the now very dense yolk cannot be seen (fig. 81). The tail was curved underneath the yolk where it could not be seen and for that reason was not shown in figure 81.

The development proceeds slowly for such a small egg after the embryo once is well formed. The embryo may be expected to extend three-fourths of the distance around the egg in about 3 days at a water temperature of 25° to 27° C. Somites are evident in at least a part of the body, the eyes are well formed and punctuated with dark dots, and circulation is established, although the blood flows slowly. The heart is situated under the anterior tip of the head. A large artery courses through the ventral part of the embryo. It recurves rather sharply in the caudal portion where it leaves the embryo. This vessel then divides and several branches course over the yolk, reuniting just before reaching the heart. No return circulation is established in the embryo. Large dark blotches with irregular outlines, sometimes merely

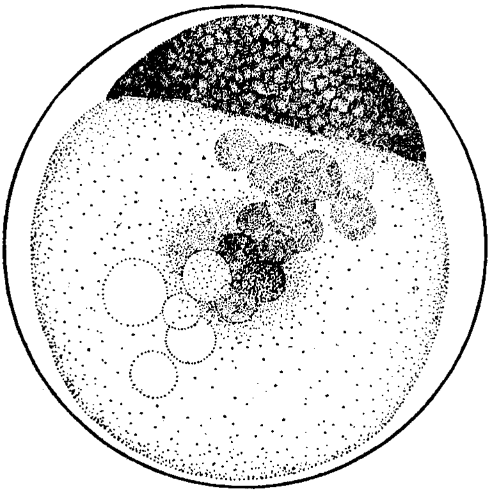

FIGURE 79.—*Hypsoblennius hentz.* From egg in an advanced cleavage stage; probably about 8 hours after fertilization. (Drawn by Nell Henry.)

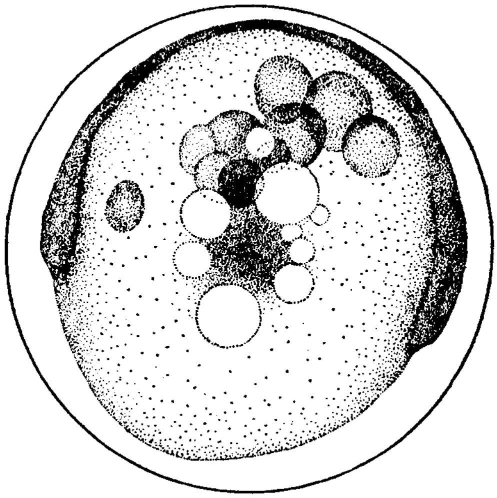

FIGURE 80.—*Hypsoblennius hentz.* From egg showing blastoderm growing around egg; about 1 day after fertilization. (Drawn by Nell Henry.)

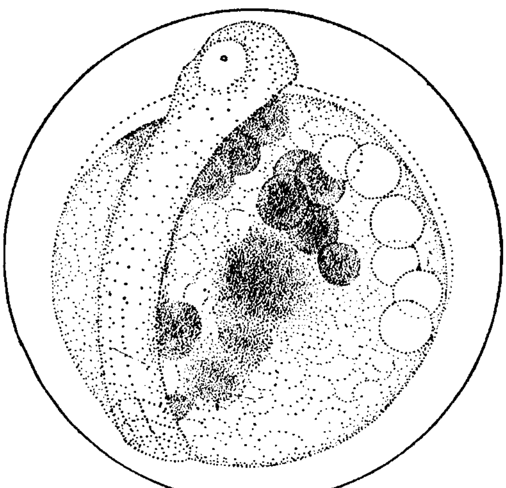

FIGURE 81.—*Hypsoblennius hentz.* From egg with an early embryo; tail underneath the opaque yolk; about 2 days after fertilization. (Drawn by Nell Henry.)

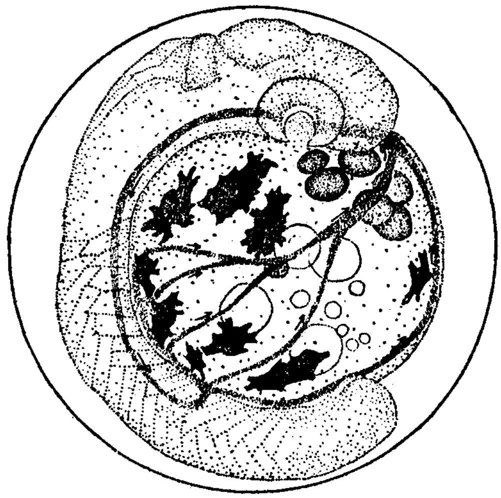

FIGURE 82.—*Hypsoblennius hentz.* From egg with well-formed embryo, showing blood vessels. Arrows indicate direction of flow of blood. About 3 days after fertilization. (Drawn by Nell Henry.)

branching blotches resembling crows feet, are now present on the surface of the yolk (fig. 82).

In about 6 days the embryo encircles the egg, the tip of the tail reaching to or past the head. The eyes are very large and black with a greenish sheen. Heart action is very brisk, the beats following each other so rapidly that it is difficult to enumerate them accurately. The number of beats probably is close to 200 per minute. A return circulation is now established in the embryo. Large vessels still course over the yolk and these together with the large vein in the embryo all pour their contents into the heart which has somewhat the appearance of a pit. Corpuscles are plainly evident, and from their rapid progress it is obvious that circulation is brisk. The old-rose colored bodies previously present have disappeared. However, some eggs retain a diffuse pinkish cast in the yolk near the heart of the embryo. The embryo is capable of much movement. The tail is free and is switched frequently. The embryo is able to turn within the egg membrane, carrying the yolk with it in its movements. (fig. 83).

Progress in the development after about the sixth day of incubation seems particularly slow. The embryo increases little in length and the yolk is absorbed very slowly. Dark markings on the yolk, which tend to decrease in size after about the fourth or fifth day of incubation, generally disappear entirely a day or two before hatching. In the meantime black markings become evident on the embryo. A rather large branching blotch is present on the head between the eyes, numerous black chromatophores also appear on the comparatively large pectorals, and short branching cross lines mark the myomeres along the ventral surface of the caudal region of the embryo. Just before hatching the egg becomes somewhat distorted, the egg membrane being pushed out somewhat at the head of the embryo.

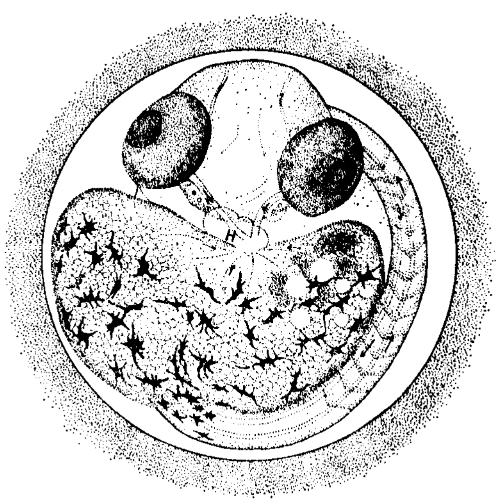

FIGURE 83.—*Hypsoblennius hentz.* From egg with large embryo: about 6 days after fertilization. H, heart. Arrows show direction of blood flow in the larger vessels. (Drawn by Nell Henry.)

Eggs taken on May 31, 1932, which were in several different stages of development, ranging at the time of collection from a rather advanced cleavage stage to a stage in which the embryo already was well differentiated, hatched from June 8 to 12. The temperature of the water during this time varied from about 25° to 27° C. The eggs in a nest taken June 16, 1932, which ranged in development about equally as much as those taken on May 31, hatched from June 24 to 26. The temperature of the water during this period varied from about 24.5° to 27° C. Assuming that the last eggs hatched in each nest were those which were in an advanced cleavage stage when taken, and that these eggs were laid on the day of collection (concerning which there can be little or no doubt), the incubation period has a duration, at the temperatures stated, of about 10 to 12 days. The incubation period in this species, therefore, is longer than in *Hypleurochilus geminatus* (see pp. 596 and 610), and about the same as in *Chasmodes bosquianus.*

Hatching, like spawning, apparently takes place early in the morning. At the time of hatching, the yolk was almost wholly absorbed and the young fish generally died by the evening of the day on which they were hatched. However, for 4 days in succession a new lot was present each morning. Several efforts were made to keep the fish alive and to induce them to feed and to grow. Some were kept in a tank with running water, others were transferred to shallow glass bowls with standing sea water. The lots in running water were not fed, those in standing water in part were offered towings and in part very finely minced oyster. However, none lived more than 2

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days. The fish presumably did not feed, but it is quite unlikely that they died of starvation as a bit of the yolksac remained even in those individuals that lived longest.

Newly hatched fish.—The newly hatched fish range in length from about 2.6 to 2.8 mm. The yolk is nearly all absorbed at hatching. The fish are robust anteriorly, with a broad depressed head. The tail is long and slender, with the vent situated much in advance of midbody length; distance from snout to vent about 1.0 mm, from vent to tip of tail, without finfold, about 1.5 mm. The snout is short and very blunt; the eye is large, having a diameter of about a quarter of a millimeter; the mouth is large, the gape reaching to or past the middle of eye. Large pectorals with suggestions of rays are present. The body is fairly transparent. Consequently the outline of the brain and the circulation can be seen rather definitely. The aorta may be seen close to the notochord, turning upon itself about an eye's diameter from the tip of the tail to form the caudal vein. Heart action is too rapid to permit accurate enumeration of the beats. However, the number of beats probably is close to 230 per minute. About 28 to 30 myomeres may be enumerated, being indefinite in advance of the vent (only 3 or 4 visible) and again toward the tip of the tail. The vertebrae count in the adult is 33, there being 9 body and 24 caudal ones. The number of more or less definitely outlined myomeres in the newly hatched fish, therefore, is not far below the number of vertebrae in the adult.

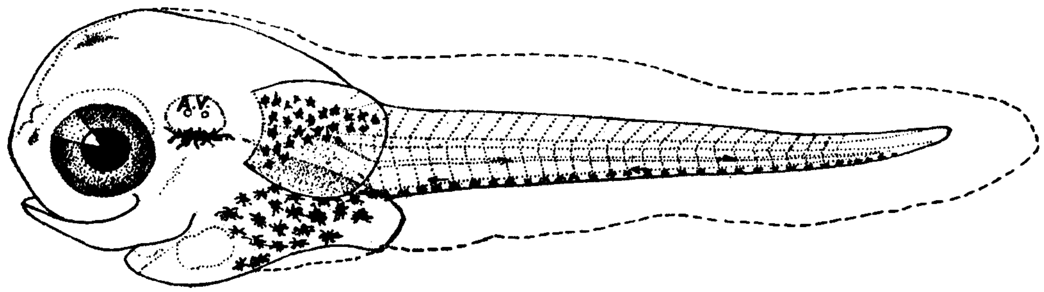

FIGURE 84.—*Hypsoblennius hentz.* From newly hatched fish. Length of live specimen 2.6 mm. AV, auditory vesicle. (Drawn by Nell Henry.)

Several dark markings are present on the newly hatched fish which correspond for the most part with those already present in the advanced embryo as described elsewhere. The eye is very dark with a greenish sheen above the pupil; an irregularly outlined dark spot is present on the head between the anterior part of the eyes, or in some specimens several black chromatophores are distributed over the snout to the interorbital; generally a blackish blotch with branches is present at the auditory vesicle; many black chromatophores (or in some specimens in part solid black) are present on the abdominal region; and the ventral side of the tail is marked by short black branching cross lines. The large pectorals are marked on the inner surface, with dark chromatophores. The dark markings often are present only on the basal two-thirds, although sometimes they may cover nearly the entire inner surface and extend to the margin of the fin (fig. 84).

Comparatively few of the numerous fish hatched lived as long as 2 days. At 2 days after hatching the fish apparently had become more slender and had increased in length only slightly, being 1.8 to 1.9 mm long. The yolksac was almost all absorbed. Only minor changes in color had taken place. The black chromatophores on the abdominal region had become more concentrated along the side near the upper boundary of the abdomen in the form of an indefinitely outlined oblique band extending from near the eye to the vent. Only a few separate black branched markings remained on the ventral surface of the abdomen (yolksac) where a shade of yellow had appeared. Other color markings remained essentially as in the newly hatched larvae. The black color along the upper margin of the abdomen, described in the foregoing lines; the short black lines on the ventral surface of the tail, which remain as in the newly hatched fish; and the black chromatophores on the pectoral fins are very useful characters in identifying the larvae hatched in the laboratory with others taken in towing and described in the following pages.

Specimens 1.5 to 2.0 mm long.—Although the newly hatched fish when alive, or before preservation, were around 2.7 mm in length, the smallest specimens taken in the tow are only 1.5 to about 2.0 mm long. These small larvae quite surely belong to the species under discussion. Their size does not exclude them, as young tender fish generally shrink greatly when preserved in formalin and alcohol. Young hatched in the laboratory, preserved when less than a day old in 65 percent alcohol, for example, decreased in length from about 2.7 to 2.0 mm. The specimens taken in the tow were killed in formalin and later transferred to about 75 percent alcohol. Some of these specimens, although 2.0 mm and less in length, evidently are several days old, as shown by the more advanced development. The older fish are less robust anteriorly, the pectoral fins are more elongate and less broadly rounded, and suggestions of rays are present. Indications of rays also are appearing in the vertical finfold around the tip of the tail. The color on the abdomen has become more concentrated along the upper margin of the abdominal mass, the black spots on the inner surface of the pec-

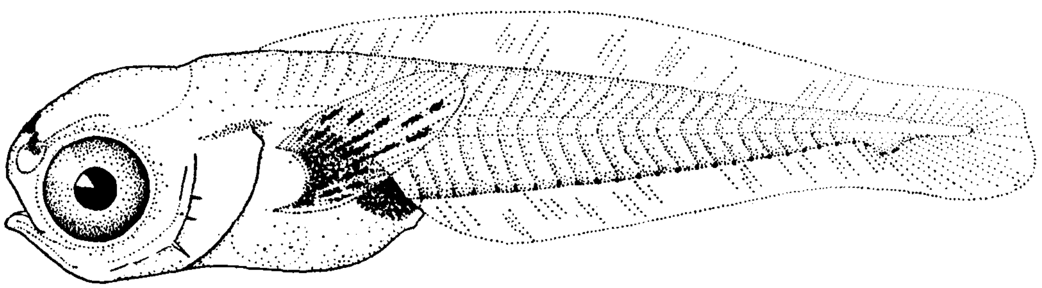

FIGURE 85.—*Hypsoblennius hentz.* From a preserved specimen 3.0 mm long.

torals are prominent, and the cross lines on the ventral edge of the caudal region remain as in younger fish.

Specimens 2.5 to 3.0 mm long.—The head and trunk are robust, the head being about two-thirds as broad as deep. The head and trunk have become longer in proportion to the tail, the distance from tip of snout to vent being contained about 2.4 times in the total length without the caudal finfold. The snout is very short and blunt, scarcely longer than the pupil, the forehead is very steep, and the mouth is slightly inferior, moderately oblique, with the tip of the lower jaw a little below the level of the middle of eye. Three minute preopercular spines are evident in some specimens. The vertical finfold remains continuous, with indications of rays posteriorly. The pectoral fins are long and rather narrow, with definite rays, and about three-fourths as long as the head. The most prominent color marking is an oblique black bar extending from the axile of the pectoral to the ventral outline just in front of the somewhat protruding hindgut. Several dark dots are present on the ventral surface in advance of the vent, a distinct dark bar crosses the forehead between the eyes, and generally several chromatophores are present on the upper surface of the head and nape. A row of small, vertically elongate, dark spots is situated on the ventral outline of the tail. The most important color markings for the purpose of identification are dark dots, covering most of the pectoral fins, which extend to the tips of at least some of the rays (fig. 85).

Specimens 4.0 to 4.5 mm long.—The head and trunk remain rather robust, although less so than in somewhat smaller specimens. The caudal portion of the body is moderately deep, strongly compressed, and scarcely longer than the head and trunk, the vent being situated at about midbody length, exclusive of the caudal fin. The head is deep and rather broad, the interorbital space being scarcely narrower than the eye. The snout is very short and round, projecting scarcely half the diameter of the orbit in front of the eye. The mouth is placed low, slightly inferior, oblique, the tip of the lower jaw being only a little above the level of the lower margin of the eye. The eye is placed low, that is, nearer to the ventral than the dorsal outline of the head. Fin rays are only partly developed in the dorsal and anal fins, but more fully in the caudal fin which is round in outline. The notochord is bent upward at the base of the fin, as usual in larval teleosts at about this stage of development. Ventral fins are not evident. The pectorals, however, are long and rather narrow, and scarcely shorter than the head. A few obscure dark markings generally are present on the ventral surface of the chest and abdomen; a dark band extends across the forehead between the eyes; the occipital surface of the head has one to several dark dots and a large median black spot is present at the nape. An oblique black band extends from the axile of the pectoral nearly to the vent; the long pectoral fin, exclusive of two or three of the upper rays, is densely dotted with black; and a row of very small black points begins a short distance behind the vent and extends to the base of the caudal fin (fig. 86).

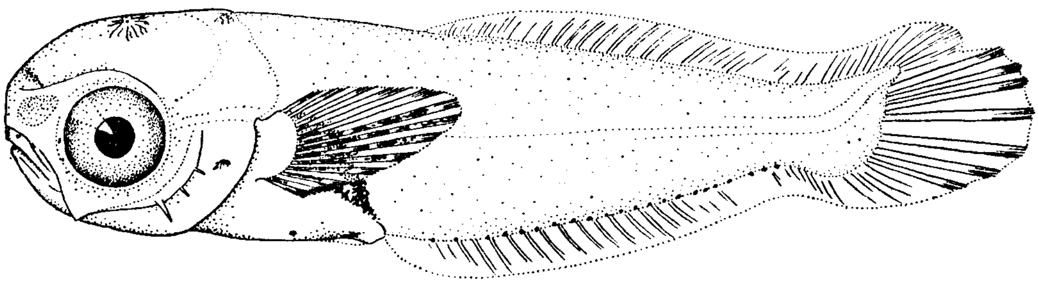

FIGURE 86.—*Hypsoblennius hentz.* From a young fish 4.45 mm long.

Specimens 5.0 to 6.0 mm long.—The body has continued to grow deeper and somewhat more compressed since a length of about 4.0 to 4.5 mm was attained. The head especially is deep and short; the snout remains very short and blunt, being scarcely more than half as long as the eye. A rather definite bony ridge is evident now over and in front of the orbit, making the interorbital space quite flat and fully as broad as the eye. The position of the mouth remains low and is slightly inferior, the tip of the lower jaw being only a little above the level of the lower margin of the eye. Five preopercular spines are now visible. Advancement in the development of rays in the dorsal and anal fins is not pronounced. The caudal fin, however, has grown proportionately longer and remains round. Ventral fins now are evident as mere tufts of membrane. The pectoral fins are fully equal to the length of the head and, exclusive of the upper rays, are dotted with black as in the younger fish, and the oblique, dark bar behind them remains as described in smaller specimens. A few indefinite dark spots occur on the chest and sides of the head, and several rather definite dark chromatophores usually are present on the occipital surface of the head and nape. A row of very small dark dots on the ventral outline of the tail, or base of the anal, described in smaller specimens, remains (fig. 87).

Specimens 8.0 to 10 mm long.—The body is rather deep and strongly compressed, the depth being contained about 3.4 to 4.0 times in the length without the caudal fin. The head is deep, the snout remains excessively short, as in smaller specimens, and the forehead is very steep. The snout projects in front of the orbit a distance scarcely equal to half the diameter of the eye. The mouth is small, placed very low, almost horizontal, and terminal to slightly inferior. The tip of the lower jaw is on, or a little below, the level of the lower margin of the eye, and the maxillary reaches to, or slightly past, the anterior margin of the pupil. The interorbital remains quite flat,

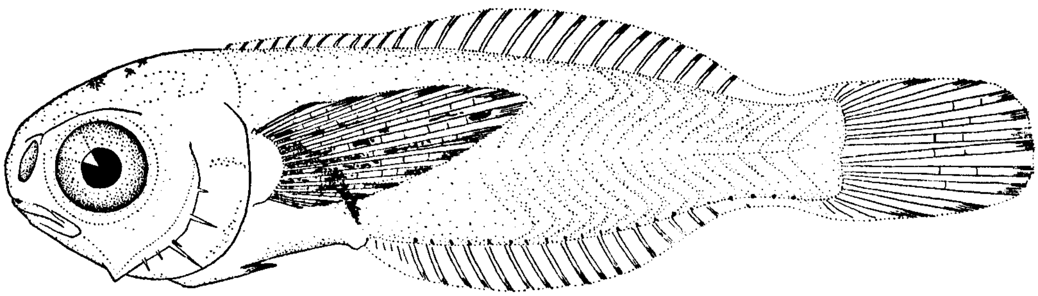

FIGURE 87.—*Hypsoblennius hentz.* From a young fish 6.2 mm long.

with a prominent bony ridge over and in front of the eye. The preopercular spines, while well developed in specimens 8.0 mm long, are proportionately longer in specimens 10 mm in length. The dorsal and anal fins are quite fully developed and a fairly accurate count of the rays can be made; the caudal fin has an almost straight margin and is about as long as the head; the ventral fins are well developed and are long and slender, being nearly as long as the head without the snout; and the pectoral fins are large, being nearly or quite as long as the head. The lower surface of the head and chest is variously dotted with black, generally with a few definite dark spots slightly behind the articulation of the lower jaw, also with a pair of dark spots a short distance

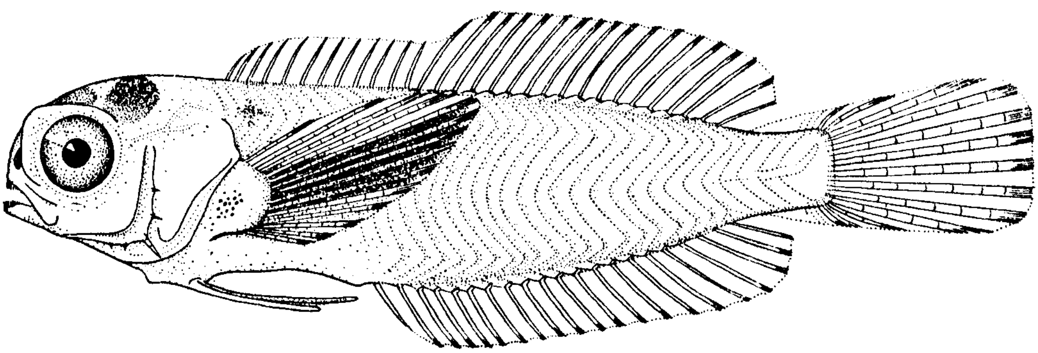

FIGURE 88.—*Hypsoblennius hentz.* From a young fish 9.8 mm long.

in advance of the ventral fins, and another pair in the axiles of the ventrals. The side of the head has a few indefinite spots or blotches and the upper surface of the head, that is from the interorbital backward, bears brownish spots with dark center and dark outline. The pectoral fin is almost wholly black in some specimens; in others two to four of the upper rays are pale, while the rest of the fin is black, and the oblique dark bar behind the pectoral, very prominent in smaller fish, has become quite obscure in 10-mm fish. A row of fine dark points along the base of the anal is present in some specimens, but not evident in others (fig. 88).

Specimens about 12 mm long.—The differences between fish 10 and 12 mm long are not pronounced. However, the body in the larger fish is considerably more robust, especially anteriorly, the depth as in the smaller specimens being contained 3.4 to 4.0 times in the length without the caudal fin. The bony ridge over and in advance of the eye is quite as prominent as in the smaller fish. The forehead remains very steep to vertical and projects slightly beyond the low, almost horizontal mouth. The gape of the mouth is now wholly below the level of the lower margin of the mouth as in the adult. The preopercular spines have continued to increase in proportionate length, the one situated at the lower posterior angle having become much larger than the other, being equal to the length of the eye in one specimen, but somewhat shorter in others. It is probable that the preopercular spines, which are not present in the adult, reach their greatest development at this stage and that they gradually decrease in size in larger fish. Specimens of the proper sizes for a study of the recession of these spines, however, are not at hand. A small fleshy tentacle is now visible over the eye for the first time. Although nearly or quite as long as the eye in the adult it is scarcely as long as the pupil in fish 12 mm long. A definite notch between the spinous and soft portions of the dorsal fin is present, as in the adult. No pronounced development in pigmentation has taken place since a length of 10 mm was attained. However, dark areas and spots about the head have increased somewhat in size and number in at least some specimens. A row of very small black dots still persists on the base of the anal. The dots are not evenly spaced and not definitely on each interradial membrane, although some variation in this respect exists (fig. 89).

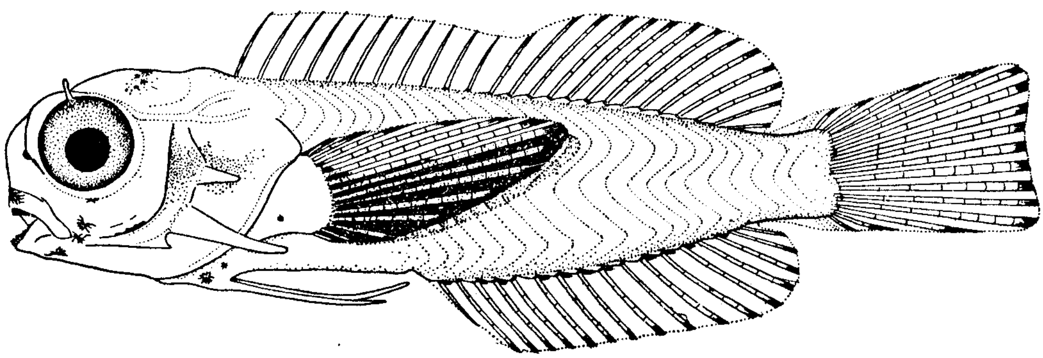

FIGURE 89.—*Hypsoblennius hentz.* From a young fish 12 mm long.

Unfortunately no specimens ranging from about 13 to 24 mm in length are at hand, and therefore, a complete picture of the development of the late juvenile stages cannot be given at this time. Specimens 25 mm long are "young adults" and have virtually all the characters of mature fish. In such specimens the prominent bony ridge over each eye, very characteristic of the young, has disappeared entirely; the fleshy tentacle over the eye is nearly or quite as long as the orbit, the preopercular spines no longer are evident; the caudal fin is round; and pigmentation is complete and similar to that of fully matured fish. Although the series is not complete, the largest young (12 mm long) at hand have developed sufficient adult characters to make identification certain. The extremely steep forehead in the young and the size, shape, and position of the mouth are quite characteristic of the adults and unlike the other local species of blennies. Furthermore, the fins are rather fully developed and the shape and number of their rays agree with those of the adult.

DISTRIBUTION OF THE YOUNG

The fry were taken in towings in outside waters 39 times and in inside waters 28 times. No definite record of the number of hauls made was kept. It is probable, however, that nearly an equal number of towings was made in the inside and outside waters. Therefore, the indications are that the fry are somewhat more common off Beaufort Inlet than in Beaufort Harbor and adjacent sounds and estuaries.

The fry were taken in surface towings 48 times and in bottom ones only 16 times. Although a considerably larger number of surface than bottom hauls was made, the discrepancy in the number of hauls certainly is not great enough to account entirely for the difference. Furthermore in 1927 and 1928 the number of surface and bottom hauls made was about equal and during those years the fry appeared 21 times in the surface nets, and only 11 times in the bottom ones. Since the bottom nets were not closed while they were lifted, it is entirely possible that some of the fry occurring in these nets were not actually taken on the bottom. The larger larvae, 5.0 to about 10 mm in length (after which they seldom appeared in the tow), occurred in the surface nets quite as frequently as the smaller ones. It may be concluded, therefore, that the young of this species, until they reach a length of at least 10 mm, occur in the open waters and are chiefly surface dwelling.

The size at which the young cease to be chiefly pelagic and begin to occupy the habitat of their parents (mainly shallow "grassy" areas) is not definitely known, as no specimens ranging from about 13 to 24 mm in length were taken. Fish 24 mm in length are "young adults" and may be taken with collecting seines in shallow water in the usual summer habitat of the adult, while the fish of the smaller size (13 mm) are still pelagic.

GROWTH

Insufficient specimens were taken to determine the rate of growth. Specimens 5.0 to 6.0 mm in length first occurred in towings early in June and several specimens 10 mm and one 12 mm long were taken in July. Therefore, the indications are that the larval stages are passed rather quickly, or within 2 or 3 months, and the earliest young of the season probably become "young adults" during their first summer. Specimens ranging from about 13 to 24 mm in length are lacking in the collection.

HYPLEUROCHILUS GEMINATUS (WOOD). BLENNY

The genus Hypleurochilus contains a single species, which is common at Beaufort, N. C., and from there it ranges southward to the coast of Texas. This blenny, in general, is recognized by its rather deep, compressed, naked body; short, blunt head; low horizontal mouth, with a strong canine tooth on the posterior part of each jaw; broad pectoral, with 14 rays; long, low, continuous dorsal fin, with 11 to 13 spines and 14 or 15 soft rays; and by a tentacle over the eye; which is much larger in the male than in the female. Adult males differ from the females, furthermore, in having fleshy bulbs, covered with folded or creased skin, on the two anal spines, and an eliptical membranous hood in advance of the anal fin and in the presence of folds of skin around the vent. Females have a very distinct genital papilla, at least during the breeding season, which is not evident in the other sex (fig. 90).

Males reach a larger size than the females, for the largest fish in the numerous catches invariably were males. Furthermore, the largest male seen was 72 mm long and many others nearly as large were present in the collections, whereas the largest female was only 58 mm in length.

The common habitat of this blenny locally is among marine growths attached to wharf and bridge piling and to rocks of breakwaters. The ripe fish used in the present investigations were secured from the marine growths (principally ascidians) attached to the wooden piling of a railroad bridge near the laboratory. The fish were caught with a scrape net, that is, a dip net with a flattened side, provided with a blunt cutting edge. With such a net the marine growths, in part, may be scraped from the piling and frequently a blenny is contained among them. Collecting is most conveniently and efficiently done on low tide. During July and August 1930, one man could catch from two to four dozen fish with a scrape net on the low stages of a single tide.

Hypleurochilus geminatus is very hardy and it lives well in an aquarium. Therefore, if captured specimens were not quite ripe, they could be retained several days until their sexual products matured.

This species occupies a habitat which is almost identical with that of the adult sheepshead (*Archosargus probatocephalus*), the gamest of the locally represented salt water fishes. Both species feed on attached marine growths and on free swimming forms (principally crustaceans) which also frequent these marine growths. However,

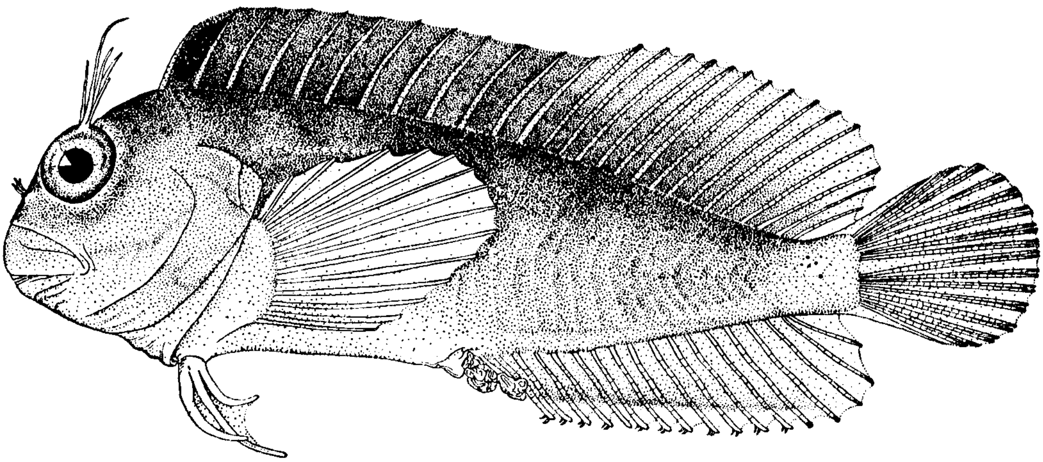

FIGURE 90.—*Hypleurochilus geminatus*. From adult male 55 mm long. Note plicate membranous bulbs attached to anal spines, covering the anterior one almost completely.

the competition probably is not great, as the blenny requires much smaller bits of food than the sheepshead. And young sheepsheads do not enter into the competition, because they have an entirely different habitat. (See p. 532.)

Hypleurochilus probably is preyed upon to a limited extent by predatory fishes, but its habitat is very restricted, as already shown, and of such a nature that it is not visited by many species. Neither is this blenny abundant enough to be of much importance as a forage fish. Therefore, its economic value locally must be very slight.

SPAWNING

The presence of eggs of several different sizes within the ovary at one time, as will be pointed out subsequently, suggests a long spawning season. That the period of reproduction is a long one is substantiated by the presence of small fry, under 5.0 mm in length, in the tow from spring to autumn, or to be exact, from May 11 (1929) to October 5 (1927). Such small young were common from the last half of May, through June, July, and August. In September they became less numerous. It seems evident, therefore, that the spawning period extends from May to September, inclusive, or possibly into the early part of October, with the principal spawning activities taking place during May, June, July, and August.

Adult fish were examined for their spawning condition only during July and August when the egg development reported upon in the following pages was studied. Nearly all the adults taken during July contained ripe or nearly ripe roe. However, during August the percentage of spawned-out fish increased steadily, indicating that the end of the spawning season was approaching.

"Nests" containing the eggs of this blenny have been found from time to time for several years and were first reported by Dr. R. E. Coker (in Smith, 1907, p. 377), who found them attached to "rocks, ascidians, shells, etc." During the present investigation they have been taken on ascidians only. The ova are neatly arranged in rather regular series and in a single layer. They are placed close together, but do not touch, and one nest may cover an area of 2 to 3 square inches.

Although naturally spawned eggs were taken several times, the development could not be observed satisfactorily within the nests, and it was found impracticable to remove the eggs from their place of attachment without injury. Therefore, other means and methods for their study had to be devised.

On one occasion ripe fish were secured and artificially spawned in a glass dish. The eggs adhered equally as tightly to the glass as to the ascidians.

Ripe or nearly ripe fish were confined in 1930 in a small aquarium, the bottom of which had been covered with microscope slides. It was hoped that the slides would receive the eggs when cast and, if so, they could be placed under the microscope for the study of the development. Eggs apparently were cast, as shown by "marks" on the slides where they had been attached. However, they apparently had been eaten by the fish. Thereupon, ripe fish were secured and the eggs were expressed directly on microscope slides where they were fertilized and then placed into sediment dishes, containing sea water, for development. The slides with the eggs attached were removed from the water from time to time for study under the microscope. The eggs did not suffer injury by being exposed to the air for several minutes at a time. By adding water at frequent intervals in sufficient amounts to keep them moist, the observation could be carried on as long as desired.

The presence of several different sizes of eggs within the ovary and the comparatively small number that ripens at one time suggest that this blenny spawns several times during a breeding season. The eggs in the "nests" observed also were in several different stages of development, ranging from apparently recently laid eggs to others with large embryos, showing that they were not all deposited at the same time. It is not known, however, whether a nest is the product of a single female or whether it receives eggs from two or more individuals. Since all the ovaries examined contained eggs of several sizes, it seems possible that a nest may be the product of a single female and that it returns from time to time to deposit additional eggs as they become mature. (See footnote 7, p. 578).

No males were found from which milt could be expressed. To obtain fertilization, males were killed, the testes removed, placed on a slide or in a small dish, with several drops of sea water, and cut and mashed into a pulp with a scalpel. Then the liquid was drawn off with a pipette, distributed over the freshly expressed eggs, and allowed to remain there for about 5 minutes before the eggs were transferred to sea water. Fertilization resulted readily.

It was not observed that the nests of *Hypleurochilus geminatus* are protected by a parent fish like those of *Hypsoblennius hentz* and *Chasmodes bosquianus*, as stated elsewhere in this paper. Since the eggs of nearly all species of blennies, as far as known, are guarded by a parent fish, it seems probable that they are similarly protected in the present species.

DESCRIPTIONS OF THE EGG AND YOUNG

Description of the eggs.—Mature eggs within the ovary, according to preserved material examined, are slightly flat on one side to which a sort of disk, or "foot", is attached. Immediately after spawning the eggs adhere firmly, by means of this disk, to objects (probably principally ascidians in nature) with which they come in contact. The disk as seen under the microscope in newly spawned eggs is granular, slightly irregular in shape, and a little greater in diameter than the egg. The eggs are relatively small, as the diameter of 25 ova secured from several different females (measured in the same plane as the surface to which they were attached) ranged from 0.6 to 0.75 mm, with an average of 0.694 mm.

The mature unfertilized egg is so opaque that its structure cannot be seen definitely. The center of the egg as seen with the microscope, using transmitted light, is somewhat paler in color and more densely opaque than the rest of the egg. The pale center is surrounded by purple and orange spots, or spheres, which vary among themselves

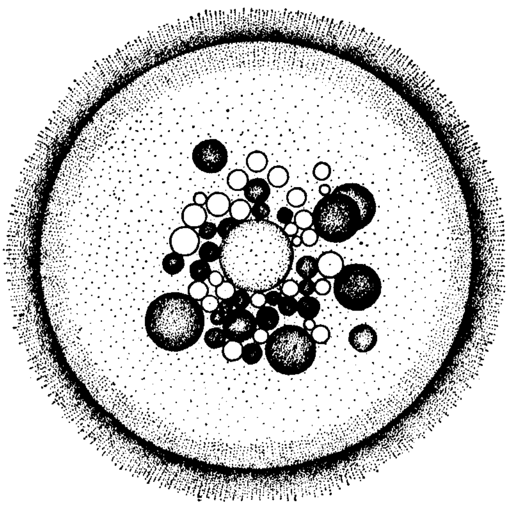

FIGURE 91.—*Hypleurochilus geminatus.* From egg before fertilization. The adhesive foot is shown extending beyond the outline of the egg.

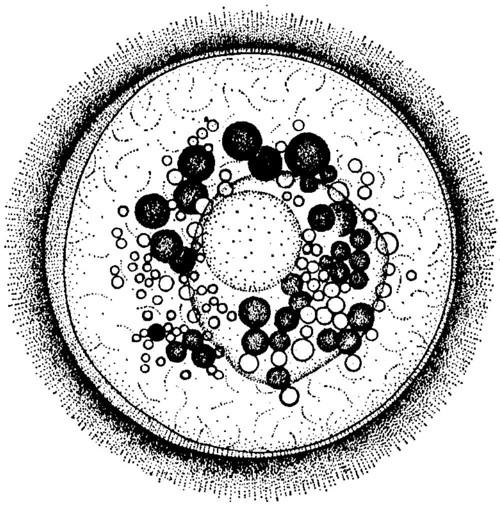

FIGURE 92.—*Hypleurochilus geminatus.* From egg with blastodisc, shortly before the first cleavage; about 25 minutes after fertilization.

in the intensity of their color. By changing the focus of the microscope a slight network of cellular structures, too, is evident on the surface of the egg. The perivitelline space is very small and the yolk is slightly granular (fig. 91).[10]

Segmentation and the development of the embryo.—Fertilization does not cause a change in the size and shape of the egg. The blastodisc becomes evident about 25 to 35 minutes after fertilization at a water temperature of about 28° C. It is not a perfect disc, however, as it is somewhat irregular in shape and generally slightly elongate. Neither does it occupy the center of the upper surface of the egg. Owing to the density of the egg its outline usually cannot be seen definitely (fig. 92).

The first cleavage occurs about 1¾ to 2 hours after fertilization at a water temperature of 27° to 28° C. The cells, while not plainly visible throughout, appear unequal in size. Some variation in this respect, however, is evident. Upon completion of

[10] Figures 89 to 102 were drawn from live material; those from 103 to 107 from preserved specimens.

the first cleavage some influence is exerted on the color markings within the egg (previously described as clustered rather closely around the opaque center), which suddenly, as through an explosion, become rather widely scattered within the egg (fig. 93).

The second cleavage plane generally follows the first very quickly. In fact some eggs reach the four-cell stage as quickly as the two-cell stage is attained in others. An irregularity in size and shape of the cells remains evident. It is obvious, also, that the purple and orange markings have increased somewhat in size (fig. 94).

The eight-cell stage may be expected about 2¼ to 3 hours after fertilization, when the water temperature ranges from 27° to 28° C. The cells, although not plainly evident throughout, appear even more irregular and unequal in size than in the earlier stages. The purple and orange spots, or spheres, have continued to increase in size,

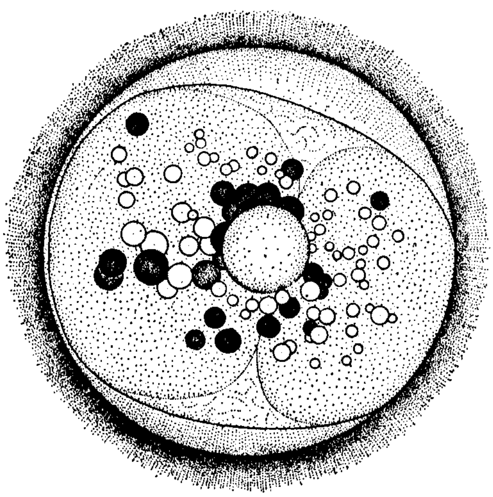

FIGURE 93.—*Hypleurochilus geminatus.* From egg in 2-cell stage; 1¾ hours after fertilization.

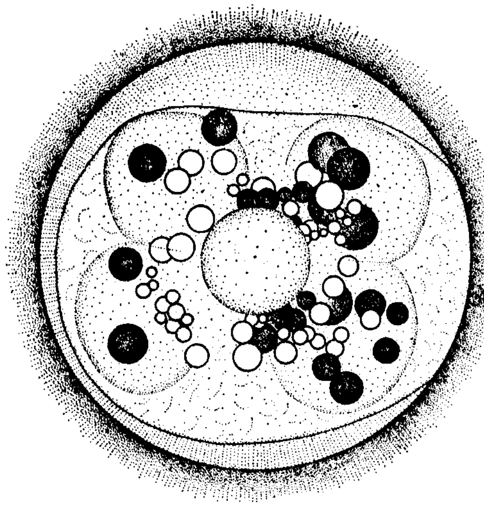

FIGURE 94.—*Hypleurochilus geminatus.* From egg in 4-cell stage; 1¾ hours after fertilization.

some of them being nearly twice as large as in the four-cell stage, and they cover most of the germinal disc, further obscuring vision of the segmental processes (fig. 95).

The eggs that failed to adhere to the slides by means of the foot, because of crowding or other causes, did not develop. It is important, therefore, that they become attached in the proper position. Judging from the neat and even arrangement of the eggs in the "nests", it would seem highly improbable that a loss from a similar source would occur in nature.

The 16-cell stage follows the 8-cell stage rather quickly and may be expected within about 2¾ to 3½ hours after fertilization at a water temperature of 27° to 28° C. The cells remain irregular in shape and unequal in size. The germinal disc now spreads over nearly the entire upper surface of the yolk (fig. 96).

Cell division continues to progress rapidly, the 32-cell stage following the 16-cell one very quickly. Owing to the opaqueness of the egg and the large color markings, segmentation is very obscure and it generally cannot be followed after the 32-cell stage is reached. The germinal disc now appears to cover the entire upper surface of the yolk. The large opaque center of the egg remains unchanged. In the advanced cell stages the purple spots, varying among themselves in intensity, have all become somewhat less brilliant in color and are irregularly distributed in the yolk. The orange and yellow spots, too, are much scattered, but appear to remain unchanged in the intensity of color.

It has been stated that the development cannot be followed for some time after the early cleavage stages, owing to the opaqueness of the egg. As a result, the next phase in the process that is clearly evident is the appearance of a notch in the edge of the yolk which no doubt is occupied by the head of the newly formed embryo. This stage is reached in about 20 to 40 hours at a water temperature of 27° to 28° C. (fig. 97).

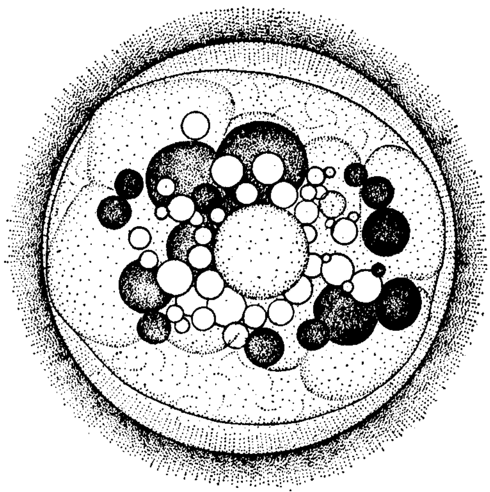

FIGURE 95.—*Hypleurochilus geminatus*. From egg in 8-cell stage; about 2¼ hours after fertilization.

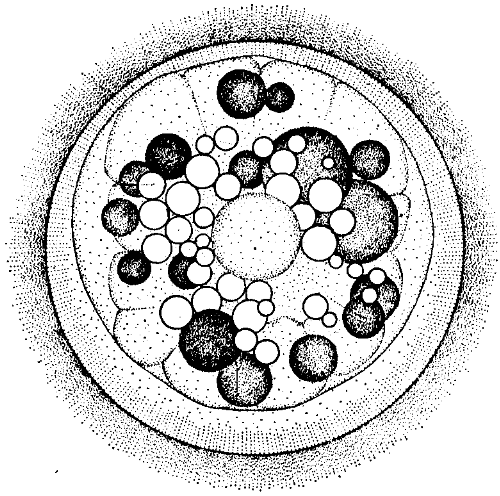

FIGURE 96.—*Hypleurochilus geminatus*. From egg in about 16-cell stage; 2¾ hours after fertilization.

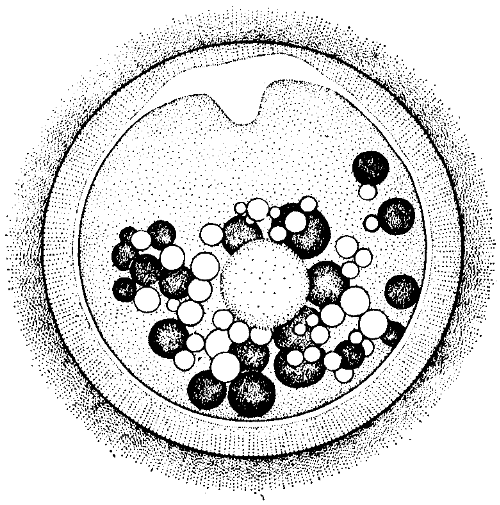

FIGURE 97.—*Hypleurochilus geminatus*. From egg showing early stage of differentiation of embryo, 21 hours after fertilization.

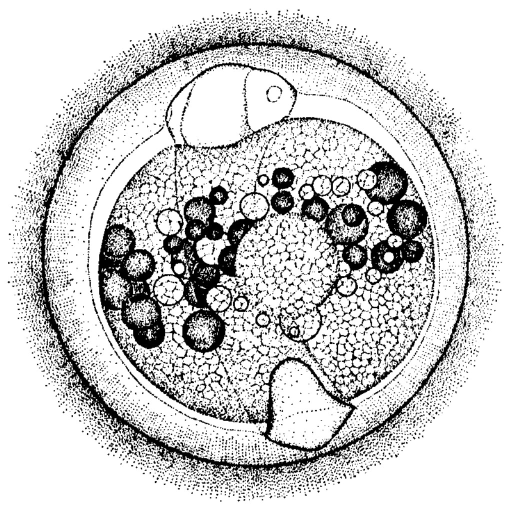

FIGURE 98.—*Hypleurochilus geminatus*. From egg with well-differentiated embryo; 26 hours after fertilization.

The outline of at least the head (with large eyes) and tail, which extend beyond the periphery of the opaque yolk, becomes distinctly visible about 25 to 27 hours after fertilization at a water temperature of 27° to 28° C. It is evident now that the embryos are not all in the same position. Some of them lie above the yolk, others curve underneath it, and still others occupy positions intermediate between the ones mentioned (fig. 98).

Very soon after the embryo becomes well differentiated the purple spots become quite diffuse and shortly disappear. The pale, densely opaque center and the yellow spheres persist somewhat longer. At about this stage two black wavy lines or bars become evident on the yolk. These bars usually meet at one end in the form of a U or a V, although occasionally they are separate. The cellular structures on the yolk of the egg, mentioned previously, have become smaller and much less definite.

About 48 hours (2 days) after fertilization at a water temperature of 26° to 28° C. the embryo has nearly encircled the egg. Several somites are visible, but a definite count cannot be made. Circulation is evident. The heart is located under the anterior part of the head, from which a large blood vessel rises and courses through the length of the embryo to near the tip of the tail and then runs across the yolk back to the heart. If other blood vessels are present, they cannot be seen. The embryo already is capable of some movement. The black bars on the yolk, previously mentioned, are now broad and distinct and show indications of breaking up into spots in some specimens. The opaque center of the egg has disappeared, and very rarely a few spots, previously purple but now changed to pink, remain. In some eggs yellow spots are still definitely present. In others they seem to have become diffuse, giving the yolk a yellowish tinge (fig. 99).

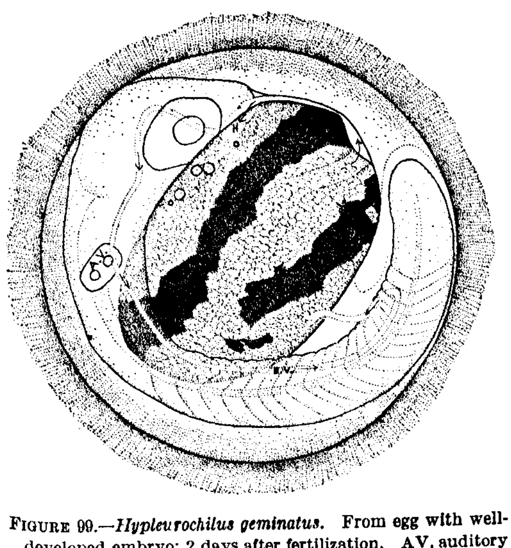

FIGURE 99.—*Hypleurochilus geminatus.* From egg with well-developed embryo; 2 days after fertilization. AV, auditory vesicle; H, heart; BV, blood vessels. Arrows indicate direction of flow of blood.

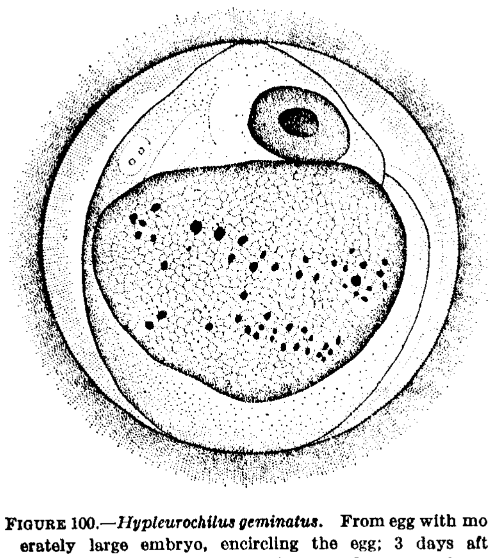

FIGURE 100.—*Hypleurochilus geminatus.* From egg with moderately large embryo, encircling the egg; 3 days after fertilization. Note pigment on the eye and compare pigment on the yolk with that shown in figures 98, 99, and 101.

About 72 hours (3 days) after fertilization, at a water temperature of 26° to 28° C., the embryo slightly more than encircles the egg, although its entire outline generally cannot be seen. The eyes now are completely pigmented with black and overcast with green, particularly above the pupil. Circulation is brisk. The violet colors have entirely disappeared from the yolk, but a few yellow spheres still persist in some specimens. The two dark bars on the yolk usually are broken up into dark spots at this stage. Considerable variation in this respect, however, was noticed. The yolk has been reduced greatly and now occupies only about half the space within the egg case (fig. 100).

Development progresses rather slowly in the advanced embryonic stages. About 96 hours (4 days) after fertilization, at a water temperature of 26° to 28° C., the embryo has curved somewhat further round the periphery of the egg than in the last-described stage (72 hours), and shows greater activity. The tail appears to be quite free and the eyes, which are very prominent, frequently are "rolled" within their sockets. Circulation is very brisk, corpuscles now being plainly evident in the blood. The aorta can be seen to turn on itself in the tail of the embryo in those specimens that happen to be in such a position that a lateral view is obtainable. Several blood vessels are now visible in the yolk. Some golden color markings without definite outlines have appeared on the head of the embryo in some of the eggs and mixed with the golden color are two dark chromatophores. The yolk which has become greatly reduced and somewhat half-moon shaped usually is marked with several large irregularly shaped dark spots or blotches. Much variation in the size, shape, and number of these spots exists among specimens. One specimen, for example, had a single large elongate black blotch, whereas others had many smaller spots. A few specimens were seen in which a few yellow spheres remained in the yolk. The egg remains round, as seen from above in its attached position, and according to measurements made of four eggs no measurable change in the diameter has occurred (fig. 101).

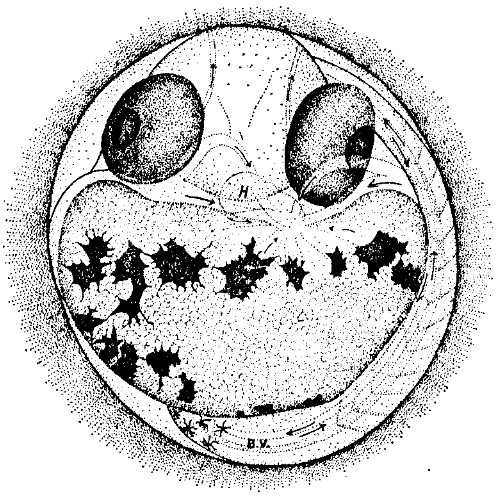

FIGURE 101.—*Hypleurochilus geminatus*. From egg with large embryo: 4 days after fertilization. H, heart; BV, blood vessels. Arrows indicate direction of flow of blood.

Hatching begins during the sixth or seventh day after fertilization when a temperature of about 26° to 28° C. prevails, and it may extend over a period of at least 24 hours. That is, among a batch of eggs all fertilized at the same time, some of the eggs may hatch fully a day earlier than others. An incubation period of 6 to 8 days at the comparatively high temperature which pervailed during the present study is regarded as a very long one for such a small egg. Many other marine fish eggs of similar size which have been studied hatched in 2 to 3 days.

Just before hatching, the eggs become somewhat distorted, that is, the portion of the egg case at the head of the embryo protrudes, causing the egg to become elongate and to have a somewhat uneven outline. The egg and embryo are more opaque than previously and the structures are even more difficult to see. On the head of the embryo is a network of yellow and black markings, and at midbody length are dark, more or less branched, cross lines. The embryo is capable of much movement and appears to struggle, probably in an effort to break the egg case.

Newly hatched fish.—The newly hatched fish is close to 2.4 mm long. It emerges with an extremely small yolksac. Although the fish is very stocky anteriorly its tail is long and rather slender; preanal length is contained 2.45, and postanal length 1.7 times in total length without the caudal fin membrane. The head is blunt, the mouth large and slightly inferior, and the pectoral finfold is prominent. The eye is relatively large, much longer than the snout, and nearly half the length of the head. About 26 myomeres are present. The body is quite transparent and the outline of the brain, the heart, and the circulation can be seen rather plainly.

The head and trunk are largely overcast with a yellowish tinge; two irregular dark spots (or simply a blotch in some specimens) are present below the auditory vesicle; a large dark area is present on the upper part of the abdominal mass; and generally several dark chromatophores occupy the ventral edge of the abdomen, besides a few to several dots which are variously distributed. Dark bars, appearing as spots in a lateral view, are present on the ventral edge of several of the caudal myomeres in some specimens, and on most of them in others. The large eyes are black with a greenish sheen over the pupil. The newly hatched fish swims or floats on its back and is very active (fig. 102).

The fish hatched in the laboratory lived only about 2 days. No change worthy of note, except that the color on the abdomen became more diffuse, took place in the meantime.

Newly hatched larvae of this species are a little smaller (length 2.4 mm) than those of *Hypsoblennius hentz* (length 2.7 mm). The larvae of the latter species are also rather more stocky anteriorly. Furthermore, the black marks on the abdomen appear as separate branching chromatophores and are quite generally distributed, whereas in *H. geminatus* the black is concentrated mostly on the side near the upper margin of the

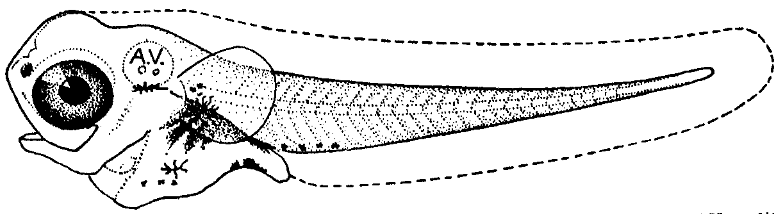

FIGURE 102.—*Hypleurochilus geminatus.* From a newly hatched fish 2.4 mm long when alive. AV, auditory vesicle.

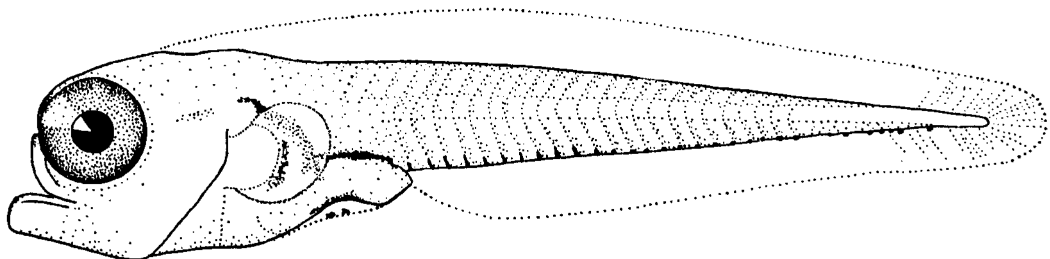

FIGURE 103.—*Hypleurochilus geminatus.* From a preserved specimen 1.6 mm long. This larva is smaller than the newly hatched live fish (Fig. 102) quite certainly because of shrinkage in preservative.

abdominal mass into almost solid black with only a few scattered chromatophores elsewhere. In *H. hentz* most of the inner surface of the pectoral fin membrane is dotted with black branching chromatophores, whereas in *H. geminatus* only a few black dots at most are present at the base of this fin.

Specimens 1.5 mm long.—The head and trunk in preserved specimens of this size are short and rather robust, while the tail is long, rather slender and compressed, the head and trunk being contained about 2.4 to 2.9 times in the total length without the caudal finfold. The snout is very short and round, scarcely extending beyond anterior margin of eye. The mouth is small, oblique, and terminal, with the tip of the lower jaw slightly below the level of the middle of the eye when the mouth is closed. The vertical finfold is continuous and without rays. The pectoral fins appear as mere tufts of membrane, scarcely longer than the pupil and the ventral fins are not evident. An oblique dark bar extends from the axile of the pectoral to the ventral outline just above the vent; the ventral surface of the chest and abdomen generally is marked with a few to several dark points; and a distinct dark bar crosses the forehead between the eyes. A rather close-set row of fine, vertically elongate, dark spots is present on the ventral outline of the tail, and the base of the rudimentary pectoral is mostly black (fig. 103).

Blennies of this size are difficult to identify. However, the specimens assigned to this species are a little less robust than those referred to *Hypsoblennius hentz.* Furthermore, those of the last-mentioned species have rather larger pectoral fin membranes with the basal two-thirds or three-fourths spotted with black, whereas specimens of *H. geminatus* have black only on the fleshy base of that fin.

It will be seen from the two foregoing descriptions that the live fish at hatching are longer than the larvae just described, although the latter are somewhat more advanced in development. The difference, no doubt, is the result of shrinkage during preservation in the last-mentioned group.

Specimens 2.0 to 3.0 mm long.—The body is rather strongly compressed throughout, the head being about half as broad as deep. The head and trunk are short in proportion to the tail, the distance from the tip of the snout to the vent being contained about 2.9 times in the total length without the caudal finfold. The snout, although rather blunt, especially in 2.0-mm fish, is more pointed than in *Hypsoblennius hentz* and about one-third (in 2.0-mm fish) to two-thirds (in 3.0-mm fish) the length of the eye. The mouth is terminal and strongly oblique, with the tip of the lower jaw a little above the level of the middle of the eye when the mouth is closed. The vertical finfold is continuous with indications of rays posteriorly in 3.0-mm fish, but not in smaller ones. The pectoral fins are short and broad and scarcely longer than the eye.

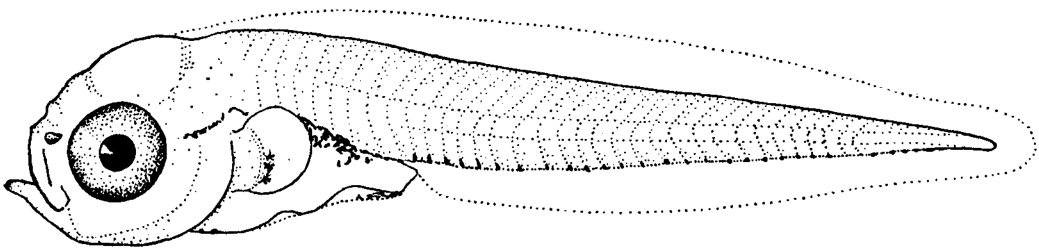

FIGURE 104.—*Hypleurochilus geminatus.* From a larva 2.1 mm long from the tow.

A broad black oblique band extends from the axile of the pectoral to ventral outline just above the protruding hindgut. The ventral outline of the chest and abdomen usually bear a few dark dots, the upper surface of the head and nape generally has one or more dark chromatophores, and usually a faint dark bar across the forehead between the eyes. A row of small, vertical, slightly elongate dark spots is situated on the ventral outline of the tail. Dark dots also are present on the base of the inner surface of the short pectorals (fig. 104).

This species is distinguished from *Hypsoblennius hentz* at this size chiefly by the longer and more pointed snout, less strongly elevated forehead, the more strongly oblique mouth, and the much shorter and broader pectorals which bear dark dots only at the base on the inner surface, whereas in *H. hentz* the dark specks extend to the tips of the fins. These differences are evident in specimens as small as 2.0 mm in length. Smaller larvae, as already stated, are difficult to identify.

Specimens 4.0 to 4.5 mm long.—The head and body are compressed, the caudal portion of the body being longer than the head and trunk, with the vent situated well in advance of midbody length. The head is deep and rather narrow, the interorbital space being only about half the width of eye. The snout is moderately pointed and about three-fourths as long as eye. The mouth is terminal, rather strongly oblique, the tip of the lower jaw being scarcely below the level of the middle of the eye. The eye is placed moderately high and is about equidistant from the dorsal and ventral outlines of the head. Fin rays are only partly developed in the dorsal and anal fins, but much better in the caudal fin which has a round outline. Ventral fins are not evident and the pectoral fins are short and broad, and scarcely longer than the eye. Several more or less distinct dark dots are present on the ventral surface of the chest and abdomen, and on the head and nape; an obscure dark bar crosses the forehead between the eyes. An oblique black bar extends from the axile of the pectoral nearly to the vent; and the inner surface, only, of the base of the pectoral is black. A row of small black dots begins a short distance behind the vent and extends to the base of the caudal fin (fig. 105).

Specimens of this species at this size differ from those of the same size of *Hypsoblennius hentz* principally in the longer and more pointed snout, more strongly oblique, terminal mouth, in the much shorter pectoral fins, which are black at the base on the inner surface only, and in the somewhat more anterior position of the vent, the caudal portion of the body being longer than the head and trunk.

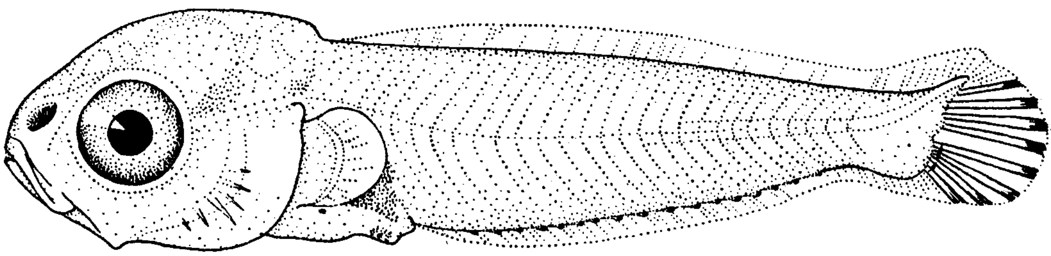

FIGURE 105.—*Hypleurochilus geminatus.* From a young fish 4.5 mm long.

Specimens 5.0 to 6.0 mm long.—The body is moderately deep and rather strongly compressed, having made no pronounced change in shape since a length of 4.0 mm was attained. The snout is slightly more rounded than in smaller specimens and usually only a little shorter than the eye. The interorbital is strongly convex and somewhat narrower than the eye. The mouth is terminal and the tip of the lower jaw is on or somewhat below the level of the center of the eye. The preopercle in some specimens shows indications of minute spines, but it appears to be smooth in others. Advancement in the development of rays in the dorsal and anal fins, since a length of 4.0 mm was attained, is not pronounced and a definite enumeration of the rays cannot be made. The caudal fin, however, has grown proportionately longer, is broadly rounded, and similar to the adult. Very minute ventrals are evident in only a few of the rather numerous specimens of this size examined. The pectorals have increased in proportionate length and frequently are about as long as the eye and snout. The black, confined to the inner base of the pectoral fin in smaller specimens, now extends somewhat on the lower rays of the fin, and the prominent oblique dark bar originating in the axile remains as described in smaller specimens. The ventral surface of the chest and abdomen usually bears several indefinite dark spots; the sides of the head generally have a few very small dark points; and the occipital surface of the head and nape has several more definite ones. A row of somewhat obliquely elongate dark spots begins a short distance behind the vent and extends to the base of the caudal fin, It is evident now that the spots are situated between the bases of the anal rays (fig. 106).

The principal characters distinguishing this species from *Hypsoblennius hentz* at this size do not differ greatly from the ones mentioned for specimens 4.0 to 4.5 mm in length. The snout in *H. geminatus* remains longer, although scarcely as pointed; the mouth is terminal and more strongly oblique; the pectoral fins, although they have increased in proportionate length, remain shorter and the black on their bases is much less extensive. *H. hentz*, in the meantime, has developed a bony ridge over and in advance of the eye making the interorbital quite flat. This bony ridge is entirely missing in *H. geminatus* and the interorbital is strongly convex.

Specimens 8.0 to 10 mm long.—The body is moderately elongate and rather strongly compressed, the depth being contained about 5.3 to 5.7 times in the length without the caudal fin. The head is moderately deep; the snout tapers and is about three-fourths as long as the eye; and the forehead is not very steep, being rather evenly and fairly strongly convex. The mouth remains rather strongly oblique and terminal, as in smaller specimens. The tip of the lower jaw is slightly below the level of the middle of the eye, and the maxillary reaches only a little past the anterior margin of the orbit. The interobital remains strongly convex, with only slight indications of a bony ridge over and in advance of the eye. Very small preopercular spines are present, the longest scarcely exceeding the length of the pupil. The dorsal and anal fins are quite fully developed and a fairly accurate count of the rays can be made. The caudal fin has a straight to a round margin and is nearly as long as the head without the snout.

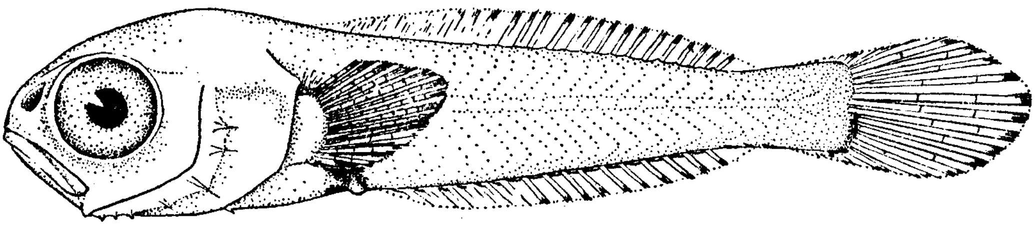

FIGURE 106.—*Hypleurochilus geminatus*. From a young fish 6 mm long.

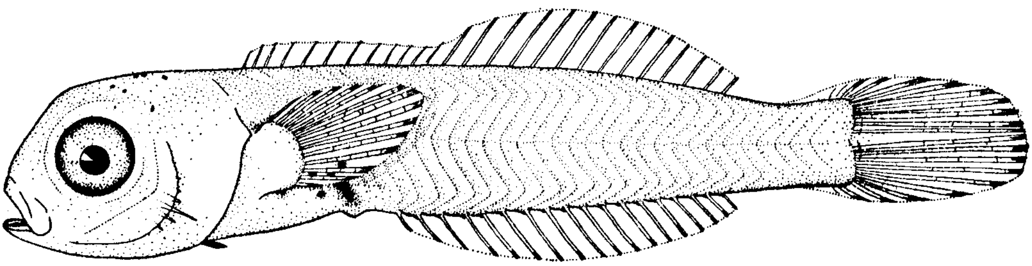

FIGURE 107. *Hypleurochilus geminatus*. From a young fish 8.5 mm long.

The ventral fins remain very small in specimens 8.0 mm long, but have increased considerably in length in fish 10 mm long, when they are about equal to the eye. The pectoral fins are broad at the base, the middle rays being somewhat produced and about as long as the head without the snout. The ventral surface of the chest and abdomen usually bears a few to several dark dots, sometimes a few dark markings also are present on the sides of the head, and the occipital portion of the head is marked either with small dark dots or with somewhat larger, less well-defined dark or brownish spots. The pectoral fin has a few to several dark dots at the base on its inner surface, and the oblique dark bar behind the pectoral, prominent in smaller specimens, has become quite indistinct in some specimens. Small elongate dark dots situated between the bases of the anal rays, described in smaller specimens, have become more elongate. Each one bends back abruptly and reaches the ray situated immediately behind it a short distance above the base of that ray (fig. 107).

The characters distinguishing the young of this species, when 5.0 to 6.0 mm long, from *Hypsoblennius hentz* of the same size, in general, also separate young 8 to

10 mm long. The difference in the depth of the body is somewhat more evident than in smaller fish, *H. hentz* being notably deeper and also somewhat stockier. The much longer preopercular spines, particularly those at the lower posterior angle in *H. hentz*, too, are useful in separating the species. Another helpful difference is found in the shape of the dark dots at the base of the anal, which have become elongate and form lines in *H. geminatus*, whereas they are round in *H. hentz*.

Specimens about 12 mm long.—The body has increased somewhat in robustness since a length of 10 mm was reached, but it remains much more slender than in specimens of *Hypsoblennius hentz*, of this size, the depth being contained in the length without the caudal fin 4.4 to 4.75 times. The forehead is strongly convex, but not vertical; the snout projects quite prominently, being fully three-fourths as long as the eye; and the mouth is terminal and only slightly oblique, with the tip of the lower jaw scarcely above the level of the lower margin of the eye. A low bony ridge, evident over the eye in somewhat smaller specimens, is scarcely visible now and the interorbital remains strongly convex. Minute preopercular spines remain present and do not seem to have either increased or decreased in proportionate length since the fish attained a size of 10 mm. A small fleshy tentacle, notably shorter than the pupil, is visible over the eye for the first time. The dorsal spines, as in the adult, are shorter than the soft rays of that fin; the caudal fin has a nearly straight margin; and the ventral fins have increased in proportionate length, being almost twice as long as the eye. Pigmentation remains virtually as in the smaller fish described in the preceding paragraph (fig. 108).

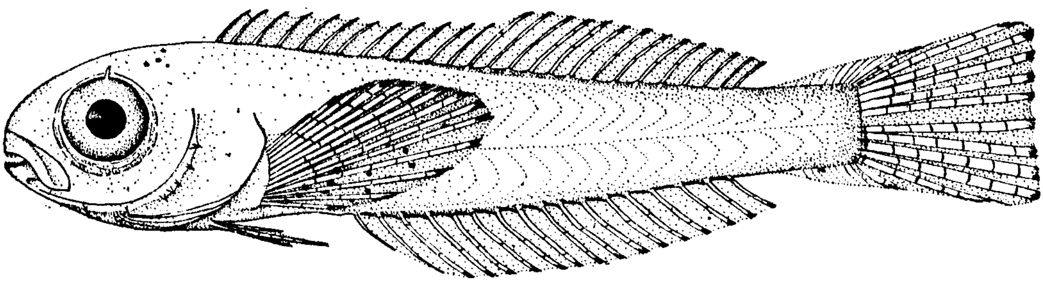

FIGURE 108.—*Hypleurochilus geminatus.* From a young fish 12 mm long.

Hypsoblennius hentz is distinguished from the present species at this size (as in smaller fish) by the vertical forehead, the slightly inferior horizontal mouth, the prominent bony ridge over and in advance of the eye, by the much larger preopercular spines, and by the greater amount of black color on the pectoral fins.

Specimens 15 to 16 mm long.—Specimens of this size are very similar in shape to the adult, and they have the appearance of being much older fish than 12- or even 14-mm specimens. The body has become deeper and more robust, the depth being contained in the length, without the caudal fin, 3.3 to 3.6 times. The snout projects rather prominently in advance of the forehead and it is nearly or quite equal to the length of the eye. The small mouth is now wholly below the level of the lower margin of the eye. It is almost horizontal, as in the adult. The lower jaw is slightly shorter than the upper one and the maxillary scarcely reaches beyond the anterior margin of the pupil. Preopercular spines, present in somewhat smaller specimens, are not evident. Three or four fleshy tentacles, placed close together and in a transverse row and rising from a common base, are present over each eye, the longest one being about as long as the pupil. Another fleshy tentacle is present behind the nostril. The fins are all shaped virtually as in the adult. The color cannot be fully described, as only old alcoholic specimens (collected in 1912 and 1913) of this size are at hand. They are rather pale in color and have only a few dark points in advance of, as well as behind, the ventral and pectoral fins. Similar dots occur on the occipital portion of the head, and a row of elongate dark spots are present on the base of the anal fin (fig. 109).

Specimens 20 to 22 mm long.—A canine tooth on the posterior part of each jaw, constituting a generic character, has become evident at about this size. Pigmentation is general and complete, and similar to that of the adult. Recently preserved specimens (which do not differ greatly in color from live fish) are brownish. Some are plain dark brown and others, somewhat lighter in color, have indications of dark bars on the upper part of the sides. Indefinitely outlined dark spots are present along the middle of the sides and also on the base of the anal fin. The dorsal and anal fins are profusely dotted with brown, similar to the body, as seen under magnification. A dark spot is present on the membrane between the first two dorsal spines, the margin of the anal is pale, and the caudal fin has dark cross bars. The ventral and pectoral fins are finely dotted like the dorsal and anal, and the pectorals in addition bear larger dark spots.

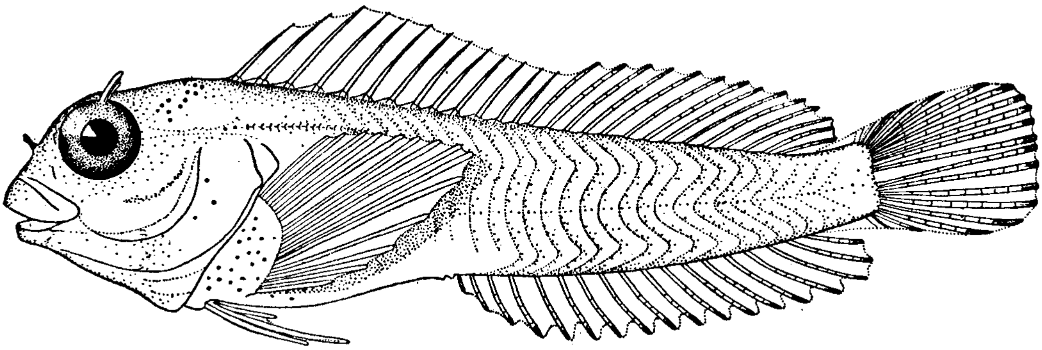

FIGURE 109.—*Hypleurochilus geminatus.* From a young fish 16 mm long.

Specimens 20 to 22 mm long virtually are "young adults" with posterior canines, and with the color almost identical with that of the adult. The size of the fish at which general pigmentation takes place, however, has not been determined, as only greatly bleached alcoholic specimens ranging from 14 to 18 mm in length are at hand. It can be stated at this time only that general pigmentation has not begun at a length of 14 mm, whereas it is complete at 20 mm.

DISTRIBUTION OF THE YOUNG

The fry were taken in towings in outside waters 76 times and in inside waters 12 times. No record of the numbers of towings taken was kept, but it is probable that nearly as many hauls were made in inside waters as in the outside ones. The collections show, therefore, that the young are more numerous off Beaufort Inlet than they are in Beaufort Harbor and adjacent sounds and estuaries.

The fry were taken in surface towings 65 times and in bottom hauls only 16 times. Although a considerably larger number of surface than bottom hauls was made, the discrepancy in the numbers of hauls certainly was not great enough to equalize the difference. Furthermore, in 1927 and 1928 the surface and bottom hauls were nearly equal in number and during those years the fry occurred in surface towings 51 times and in bottom drags 9 times. Since the bottom nets were not closed while they were hauled in, it is possible that some of the fry caught may have been taken somewhere between the bottom and the surface. The larger fry (5.0 to 10 mm) were taken no more frequently in bottom drags than the smaller ones. Therefore, the evidence is that the larvae of this species, until a length of about 10 mm is reached, live in the open waters and are chiefly surface dwelling.

Fish of all sorts, after reaching a length of about 10 to 15 mm, are taken sparingly in 1-meter tow nets. Many species at this size may be taken in an otter trawl, having the cod end covered with bobbinet. That mode of collecting failed, however, for the present species, very probably because the fish no longer occurred in the open waters. The usual habitat of the adults, as stated elsewhere, is among marine growths attached to wharf and bridge piling, rocks, shells, etc., and specimens as small at 16 mm in length have been taken in such an environment. However, no special effort to collect small fish in the favorite haunts of the adults has been made. It seems probable that the young fish, after abandoning the open waters, take up their abode with the adults and that they will be found there when collections are made with suitable apparatus.

GROWTH

The data on the rate of growth are meager, owing to the scarcity in the collections of specimens ranging from about 10 to 15 mm in length. A change in habitat apparently takes place at about this time in the life of the fish, as already shown. The new habitat is not well known and requires further exploration. Examples around 8.0 mm long occurred in the tow as early as June 2 (1928), and are rather common thereafter throughout the summer. Also, several specimens about 10 mm long were caught in the tow during the summer, the first one of this size having been taken on July 3 (1928). However, a larger one (12 mm) was caught as early as June 28 (1927). These data indicate, therefore, that the larval stages are passed rather quickly and that a length of 8.0 to 10 or even 12 mm may be attained within 1 to 2 months after hatching.

Specimens 16 to 22 mm long were dredged on shelly bottom and caught on wharf piling in July and August. Such fish are "young adults" and may or may not belong to an older year class. They, at least, look much older and more mature than the single 14-mm specimen secured in the tow. The indications are, therefore, that no great increase in length takes place at the time (between about 14.0 and 16.0 mm) when the fish acquires nearly all the characters of the adult. It is during this time and probably somewhat earlier, as already pointed out, that the fish leaves the surface waters and begins to live with the adults among marine growths attached to rocks, shells, submerged timbers, wharf piling, and other objects.

CHASMODES BOSQUIANUS (LACÉPÈDE). BANDED BLENNY

This blenny is not very common at Beaufort, and the least numerous of the three local species. It is reported from New York to Florida, apparently being more numerous in Chesapeake Bay than elsewhere. It may be distinguished from the other blennies occurring locally by the more pointed snout, by the larger mouth (the maxillary reaching to or past posterior margin of the eye), the absence of canine teeth (present in *Hypleurochilus geminatus* only), by the rather longer dorsal and anal fins (the dorsal formula being XII, 18, and that of the anal II, 17 or 18), and the fewer rays in the pectoral fin (12, rarely only 11).

Insufficient specimens are at hand to determine the relative sizes attained by the sexes. No males or females exceeding a length of 70 mm were seen at Beaufort.

The secondary sex characters do not differ noticeably from those of the other local species. Each anal spine bears a fleshy expansion at the tip in adult males, and a membranous expansion is present immediately in advance of the anal fin. Also the female has a more or less distinct anal papilla (fig. 110).

This blenny apparently inhabits shelly bottom only at Beaufort, though in Chesapeake Bay it was taken on clay, mud, and sand (Hildebrand and Schroeder, 1928, p. 333). A few specimens were taken at Beaufort in nets hauled over shelly grounds. A somewhat larger number of fish, however, was taken by hand in oyster, clam, and scallop shells. The shells were occupied not only during the spawning season, but at other times also and by both sexes.

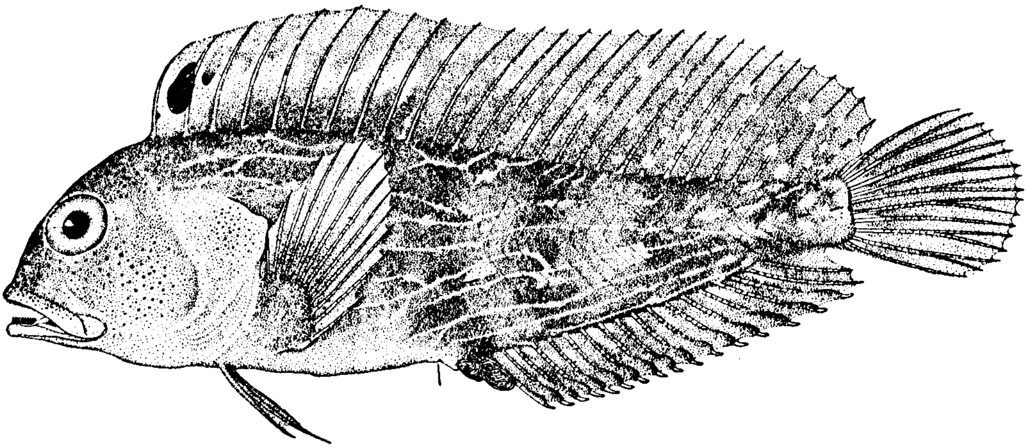

FIGURE 110.—*Chasmodes bosquianus.* From adult male.

The banded blenny is hardy. It lives well in confinement, and during cool weather at least it can live out of water a long time. For example, on the afternoon of November 24, 1927, an individual occupying a scallop shell containing some sand and mud was picked up by hand. It was placed in a dry container with the shell and left over night. The next morning the fish was still in a lively condition. Upon being placed in an aquarium it at first deserted the shell, but soon afterwards reoccupied it. It lived in the aquarium for several weeks, and allowed itself to be lifted from the water with the shell numerous times. Some of the nests found were so near the usual low-tide line that they must become exposed when rather exceptionally low tides occur. At such times if the male fish guarding the nest does not desert it, he may have to live for a while either without water, or at most only from water brought by the wash of waves. Observations indicate, however, that if the nest is deserted the eggs most probably will be destroyed soon by enemies, as explained subsequently.

This little fish is game and when handled fights vigorously. It will grasp the skin and flesh of the hand and hold on bulldog fashion. However, its jaws and teeth are too weak to inflict a wound.

The illustrations of the development of the egg and of the newly hatched fish, presented herewith, are all based on live specimens. The young were not taken in collections made in nature, and those hatched in the laboratory died within a day or so after hatching. Consequently, no material for the study of their development is available.

SPAWNING

This blenny, like the others reported upon in this paper, evidently does not spawn all of its eggs at one time, as ova of several different sizes are present in the ovary during the spawning period. The length of the spawning season has not been determined fully. The young have not been taken, and insufficient adults have been collected to make a full determination from the study of the gonads. However, a nest was found as early as May 15 (1920), and as late as August 14 (1930). Other nests were taken in June and July. Hildebrand and Schroeder (1928) report a nest taken May 22 (1922), at Cherrystone Island, Va. From these data it may be concluded that the spawning season extends at least from May to August.

The nesting habits of this blenny, so far as known, are identical with those of *Hypsoblennius hentz*. The eggs have been found only in oyster shells, although clam and scallop shells probably also are used. A full nest covers the entire inside of both valves of an oyster shell. The eggs are firmly attached in a single layer, though not always in definite rows, and are well separated by the adhesive disk which has a greater diameter than the egg itself. For study, the eggs with the disk may be removed from the shell with a sharp instrument, but the disk could not be separated from the egg.

In this species, as noted for *Hypsoblennius hentz* and *Hypleurochilus geminatus*, the eggs in a nest are not all in the same stage of development, a range from an early cleaveage stage to an advanced embryonic stage having been observed. The remarks made under the discussion of *Hypsoblennius hentz* (p. 578) as to whether all the eggs in one nest are the product of one female apply equally as well to *Chasmodes bosquianus*.

Presumably the nests are always guarded by the male, as already indicated. The care of the male is evidently necessary to prevent the destruction of the eggs by enemies and to keep them clean and healthy. The eggs in a deserted nest in nature were destroyed quickly by the small flat mud crab, *Eurypanopeus depressus* (Smith), that also attacked the eggs of *Hypsoblennius hentz* (p. 579). Those in two other deserted nests, placed in tanks with running water, all died in an advanced embryonic stage, having become infested with hydroids and a copepod, *Tisbe furcata* (Baird).[11] A small percentage of several dozen eggs removed from a nest when in rather early developmental stages and placed in glass bowls, in which the water was changed twice daily, hatched successfully.

Spawning in this species, as in *Hypsoblennius hentz,* apparently takes place early in the morning, as only those nests taken before 10 o'clock contained eggs in the early cleavage stages.

DESCRIPTIONS OF THE EGGS AND THE NEWLY HATCHED YOUNG

Description of the egg.—The eggs of *Chasmodes bosquianus* are slightly flattened next to the adhesive disk or "foot" which attaches them to the inside of oyster shells and possibly to other bivalve mollusks also, as already explained. The eggs of the present species are larger than those of the other blennies discussed in the preceding pages. The greater axis has a length of 0.93 to 1.1 mm in 27 eggs measured and an average length of 1.04 mm. The lesser axis which cannot be measured accurately, because the grayish opaque adhesive disk obscures the outline of the egg, has a length of about 0.8 to 0.9 mm. The slightly flattened contour of the egg at the place of attachment is not shown in the drawings portraying lateral views, as the degree of depression could not be determined definitely.

[11] The writers are indebted to Dr. C. B. Wilson, State Teachers College, Westfield, Mass., for this identification.

The eggs as seen on an oyster shell with the unaided eye are very pale yellow. Under magnification just a tinge of yellow is evident. Numerous yellowish oil globules, mostly in that half of the yolk nearest the adhesive disc, are present. The eggs have a dense opaque central body, as in the other blennies studied. No bluish or reddish spots are present in the yolk and therein the eggs of this species differ conspicuously from those of the other local forms.

The eggs of this species apparently are even more opaque than those of the other blennies studied. The yolk is quite granular, becoming more so as development progresses. The egg membrane is cellular in appearance. When the microscope is refocused the lines have the appearance of deep ravines with elevations between them. This sculpture of the egg membrane is not shown in the accompanying illustrations. The adhesive disk described above, is shown in only one drawing (fig. 118), although of course it is always present.

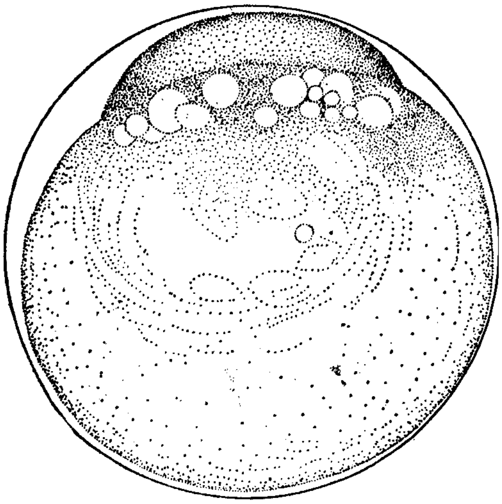

FIGURE 111.—*Chasmodes bosquianus*. From egg with blastodisc; shortly before the first cleavage; probably about an hour after fertilization. (Drawn by Nell Henry.)

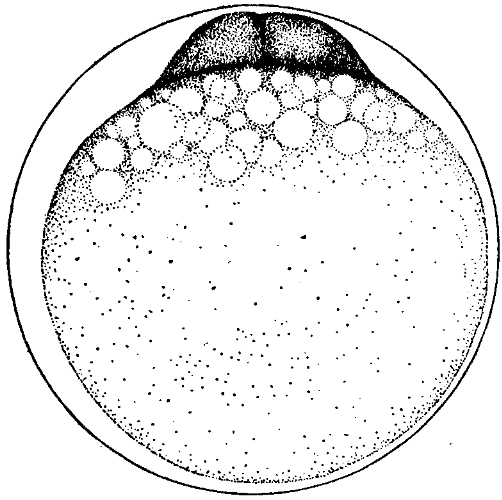

FIGURE 112.—*Chasmodes bosquianus*. From egg in 2-cell stage; about 2 hours after fertilization. (Drawn by Nell Henry.)

Segmentation and the development of the embryo.—The following account is based entirely upon eggs collected in nature. The exact time of spawning and fertilization is not known. Therefore, the time intervening between fertilization and the beginning of cleavage cannot be stated definitely. In a nest taken at 9:30 o'clock in the morning eggs were present in which the first cleavage took place about an hour after collection. It seems probable that these eggs were laid early on the morning the nest was brought to the laboratory, as already explained (p. 605). In *Hypleurochilus geminatus* about 2 hours intervened between fertilization and cleavage at a temperature of 26° to 28° C. It probably may be assumed that in Chasmodes about an equal length of time elapses between fertilization and segmentation, at nearly identical temperatures.

The blastodisc in all the eggs examined lay next to the adhesive foot by which it was largely obscured when viewed in the normal position. However, when the egg was turned so that the adhesive surface of the disk was at right angles to the side upon which it rested, a fair lateral view of the blastodisc and segmentation was obtainable. Accordingly, the illustrations showing different stages of cleavage are all lateral views. In general, only that part of the disc extending beyond the yolk is shown, as the opaqueness of the egg obscured the rest.

The blastodisc is large and projects prominently beyond the yolk. The perivitelline space is wide at the positive pole of the egg and very narrow or wanting at the negative pole (fig. 111). The first blastomeres are large and about equal in size, as usual in teleosts (fig. 112). The second cleavage plane is approximately at right angles to the first, and it followed the first, at a water temperature of about 26° C., in about 20 minutes (fig. 113). The third and fourth cleavages followed equally as rapidly.

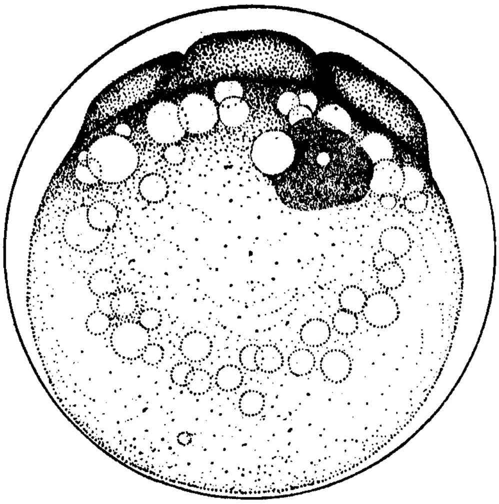

FIGURE 113.—*Chasmodes bosquianus*. From egg in 4-cell stage; about 2½ hours after fertilization. Owing to opaqueness of egg all the cells could not be seen from one viewpoint. (Drawn by Nell Henry.)

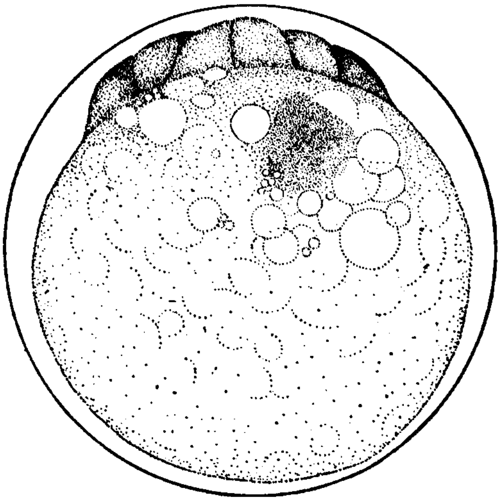

FIGURE 114.—*Chasmodes bosquianus*. From egg in 16-cell stage; about 3 hours after fertilization. (Drawn by Nell Henry.)

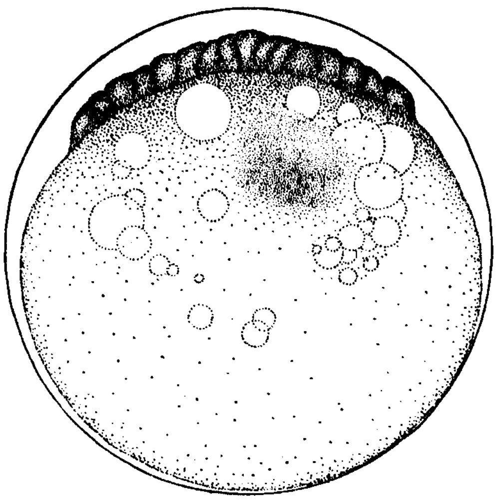

FIGURE 115.—*Chasmodes bosquianus*. From egg probably in the 64-cell stage; about 3½ hours after fertilization. Owing to opaqueness of the egg the cells could not be counted accurately. (Drawn by Nell Henry.)

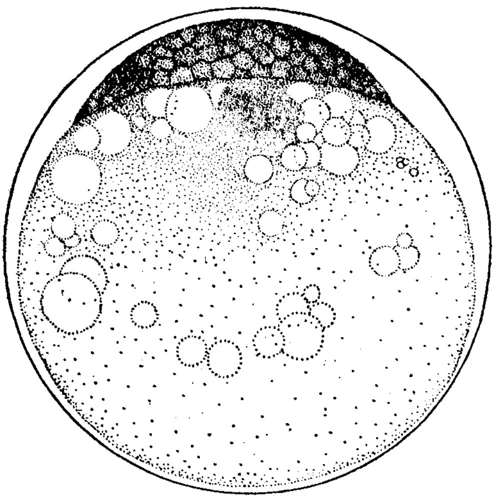

FIGURE 116.—*Chasmodes bosquianus*. From egg in rather advanced cleavage stage; about 6 or 7 hours after fertilization. Owing to opaqueness of the egg only that part of the blastoderm projecting above the yolk is visible from one view point. (Drawn by Nell Henry.)

When the eight-cell stage is reached, all the cells are no longer visible in a lateral view, and they cannot be seen in a surface view, as already explained. Therefore, further divisions cannot be clearly observed. The blastomeres are large and prominent until about the 16-cell stage is reached (fig. 114). Thereafter they get smaller and flatter rather rapidly (fig. 115).

The eggs in which cleavage started at about 10:30 in the morning reached a fairly advanced cleavage stage by the evening of the same day (fig. 116). The temperature of the water had remained near 26° C. throughout the period. No pronounced changes had taken place in the egg in the meantime, except that the yolk apparently had become more granular and rather more opaque.

Twenty-four hours after cleavage started a very early embryonic stage was reached, that is, the embryo was just becoming differentiated, though it was not yet possible to distinguish between the head and tail. The temperature of the water had dropped to 24.5° C. Little obvious headway was made during the next 12 hours. However, a fairly well-formed embryo, with the eyes partly developed, was present, at about 48 hours after fertilization. The temperature of the water had advanced to 26° C. The embryos evidently were not all in the same position in relation to the adhesive foot. In some eggs the embryo lay underneath the yolk, next to the foot, with only the head and tail visible if viewed from the side opposite the foot. Other embryos lay mostly above the yolk and therefore were entirely visible in eggs seen from the same angle. Positions intermediate of these also were observed. A few grayish blotches, variable in size, were noticed on the yolk for the first time (fig. 117).

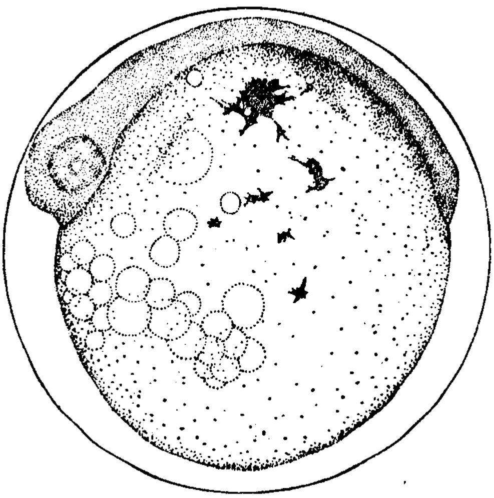

FIGURE 117.—*Chasmodes bosquianus*. From egg with moderately well-differentiated embryo; 2 days after fertilization. (Drawn by Nell Henry.)

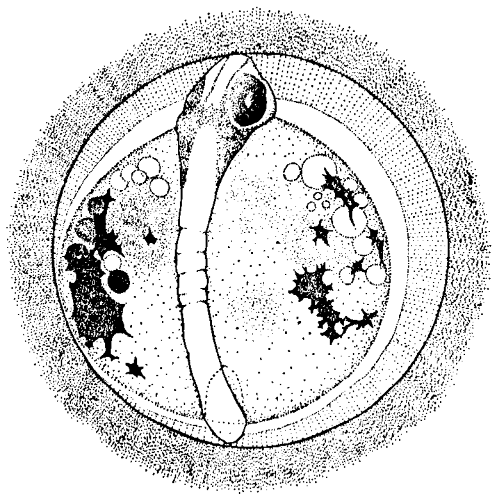

FIGURE 118.—*Chasmodes bosquianus*. From egg with well-formed embryo; 2½ days after fertilization. Tail of embryo curved under the opaque yolk. (Drawn by Nell Henry.)

About 60 hours (2½ days) after fertilization, the temperature of the water remaining near 26° C., the embryo was well formed, with a large head and partly pigmented eyes. It curved about two-thirds the distance around the egg. Indications of somites were present at midbody length and the heart beat slowly and rather feebly (about 90 beats per minute). Circulation was evident only near the heart, no definite blood vessels apparently having been formed. Black blotches, with irregular outlines, variable in size and shape in any one egg and variable in number in different eggs were present on the surface of the yolk (fig. 118).

On the fourth day of incubation, with the temperature of the water remaining quite constant at 26° C., the body segments had become plainly marked in the anterior caudal region, although the embryo had gained little in length. The eyes had many black pigment dots, most numerous along the upper margin; the yolk appeared very granular and had been cut into deeply by the embryo, and the dark spots on its surface in general had become smaller and more numerous. The heart was beating rapidly, sending the blood to the body through a large vessel situated near the ventral outline. This artery left the embryo somewhat more than an eye's diameter from the tip of the tail where it entered the yolk and divided into several branches. These branches all coursed over the yolk and in a general way ran toward the snout of the embryo, underneath which the heart is situated. There they united just before pouring their contents into the heart (fig. 119).

On the fifth day of incubation, with the temperature of the water still remaining near 26° C., the embryo had encircled the egg. The tail reached opposite the head. It was free and moved frequently. The eyes were very prominent, being fully pigmented, and visible without magnification. The yolk was reduced to about two-thirds its original size and more or less crescent-shaped, having been cut into very deeply in the head region of the embryo. Oil globules of various sizes remained distributed throughout the yolk. The central opaque body, previously described, and still visible a day or so earlier, had disappeared. Dark markings on the yolk had become more

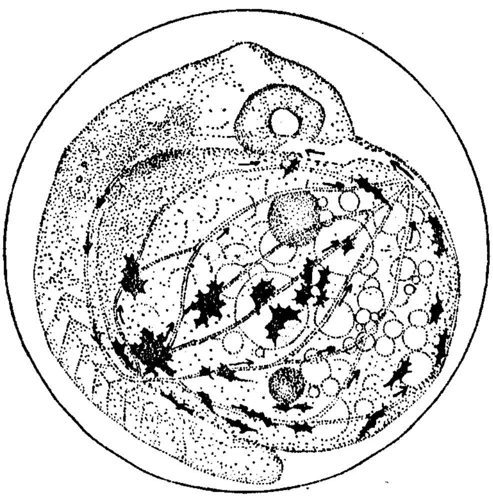

FIGURE 119.—*Chasmodes bosquianus*. From egg with developing embryo; 4 days after fertilization. Arrows indicate the direction of the flow of blood in the larger vessels. (Drawn by Nell Henry.)

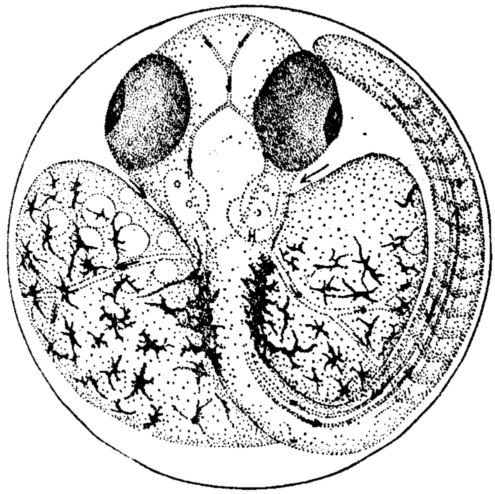

FIGURE 120.—*Chasmodes bosquianus*. From egg with advanced embryo; 5 days after fertilization. H, heart. Arrows indicate direction of flow of blood in the larger vessels. (Drawn by Nell Henry.)

numerous and in general smaller. They now consisted mostly of lines branching more or less from a central point, and many of them were shaped somewhat like crow's feet. A concentration of dark markings was taking place in the trunk region of the embryo. Circulation was brisk, and the blood returned within the embryo, the caudal vein being quite fully developed. Corpuscles were distinct, and the heart and large vessels near it had a pinkish tinge (fig. 120).

Development progressed slowly after about the fifth day of incubation. By the seventh day, with a drop in temperature to 24.5° C. between the sixth and seventh day, the tail of the embryo reached a little past the head. The embryo was capable of considerable movement, carrying the yolk with it as it turned in the egg case. The yolk had been cut into more deeply and was definitely crescent-shaped. The black markings on the yolk, described in the foregoing paragraph, although variable in number in different eggs, had become less numerous, and a further concentration of black had taken place in the trunk region of the embryo. Also an irregular black blotch was present at each auditory vesicle. Almost innumerable blood vessels were visible in the vicinity of the head of the embryo and all poured their contents into the heart, which had the appearance of a pit (fig. 121).

No important changes in the embryo itself appeared after about the seventh day of incubation. The temperature remained near 24.5° C. from the fifth to the ninth day when it advanced to 26° C. On about the ninth day it was evident that the black color concentrated in the abdominal region of the embryo, first noticed on the fifth day, was on the embryo, whereas it at first appeared to be on the yolk. On some eggs a few "crow's feet" remained on the yolk, whereas in others they had all disappeared. A dark blotch was present between the anterior part of the eyes, and in some specimens short, branching, cross lines were evident on the ventral margin of some of the caudal myomeres. Also distinct black spots were present on the pectoral fin membranes which could be seen clearly through the egg case. The eggs in two unguarded nests (the writer was not successful in inducing a male of this species, to stay with his nest in the aquarium) all died between the fifth and ninth days of incubation, having become infested with hydroids and protozoa. Eggs removed from the nests while in early cleavage stages and placed in glass bowls, in which the water was changed twice daily, also nearly all became infested and only four hatched. The rest of this account is based on the few remaining eggs and the four larvae that emerged successfully.

On the tenth day of the incubation period the temperature of the water advanced to 27° C. The embryos were very active. The dark color markings on the embryo, already evident on the ninth day or earlier, had become more distinct. The number of blood vessels had increased and the blood, when viewed under moderately low magnification, was seen pouring over the head and eyes in minute vessels as if in a sheet. Heart action was extremely rapid, the beats following each other in such close succession that they could not be enumerated accurately. The heart had a distinct reddish tinge, the red probably being in the blood.

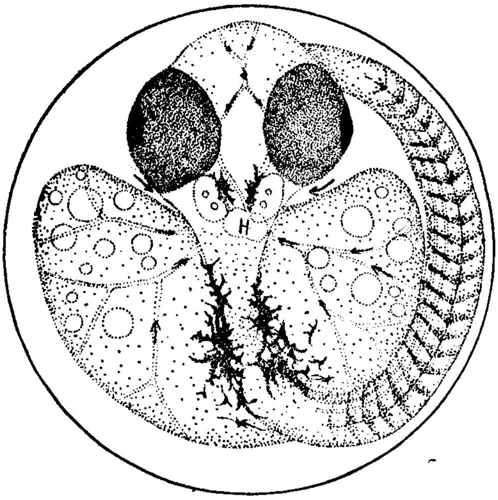

FIGURE 121.—*Chasmodes bosquianus*. From egg with large embryo; about 7 days after fertilization. H, heart. Arrows indicate direction of flow of blood in the larger vessels. (Drawn by Nell Henry.)

Only four eggs survived, as previously stated, and these all hatched on the eleventh day of incubation. The temperature dropped from 27° to 25° C. between the tenth and the eleventh day. The incubation period of this blenny, therefore, is around 11 days when the temperature of the water in which the eggs are incubated ranges between 24.5° and 27° C., with a mean temperature around 26° C.

No attempt was made to keep the larvae alive. After measurements and a sketch had been made and a description prepared they were preserved.

Newly hatched fish.—The newly hatched fish range in length from 3.56 to 3.78 mm. The yolk is small at hatching. The head and trunk are short and robust, and the tail is long and slender. The vent is situated far in advance of midbody length; distance from snout to vent being 1.25 to 1.3 mm, from vent to tip of tail without finfold 2.1 to 2.3 mm. The snout is short and blunt, its length being less than half the diameter of the eye. The eye is large, its diameter (0.36 mm) being a little greater than the depth of the body just behind the vent (0.32 mm). The mouth is placed rather low, anteriorly scarcely above the lower margin of the eye. The gape reaches to or a little behind the vertical from the anterior margin of eye. The vertical finfold is rather broad; originating above the auditory vesicle, it is continuous and extends to the vent. Large pectoral fin membranes, somewhat longer than the diameter of the eye, are also present. The body is fairly transparent. As a consequence, the outline of the brain and the circulation of the blood can be seen rather clearly. The aorta and the caudal vein remain rather close together, as in the embryo, both being located ventrally in the long tail. About 8 or 9 partly indefinitely outlined myomeres may be counted in advance of the vent and from 28 to 30 behind it. The vertebra count in two adults examined was 9+24 and 10+23. These counts seem to indicate that the total number of myomeres in the newly hatched fish is greater than the number of vertebrae in the adult. Since the demarcations between the myomeres both anteriorly and posteriorly are indistinct, it is barely possible that the count is excessive.

Nearly all the color markings on the newly hatched fish already were evident on the embryo several days before hatching. The black on the snout is in elongate "twin" blotches, situated over the anterior part of and somewhat in advance of the eye. The abdomen is largely black along its upper margin, the black reaching from the upper edge of the base of the pectoral to the vent. A few small black chromatophores remain on the ventral surface of the abdomen (yolksac). The tail has short branching cross lines on the ventral edge, which sometimes are wanting anteriorly and also posteriorly. The basal three-fourths of the inner surface of the pectoral has black chromatophores, the lowermost spot being very large, while those more distant from the base of the fin are smaller (fig. 122).

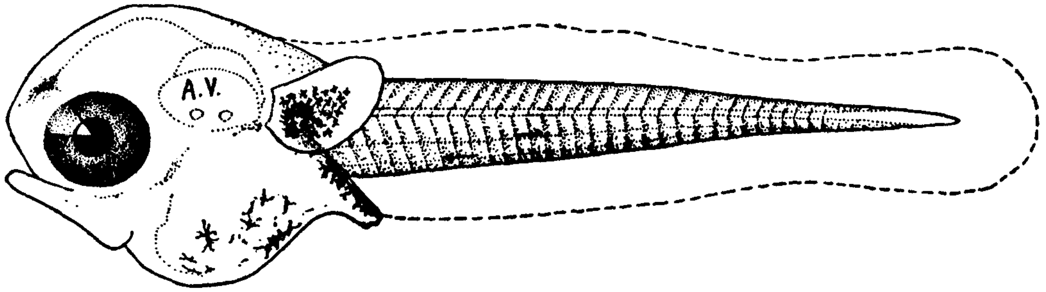

FIGURE 122.—*Chasmodes bosquianus.* From a newly hatched fish, 3.6 mm long. AV, auditory vesicle. Arrows indicate position and direction of the flow of blood in the aorta and caudal vein. (Drawn by Nell Henry.)

Chasmodes bosquianus is about 3.6 mm long at hatching, whereas *Hypsoblennius hentz* is about 2.7 mm long, and *Hypleurochilus geminatus* is only about 2.4 mm. Chasmodes apparently has a larger number of myomeres behind the vent, having about 28 to 30, whereas the other species have only about 23 or 24 at hatching. No black color markings were noticed under the auditory vesicle in Chasmodes, whereas more or less black is present in the other species. Chasmodes and Hypsoblennius agree in having most of the inner surface of the pectoral fin membrane dotted with black chromatophores, whereas Hypleurochilus at most has only a few black dots on the base of that fin. On the other hand, Chasmodes and Hypleurochilus agree in having a concentration of black points, forming almost solid black, along the upper margin of the abdomen, extending from above the base of the pectoral to the vent, while Hypsoblennius more usually has scattered branching chromatophores quite generally distributed over the abdomen. Considerable variation in the distribution of the black markings on the abdomen, however, has been noticed in all three species.

THE HAKES OF THE GENUS UROPHYCIS

The development and other life history data of four species of Urophycis, namely *chuss*, *regius*, *floridanus*, and *earlli*,[12] are discussed in the following pages.

Some of the hakes are rather widely distributed. *U. chuss* has been recorded from the Gulf of St. Lawrence southward to Cape Henry, Va. The known range is now extended southward to the coast of North Carolina, on the basis of some small specimens at hand, taken by the *Albatross* at sea off Kitty Hawk. *U. regius* is known to range from Nova Scotia southward to South Carolina; *U. floridanus* from Beaufort, N. C., to Pensacola, Fla., and *U. earlli* from Beaufort, N. C., to Charleston, S. C.

U. floridanus was first recorded from Beaufort by Hildebrand (1916, p. 306). Since that time, the young of this species, have been found to be common locally in shallow water during the winter and early spring, but the species apparently is absent there during the summer. *U. regius* is more common, the young being numerous during their first winter, but adults were rather rarely taken. It seems possible that these hakes, after spending the first several months in shallow water, live chiefly in deep water offshore where very little collecting has been done. The habitat of both the young and adults is discussed under the heading, "The distribution of the young."

According to our field records only four specimens of *U. earlli* were taken during the senior author's connection with the biological station at Beaufort from 1914 to 1917 and 1925 to 1931, notwithstanding that Smith (1907, p. 384) stated, "This hake * * * is not uncommon in the Beaufort and Cape Lookout regions. * * * On the adjacent shores the fish is common enough to have received a local name, 'Dickie,' although it has no economic value as yet." In view of the later, much more intensive collecting, one wonders if there was not confusion with one of the other more common species.

The southern species of hake do not grow large. *U. regius* is reported to attain a maximum length of 16 inches. The largest individual seen at Beaufort was 13½ inches long. The largest specimen of *floridanus* taken was only 8¼ inches long, and the largest one of *earlli* 15½ inches, though one 18 inches long has been recorded. *U. chuss* is reported to reach a length of about 30 inches, or even 42 inches, if *tenuis* is not distinguishable from that species, as suggested by Vladykov and McKenzie (1935, p. 71).

The hakes as yet are of no commercial value in North Carolina. Small catches are made in Chesapeake Bay and off Cape Henry, Va. The catch for Virginia (not separated by species) for 1934 is given as 21,000 pounds in the statistical report of the Bureau of Fisheries. Northward the hakes increase in importance, the catch for New Jersey for 1934 being 22,171 pounds, and for New York 139,954 pounds. Large catches are made in Massachusetts and Maine, and smaller ones in the other New England States, the total catch for those states for 1934 being 15,319,692 pounds. The meat of the hakes is soft, but it is of good flavor, and generally sells readily.

Adult hakes of the genus Urophycis, as here understood, are recognized by the elongate somewhat compressed body; subconical head; rather large, nearly horizontal mouth, with the maxillary generally reaching to or beyond the posterior margin of the eye; with unequal teeth on the jaws and vomer, none on the palatines; a small barbel

[12] Jordan, Evermann, and Clark (1930, pp. 212–213) place *earlli* in the older genus Phycis, leaving the other three species herein discussed in Urophycis. This classification does not seem justifiable, as *earlli* is closely related to *floridanus*, differing only in the smaller scales, rather longer dorsal and anal fins, and in color. In turn, *floridanus* differs in the same characters and in about the same degree from *regius*, the type of Urophycis. In addition, *floridanus* has a longer chin barbel, wherein it agrees with *earlli*. Certainly *earlli* is more closely related to *regius* than to *chuss* with its low broad head, large eyes, and produced dorsal ray. Evidently a further study of the group is necessary to determine the status of Urophycis. Perhaps all the species herein discussed should be assigned to the genus Phycis.

at the chin; and two dorsal fins, composed of soft rays only, the first one short, the second one long, and similar to the anal.

The ventral fins are described in current works as consisting of three slender rays, closely joined, and appearing as a bifid filament. In the young three separate rays are plainly evident, and sometimes a fourth one may be discernible. Upon removing the skin, it was found that two articulated rays are enclosed in each filament of the adult and a short "remanent" of a fifth ray (unarticulated) is present at the inner side of the base of the fin. These hakes, therefore, actually have four-rayed, or five-rayed ventral fins if the unarticulated remanent is counted.

The distinguishing characters of the adults of the species herein discussed are most readily shown in a key.

KEY TO THE SPECIES

a. Chin barbel very short, not exceeding the pupil of the eye in length.

b. Head depressed, notably broader than deep; eye large, equal to or wider than interorbital; scales small, 104 to 112 or more oblique series above the lateral line; first dorsal with a long filamentous ray; dorsal rays 9 to 11—56 to 61; anal rays 52 to 56; lateral line not in a black streak and without white spots; no white on first dorsal .... *chuss*.

bb. Head scarcely depressed, deeper, its depth about equal to its width; eye smaller, not as wide as interorbital; scales larger, 89 to 97 oblique series above lateral line; first dorsal without a produced ray; dorsal rays 8 or 9—46 to 51; anal rays 43 to 49; lateral line in a black streak, interrupted by pale spots; first dorsal largely black, margined with white .... *regius*.

aa. Chin barbel notably longer, always longer than the pupil, frequently nearly or fully as long as eye.

c. Scales moderately small, 110 to 130 oblique series above lateral line; dorsal rays 12 or 13—54 to 59; anal rays 40 to 49; color bluish or brownish above, silvery below; lateral line in a black streak, interrupted by pale spots; vertical fins mostly pale brownish, often with dusky margins, the first dorsal largely black, not margined with white .... *floridanus*.

cc. Scales very small, 153 to 175 oblique series above lateral line; dorsal rays 8 or 9—54 to 63; anal rays 50 to 56; color dark brown to nearly black, sometimes with pale blotches; lateral line not in a black streak and without pale spots; the vertical fins frequently nearly black, no white on first dorsal .... *earlli*.

SPAWNING

The eggs of Urophycis, as already stated, were not secured at Beaufort. Neither were ripe adult fish seen by us. However, the capture of spawning fish by the *Albatross* on the coast of the Carolinas in December, 1919 is reported in the field notes by the late W. W. Welsh. Small larvae, that is, young under 5.0 mm in length, were taken only a few times, as follows: One, 3.0 mm long, November 12, 1927, 13 miles west southwest of Cape Lookout; 13, ranging in length from 2.75 to 4.5 mm, December 6, 1927, at the same station; and 1, 3.0 mm long, December 6, 1927, 6 miles west southwest of Cape Lookout. These larvae, as stated elsewhere, apparently represent about equally *regius* and *floridanus*. Larger young were taken frequently and sometimes in abundance, during December and the following several months, as shown by tables 1 and 3.

The very small larvae taken are very probably only several days old, which seems to show that both *regius* and *floridanus* spawn in the general latitude of Beaufort at least during November and December. The small size of some of the young, though beyond the larval stage, taken during the several succeeding months suggests, however, that the spawning season extends over a longer period of time. A few specimens of *floridanus* and several of *regius*, 30 to 40 mm long, were collected as late as March, and a few of *regius* 38 and 39 mm long as late as April 15 (1931). Judging from the growth data contained in tables 1–4, it apparently may be assumed that these species in the general latitude of Beaufort spawn from about November to February.

U. earlli is so scarce at Beaufort that very little material was obtainable. In fact only three young, 37, 75, and 103 mm long, were secured. Therefore, virtually nothing was learned concerning its life history. However, the two larger young were taken March 24 (1931), and the smallest one April 15 (1931), when *regius* of about the same size also were taken. It is possible, therefore, that *earlli,* like the other local species of hake spawns during the winter on the coast of North Carolina.

It may be stated with some assurance that the hakes do not spawn in the bays and estuaries at Beaufort, as the eggs and larvae were not taken in these waters during several years of intensive collecting. All the larvae of *regius* and *floridanus* at hand were taken at sea from 6 to 13 miles offshore, beyond which no collecting was done. It apparently may be assumed, therefore, that these hakes spawn only at sea in the vicinity of Beaufort. The abundance of young *floridanus,* and especially of *regius,* during the winter and early spring indicates rather extensive spawning in the Beaufort region.

We have included in the present discussion *U. chuss* for reasons already stated, though this species is not recorded from Beaufort. In regard to the spawning Bigelow and Welsh (1925, p. 452) stated that the height of the spawning season of this species falls in early summer in the Massachusetts Bay region and at least as early as June south of Cape Cod. Also, that the extreme limits of the spawning season were not known, but that the evidence collected indicated that it spawns in the Gulf of Maine from late spring until early autumn. We have at hand specimens 2.75 to 15 mm in length collected by the *Albatross* off Cape Henry, Va., October 30, 1919, and off Kitty Hawk, N. C., October 31, 1919. We, also, have specimens of similar size collected on the coast of New Jersey by the *Grampus,* July 19, 1912. It seems, therefore, that the spawning season of this species is a very long one.

DESCRIPTIONS OF THE EGGS AND YOUNG

The eggs of Urophycis were not recognized in collections made at Beaufort, and the larvae were not taken often. Those collected apparently are separable into two species, namely, *regius* and *floridanus,* as shown subsequently. The smallest specimen of *earlli* taken, the only other species of Urophycis known from Beaufort, is 38 mm long.

Various additional collections of young hakes from both north and south of Beaufort, made principally by the *Albatross,* the *Grampus* and the *Fish Hawk,* are at hand for study. These include almost a complete series of the northern hake, *U. chuss,* which is not known from Beaufort, though specimens taken off Kitty Hawk, N. C., are at hand.

We also have the notes and some rough camera lucida drawing of the development of the eggs, and newly hatched young of *chuss,* made by the late W. W. Welsh. Some of this information, together with two of the drawings, already has been published by Bigelow and Welsh (1925, p. 454). It seems desirable to bring to light more of the information gathered long ago (1916) by Mr. Welsh, and to include as full an account of the development of this species as the data and specimens at hand permit. This seems especially desirable because of the close similarity of the young to the species occurring at Beaufort.

The development of the shape of the body is most peculiar, as may be seen from the descriptions and illustrations of the stages of development. The early larvae are slender; next, at a length of 4.0 mm or so, they become considerably deeper and more compressed. Then, at a length of about 10 mm, they have become slender again, and they remain so until they are fairly large fish, ranging upward of 100 mm in length, when, at least *regius* and *floridanus* again become deeper, and especially more robust, that is, less strongly compressed. It is interesting also that contrary to most of the other species discussed in this paper, the hakes, at no time have spines on the preopercular margin.

The eggs of U. chuss and their development.—The eggs were obtained by Mr. Welsh at Gloucester, Mass., evidently directly from ripe fish. It may be assumed that the eggs of all the species of Urophycis are similar. Therefore, the descriptions and drawings of those of *chuss*, offered herewith, may be useful in identifying those of the other species when they are taken.

The eggs are small and vary little in size. The diameter of 10 eggs ranged from 0.72 to 0.76 mm, the average being 0.74 mm. They are clear and buoyant, and contain many (54 counted in one egg) oil globules when first spawned. During incubation the oil globules decreased rapidly in number, until most eggs retained a single large one, much larger than any originally present, 6 hours after fertilization. Occasionally, however, a few minute scattered ones, in addition to the large one, were retained 26 hours after feritlization.

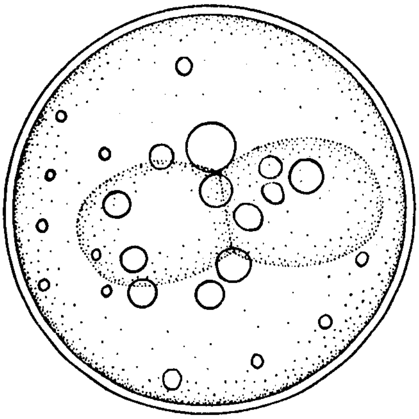

FIGURE 123.—*Urophycis chuss.* From egg in 2-cell stage; 1½ hours after fertilization. (From a camera lucida drawing by W. W. Welsh.)

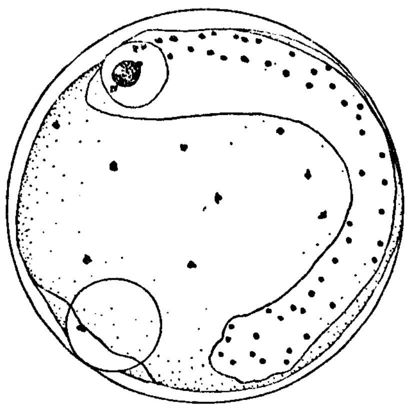

FIGURE 124.—*Urophycis chuss.* From egg with early embryo; 50 hours after fertilization. (From a camera lucida drawing by W. W. Welsh.)

The first cleavage took place 1½ hours after fertilization at a temperature of about 60° F. The number of oil globules already had decreased (fig. 123). Segmentation progressed rather rapidly, as the morula stage was attained about 26 hours after fertilization.

The embryo was well formed 50 hours after fertilization. It extended fully half the distance around the periphery of the egg, and the eyes were evident. Black chromatophores dotted the embryo (fig. 124). During the next 24 hours, that is, 74 hours after fertilization, no important changes took place, except that the embryo grew larger, and the amount of yolk was reduced. Pigmentation of the embryo remained unchanged. Some convulsive movements now were noticed (fig. 125).

At 90 hours of incubation, with a more or less constant temperature of 60° F., the eggs were ready to hatch. The pigment spots on the embryo had become notably larger and had branched. The eyes, too, were now slightly pigmented. The single remaining oil globule lay under the abdomen (fig. 126).

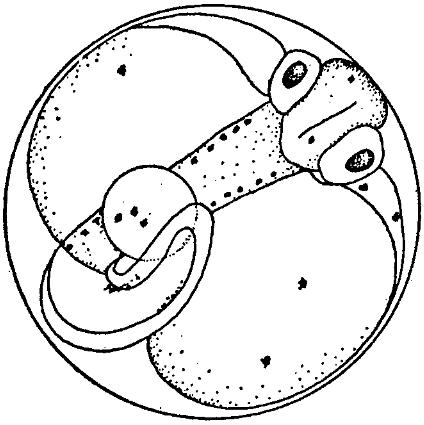

FIGURE 125.—*Urophycis chuss.* From egg with well-formed embryo; 74 hours after fertilization. (From a camera lucida drawing by W. W. Welsh.)

FIGURE 126.—*Urophycis chuss.* From egg with large embryo; 90 hours after fertilization. (From a camera lucida drawing by W. W. Welsh.)

Newly hatched U. chuss.—The newly hatched larvae ranged from 1.83 to 1.98 mm in length. The oil globule lay in the posterior part of the yolksac, or at midlength of the larva. Large pigment spots were present, principally along the dorsal and ventral outline, and also on top of the head. A few small dots were present on the eye, a few larger ones on the yolksac, and about three large branched ones on the oil globule (fig. 127).

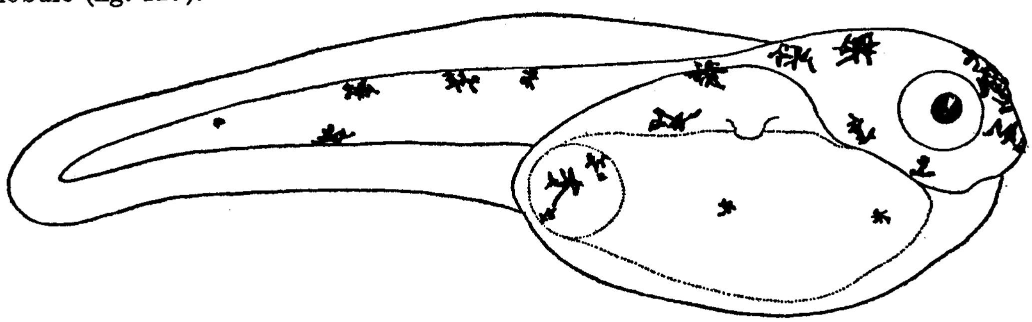

FIGURE 127.—*Urophycis chuss.* From newly hatched larva. (From a camera lucida drawing by W. W. Welsh.)

Specimens of U. floridanus (?) 2.75 to 3.0 mm long.—The body is rather deep, robust, the greatest depth being contained 3.0 to 3.3 times in the length to the end of the notochord. The caudal portion of the body is relatively short and deep, notably shorter (without caudal fin membrane) than head and trunk, its depth just posterior to vent being contained about 2.2 times in its length. Myomeres are indistinct posteriorly. Upward of 40 may be counted. (Number of vertebrae in *regius*, 14+31; in *floridanus*, 16+34; one specimen of each species examined.) The head is large, compressed, and is contained about 3.0 times in the length to the end of the notochord. The mouth is almost vertical, the tip of the lower jaw being about at a level with the upper margin of the eye. The eye is large, fully twice as long as the snout, being contained about 2.0 times in the head. The vertical fin membranes remain continuous around the tail where there are rather distinct indications of the formation of rays. The pectorals are represented by broad short membranes, and the ventrals appear as three hairlike rays, which do not nearly reach the vent, and which at this stage are inserted laterally below the base of the pectorals.

The color markings consist of some dark chromatophores on the head, some more on the back at the base of the dorsal finfold, one to several on the ventral edge of the body above base of the anal, and generally a few to several on the middle of the side, sometimes forming a more or less continuous black line. A few dark dots frequently are present around the mouth, and on the side along the upper margin of the abdomen. The distal part of the ventrals already are slightly dusky (fig. 128).

The specimens described in the foregoing paragraphs are from Beaufort, N. C., and may be *U. floridanus*. In the same lot are specimens that apparently differ only in the absence of dusky color on the ventral fins and generally in having no color markings above the base of the anal. As larger easily recognizable specimens of *U. regius* have no black on the ventral fins, it seems probable that small specimens destitute of this color also are *U. regius*.

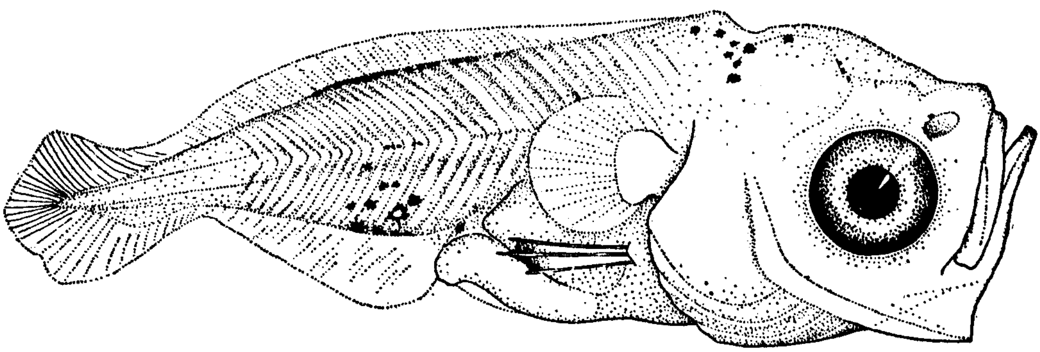

FIGURE 128.—*Urophycis floridanus* (?). From a specimen 3 mm long.

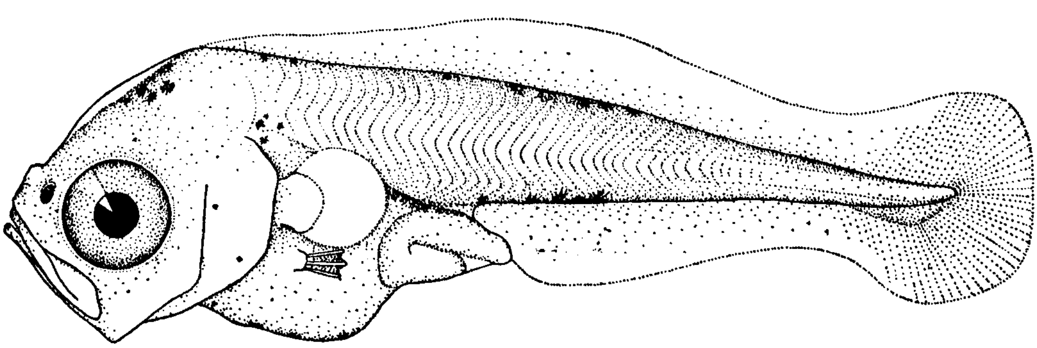

FIGURE 129.—*Urophycis chuss*. From a specimen 2.75 mm long.

In addition to the specimens already described, there are at hand specimens of the same size, taken off Cape Henry, Va., which apparently are representatives of a third species. The larvae differ rather markedly in having a proportionately much longer and more slender tail, the caudal portion of the body (without the finfold) being about equal in length to the head and trunk, and its depth just posterior to the vent is contained about 4.0 times in its length. The development of the ventral fins is somewhat more retarded in these specimens, no rays being present. However, in slightly larger ones in the same lot they are developed, and are distinctly black distally. Other color markings agree with the specimens already described. Larger and easily recognizable specimens of *U. chuss* have the distal parts of the ventrals black. As *U. floridanus*, which also has black ventrals, is not known to occur as far north as Cape Henry, it seems probable that the last described larvae are *U. chuss* (fig. 129).

Specimens about 4.0 mm long.—The advancement in development is not great. In specimens probably of *U. floridanus* the body has become rather more robust, the depth being contained in the length to the end of the notochord about 3.0 times. The caudal portion of the body has become proportionately rather longer, yet it remains decidedly shorter than the rest of the body. The mouth is less strongly vertical, the tip of the lower jaw now being slightly below the level of the middle of the eye. The ventral fins have increased in length and reach to or a little beyond the vent.

No change in color apparently has taken place. Most larvae have more dark dots above the base of the anal than the specimen drawn (fig. 130).

The difference between *U. floridanus* and *U. regius* remains one of color only, as in the smaller specimens, if both species actually are represented among the young at hand. The distal part of the membranes of the ventrals being black in *floridanus*, and pale in *regius*. Furthermore, in *regius* of this size, there generally are no black chromatophores above the base of the anal, though a few exceptions have been noticed.

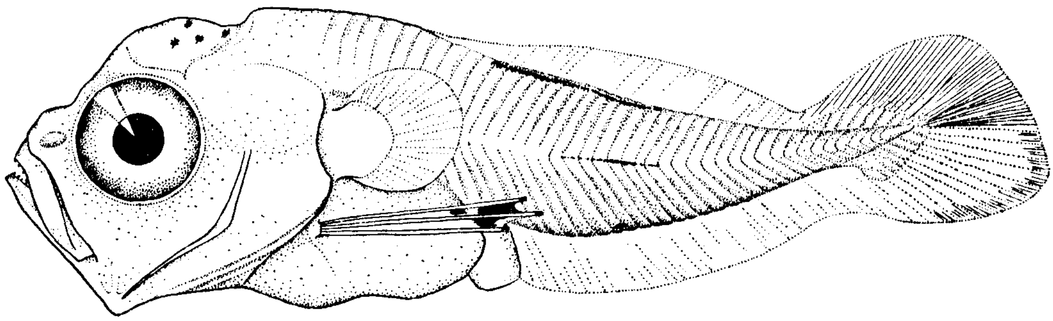

FIGURE 130.—*Urophycis floridanus* (?). From a specimen 4 mm long.

U. chuss continues to differ from both *regius* and *floridanus* in having a longer and more slender tail, though it has become proportionately shorter. Yet it is fully equal (without the caudal finfold) in length to the rest of the body, and its depth just posterior to the vent is contained 3.2 times in its length. The mouth is less nearly vertical than in the other species, and the dorsal profile is rounder. In color this species differs very little from *floridanus*, the black markings being similarly placed, though rather more numerous.

Specimens about 5.0 mm long.—*U. floridanus* apparently is missing among the specimens of this size. In fact, no specimens between a length of about 4.0 and 21 mm appear to be at hand.

In *U. regius* the body has continued to increase in robustness, the depth now being contained in the length to the end of the notochord about 2.8 times. The caudal portion of the body has increased further in proportionate length, and is contained about 1.6 times in the length to the end of the notochord.

It is deep and compressed, its depth just posterior to the vent being contained about 2.0 times in its length. The head is rather deep, compressed, and is contained 2.75 times in the length to the end of the notochord. The eye is nearly twice as long as the snout and is contained 2.75 in the head. The mouth is strongly oblique (not vertical), the tip of the lower jaw being slightly below the middle of the eye, and the maxillary reaches about under the middle of the eye. The notochord is bent upward very slightly distally. The vertical fin membranes remain continuous. The rounded caudal contains fairly well developed rays, but the dorsal and anal are more retarded in development. The pectoral fin membranes remain short and broad, and without definite rays. The ventral hairlike rays (apparently three in number) have increased in length and reach well beyond the vent, the fins remaining inserted laterally below the base of the pectorals.

Black chromatophores remain present on the upper surface of the head, on the back below the anterior half to two-thirds of the dorsal, and occasionally one or more black dots are present at the base of anal. A dark lateral stripe, variable in length, is generally situated above the anterior half of the anal. A dusky area extends upward and forward from the vent, and often a dusky area is present at the upper angle of the gill opening, sometimes extending downward just posterior to the opercle. The fins remain without color, the ventrals being pale throughout.

U. chuss seems to differ from *U. regius* principally in the rather more slender body and in having a proportionately longer and more slender tail, the depth of the body being contained 3.5 times in the length to the end of the notochord; and the tail, from the vent to the tip of the notochord, is contained 2.2 times in the length. The depth just posterior to the vent is contained 2.3 times in the length of the caudal portion of the body to the tip of the notochord. In color *U. chuss* differs principally in that the interradial membranes of the ventrals are black distally (fig. 131).

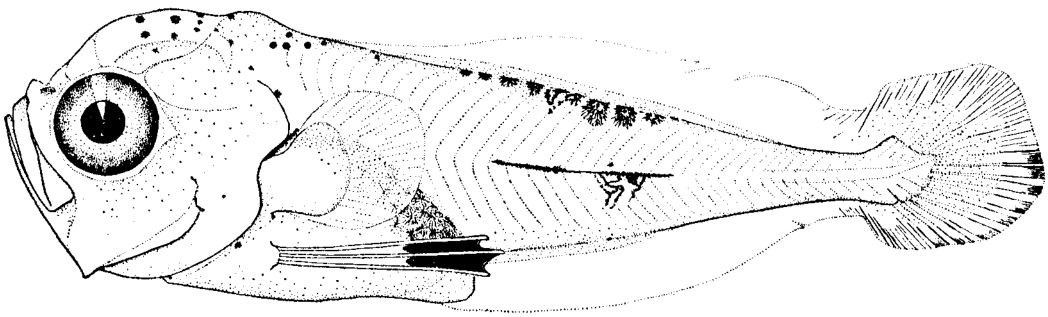

FIGURE 131.—*Urophycis chuss*. From a specimen 5 mm long.

Specimens about 7.0 mm long.—The most important advancement is the development of rays, or at least the fulcra, of most of the dorsal, and to a somewhat lesser extent of the anal rays. The number of rays in the second dorsal, as pointed out elsewhere, is diagnostic, as thereby *regius* (with 46 to 51 rays) is distinguished from the other local species, which have a greater number of rays. It is possible now, with transmitted light and fairly high magnification, to count about 43 fulcra in the second dorsal and about 45 in the anal in specimens with deep short tails, which have no black on the ventral fins. The specimens with short deep tails and without black on the ventrals among the younger stages, as indicated, were suspected of being *regius*. At a length of about 7.0 mm they may be so designated quite definitely, as shown subsequently.

The specimens with the rather longer and more slender tails, and with the ventrals distally black have about 50 to 52 fulcra developed in the second dorsal. The anal is somewhat more retarded in development than the dorsal and the rays and fulcra are not nearly all developed. Although the dorsal fulcra evidently, too, are not quite all developed, it is evident that the number that will be developed is greater than in adult *regius*. The specimens with the higher number of fulcra, developed at a length of about 7.0 mm, are from the vicinity of Cape Henry, Va., farther north than *floridanus* is known to occur. The only species recorded from the coast of Virginia are *regius* and *chuss*. The specimens with the larger number of rays or fulcra in the dorsal certainly are not *regius*, and therefore apparently must be *chuss*.

It has been pointed out that in smaller specimens the caudal portion of the body was proportionately longer and more slender in *chuss* than in *regius*. This difference persists, but it is no longer pronounced. The distance from the vent to the tip of the notochord, in specimens about 7.0 mm long, is contained in the length of the fish, without the caudal fin, about 2.25 times in *regius*, and 2.1 times in *chuss*, and the depth just posterior to the vent is contained in the length of the tail 2.1 times in *regius*, and 2.5 times in *chuss*.

The body in both species has become more elongate, the depth in *regius* being contained 3.4 times in the length without the caudal fin, and 3.6 times in *chuss*.

The color is variable among specimens of both species, though not essentially different from smaller ones already described (figs. 132 and 133).

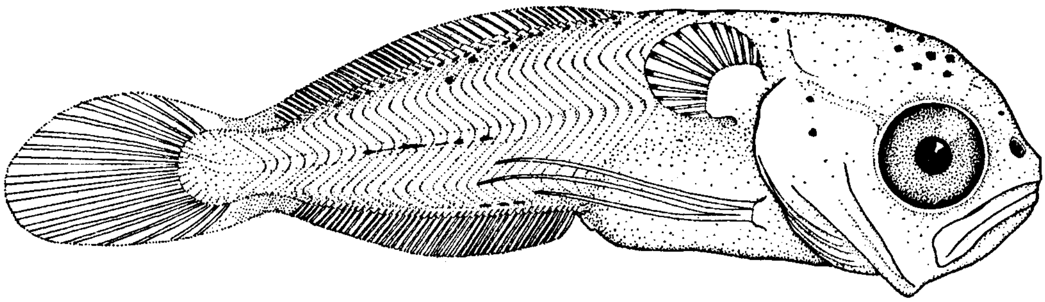

FIGURE 132.—*Urophycis regius*. From a specimen 7 mm long.

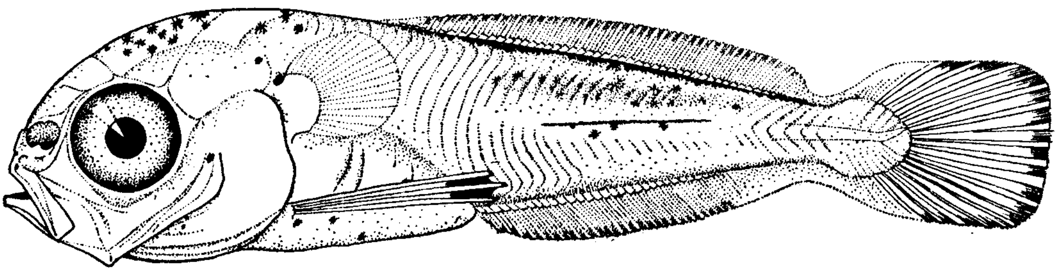

FIGURE 133.—*Urophycis chuss*. From a specimen 7.25 mm long.

Specimens 9.0 to 11 mm long.—The body in *regius*, as well as in *chuss*, has continued to grow proportionately more elongate, though it remains decidedly compressed. The depth in *regius* is contained 3.8 to 3.9 times in the standard length, and in *chuss* 4.0 to 4.3 times. The caudal portion of the body (without the caudal fin) is almost exactly equal in length to the head and trunk in *regius*, whereas in *chuss* it is noticeably longer. It is also deeper in *regius*, the depth just behind the vent being contained 2.9 times in the distance from the vent to the base of the caudal, whereas it is contained 3.1 to 3.3 times in that distance in *chuss*.

The mouth has become much less strongly oblique. However, it remains a little more strongly oblique in *regius* (wherein the tip of the lower jaw is about at the level of the lower margin of the eye) than in *chuss*, in which it is well below the eye.

The first dorsal is partly formed in both species under discussion, and is situated over the base of the pectoral. The second dorsal is well enough developed to permit a fairly accurate count of the rays, and especially of the fulcra. In *regius* 47 and 50 fulcra were counted, and in *chuss* 55 and 56, in two specimens of each species examined.

The anal rays are more retarded in development, and a full count is not yet obtainable. The pectoral fins remain short and rounded in both species. The ventral fins, though still lateral, are lower on the side and rather farther forward than in smaller fish, being inserted somewhat in advance of the base of pectorals, and the rays, of which three distinct ones of about equal length are present, reach well beyond the origin of the anal.

In color the two species do not seem to differ, except for the black on the ventrals in *chuss*, which is missing in *regius*. The number of dark dots have increased somewhat, though there is much variation among specimens. All specimens at hand of both species have black chromatophores on the head and back. Some specimens have black dots on the cheeks and opercles, some have a dark lateral stripe variable in length, and in others these markings are missing, apparently without regard to species. In the larger specimens of this group, dusky specks have begun to appear on the first dorsal (fig. 134).

Specimens about 15 mm long.—No pronounced changes in development have taken place since a length of 9.0 to 11 mm was attained in either species. However, the first dorsal is considerably higher and better developed, and the pectoral fins have become much longer, as shown in the accompanying illustrations. The caudal fin is quite variable in shape, for it may be rounded, straight, or slightly concave. The chin barbel first becomes evident in specimens of about this size.

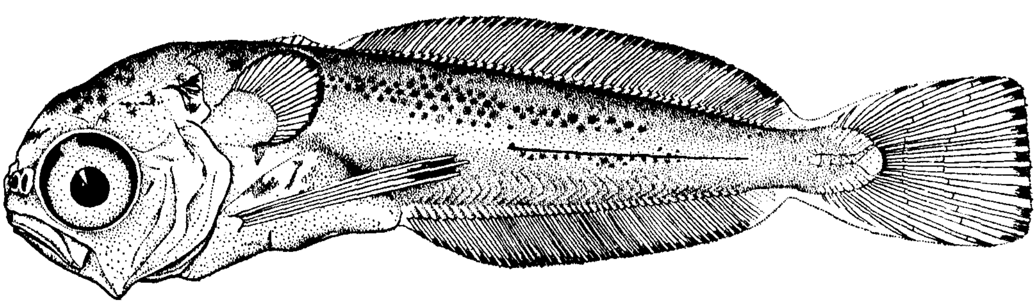

FIGURE 134.—*Urophycis chuss*. From a specimen 9.5 mm long.

The color is variable among specimens, some being more profusely spotted than others. In general, dark pigment has increased in both species. However, the only distinguishing feature in color noticed is the black on the distal part of the ventral in *chuss*, which is missing in *regius*, just as in much smaller specimens (figs. 135 and 136).

The proportionate length and depth of the caudal portion of the body, which aided in separating smaller specimens of *regius* and *chuss*, are now so nearly the same that the distinction has vanished.

The rays in the dorsal and anal, at least in some specimens, are not quite all formed. The development in 15-mm specimens, as in smaller ones, is rather more retarded in *chuss* than in *regius*. Some of the rays and fulcra remain difficult to see. However, with the use of comparatively high magnification and transmitted light, 9–54 rays were counted in the dorsal and 54 or 55 in the anal in three specimens of *chuss*. In two specimens of *regius* 7–46 and 7–47 rays were counted in the dorsal, and 44 and 47 in the anal. The counts, as shown in the key to the species, for adult *chuss* are—dorsal 9 to 11–56 to 61, anal 52 to 56; and for adult *regius*, dorsal 8 or 9–46 to 51, anal 39 to 49. Therefore, the difference in the counts between the two species in 15-mm specimens is quite evident.

The anal ray counts definitely separate *chuss* from *floridanus*, as the adults of the latter have only 40 to 49 anal rays. The specimens herein described as *chuss* were taken off Kitty Hawk, N. C., and northward, where *floridanus* is not known to occur. The smaller specimens were so identified largely by "locality", as in the absence of specimens of *floridanus* of similar size it was not possible to know how the two species differed. The anal fin ray counts in 15-mm fish, however, aid in establishing the identification on a morphological basis.

Specimens about 25 mm long.—At this length three species; namely, *regius*, *floridanus*, and *chuss*, are recognizable among the specimens studied, principally by the number of rays in the dorsal and anal fins, and by the length of the chin barbel, as shown subsequently.

The species are not distinguishable by the shape of the body, the shape and length of the head, the eye, the snout, nor the mouth. The body has become quite slender, and remains compressed, the depth in any one of the three species named being contained about 4.0 to 4.6 times in the standard length, and the head 3.3 to

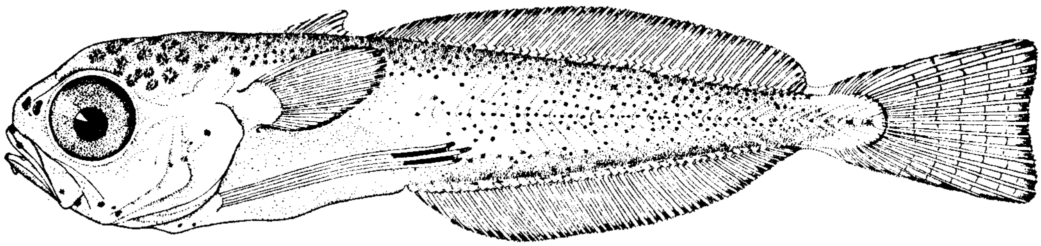

FIGURE 135.—*Urophycis chuss*. From a specimen 15 mm long.

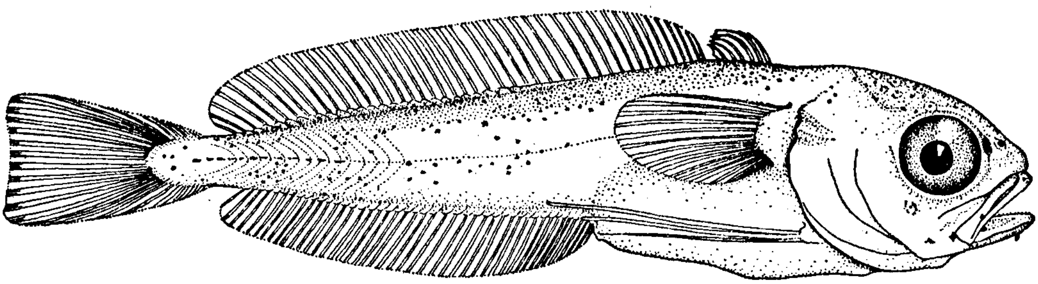

FIGURE 136.—*Urophycis regius*. From a specimen 15 mm long.

4.0 times. The snout is gradually increasing in length, being contained in the head about 4.0 to 4.4 times, and the eye 3.3 to 3.6 times. The mouth remains only slightly oblique, and it has become somewhat inferior, with the upper jaw a little in advance of the lower one, and the snout projecting slightly beyond the upper jaw. The maxillary reaches to or a little beyond the posterior margin of the pupil.

The barbel at the symphysis of the lower jaw, which first made its appearance in *regius* and *chuss* when about 15 mm long, remains minute, being scarcely a fourth the length of the pupil in those species. No specimens of *floridanus* around 15 mm in length are at hand. In specimens of this species, about 25 mm long, it is much longer than in the other species, being fully equal to the length of the pupil. The greater length of the chin barbel is a readily available morphological character at this size, as well as among larger fish, for separating *floridanus* from both *regius* and *chuss*.

Scales are present at a length of 25 mm in all three species, though not shown in the accompanying illustration. The series cannot be definitely enumerated, but it is evident already that the scales are larger in *regius* than in the other species.

The difference in the number of dorsal rays between *regius* and *chuss* is pointed out in a preceding section, as well as in the key to the species. However, *chuss* and *floridanus* have so nearly the same number of rays in the dorsal that they cannot be separated readily, if at all, by that character. Nevertheless, the last-mentioned species differ in the number of anal rays, *chuss* having 52 to 56, whereas *floridanus* has only 40 to 49 (the same number as in *regius*), as shown in the key to the species. The anal rays are well enough developed when the fish reach a length of about 25 mm to permit the use of this distinguishing character.

Much variation in color exists among specimens, some individuals being much more profusely spotted than others. The two specimens of *chuss* of this size at hand are much more profusely dotted than any others. However, insufficient specimens are available to determine whether it is of specific significance. The ventral fins of *floridanus* are black distally. However, no black is evident on these fins in the old preserved specimens of *chuss*, though of course the smaller ones have it. The first dorsal is partly dusky, there being as yet no distinction among the species in this respect (fig. 137).

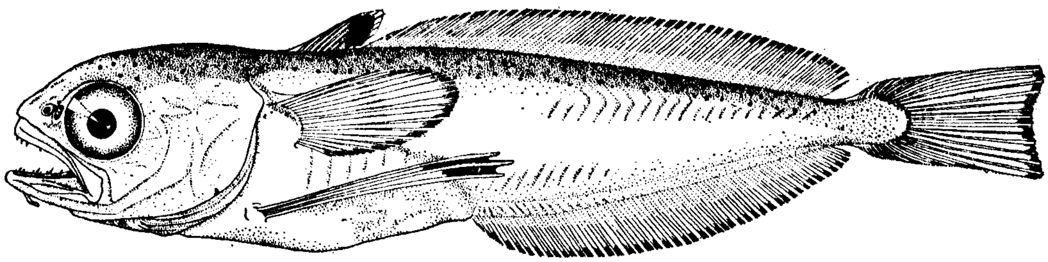

FIGURE 137.—*Urophycis floridanus*. From a specimen 26 mm long.

Specimens 35 to 50 mm long.—The three species; namely, *regius*, *floridanus*, and *chuss*, discussed in the preceding section, are readily recognizable among specimens 40 to 55 mm in length. They are distinguishable by the characters pointed out in the preceding section and some additional ones, as shown subsequently. A fourth species, namely, *earlli*, also is present. This species is discussed separately.

The body has continued to grow more slender and less strongly compressed, especially anteriorly, in *regius*, *floridanus*, and *chuss*. No measurable difference in the range in depth seems to exist among these species. In nine specimens, including three of each species, the range of the depth in the standard length is 5.0 to 5.75. In the same specimens, the head is contained 3.7 to 4.1 times in the standard length. The snout now is equal to, or only slightly shorter than the eye, being contained 3.75 to 4.5 in the head. The mouth is slightly oblique, and is definitely inferior, being situated essentially as in adults. The maxillary is broad posteriorly, and reaches nearly or quite opposite the posterior margin of the eye, being contained 1.8 to 2.2 times in the head.

The maxillary barbel remains minute in *regius* and *chuss*, wherein it is scarcely half as long as the pupil. In *floridanus* it is much longer, being equal to fully half the diameter of the eye.

The scales are quite fully developed and the series can be counted fairly accurately. (The number present in the different species is shown in the key to the species.) It is plainly evident, under magnification, without counting, that *regius* has notably larger scales than the other species.

The fins are all developed essentially as in adults. The pectoral fins are longer in *regius*, wherein they reach beyond the origin of the anal, than in the other species in which they generally fail to reach opposite the origin of the anal. The ventrals are scarcely lateral; they are inserted well in advance of the pectorals, or nearly under the margin of the preopercle. The rays now generally appear as two in number, though a third short one sometimes remains evident. The two long rays (filaments) are free from each other distally, and they are rather variable in length, within any one species, the upper or outer one, which is the longer, generally reaches to or beyond the origin of the anal. The caudal fin varies in shape in all species, as its margin may be round, straight, or concave. The differences in the counts of the rays in the dorsal and anal fins are shown in the key to the species.

Pigmentation has become quite general, though variable among specimens of any one species. The color of preserved specimens is pale to rather dark brown above, and generally silvery below. In life *regius* and *floridanus* (no fresh specimens of *chuss* seen by us) may be bright green to bluish above, and the sides and lower parts bright silvery. The extent to which the body is covered with brownish dots varies even among specimens of the same species caught in one haul. The black on the distal part of the ventrals, present in smaller specimens of *floridanus* and *chuss*, rarely remains visible in specimens 40 mm long, and was not seen in any fish 50 mm and upward in length. The black on the first dorsal is now quite definitely surrounded by white, at least distally, in *regius* and distinguishes that species from *floridanus* and *chuss* in which the black extends nearly or quite to the margin of the fin and is not surrounded by white (fig. 138).

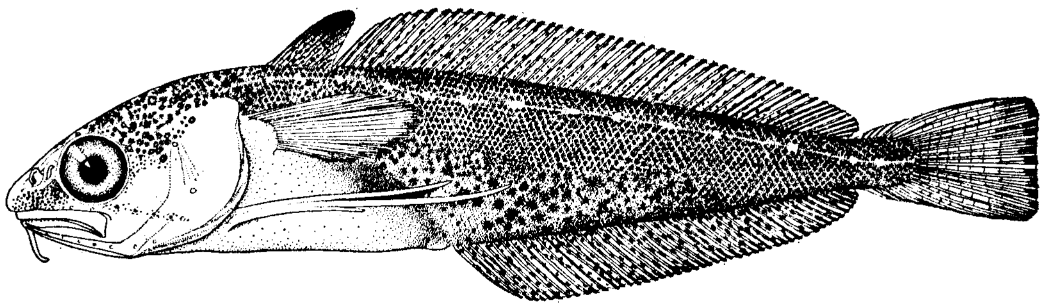

FIGURE 138.—*Urophycis floridanus*. From a specimen 40 mm long.

The fourth species, namely, *earlli*, is represented by a single specimen 37 mm long. This fish does not differ from the other species in the proportions usually calculated. However, it has much smaller scales, and the dorsal and anal rays are more numerous. (The counts are given in the key to the species.) The mouth is nearly horizontal and inferior, as in the other species, and the maxillary reaches almost below the posterior margin of the eye. The chin barbel is long and slender, even longer than in *floridanus*, as it exceeds half the length of eye.

The general color is dark brown, much darker than the darkest specimens of the other species, and this color extends on the dorsal and anal fins, only the margins posteriorly being pale. In fact, these fins are darker than the body. Only the chest and abdomen are silvery. The first dorsal is no darker than most of the second one. The caudal fin is dark brown at the base, and the rest of the fin is plain translucent. The pectorals and ventrals are brown at the base and colorless elsewhere (fig. 139).

Specimens 60 to 75 mm long.—The four species discussed in this work; namely, *chuss*, *regius*, *floridans*, and *earlli*, are all represented among the specimens of this size. In general, the characters of the adults, pointed out in the key to the species, can be used in separating the species. Therefore, only changes in development are pointed out in the following paragraphs.

The body has become slightly more elongate, and the head proportionately lower and broader. The interorbital now is equal to or wider than the eye in all four species. The snout has increased in proportionate length, and is definitely longer than the eye. If specimens of equal length are compared it is evident that *regius*, and especially *chuss*, have somewhat larger eyes than the other species. The longer pectoral of *regius* is quite distinctive at this size, falling short of the length of the head by only half the snout, whereas in the other species this fin does not exceed the length of the head without the snout.

The color continues to vary markedly among the specimens of any one species. However, *earlli* is notably darker, and has almost black fins. The dark stripe, broken by roundish pale spots at intervals, rather shorter than the diameter of the eye, in which the lateral line lies in adults of *regius* and *floridanus*, only, sometimes is present when the fish have reached a length of 60 mm, but often not until much later. Sometimes the pale spots appear in advance of the black stripe. In *regius* and *floridanus* four black dots in a vertical row sometimes are present behind the eye in specimens 60 mm long, but often not until much later, the upper one of which is in line with another spot over the eye and a third one over the posterior nostril. In addition about three dark dots are situated on the opercle. A pore is present in the center of each black spot. The pores, apparently are present in *chuss* and *earlli*, too, but in those species they are not surrounded with black.

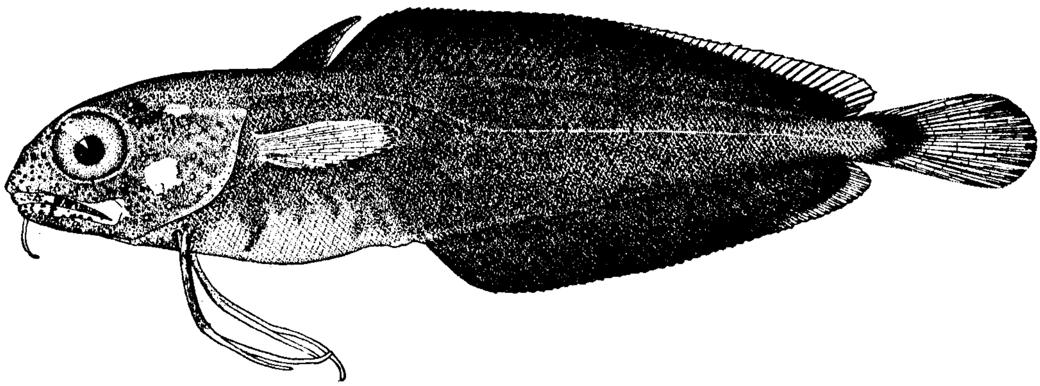

FIGURE 139.—*Urophycis earlli.* From a specimen 37 mm long.

Specimens 100 mm and upward in length.—The body in *regius*, *floridanus*, and *earlli* becomes more robust with age, and also rather deeper, the proportionate depth being about equal in all these species and contained 3.9 to 5.0 times in the standard length. Adults of *chuss* are notably more elongate, especially large fish, than those of the other species, the depth being contained 5.1 to 5.5 times in the length.

The head becomes broader and more depressed with age. This change is especially pronounced in *chuss*, for in large specimens of this species it is notably wider than deep, at the middle of the eyes, whereas in the other species the width of the head at the same point is about equal to its depth.

The larger eye in *chuss* becomes more noticeable with age. It is quite as wide as the interorbital in fish about 200 mm long, and is contained 4.1 to 4.6 times in the head. In specimens of about the same size of *regius*, which have a rather larger eye than those of *floridanus* and *earlli*, it is much narrower than the interorbital, and is contained 5.1 to 6.5 times in the head. The snout increases in proportionate length as the eye decreases, and in all species in specimens 100 mm and upward in length the snout is noticeably longer than the eye. It is a little broader in *chuss* than in the other species, and, perhaps because of the larger eye, the maxillary reaches only to the posterior margin of the eye, whereas it reaches well beyond this point in large specimens of the other species. The snout projects more prominently beyond the mouth with age in all the species, and it becomes quite conical, though a little depressed in *chuss*.

The chin barbel remains short throughout life in *regius* and *chuss*, in which it never exceeds the pupil of the eye in length. In large specimens of *floridanus* and *earlli* it is nearly or quite equal to the diameter of the eye.

The third ray of the first dorsal is greatly produced in adults of *chuss*, reaching about to the end of the first third of the second dorsal. It is not evident at what size the ray becomes produced from the specimens at hand, as fish ranging from 70 to 185 mm in length are missing. In the smaller fish it is not produced, but in the larger ones it is long. In all the other species the first dorsal becomes rather pointed, but none of the rays are especially produced. The differences in the length and shape of the other fins remain about the same as in smaller specimens already discussed.

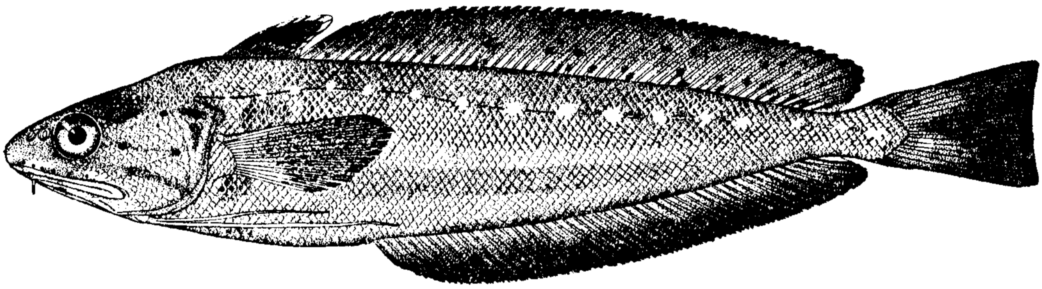

FIGURE 140.—*Urophycis regius*. From a specimen 124 mm long.

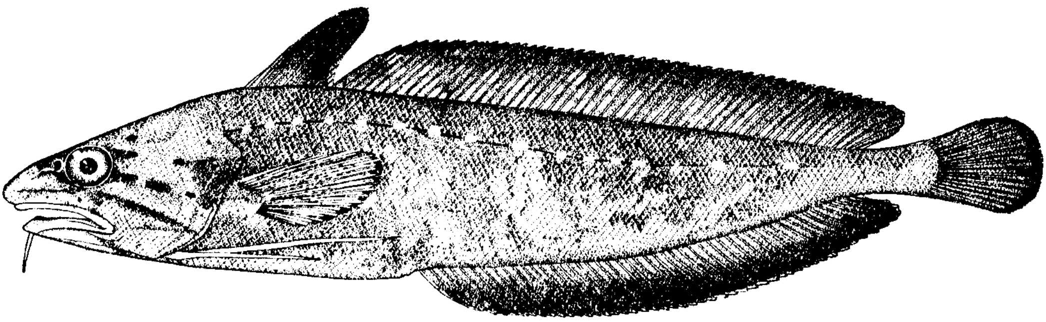

FIGURE 141.—*Urophycis floridanus*. From a specimen 126 mm long.

The differences in color remain virtually the same as in the smaller specimens described in the immediately preceding section. The general color of *earlli* remains much darker than in any of the other species. A specimen about 100 mm long is uniform dark brown, with the vertical fins almost black. Larger fish sometimes are more or less blotched with pale color. No deep black is evident on the first dorsal, as in the other species herein considered. Of these, *regius* differs strikingly in having the deep black color of this fin margined with snow white (figs. 140 and 141).

DISTRIBUTION OF THE YOUNG

It is shown under the heading, "Spawning," that the early larvae, under 5.0 mm in length, apparently consisting of both *regius* and *floridanus*, the only common species of Urophycis at Beaufort, were taken only at stations 6 to 13 miles offshore, beyond which no collecting was done. Larger young, too, were taken offshore as well as near the shore. However, no young measuring less than 40 mm long were found in the bays and estuaries, and not many until a length of 50 to 60 mm had been attained. Thereafter, for a period of about 3 months, February, March, and April, they were common to numerous on muddy bottom in the estuary of Newport River, but no more so than on the very muddy bottom in the vicinity of the "sea buoy" at the entrance of Beaufort Inlet. However, those taken in Newport River averaged larger in size. *U. regius* nearly always was greatly in the majority, though in its habitat it did not seem to differ from *floridanus*.

The young, up to 40 mm in length, sometimes were taken at the surface, though more frequently at the bottom. All the larvae, except one specimen measuring under 10 mm in length were taken in surface nets. Presuming that the eggs of *regius* and *floridanus* are pelagic, like those of *chuss*, the young would be expected to remain at the surface, where they are hatched, at least until the yolksac, with its oil globule, is absorbed. That they not only stay there until the yolk is absorbed but for some time afterward, is indicated by the catches made. However, the hakes, with inferior mouths and ventral fins developed as feelers (presumably for prowling around on the bottom), are typical bottom-dwelling fishes. According to our data that is the common, if not the exclusive, habitat after a length of 40 mm or so is attained. Futhermore, they seem to prefer muddy bottom, as already stated.

Although young *regius* and *floridanus* are common to numerous, in the areas named, during winter and early spring, they disappear almost entirely from shallow water by June 1, and the adults either are scarce or missing at all times. Definite information as to where the young go was not obtained. It seems probable, however, that they merely withdraw to deeper water. It at least seems rather certain that the adults are common in the offshore waters in the vicinity of Beaufort during the reproductive season as considerable spawning must take place locally, for the young at times were taken in great abundance, outnumbering all other species. In the absence of information to the contrary, it may perhaps be assumed that the deeper offshore water is the regular habitat of the local species of hakes. The abundance of the young in the shallow water during their first winter suggests an abundant population. It might even be possible to develop a hake fishery if their habitat could be located, which apparently should be sought in rather deep water with muddy bottom.

GROWTH

The measurements of fish tabulated in the accompanying tables are based wholly on young fish believed to be 6 or 7 months and less of age. Certainly there is no break in the growth curve. Very few larger fish were taken. Assuming that the fish for which measurements are given are all under 6 or 7 months old a rapid rate of growth is indicated, for a few individuals of both *regius* and *floridanus* apparently reached a length slightly upward of 8 inches at an age of about 6 months. If *regius* attains a length of only about 16 inches and *floridanus* is even smaller, as shown by the data available, early maturity surely would result if such a rapid rate of growth were maintained.

TABLE 1.—*Length frequencies of 2,054 hakes (Urophycis regius), all less than a year old*

[Measurements to nearest mm; in 5-mm groups]

Millimeters	November	December	January	February	March	April	May	June
0-4	1	6						
5-9		2						
10-14		1						
15-19		4						
20-24		5		1				
25-29								
30-34					1		1	
35-39			1	13		2		
40-44			4	71	4	4		
45-49			22	89	10	2		
50-54			25	53	20	12	2	
55-59			10	47	29	24	2	
60-64			4	57	31	10		
65-69			1	46	33	8		
70-74			3	56	32	7		
75-79			1	35	41	1	1	
80-84				24	62	1	1	
85-89			1	28	52	4		
90-94				23	75	7	1	
95-99				20	59	9		
100-104			2	18	66	11		
105-109				9	63	17		
110-114				12	46	31	1	
115-119				3	50	26	1	
120-124				7	46	18	2	
125-129				7	33	18	2	
130-134				5	37	24		
135-139				4	22	16		
140-144				2	28	19	2	
145-149				3	23	20	1	
150-154					11	17		1
155-159					13	16		
160-164					8	12	1	
165-169					3	15		
170-174						14		
175-179					1	7		
180-184					1	7	2	
185-189				1	2	10		
190-194					1	3		
195-199						4		
200-204						3		
205-209						2		
210-214								
215-219						1	1	

TABLE 2.—*Monthly summaries of length measurements of 2,054 hakes (Urophycis regius) during the first several months of life*

[Measurements based on the same fish as in table 1]

Month	Fish measured	Smallest	Largest	Average	Month	Fish measured	Smallest	Largest	Average
		Mm	*Mm*	*Mm*			*Mm*	*Mm*	*Mm*
November	1	3.0			March	902	30.00	192	102.3
December	18	2.75	23	18.8	April	402	38.00	215	123.9
January	74	38.00	101	53.9	May	21	33.00	219	115.3
February	634	24.00	147	67.0	June	1	152.00		

TABLE 3.—*Length frequencies of 218 hakes (Urophycis floridanus), all less than a year old*

[Measurements to nearest mm; in 5-mm groups]

Millimeters	December	January	February	March	April	May
0–4	6					
5–9						
10–14						
15–19						
20–24	1		1			
25–29	3	1				
30–34		1				
35–39			4	1		
40–44	1		13	1		
45–49		2	4			
50–54			8	1		
55–59			7	2		
60–64		1	2	6		
65–69			2	3		
70–74			3	5		
75–79			1	8		
80–84			1	5	1	
85–89				3	1	2
90–94			1	7	1	1
95–99				4	1	1
100–104				2	3	
105–109					1	1
110–114				1		3
115–119				1	3	1
120–124					1	4
125–129					2	2
130–134					4	3
135–139				1	5	3
140–144					3	2
145–149					5	3
150–154					2	1
155–159					1	2
160–164					3	2
165–169					3	
170–174					5	1
175–179					5	1
180–184					5	1
185–189					4	
190–194					2	2
195–199						1
200–204					3	1
205–209						
210–214					1	

TABLE 4.—*Monthly summaries of length measurements of 218 hakes (Urophycis floridanus), during the first several months of life*

[Measurements based on the same fish as in table 3]

Month	Fish measured	Smallest	Largest	Average	Month	Fish measured	Smallest	Largest	Average
		Mm	*Mm*	*Mm*			*Mm*	*Mm*	*Mm*
December	11	3	40	14.8	March	51	37	135	79.6
January	5	25	62	45.0	April	66	83	212	152.8
February	47	24	91	51.7	May	38	86	202	139.5

ACHIRUS FASCIATUS LACÉPÈDE. AMERICAN SOLE

The American sole, *Achirus fasciatus*,[13] as understood here, ranges from Massachusetts to Texas, and is also recorded from the Atlantic coast of Panama. This species is very common on the coast of North Carolina, where it is often found in abundance in estuaries, and the mouths of fresh-water streams, on muddy bottom. It generally may be secured in numbers in the estuary of the Newport River at Beaufort, and the young especially range in abundance up the river into fresh water.

Small examples of this sole sometimes are taken in fresh water far from the sea. For example, it is a more or less permanent resident, at least during the summer, of the Potomac River as far up as Washington. The senior author also has seen a small specimen taken in the Savannah River at Augusta, Ga., slightly more than 200 miles from the sea, following the course of the river. He also has a specimen from the Pascagoula River, taken at Merrill, Miss., probably fully 75 miles by the course of the river from the Gulf, where we were informed by a local game warden the fish, though considered a curiosity, is taken from time to time. It may be said, therefore, that this sole ranges from salt, through brackish water, and sometimes far into fresh water. However, in the vicinity of Beaufort, N. C., at least, it is most numerous in water that is more or less brackish. It is, of course, a bottom-dwelling fish, like other flatfishes.

The usual book name of this species is American sole. In the field the names, sole, flounder, and hogchoker, are heard. In North Carolina hogchoker is almost universally used. In bygone times, and to a limited extent to the present day, hogs have fed on waste fish, cast on the shore by fishermen. Among them, of course, was the sole, for it has no commercial value. It is related that occasionally this sole actually became a hogchoker. In case the hog masticated poorly and tried to swallow the fish tail foremost, the fish sometimes lodged in the hog's throat, because of its extremely rough (ctenoid) scales. The hog, apparently being unable either to swallow or regurgitate the fish, eventually was choked to death.

CHARACTERS OF THE ADULT

The hogchoker is characterized chiefly by the short deep body, the depth generally being contained in the length to the base of the caudal fin considerably less than two (1.6 to 1.81) times. The eyes, which are very small, and the color, are on the right side of the body. The color is variable; generally it is brownish with darker blotches, and with about seven or eight dark cross lines. The mouth is very small, terminal, and the jaws are twisted; the maxillary reaches under the lower eye. The dorsal and anal fins are long, the former having 50 to 56 rays and the latter 36 to 42. The caudal fin is round, and the pectoral fins are missing.

METHODS OF COLLECTING

Adult fish, as well as young ones ranging upward of 18 mm in length, were collected mostly with otter trawls, though larger ones frequently were taken with seines also.

[13] Considerable discussion relative to the correct scientific name of the American sole has taken place during the past several years The reader interested is referred to Chabanaud (1928 and 1935), Myers (1929), and Hubbs (1932.) If the set-up of genera proposed by Chabanand, who recognizes more genera than most authors, is accepted the name, *Achirus*, is not available for the American sole, and is replaced by *Trinectes*. According to Hubbs and Chabanaud, *fasciatus* should be replaced by *maculatus*. Notwithstanding that this name was assigned to a fish of the Indian fauna by the original describers, it is now claimed that the designation of that locality was an error. Therefore, the last mentioned authors arrive at the conclusion that the correct name of the American sole is *Trinectes maculatus* (Bloch and Schneider). The present writers, nevertheless, prefer to retain the long familiar name, *Achirus fasciatus*, for the reason that the extensive splitting of genera does not seem to us to be advantageous, and because there seems to be insufficient evidence that *fasciatus* actually is a synonym of *maculatus*.

The eggs were often secured in abundance with meter tow nets made of number 20 bolting silk. They were also obtained several times from the overflow of tanks supplied with running water in which gravid fish were confined. Unfortunately the eggs secured from fish in captivity never appeared to be fertilized, presumably because no ripe males were present. However, these eggs served a very useful purpose, as they aided us in positively identifying hogchoker eggs taken in the tow.

Hogchoker eggs, indeed, had been taken in the tow by us over a period of several summers before their identity became definitely known on June 8, 1929, from a comparison with eggs secured from fish held in confinement.[14]

The more advanced stages of the larvae shown in the accompanying illustrations were drawn from fish reared in the laboratory by the junior author. In the rearing experiments comparatively large numbers of young were placed in glass evaporating dishes having a depth of about 3 inches and a diameter of 8 to 10 inches. Only about an inch of water was used in each dish, thus exposing a large surface, in comparison with the small amount of water, to the air for absorption of oxygen. No artificial aeration was used. To keep the water at a fairly uniform temperature the dishes were partly submerged in the large laboratory tanks supplied with running sea water fed from a 12,000 gallon tank by gravity.

While the larvae were very small they were fed daily with towings strained through number 20 bolting silk. After the fish had gained some growth, towings were introduced without straining. Ample time for feeding, that is, an hour or so, was given after introducing the towings, and then the fish were removed with a pipette to clean dishes supplied with water brought to the laboratory in a clean container directly from the laboratory pier.

SPAWNING

The spawning season of the hogchoker seems to be a long one, the eggs having been obtained from spawning fish held in tanks, as early as May 18 (1931), and as late as August 14 (1930). In the tow the eggs were noticed as early as May 20 (1931), and as late as August 5 (1928). It is evident, then, that at Beaufort the spawning season extends, at least from midspring to midsummer.

Ripe or nearly ripe fish were taken only in the estuary of Newport River, where the eggs also were secured. However, eggs also were taken in several other localities within the harbor, as well as at sea as far out as 6 miles off Bogue Banks. Hogchoker eggs often were collected in abundance, being among the most numerous fish eggs in season.

Spawning evidently takes place only in the evening, principally from about 6 to 8 o'clock. It was during that time when the eggs were spawned in the laboratory tanks, and it was only in the *early* evening, as shown by many towings, that eggs in early cleavage stages were secured. In addition to the very recently spawned eggs, older ones with rather well-developed embryos, extending about two-thirds the distance around the periphery of the eggs, were present in the early evening towings. The older eggs evidently had been spawned the previous evening, and were about 24 hours old.

According to other studies made at Beaufort, partly published by the writers (1930) and partly still unpublished, it would seem that early evening spawning is quite usual among marine fishes.

[14] Dr. Albert Kuntz, working for the Bureau of Fisheries at Beaufort, N. C., temporarily, secured the eggs, drew up descriptions and had sketches of the development of the eggs and early young prepared (unpublished) as early as 1913. However, the eggs were not identified. In 1916 Dr. Lewis Radcliffe secured the eggs in Chesapeake Bay, drew up descriptions and some sketches (also unpublished), which he labeled "hogchoker." How he arrived at the tentative conclusion is not evident from his notes.

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Although the eggs were very numerous in the tow at times during the spawning season, the larvae were not found, notwithstanding that an extensive search was made for them. The smallest young taken in nature was 18 mm long. Therefore, nothing can be reported at this time on the habitat and distribution of the larvae.

DESCRIPTIONS OF THE EGGS AND YOUNG

The eggs are spherical, richly supplied with oil globules, and float at the surface. According to 200 unfertilized eggs, spawned in a tank on two different dates (the product of two or more fish), the diameter varies from 0.66 to 0.84 mm, the average being 0.73 mm. Eggs especially selected for range in size from several hundred taken in the tow, and in an advanced cleavage stage when measured, ranged in diameter from 0.67 to 0.71 mm.

The oil globules are variable in number, as few as 15 and as many as 34 having been counted. They also are variable in distribution, sometimes lying close together, giving the egg a beaded appearance, and sometimes more or less uniformily distributed over the surface of the egg. They also vary in size from very minute dots to about 0.06 mm in diameter. The variation in position, number, and size is shown, at least in part, in the accompanying drawings. The large number of oil gloubles give the egg buoyancy. No perivitalline space is noticeable (fig. 142).

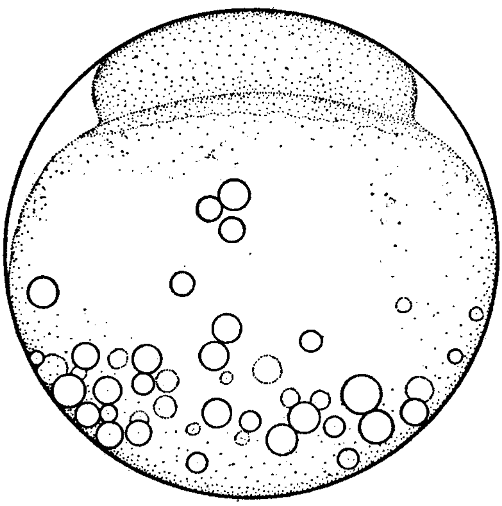

FIGURE 142.—*Achirus fasciatus*. From egg with fully formed blastodisc.

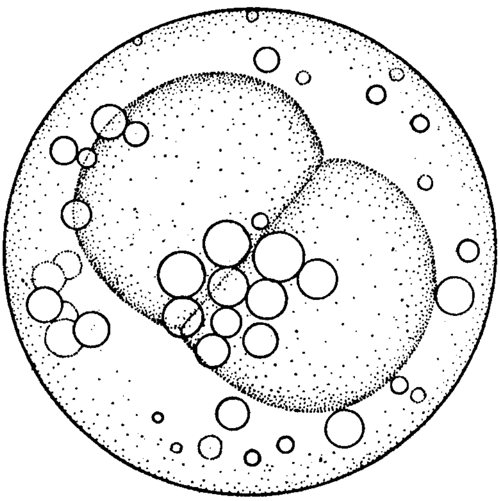

FIGURE 143.—*Achirus fasciatus*. From egg in 2-cell stage; about half hour after fertilization.

The eggs, though quite transparent, have a slight greenish tinge (described as yellowish by Albert Kuntz, MS.) This color seems to be contained in minute yolk granules, discernible under rather high magnification (fig. 143).

Cell division proceeds rapidly after fertilization. Eggs collected between 7:30 and 8 p. m. (May 20, 1931), quite surely spawned after 6 p. m. of the same day, ranged from four-cell to many-cell stages when examined in the laboratory at 8:30 p. m. on the same evening (figs. 144 to 147). An hour later, or from about 2 to 3 hours after fertilization, all had reached advanced cleavage stages (fig. 147).

On the morning of the following day, or about 13 to 14 hours after fertilization, the eggs contained well-outlined embryos, with eyes just becoming visible, the stage showing the embryonic streak having been passed in the meantime (figs. 148 and 149). About 20 hours after fertilization the embryo extended almost two-thirds the distance around the periphery of the egg; and at 26 hours after fertilization it extended fully three-fourths the distance around the egg. Its tail was sharply recurved, its heart was beating slowly, and it was capable of considerable movement (fig. 150).

When next observed, about 36 hours after fertilization, the eggs had hatched; that is, hatching had taken place sometime between 26 and 36 hours after fertilization. The temperature of the water in the dishes in which the eggs were hatched had varied only from about 74° to 76° F.

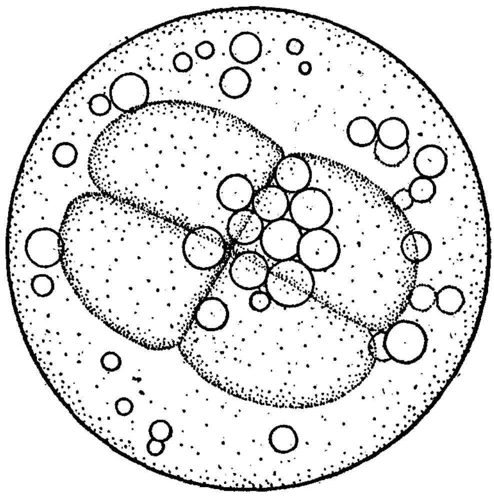

FIGURE 144.—*Achirus fasciatus.* From egg in 4-cell stage, following the 2-cell stage in about 15 minutes.

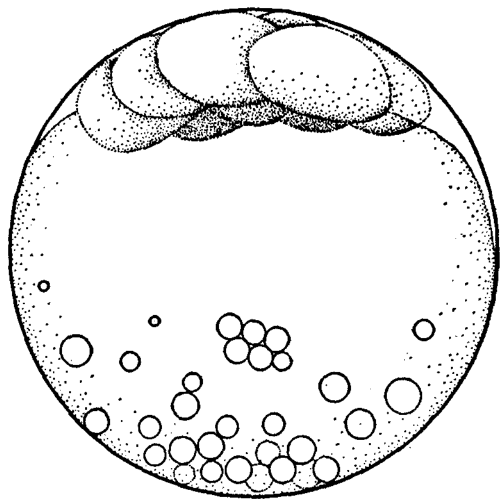

FIGURE 145.—*Achirus fasciatus.* From egg in 8-cell stage, following the 4-cell stage in about 15 minutes.

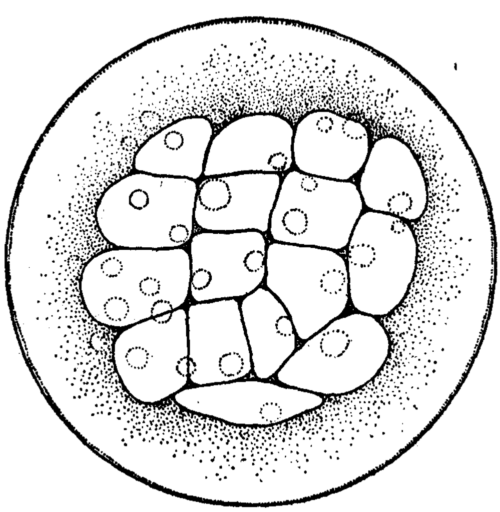

FIGURE 146.—*Achirus fasciatus.* From egg in 16-cell stage, showing irregularity of cells. (Drawn by Effie B. Decker.)

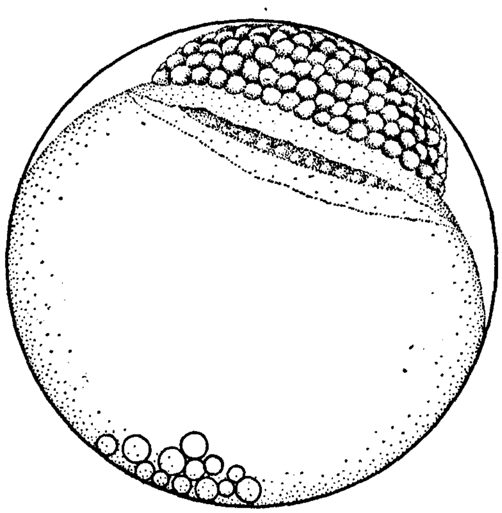

FIGURE 147.—*Achirus fasciatus.* From egg in advanced cleavage stage; about 3 to 4 hours after fertilization.

The older eggs taken at the same time as those for which the development is described in the foregoing paragraphs, which contained advanced embryos, hatched within 12 hours after collection. As these eggs quite certainly were spawned a day earlier than the others, the period of incubation also fell between 26 and 36 hours. It may be stated rather definitely, therefore, that the incubation period almost surely does not exceed 36 hours, at temperatures usually prevailing at Beaufort during the spawning period of the hogchoker.

The development of the egg of the hogchoker is quite usual for a teleost and is well shown by the drawings presented herewith. Therefore, extended descriptions of the different stages in the development are not necessary. In the series of illustrations prepared during our investigation the cells are all shown as of fairly uniform size and shape. Some eggs were observed, however, in which the cells were more or less unequal in size and somewhat different in shape. Figure 146, prepared by Mrs. Effie B. Decker under the supervision of Dr. Albert Kuntz, is introduced to show a rather extreme case of unsymmetrical cleavage. Too many eggs with more or less unequal cells were seen to permit us to consider variation an abnormality. It may be assumed, therefore, that the cells in the early cleavage stages are apt to vary somewhat.

During the early cleavage stages the blastoderm appears as a rather flat mass of cells. However, in the more advanced cleavage stages it is very distinctly dome-shaped, with a cavity beneath it, as shown in a side view, in figure 147. This stage apparently is reached within 2 or 3 hours after fertilization.

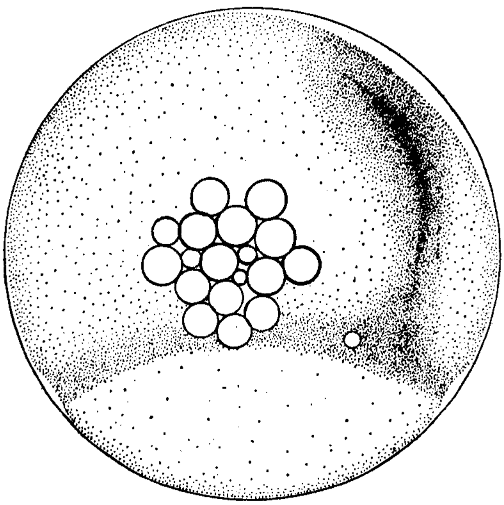

FIGURE 148.—*Achirus fasciatus*. From egg showing an early stage in the differentiation of the embryo (the shaded streak to the right).

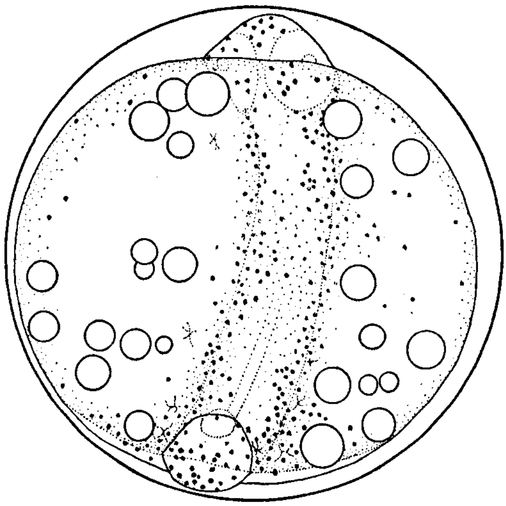

FIGURE 149.—*Achirus fasciatus*. Egg showing later stage in differentiation of embryo; about 12 hours after fertilization.

The development shown in figure 148, a rather early stage in the differentiation of the embryonic axis (the dark streak to the right), is attained about 6 to 8 hours after fertilization. Many greenish granules are present within the egg. Note the concentration of the oil globules in figure 148 in contrast with their scattered positions in figure 149, as well as in some of the other illustrations. This concentration is not characteristic of this nor any other particular stage of development, but varies in individual eggs.

The rather early embryonic stage shown in figure 149 was attained in about 13 to 14 hours. Note that the eyes with lenses are just becoming differentiated. No somites are visible, probably because the embryo is too opaque. Many greenish specks are present on the embryo and some scattered ones on the yolk. A few more or less definitely formed chromatophores, too, are becoming visible.

The moderately advanced embryonic stage shown in figure 150 was attained in about 26 hours. The embryo evidentally is too opaque to allow the somites to be seen. It is capable of considerable movement, and slow heart action may be seen. Green specks still are numerous, and comparatively many chromatophores are present, both on the embryo and the yolk. Note that few oil globules, most of them being small, are present. This again is not characteristic of this stage, but only of the particular egg drawn.

Newly hatched larvae.—The newly hatched fish is only about 1.7 to 1.9 mm long. The dorsal and ventral finfolds are very wide, making the larva seem short and deep. The head is slightly deflected, and on its dorsal surface is a pronounced hump. The tail is straight and pointed.

The yolksac is comparatively large and some or all the oil globules present in the egg are retained. The number of globules in the yolksac is equally as variable as in the egg. The yolksac also retains the green specks and chromatophores described for the eggs in advanced embryonic stages.

Green specks also are present on the body of the larva, except on the distal part of the tail. On the vertical finfolds green specks are concentrated to form blotches, which are somewhat variable among individuals in size, intensity, and position. There is one on the dorsal finfold above the yolksac; another on the fold above the vent; generally a more or less definite corresponding one on the ventral finfold just behind the vent; and another pair on the fold at about midcaudal length. In some individuals the concentration of color is continued more or less on the body of the larvae, forming indications of cross bars, which become more distinct as the fish grow. In addition to the green specks more or less definite dark chromatophores are variously distributed over the body and finfolds.

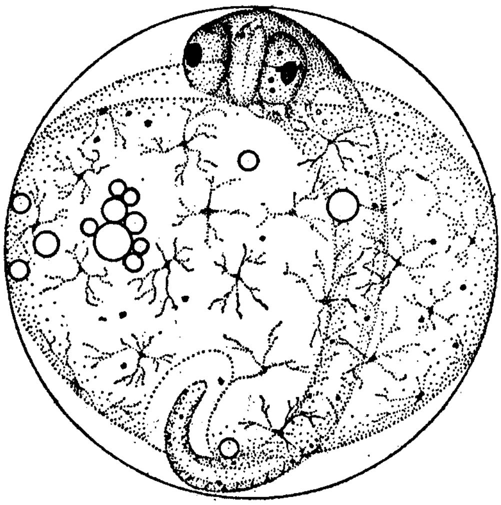

FIGURE 150.—*Achirus fasciatus.* From egg with rather advanced embryo.

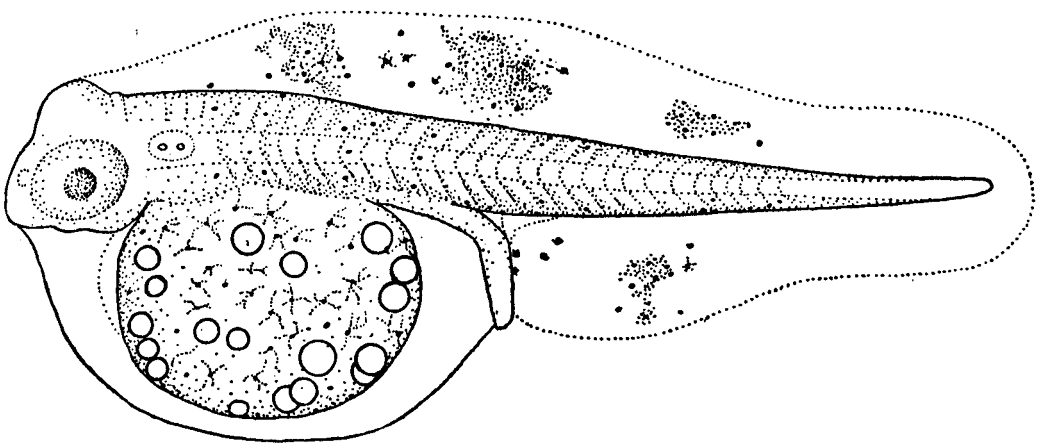

FIGURE 151.—*Achirus fasciatus.* From newly hatched young 1.8 mm long.

Heart action is visible, but due to the opaqueness of the fish the circulation cannot be seen. The vent is located at about midbody length. The newly hatched fish swims, or floats on its back, presumably being held in that position by the bouyancy of the many oil globules in the yolksac (fig. 151).

Larvae 16 hours old, 2.2 to 2.4 mm long.—In about 16 hours the yolksac is nearly all absorbed. The very small amount remaining is crowded with oil globules. The fish is now about 2.2 to 2.4 mm long. The head no longer is deflexed, but is rather elevated, with the hump even more prominent than in the newly hatched fish. The mouth is open, and the pectoral finfold on each side is plainly visible.

It is interesting that, although pectoral finfolds are present in the larvae, pectoral fins are not developed. At least, not a rudiment of a pectoral fin was found in 186 adults, collected at various places along the Atlantic and Gulf coasts of the United States, especially examined for this character (fig. 152).

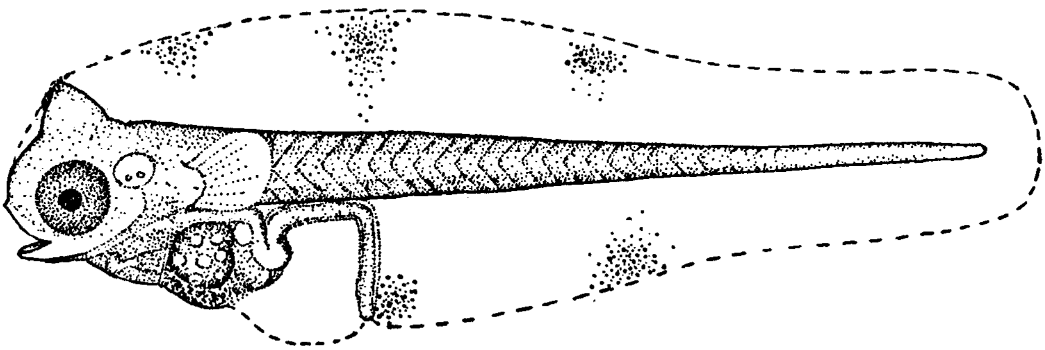

FIGURE 152.—*Achirus fasciatus.* From a young fish with yolk mostly absorbed, 2.4 mm long.

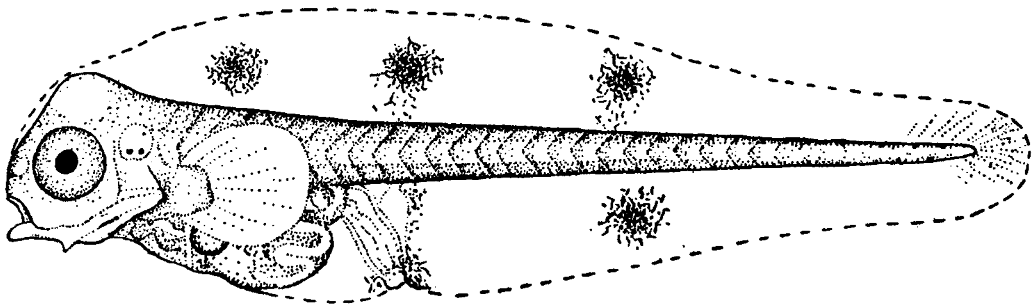

FIGURE 153.—*Achirus fasciatus.* From a young fish with yolk absorbed, 2.2 mm long.

Larvae 24 hours old.—In the aquarium the fish did not increase much, if any, in length for several days after the yolk was absorbed. The fish shown in figure 153 was only 2.18 mm long at 2 days of age, and therefore a little shorter than the younger fish shown in figure 152. Development, nevertheless, progressed somewhat. The yolksac with its oil globules had entirely disappeared. In its place there was a body wall through which the internal organs in part were visible. The hump on the head had become rather lower, and the mouth had moved forward somewhat with the lower jaw projecting slightly. The general color remained about the same as in the younger larvae. However, the pigment areas in the finfolds had become smaller and the pigment dots more concentrated (fig. 153).

Larvae 4 days old.—Four days after hatching the larvae still did not exceed a length of 2.5 mm. The head now had become more elongate, and the mouth more prominent with the lower jaw projecting rather strongly. The body had remained slender, as in the younger larvae.

The critical stage in the life of the larvae seems to be reached about the fourth day, and few survived until the fifth in the glass dishes in which they were kept in the laboratory. However, among those fed with towings, of which mention already has been made, a few survived much longer and those specimens furnish the clue to the further development of the larvae.

Larvae 7 days old.—The fish shown in figure 154 is 7 days old and was 3.0 mm long. This fish differs little from the 4-day old one, already described. Very definite dark chromatophores are now present on the head and abdomen, and rather definite cross bars generally are present. Anteriorly the body has increased considerably in depth.

Larvae 14 days old.—Figure 155 is based on a preserved specimen 14 days old, measuring only 2.0 mm in length after preservation. It may be assumed that considerable shrinkage had taken place. The fish at this stage is deep and strongly compressed. The pigment spots on the dorsal finfold, tending to form bars on the body, are present

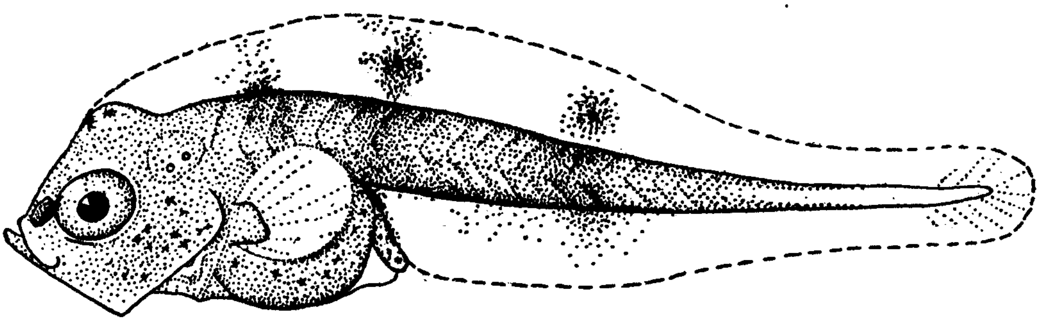

FIGURE 154.—*Achirus fasciatus.* From a young fish, 7 days old, 3 mm long.

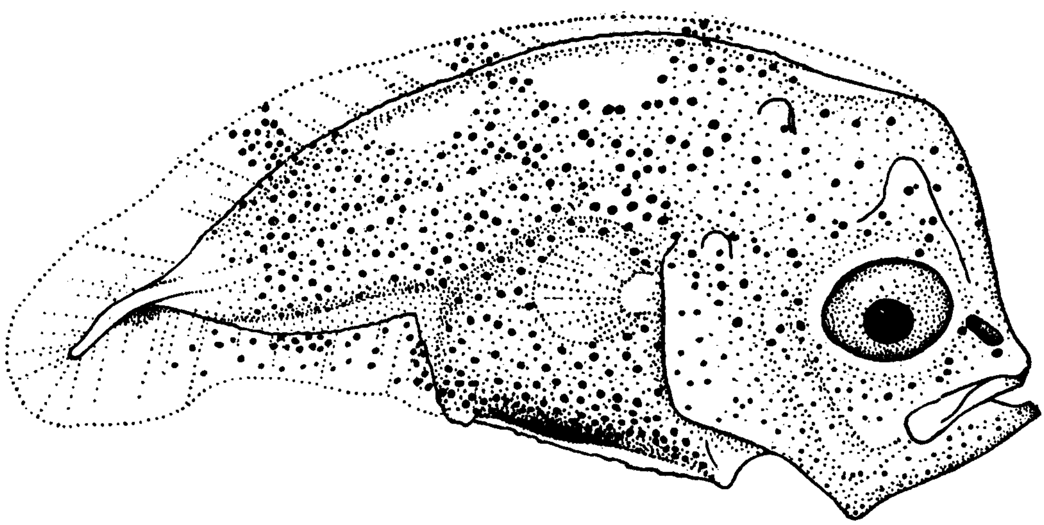

FIGURE 155.—*Achirus fasciatus.* From a young fish 14 days old.

about as in the early larvae. The pigment on the ventral finfold, however, is not concentrated in blotches in the single specimen studied. A great increase in dark dots on the body has taken place.

Young fish 17 days old.—It is evident from figure 156, based on a specimen 17 days old, 3.8 mm long after preservation, that development progressed rapidly. The fish has become much more shapely. The distal part of the tail, instead of being curved downward, is now bent upward, giving it the heterocercal appearance characteristic at this stage of development of telosts with homocercal tails. Indications of rays are present in the finfolds. Note that the pectoral finfold remains prominent. The eyes are quite symmetrically placed on the opposite sides of the head, and there is as yet no indication that one of them (the left one) will "migrate." Pigmentation has increased greatly, and is equally developed on both sides.

Young fish 26 days old.—Growth among the five fish alive at the age of 26 days was quite unequal. In the larger ones, 3.8 mm long when alive, rays are quite fully

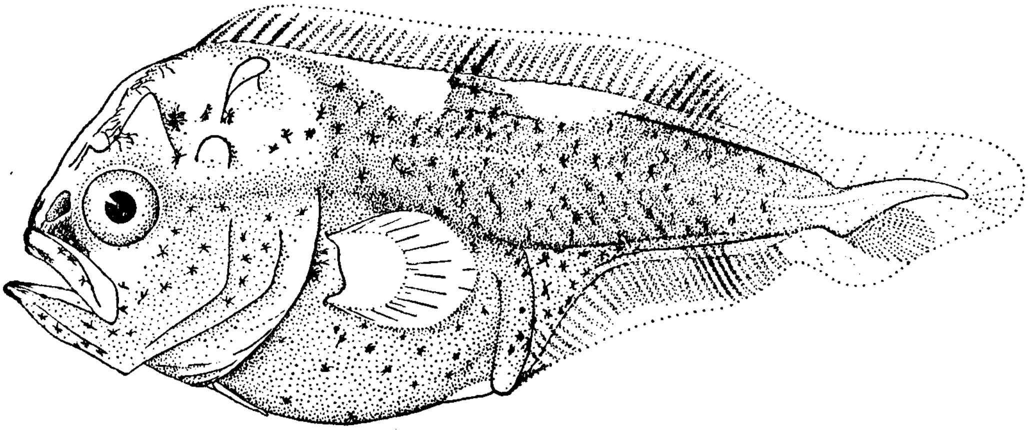

FIGURE 156.—*Achirus fasciatus.* From a young fish 17 days old.

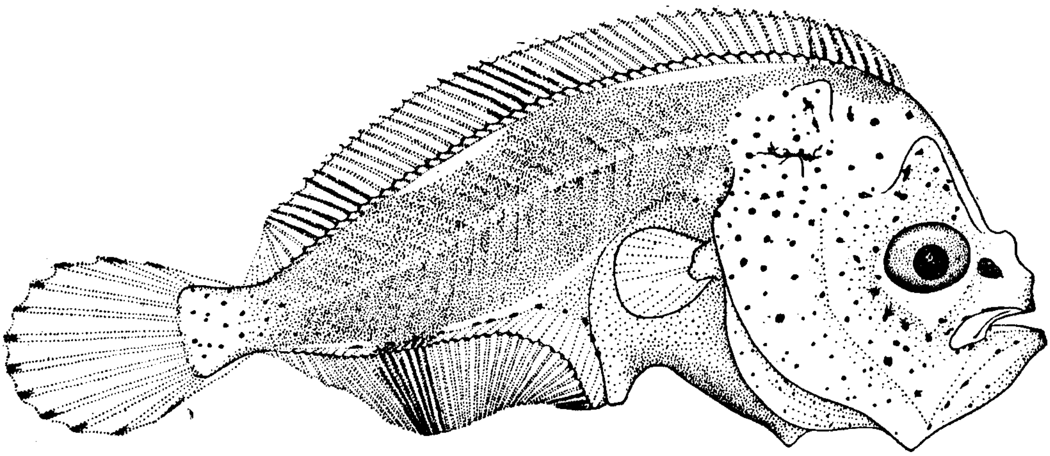

FIGURE 157.—*Achirus fasciatus.* From a young fish 32 days old.

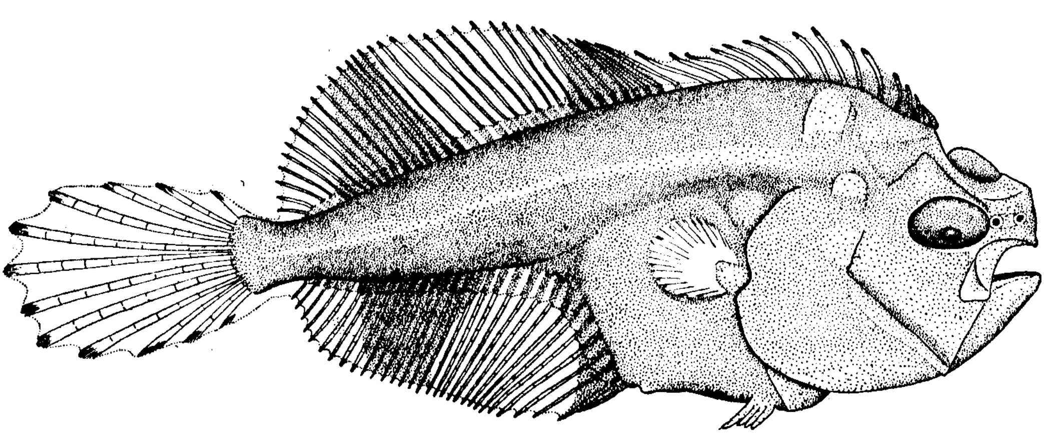

FIGURE 158.—*Achirus fasciatus.* From a young fish 34 days old. Though only a few days older than the one illustrated in fig. 157, development is much further advanced.

developed in the vertical fins. A slight depression is evident above the right eye through which the left eye is destined to migrate, as illustrated in the older fish shown in figure 158. However, at this stage the eyes remain symmetrically placed. The fish still swam upright in deep water, but on a hollowed microscope slide containing insufficient water to "float" them vertically, they invaribly swam or rested on the left side.

Young fish 32 days old.—The specimen illustrated in figure 157, which is 32 days old and 3.0 mm long, after preservation, has the depression over the right eye, described for the fish 26 days old, more pronounced. The second line shown in the drawing is the actual outline of the interorbital, for above it is only a transparent membrane. However, the eyes remain symmetrically placed on the opposite sides of the head. Note in the illustration that the pigment blotches on the dorsal and anal fins remain placed essentially as in the early larvae.

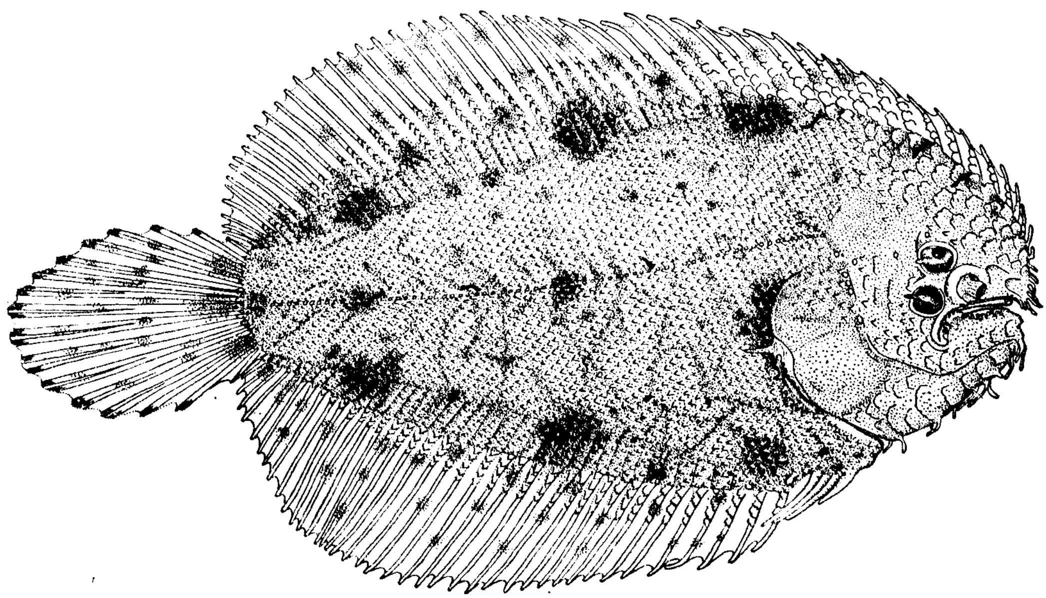

FIGURE 159.—*Achirus fasciatus.* From a young adult 18 mm long.

Young fish 34 days old.—The fish illustrated in figure 158 is 34 days old. Therefore, only 2 days older than the one shown in figure 157. However, this fish is larger, being 5.0 mm long after preservation, and it is much advanced in development. Note in the illustration that the left eye has just entered the depression in the forehead. At this size the mouth already is much twisted, essentially as in the adult. Ventral fins now are developed. Note also that the pectoral fin membranes persist. It seems significant, however, that in contrast with the other fins no definite rays have developed. It is, furthermore, noteworthy that the pigment spots on the dorsal and anal fins persist essentially as in the early larvae. No loss of pigmentation on the blind side has taken place.

Although one fish lived in the aquarium to reach the age of 41 days, development had not proceeded as far as in the specimen 34 days old, just described. As the smallest specimen taken in nature is 18 mm long, and essentially a young adult, an unfilled gap in the development remains between this specimen and the 5.0-mm one, described in the foregoing paragraph.

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Young fish 18 mm long.—The 18-mm specimen illustrated in figure 159 already is fully scaled. Fleshy tentacles are developed on the head, though not in the profusion of fully grown fish. The left eye has completed the migration, both eyes appearing close together on the right side of the head, the upper one (originally the left one) being a little in advance of the lower one just as in the fully grown fish. The pectoral finfold remains in part, having the appearance of a fleshy tentacle as shown in the illustration. Most of the fish examined had lost this rudiment of a pectoral at a length of 25 to 30 mm. However, one specimen 43 mm long retained it. It would not be surprising, therefore, if occasionally it were retained longer, or even throughout life. The ventral and anal fins have approached each other as in the adult. In the process the vent and the anal fin have "migrated" forward. (See figures 158 and 159.)

The 18-mm specimen is fully pigmented on the right or eyed side. It is interesting that the dark blotches on the dorsal and ventral fin folds of the newly hatched larvae have been retained on the right side of this fish in essentially the same position. These juvenile spots are lost, however, when the fish reach a length of about 25 mm. As the fish grows, spots generally become much more numerous than in the 18-mm one illustrated. Frequently about seven or eight more or less definite blackish cross lines are also developed in adults. Much variation in color among individuals exists. The small specimen drawn is destitute of pigment on the blind side, which is quite usual among adults. Yet, many exceptions have been noticed. In fact, various degrees of pigmentation have been seen, ranging from a few obscure dusky spots or a dusky shade here and there to a general dusky to blackish coloration with definite blackish spots.

GROWTH

An insufficient number of hogchokers has been measured to determine the rate of growth with any degree of certainty. According to length measurements of 440 specimens, regarded as belonging to the 0-class, taken during April (1931), this class ranges in length from 18 to about 100 mm, the mode being at about 55 mm. A considerable range in size would be expected because of the very long spawning season, which extends at least from May to August. The specimens measured, therefore, may have varied in age from about 7 to nearly 12 months.

Subsequent growth remains almost entirely undertermined, though among a limited number of larger specimens, measured in April (1931), there is another slight mode around 140 mm, indicating that fish approaching an age of 2 years probably are fully grown.

The largest hogchocker taken at Beaufort was 184 mm (7½ inches) long. The largest one ever reported (Hildebrand & Schroeder, 1928, p. 176), so far as known to the writers, was 200 mm (8 inches) long. The average size of mature fish apparently is around 125 mm (5 inches). It is obvious, therefore, that the hogchocker is too small to be of commercial value. So far as the writers are aware it is never eaten.

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THE MIGRATIONS OF PINK SALMON (*ONCORHYNCHUS GORBUSCHA*) IN THE CLARENCE AND SUMNER STRAITS REGIONS OF SOUTHEASTERN ALASKA

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By FREDERICK A. DAVIDSON, Ph. D., *Aquatic Biologist*, and LEROY S. CHRISTEY, *Field Assistant*, *United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

Southeastern Alaska lies on the Pacific shore of North America between latitudes 54° and 60° N. It is composed of a narrow coastal strip and a broken chain of mountainous islands known as the Alexander Archipelago. The geography of that part which includes the Alexander Archipelago is illustrated in figure 1. Owing to the temperate climate and heavy rainfall of this region most of the islands and mainland shore are covered with dense growths of timber and are drained by hundreds of streams that range in size from brooks to small rivers. These streams support one of southeastern Alaska's most valuable natural resources in that they form the breeding grounds for millions of salmon that migrate into them each year to spawn. Through the utilization of these salmon a large and flourishing food-packing industry has developed which is providing nutritious food for the nation as well as a substantial income to the citizens engaged in it.

The Pacific salmon of the genus *Oncorhynchus* spend part of their lives in the sea where they mature and part in the streams where they spawn and then die. The period during which the adults migrate from the sea extends from early summer to

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late fall. The eggs are deposited in the gravel beds of the streams to incubate during the winter months. They hatch out in the following spring and early summer. The young of some of the species remain in fresh water for a few years but they all eventually migrate to the sea where they mature. Since no definite knowledge has yet been obtained as to the location of most species of these salmon during their sojourn in the sea, their spawning migration is of primary importance to the fishing industry for it is only at this time that they are captured in large numbers.

The responsibility of protecting this natural resource of Alaska from overexploitation, so that it may be preserved for future generations, is vested in the Secretary of Commerce who is advised by the United States Bureau of Fisheries. Since the demands of the industry for salmon are usually greater than the supply, the Bureau has found it necessary to regulate the fishery. This regulation aims to provide for an adequate escapement of the adult salmon to the streams so that they may reproduce and maintain their bounteous numbers.

In the life-history studies of the Pacific salmon it was found that they have a high degree of homing instinct; i. e., the majority of the adults return to spawn in the streams of their origin. A discussion of the results of these studies may be found in the following references: Gilbert (1913), Snyder (1921 to 1924), Rich and Holmes (1928), Foerster (1929), Pritchard (1933 and 1934), and Davidson (1934). Owing to this peculiar characteristic of the salmon the population in each stream is self perpetuating and if once destroyed it will not be readily restocked through the straying of salmon native to other streams. Hence, in order to insure the maintenance of the salmon populations in the streams, it was necessary for the Bureau to provide for the protection of the spawning fish each season. In general it imposes definite limitations on the length of time fishing may be carried on in each locality, and prohibits fishing in and near the mouths of the streams and in the small bays that form resting areas for the migrating salmon.[2]

CHANNELS OF MIGRATION

Figure 1 shows six main channels through which salmon may enter the inside waters among the islands on their way to the streams. These are, namely: Icy Strait-Lynn Canal, Chatham Strait-Frederick Sound-Stephens Passage, Sumner Strait, Cordova Bay, Clarence Strait-Ernest Sound, and Revillagigedo Channel-Behm Canal. Most salmon spawning in interior localities migrate through one or more of these channels to reach their destinations. In considering the conservation of the salmon populations in each locality the Bureau realized that some provision had to be made for the protection of these populations during their migration through the channels as well as in the streams. Hence, in order to expedite the patrol and regulation of the commercial fishery, the first and most logical step was to set apart the various spawning localities into fishing districts according to the main channels of entry through which their populations migrated from the sea. Before this could be accomplished satisfactorily, however, it was necessary to make a study of the migratory routes and destinations of the salmon populations passing through each main channel.

[2] For detailed information concerning the regulation of the salmon industry in Alaska see Laws and Regulations for the Protection of the Fisheries of Alaska. Department Circular 251. Department of Commerce, Bureau of Fisheries, Washington, D. C.

TAGGING METHODS

In 1924 the Bureau started a series of salmon-tagging experiments in each of the main channels of entry for the purpose of securing this information. The work of the experiments was carried on as follows: The trap was first closed and the web of the spiller lifted to bring the salmon near the surface. They were then caught with a dip net and slid, one by one, onto the tagging table from which they were guided head first into a small box held on the outside of the table. This box was short and from 3 to 4 inches of the salmon's tail projected beyond the open end. The tagging operator was thus enabled to grasp the tail and clamp a tag, about 1½ inches long and ⅝-inch wide, on it. After tagging, the operator holding the small box tossed the salmon back into the water beyond the trap. The entire operation required but a fraction of a minute and, if conditions were favorable, from 150 to 200 fish could be tagged in an hour (see figs. 2 and 3).

It is assumed that the great majority of the tagged individuals, when released, continue to follow their original course of migration. The recovery of a few tagged fish in areas far distant from the point of liberation does not necessarily indicate that the tagging operation affected them, for it is not improbable that salmon occasionally stray from their normal course of migration. Most of those recovered are picked up by the commercial fishery at various points along the migratory routes. Small numbers have also been recovered on the spawning grounds in streams.

It has never been possible to recover all the salmon that are tagged. Many of them escape the commercial fishery and spawn in the streams unnoticed and even some of those that are caught by the fishery lose their tags in shipment and remain undiscovered. The Bureau has for several years offered a small reward, from 25 to 50 cents, for the recovery of tagged individuals, and in this way has encouraged the search for them in areas where they are being tagged. No tags, however, are accepted by the Bureau unless they are accompanied by information as to the date and place of recapture of the fish. Without this information the tags are worthless as a means of tracing the migratory routes of the salmon.

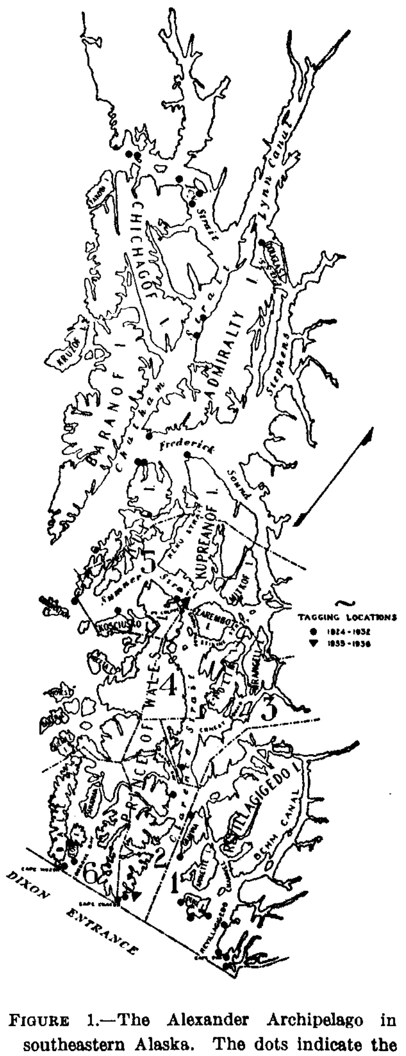

FIGURE 1.—The Alexander Archipelago in southeastern Alaska. The dots indicate the locations of the early pink-salmon tagging experiments from 1924 to 1932. The triangles indicate the locations of the 1935 and 1936 pink-salmon tagging experiments. The boundary lines and included numbers in the Clarence and Sumner Straits region show the geographic areas used in classifying the localities in which the tagged salmon were recovered.

The first tagging experiments that were carried on in southeastern Alaska attempted to locate, as quickly as possible, the general migratory routes and destinations of the salmon migrating through each of the six main channels of entry This necessitated covering the entire region in a comparatively short time and consequently it was not possible to tag more than two or three times at each location during a season. The locations of these experiments are given in figure 1. The results from them were most valuable and greatly assisted in the formation of the present fishing districts in the region.[3] Plans were made to continue these tagging experiments in a more detailed manner so that the destinations of the salmon passing through each main channel of entry at different times during the migratory season could be determined. Information of this nature is very important, for it provides a basis upon which to regulate the fishery in order to protect the salmon during their migration in the entrance channels as well as in the streams where they spawn.

The grouping of the waters of southeastern Alaska into fishing districts, for the purpose of regulating the commercial fishery, is based upon two separate studies of the life history and habits of the salmon. The first study deals with the determination of the migratory routes of the salmon. This gives a general picture of the channels of entry frequented by the salmon during their migrations to the various spawning localities. The second study—beyond the scope of this paper—deals with the time in the fishing season during which the salmon migrate through each district, and is based upon a study of the daily catch records of the fishing gear in the districts. Information from this study was used to set the opening and closing dates for fishing in the districts so as to provide for the escapement of an adequate proportion of each run of salmon to the streams for reproduction.

Since the pink salmon are by far the most abundant species of the Pacific salmon in southeastern Alaska, the grouping of the various waters in this region into fishing districts and the regulations imposed therein have, to a great extent, been directed toward the conservation of this species. Hence, the more detailed tagging experiments have been limited to the pink salmon.

The results from a study of the salmon catches, as well as from the early tagging experiments in Clarence and Sumner Straits, indicated that each of these large bodies of water formed the migratory channel of distinct runs of pink salmon. Although these waters were originally included in one fishing district, the Bureau realized that each should constitute a separate district and made the change at the first opportunity, which occurred in 1934. After making this change further tagging work was carried on in the summers of 1935 and 1936 to determine the destinations of the pink salmon passing through each of these main channels at different times in the season. In order to give as complete a picture as possible of the pink-salmon migrations in these waters, the results from the earlier tagging experiments will be summarized and compared to those of this later work.

PINK-SALMON TAGGING EXPERIMENTS IN CLARENCE STRAIT AND ADJACENT WATERS, 1924–32

An inspection of the map in figure 1 will show that Clarence Strait and its adjacent waters, Revillagigedo Channel and Cordova Bay, do not open directly into the ocean but into a large body of water known as Dixon Entrance. Early in the development of the salmon fishery in these waters it was found that the first pink salmon to appear each season usually migrated easterly through Dixon Entrance and turned northward and eastward along the mainland shores in the vicinity of Cape Fox. As the season progressed the numbers of salmon following this course of migration became more and more abundant and built up a very definite run into Revillagigedo Channel, Portland Canal, and their contiguous waters. A week to 10 days after the beginning of the

[3] For the results of the early tagging experiments see Rich (1926), Rich and Suomela (1927), Rich and Morton (1929), and Rich (1932). The locations of these experiments are given in figure 1.

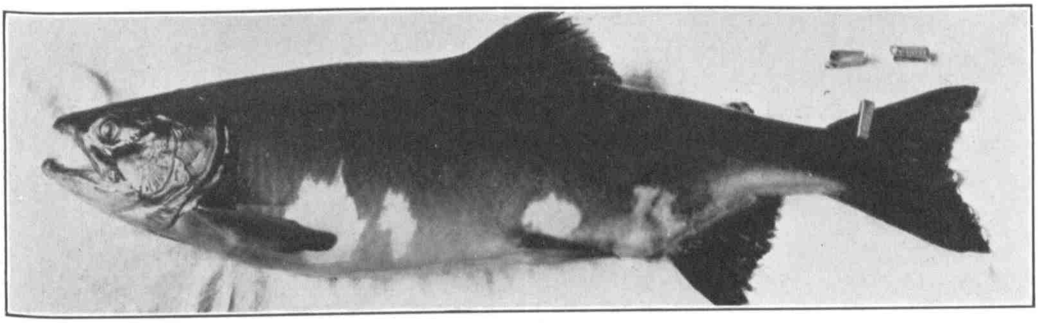

FIGURE 2.—Tagged pink salmon showing relative size of tag and location of attachment.

FIGURE 3.—Tagging pink salmon at a fish trap in southeastern Alaska.

runs in the region of Cape Fox, large numbers of the pink salmon migrating through Dixon Entrance began to turn northward into Clarence Strait along the east shore of Prince of Wales Island in the vicinity of Cape Chacon. Here again, the salmon following this course of migration increased in numbers as the season progressed and built up a separate and definite run into Clarence Strait. From a week to 10 days later a third run of pink salmon began to leave Dixon Entrance and migrate northward; this time into Cordova Bay. This run, like the others, increased in abundance as the season progressed, thus forming three definite runs of pink salmon originating in Dixon Entrance. This information was secured from a study of the daily catches of the fishing gear operating in these waters. Studies of similar recent records by the Bureau indicate that three definite runs of pink salmon continue to appear in these waters.

In order to provide a uniform method for classifying and reporting the recoveries of tagged salmon, the spawning localities of Clarence and Sumner Straits were grouped into definite areas. Although these areas include waters which are similar to those of the fishing districts, they cannot be construed as being identical. They were not formed with any idea of using them to replace the present districts as factors other than the locations of the migratory channels of the salmon enter into their formation. They will be referred to hereafter as geographic areas of recovery which are shown in figure 1 and may be described as follows: Area 1 includes all the waters of Revillagigedo Channel, Portland and Behm Canals, and the waters surrounding Duke, Annette, and Gravina Islands. Area 2 includes all the waters of Clarence Strait along the east shore of Prince of Wales Island from Cape Chacon to Approach Point. Area 3 includes all the waters of Clarence Strait above a line from Approach Point to Caamano Point and below a line from Narrow Point to Ernest Point. This area also includes the waters of Ernest Sound, Zimovia Strait, Bradfield Canal, and Blake Channel. Area 4 includes the remainder of the waters of Clarence Strait above a line from Narrow Point to Ernest Point, and the waters of Snow Passage and Stikine Strait. Area 5 includes the waters of Sumner Strait, Keku Strait, Wrangell Narrows, and the lower extremity of Frederick Sound below latitude 56°30′ N. Area 6 includes the waters of Cordova Bay and contiguous channels.

Since no information was available concerning the localities in which the salmon comprising these migration waves spawned, the Bureau, in 1924, began three series of tagging experiments in the region. The first was in the vicinity of Cape Fox, the entrance to Revillagigedo Channel, and Portland Canal; the second in the vicinity of Cape Chacon, the entrance to Clarence Strait; and the third in the vicinity of Cape Muzon, the entrance to Cordova Bay. The locations at which these tagging experiments were carried on are shown by the black dots in figure 1.

In classifying the results from the tagging experiments summarized in tables 1 to 8, all tagged salmon recovered at the location of tagging were considered as not having migrated from that location and were not included either in the number of individuals tagged, or in the number recovered. The recovery of a tagged salmon cannot be considered as indicating a route of migration unless capture has been made at some distance from the point of tagging. Accordingly, no record is given of the recoveries at the point of tagging nor those where the locality of recapture is doubtful. Hence, the total percentage of tagged fish recovered in the experiments does not represent the entire influence of the intensity of the fishery.

TAGGING EXPERIMENTS IN THE VICINITY OF CAPE FOX

The tagging experiments carried on in the vicinity of Cape Fox in 1924 were continued intermittently through 1932, and a total of 17 experiments were made during this period. Since it was not possible to tag frequently throughout the season at any one location, an effort was made to change the seasonal time of tagging each year. In this way the results from these experiments, as a whole, approximately indicate the final destinations of the salmon migrating into this region at different times during the season. A summary of the results from these experiments is given in table 1.

TABLE 1.—*Pink salmon tagged in the vicinity of Cape Fox, 1924–32, and number recovered* [1]

[Column headings indicate locality and date of tagging]

	Foggy Point, Kanagunut Island, June 24–July 1, 1926	Sitklan and Kanagunut Islands, July 13, 1930	Cape Fox, Sitklan, and Kanagunut Islands, July 25–26, 1930	Foggy Point, July 30–31, 1925	Kanagunut Island, Aug. 7, 1924	Cape Fox, Sitklan, and Kanagunut Islands, Aug. 7–8, 1930	Tree Point, Aug. 8, 1924	Duke Point, Kelp Island, Aug. 5, 1932 [2]	Duke Point, Aug. 8, 1924	Point White, Aug. 8, 1924	Total
Number tagged	137	312	685	1,000	21	667	203	467	245	194	3,931
LOCALITY OF RECOVERY											
LOWER CLARENCE STRAIT.—AREA 1											
East of Cape Fox		13	87	39	3	130	18	10	18	15	333
British Columbia	3	4	10	44		5		13			79
Revillagigedo Channel and Tongass Narrows	17	46	46	241	2	66	35	32	27	21	533
Behm Canal, south arm	2	12	33	33		4	5	4	7	3	103
Behm Canal, north arm	1	3	1			8			1		14
West shores of Gravina, Annette, and Duke Islands	3	2	10	5		8	4		3	4	39
Total recovered	26	80	187	362	5	221	62	59	56	43	1,101
Percent recovered	19.0	25.6	27.3	36.2	23.8	33.1	30.5	12.6	22.9	22.2	28.0
LOWER CLARENCE STRAIT.—AREA 2											
East shore Prince of Wales Island from Cape Chacon to Approach Point:											
Total recovered			2	2	1	4	1	22		3	35
Percent recovered	0.0	0.0	0.3	0.2	4.8	0.6	0.5	4.7	0.0	1.5	0.9
MIDDLE CLARENCE STRAIT.—AREA 3											
Approach Point, Caamano Point to Narrow Point, and Ernest Point			1	2		4		6	1		14
Ernest Sound				5				1			6
Total recovered			1	7		4		7	1		20
Percent recovered	0.0	0.0	0.2	0.7	0.0	0.6	0.0	1.5	0.4	0.0	0.5
UPPER CLARENCE STRAIT.—AREA 4											
Total recovered				3							3
Percent recovered	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1
SUMMARY:											
Total recovered	26	80	190	374	6	229	63	88	57	46	1,159
Percent recovered	19.0	25.6	27.7	37.4	28.6	34.3	31.0	18.8	23.3	23.7	29.5

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647. The original records of the tagging experiments from 1924 to 1930 are given in the reports of Rich (1926), Rich and Suomela (1927), Rich and Morton (1929), and Rich (1932).

[2] From unpublished data, U. S. Bureau of Fisheries.

From an inspection of table 1 it will be seen that, regardless of the time in the season in which the salmon were tagged, practically all those recovered were captured in area 1. A total of 3,931 pink salmon were tagged in all of the experiments, of which 1,159, or 29.5 percent, were recovered. Of the total number recovered 1,101 were captured in area 1, 35 in area 2, 20 in area 3, and 3 in area 4.

The tagging experiments conducted on the east, south, and west shores of Duke Island were included with those on and near the mainland shore in the vicinity of Cape Fox because the percentage of recoveries from these experiments shows a greater relation to those carried on near Cape Fox than to those carried on elsewhere in this general region. It will be noted in table 1 that the total number of tagged individuals recovered in areas 2 and 3 are composed largely of the recoveries reported from the Kelp Island experiment carried on in 1932. A further analysis of the recoveries reported from area 1 shows that of those captured east of Cape Fox 333 were taken in Alaskan waters and only 79 in Canadian waters. Of those captured north of Cape Fox 533 were taken in the waters of Revillagigedo Channel and Tongass Narrows, 103 in the south arm of Behm Canal, 14 in the north arm of Behm Canal, and 39 off the west shores of Duke, Annette, and Gravina Islands. Although far greater numbers were captured in the south arm of Behm Canal than in the north arm, it cannot be definitely assumed that these results represent the exact ratio of distribution, for many of the salmon bound for the north arm of Behm Canal may have been picked up enroute in Revillagigedo Channel and Tongass Narrows. However, it may be definitely assumed that most of the pink salmon migrating through Dixon Entrance to the mainland and island shores in the vicinity of Cape Fox are bound for the localities in some part of area 1; i. e., those of Portland Canal and other waters east of Cape Fox, and those of Revillagigedo Channel and Behm Canal.

TAGGING EXPERIMENTS IN THE VICINITY OF CAPE CHACON

The early tagging experiments carried on in the vicinity of Cape Chacon were not as numerous, nor as varied in the time of the season they were conducted, as those in the vicinity of Cape Fox. A total of six experiments, five in 1925 and 1 in 1926, were made during the second week of August of each year, which is beyond the middle of the migratory season for pink salmon in this region. However, the results are sufficient to show that there is a distinct difference between the final destinations of the pink salmon migrating northward from Dixon Entrance into Clarence Strait in the vicinity of Cape Chacon, and those migrating northward from Dixon Entrance along the mainland shores in the vicinity of Cape Fox.

TABLE 2.—*Pink salmon tagged in the vicinity of Cape Chacon, 1925 and 1926, and number recovered* [1]

[Column headings indicate locality and date of tagging]

	Cape Chacon, Aug. 8, 1925	Stone Rock Bay, Aug. 9, 1925	Stone Rock Bay, Aug. 9, 1926	Cape Chacon, Aug. 11, 1925	Stone Rock Bay, Aug. 12, 1925	Cape Chacon, Aug. 13, 1925	Total, Cape Chacon and Stone Rock Bay	Kaigani Strait, Aug. 10–11, 1926	Cape Muzon, Aug. 15, 1925	Kaigani Point, Aug. 16–21, 1925	Total, Kaigani Strait and Cape Muzon
Number tagged	36	504	479	546	609	455	2,629	1,354	579	1,876	3,809
LOCALITY OF RECOVERY											
LOWER CLARENCE STRAIT.—AREA 1											
East of Cape Fox	...	2	...	3	3	...	8	...	...	...	...
British Columbia	...	...	1	...	...	...	1	1	1	1	3
Revillagigedo Channel and Tongass Narrows	1	6	7	11	17	10	52	13	2	1	16
Behm Canal, south arm	1	1	...	2	2	3	9	...	...	...	...
Behm Canal, north arm	...	2	4	9	4	6	25	3	...	...	3
West shores of Gravina, Annette, and Duke Islands	1	23	25	42	39	21	151	18	11	6	35
Total recovered	3	34	37	67	65	40	246	35	14	8	57
Percent recovered	8.3	6.7	7.8	12.3	10.7	8.8	9.4	2.6	2.4	0.4	1.5
LOWER CLARENCE STRAIT.—AREA 2											
East shore Prince of Wales Island, from Cape Chacon to Approach Point (all points):											
Total recovered	4	63	38	55	50	51	261	64	26	32	122
Percent recovered	11.1	12.5	7.9	10.1	8.2	11.2	9.9	4.7	4.5	1.7	3.2
MIDDLE CLARENCE STRAIT.—AREA 3											
Approach Point, Caamano Point, to Narrow Point, and Ernest Point	3	11	10	34	23	16	97	23	3	...	26
Ernest Sound	...	7	1	11	10	2	31	...	1	1	2
Total recovered	3	18	11	45	33	18	128	23	4	1	28
Percent recovered	8.3	3.6	2.3	8.2	5.4	4.0	4.9	1.7	0.7	0.1	0.7
UPPER CLARENCE STRAIT.—AREA 4											
Narrow Point, Ernest Point to Point Harrington, and East Island	...	4	1	8	7	7	27	...	1	3	4
Snow Passage and Stikine Strait	...	2	...	...	2	4	8	...	...	...	...
Total recovered	...	6	1	8	9	11	35	...	1	3	4
Percent recovered	0.0	1.2	0.2	1.5	1.5	2.4	1.3	0.0	0.2	0.2	0.1
WEST COAST PRINCE OF WALES ISLAND (ALL POINTS).—AREA 6											
Total recovered	...	51	45	18	101	26	241	249	115	391	755
Percent recovered	0.0	10.1	9.4	3.3	16.5	5.7	9.2	18.4	19.8	20.8	19.8
OUTLYING AREAS											
Chatham Strait and Frederick Sound (all points):											
Total recovered	...	1	...	...	...	...	1	2	...	...	2
Percent recovered	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1
SUMMARY:											
Total recovered	10	173	132	193	258	146	912	373	160	435	968
Percent recovered	27.7	34.3	27.6	35.3	42.4	32.1	34.7	27.6	27.6	23.2	25.4

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647. The original records of the tagging experiments in 1925 and 1926 are given in the reports of Rich (1926), and Rich and Suomela (1927).

A total of 2,629 pink salmon were tagged, of which 912, or 34.7 percent, were recovered. Of the total number recovered 246 were captured in area 1, 261 in area 2, 128 in area 3, 35 in area 4, 241 in area 6, and 1 in Chatham Strait, an outlying district. Of the 246 salmon captured in area 1, 151 were taken by the fishery on the west shores of Annette and Gravina Islands, 25 in the north arm of Behm Canal, 9 in the south arm of Behm Canal, and the remaining 61 in Revillagigedo Channel and waters east of Cape Fox. It will be recalled that the results from the Cape Fox taggings showed more recoveries from the south arm of Behm Canal than from the north arm, whereas the results from the Cape Chacon taggings show just the reverse. That larger numbers of the salmon migrating through Clarence Strait are bound for the north arm of Behm Canal, than for the south arm, will be definitely demonstrated later in the discussion of the 1935 and 1936 taggings near Cape Chacon. Although only 35 tagged salmon were captured in area 4 it cannot be assumed that this represents the exact proportion bound for this area. Since the salmon bound for area 4, at the extreme upper end of Clarence Strait, must run the gauntlet of all the fishing gear along the shores of the strait from Cape Chacon northward, it is not unlikely that some of the tagged salmon captured in areas 1, 2, and 3 were destined for area 4 but were intercepted en route. This is one of the difficulties that make it impossible to determine the exact distribution of the salmon migrating through a main channel of entry by tagging experiments conducted near the entrance to the channel. By tagging at different points along the channel part of the difficulty encountered from interception of the tagged individuals may be overcome. However, in using this system of tagging in a channel such as Clarence Strait, where the fish are migrating in both directions, further difficulties arise that far offset the advantages gained. From the results of these experiments it appears that the pink salmon migrating into Clarence Strait during the latter part of the season are bound mainly for localities in areas 1, 2, and 6.

TAGGING EXPERIMENTS ON GRAVINA ISLAND AND IN THE VICINITY OF KASAAN BAY

The results from the early tagging experiments carried on at points in the vicinity of Kasaan Bay and along the west shore of Gravina Island will be considered next. Three experiments were carried on in the latter region; one at Nelson Cove early in July 1926, and one each at Nelson Cove and Dall Head early in August 1927. The exact locations of these points are shown by dots on Gravina Island in figure 1. Nelson Cove was reported by Rich (1927–29) as located at the north end and Dall Head at the south end of the island, and the results from the experiments are given in table 3.

TABLE 3.—*Pink salmon tagged in the vicinity of Kasaan Bay, 1926–30, and number recovered* [1]

[Column headings indicate locality and date of tagging]

	South Entrance to Kasaan Bay, July 29, 1930	South Entrance to Kasaan Bay, Aug. 14, 1930	Windfall Harbor, Aug. 3, 1930	Windfall Harbor, Aug. 14, 1930	Nelson Cove, July 6–7, 1926	Dall Head and Nelson Cove, Aug. 5–6, 1927
Number tagged	146	125	423	425	284	321
LOCALITY OF RECOVERY						
LOWER CLARENCE STRAIT.—AREA 1						
Revillagigedo Channel and Tongass Narrows	3	4	4	6	8	8
Behm Canal, south arm	1		4	2	1	1
Behm Canal, north arm		1	8	1	24	14
West shores of Gravina, Annette, and Duke Islands	6		11	6	6	13
Total recovered	10	5	27	15	39	36
Percent recovered	6.8	3.7	6.4	3.5	13.7	11.2
LOWER CLARENCE STRAIT.—AREA 2						
East shore Prince of Wales Island, from Cape Chacon to Approach Point:						
Total recovered	16	49	5	40	1	4
Percent recovered	10.9	36.2	1.2	9.5	0.4	1.2
MIDDLE CLARENCE STRAIT.—AREA 3						
Approach Point, Caamano Point to Narrow Point, and Ernest Point	9	9	20	93	13	19
Ernest Sound					4	11
Total recovered	9	9	20	93	17	30
Percent recovered	6.2	6.7	4.7	21.9	6.0	9.4
UPPER CLARENCE STRAIT.—AREA 4						
Narrow Point, Ernest Point to Point Harrington, and East Island			10	1		2
Snow Passage and Stikine Strait					1	
Total recovered			10	1	1	2
Percent recovered	0.0	0.0	2.4	0.2	0.4	0.6
WEST COAST PRINCE OF WALES ISLAND (ALL POINTS).—AREA 6						
Total recovered	1		1			
Percent recovered	0.7	0.0	0.2	0.0	0.0	0.0
OUTLYING AREAS						
Chatham Strait			1			
Stephens Passage					2	
Total recovered			1		2	
Percent recovered	0.0	0.0	0.2	0.0	0.7	0.0
SUMMARY:						
Total recovered	36	63	64	149	60	72
Percent recovered	24.6	46.6	15.1	35.1	21.1	22.4

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647. The original records of the tagging experiments from 1926 to 1930 are given in the reports of Rich and Suomela (1927), Rich and Morton (1929), and Rich (1932).

From an inspection of column 5 in table 3 it will be seen that most of the pink salmon migrating along the west shore of Gravina Island early in July are bound for the northern localities in area 1 and the general localities in areas 3 and 4, there being only a small percentage of them taken in area 2. From an inspection of column 6 in table 3 it will be seen that most of the salmon migrating along this shore in the early part of August are also bound for the northern localities in area 1 and the general localities in areas 3 and 4. However, there is the appearance of a tendency for the fish to turn back from this shore to localities in area 2, which becomes quite marked later on in August. Evidence of this is afforded by the slight increase in the number of tagged individuals recovered from area 2 as reported from the August taggings. Further reference will be made to this tendency in the discussion immediately following. In all three of these experiments the small number of recoveries in area 4 may have been due partially to interception in area 3.

Four lots of salmon were tagged in the vicinity of Kasaan Bay in 1930, 2 just south of the entrance to the bay near Island Point, 1 on July 29, and 1 on August 14, 2 just north of the bay at Windfall Harbor on August 3 and 14. The results are given in columns 1–4 in table 3. The tagged salmon recovered from the July 29 tagging just south of the bay were captured in areas 1, 2, and 3, in almost equal proportions. The largest number, however, came from area 2. Those recovered from the August 14 tagging at the same location were captured also in areas 1, 2, and 3, but this time by far the greater part were captured in area 2. In both of these experiments the localities in which the salmon were recovered in area 2 extended as far south as Cape Chacon. It is evident, then, that the majority of the pink salmon reaching the eastern shore of Prince of Wales Island, in the vicinity of Kasaan Bay, during the second week in August are migrating southward rather than northward.

The individuals recovered from the August 3 tagging at Windfall Harbor, north of Kasaan Bay, were recaptured mainly in areas 1, 3, and 4, with only a relatively small number coming from area 2. Of the 64 tagged individuals recovered, 33 came from areas south of Kasaan Bay, 27 from area 1, 5 from area 2, and 1 from area 6, while 30 came from areas north of the bay, 20 from area 3, and 10 from area 4. Thus, it may be assumed that the pink salmon at this time of the season are migrating in equal numbers in both directions from their point of tagging at Windfall Harbor. The recoveries from the August 14 tagging at this point, however, show a much different picture. Of the 149 tagged salmon recovered from this experiment, 15 were captured in area 1, 40 in area 2, 93 in area 3, and 1 in area 4. Here we find 94 of the recoveries made in areas 3 and 4, north of the point of tagging, and only 55 made in areas 1 and 2, south of the point of tagging. Hence, it may be assumed that in the latter part of the season the pink salmon reaching the shores of Clarence Strait, in the vicinity of Windfall Harbor, are migrating northward in greater numbers than southward. It is also interesting to note that the recoveries from area 2 in this experiment were more numerous than from area 1, 40 as compared to 15, whereas the reverse was true in the August 3 tagging, 5 as compared to 27. This, together with the fact that the majority of the recoveries from the tagging south of Kasaan Bay on August 14 were recovered in area 2, leads to the conclusion that most of the salmon reaching the shores of Clarence Strait below Approach Point, during the latter part of the season, are bound for localities along the east shore of Prince of Wales Island, in area 2, as far south as Cape Chacon. Where do these salmon come from? Are they part of a population migrating southward from Sumner Strait, or do they come from the populations migrating northward in Clarence Strait that have turned near Kasaan Bay and move southward? A review of the tagging experiments carried on in Sumner Strait at Point Colpoys (see table 7) will show that most of the salmon migrating southward from Sumner Strait at this time of the season are bound for localities in area 4, with only a few migrating as far south as area 2. Therefore, considering the large volume of salmon caught in area 2 from Kasaan Bay south at this time of the season, there is only one probable origin of these southward-bound salmon. They must come from populations migrating northward in Clarence Strait that have turned westward and southward from the west shore of Gravina Island and the lower shore of Cleveland Peninsula just above Caamano Point. This turning back of the salmon from the west shore of Gravina Island during the latter part of the season was indicated in the discussion of the taggings carried on along this shore in 1926 and 1927. Further evidence in support of this conclusion will be presented in the discussion of the 1935 and 1936 taggings near Cape Chacon.

TAGGING EXPERIMENTS IN THE VICINITY OF CAPE MUZON

In discussing the tagging experiments in the immediate vicinity of Cape Chacon it was pointed out that a considerable number of the recoveries were reported from area 6 and the localities of Cordova Bay and contiguous channels. Of the 924 salmon recovered from the experiments near Cape Chacon, 241 were captured in area 6. It would appear that considerable numbers of the pink salmon migrating into Clarence Strait during the latter part of the season are bound for the localities of Cordova Bay and are milling about in an attempt to find them. A review of the results from the tagging experiments carried on late in the season at Cape Muzon, Kaigani Point, and Kaigani Strait points (see table 2), located at the entrance to Cordova Bay, will show that part of the pink salmon migrating into Cordova Bay are bound for areas 1, 2, 3, and 4. The results from these experiments are given in the last four columns of table 2. A total of 3,809 pink salmon were tagged at these three locations, of which 968, or 25.4 percent, were recovered. Of the total number recovered 57 were captured in area 1, 122 in area 2, 28 in area 3, 4 in area 4, 755 in area 6, and 2 in an outlying area. Since these taggings were carried on at approximately the same time in the fishing season as those near Cape Chacon, it is not surprising to find considerable numbers of the tagged individuals captured in area 2.

In summarizing the results from the tagging experiments carried on in the vicinity of Cape Chacon and Cape Muzon, it is evident that during the latter part of the season the pink salmon move in from Dixon Entrance to the southern shores of Prince of Wales Island, and after milling about for some time separate into populations that are bound for the localities in area 6, and populations that are bound for the localities in areas 1, 2, 3, and 4.

PINK-SALMON TAGGING EXPERIMENTS IN CLARENCE STRAIT IN 1935 AND 1936

In the summers of 1935 and 1936 series of consecutive weekly taggings of pink salmon were carried on in Clarence Strait in the vicinity of Cape Chacon. These taggings were made from a trap at McLean Point, located on the east shore of Prince of Wales Island, approximately 7 miles north of Cape Chacon. The taggings at McLean Point were all made from the trap operated at this location by the Alaska Pacific Salmon Co., and the Bureau of Fisheries wishes to express its appreciation for the cooperation of this company in furnishing these facilities, and the salmon that were tagged.

In Alaska, commercial fishing for salmon is prohibited by law from 6 p. m. Saturday to 6 a. m. Monday during the entire fishing season. All of the taggings in both series, with the exception of the first and fourth in 1935, were carried on at the beginning of the weekly closed periods. This provided an opportunity for the tagged individuals to migrate from the location at which they were tagged for at least 34 hours before they were again subject to capture. By following this procedure only a few were recaptured in the trap from which they had been tagged. The dates of the weekly experiments, and the number of pink salmon tagged in each, are given in table 4 for the 1935 series and in table 5 for the 1936 series of experiments.

TABLE 4.—*Pink salmon tagged at McLean Point in 1935* [1]

[Column headings indicate date and number tagged]

Locality of recovery	Salmon recovered and average time en route											
	July 22, 381		July 27, 395		Aug. 3, 395		Aug. 12, 389		Aug. 17, 297		Total, 1,857	
	Number	*Days*	*Number*	*Days*	*Number*	*Days*	*Number*	*Days*	*Number*	*Days*	*Number*	*Days*
LOWER CLARENCE STRAIT.—AREA 1												
East of Cape Fox:												
Kanagunut Island	------	------	1	12	------	------	------	------	------	------	1	12
Sitklan Island	------	------	------	------	1	4	------	------	------	------	1	4
Revillagigedo Channel and Tongass Narrows:												
Cape Fox	2	14	------	------	1	9	------	------	------	------	3	12
Foggy Bay	------	------	------	------	1	3	1	5	------	------	2	4
Duke Point	2	6	3	10	------	------	6	6	2	2	13	6
Boca de Quadra	------	------	1	3	------	------	------	------	------	------	1	3
Lucky Cove	------	------	6	4	------	------	------	------	------	------	6	4
Thorne Arm	------	------	8	4	------	------	3	3	------	------	11	4
Carrol Point	------	------	------	------	------	------	------	------	1	0	1	0
Annette Island, north and east shores	------	------	9	6	1	9	------	------	1	1	11	6
Behm Canal, south arm:												
Roe Point	------	------	------	------	------	------	------	------	1	?	1	?
Smeaton Bay	------	------	------	------	------	------	------	------	1	?	1	?
Rudyerd Bay	------	------	------	------	------	------	------	------	1	?	1	?
Chickamin River	------	------	2	5	------	------	------	------	------	------	2	5
General	------	------	1	5	------	------	------	------	------	------	1	5
Behm Canal, north arm:												
Point Higgins	1	4	------	------	------	------	------	------	------	------	1	4
Clover Pass	1	8	2	3	3	7	------	------	------	------	6	6
Smugglers Cove	1	8	------	------	1	3	------	------	------	------	2	6
Bond Bay	8	7	9	7	3	6	------	------	------	------	20	7
Helm Bay	1	?	------	------	------	------	------	------	------	------	1	?
Naha River	------	------	------	------	------	------	------	------	1	26	1	26
Indian Point	------	------	4	6	4	3	1	4	------	------	9	4
Escape Point	6	7	3	3	3	4	1	7	------	------	13	5
Neets Bay	------	------	------	------	2	4	------	------	------	------	2	4
Yes Bay	3	4	------	------	------	------	------	------	------	------	3	4
Robinson Creek	3	12	------	------	------	------	------	------	------	------	3	12
Belle Island	1	?	------	------	------	------	------	------	------	------	1	?
General	------	------	2	8	------	------	2	3	------	------	4	6
West and south shores of Gravina, Annette, and Duke Islands:												
Percy Islands	1	7	7	5	1	4	------	------	------	------	9	5
Davidson Point	2	5	------	------	------	------	------	------	------	------	2	5
Annette Island, south shore	------	------	12	4	3	6	6	6	3	3	24	5
Annette Island, northwest shore	------	------	1	5	------	------	3	3	1	4	5	4
Seal Cove	2	19	1	0	1	?	3	5	2	4	9	8
Gravina Island, west shore	27	5	23	5	19	7	11	5	18	4	98	5
Total recoveries	61	------	95	------	44	------	37	------	32	------	269	------
Percent recoveries	16.0	------	24.0	------	11.1	------	9.5	------	10.8	------	14.5	------
LOWER CLARENCE STRAIT.—AREA 2												
Prince of Wales Island from Cape Chacon to Approach Point:												
Kendrick Bay	4	2	5	7	6	11	18	4	8	3	41	5
Polk Island	------	------	------	------	3	14	22	5	10	4	35	5
Moira Sound	------	------	------	------	2	15	4	5	5	4	11	6
Point Adams	5	3	2	7	1	10	19	6	6	4	33	5
Wedge Island	------	------	1	4	------	------	------	------	2	4	3	4
Windy Point	1	9	3	13	2	9	1	4	------	------	7	10
Chasina Point	------	------	1	13	------	------	------	------	------	------	1	13
Cholmondeley Sound	------	------	1	3	------	------	1	9	------	------	2	6
Island Point	1	?	------	------	2	8	1	4	4	5	8	5
Skowl Arm	1	7	------	------	------	------	1	7	2	5	4	6
Total recoveries	12	------	13	------	16	------	67	------	37	------	145	------
Percent recoveries	3.1	------	3.3	------	4.1	------	17.2	------	12.5	------	7.8	------
MIDDLE CLARENCE STRAIT.—AREA 3												
Approach Point, Caamano Point, to Narrow Point, and Ernest Point:												
Caamano Point	3	9	3	6	5	5	1	13	------	------	12	7
Grindall Island and Niblack Point	7	6	10	6	4	4	3	7	6	3	30	5
Niblack Point	3	5	------	------	------	------	------	------	------	------	3	5
Ship Island and Streets Island	3	8	5	10	8	6	1	14	8	7	25	8
Meyers Chuck	14	9	9	5	17	5	4	4	8	5	52	6
Ernest Sound:												
Union Point	------	------	------	------	------	------	1	13	1	8	2	10
Eaton Point	4	9	------	------	4	4	------	------	------	------	8	6
Watkins Point	------	------	1	25	------	------	------	------	------	------	1	25
Santa Anna	1	4	------	------	------	------	------	------	------	------	1	4
Point Warde	3	27	------	------	------	------	------	------	------	------	3	27
Olive Cove	------	------	------	------	1	6	------	------	------	------	1	6
Total recoveries	38	------	28	------	39	------	10	------	23	------	138	------
Percent recoveries	10.0	------	7.0	------	9.9	------	2.6	------	7.7	------	7.4	------

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647.

TABLE 4.—*Pink salmon tagged at McLean Point in 1935*—Continued

[Column headings indicate date and number tagged]

Locality of recovery	Salmon recovered and average time en route											
	July 22, 381		July 27, 395		Aug. 3, 395		Aug. 12, 389		Aug. 17, 297		Total, 1,857	
	Number	*Days*	*Number*	*Days*	*Number*	*Days*	*Number*	*Days*	*Number*	*Days*	*Number*	*Days*
UPPER CLARENCE STRAIT.—AREA 4												
Narrow Point, Ernest Point to Point Harrington, East Island:												
Ernest Point	2	5	-----	-----	1	4	-----	-----	-----	-----	3	5
Screen Islands	3	34	-----	-----	-----	-----	2	15	1	8	6	23
Lincoln Rock	-----	-----	-----	-----	2	3	-----	-----	-----	-----	2	3
Eagle Creek	-----	-----	1	11	-----	-----	1	4	2	4	4	6
Whale Passage	-----	-----	-----	-----	-----	-----	-----	-----	1	3	1	3
Snow Passage and Stikine Straits:												
Snow Passage	-----	-----	-----	-----	-----	-----	1	3	-----	-----	1	3
Total recoveries	5	-----	1	-----	3	-----	4	-----	4	-----	17	-----
Percent recoveries	1.3	-----	0.3	-----	0.7	-----	1.0	-----	1.3	-----	0.9	-----
SUMNER STRAIT.—AREA 5												
Boulder Point	-----	-----	1	6	-----	-----	-----	-----	-----	-----	1	6
Total recoveries	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	1	-----
Percent recoveries	-----	-----	0.3	-----	-----	-----	-----	-----	-----	-----	0.1	-----
WEST COAST PRINCE OF WALES ISLAND.—AREA 6												
Brownson Bay	3	6	-----	-----	2	11	-----	-----	1	9	6	8
Shipwreck Point	-----	-----	-----	-----	-----	-----	2	2	1	7	3	4
Total recoveries	3	-----	-----	-----	2	-----	2	-----	2	-----	9	-----
Percent recoveries	0.8	-----	-----	-----	0.5	-----	0.5	-----	0.7	-----	0.5	-----
Summary of all recoveries	119	-----	138	-----	104	-----	120	-----	98	-----	579	-----
Percent of all recoveries	31.2	-----	34.9	-----	26.3	-----	30.8	-----	33.0	-----	31.2	-----

In 1935, five weekly taggings were carried on from July 22 to August 17. In 1936, because of a heavy storm on the week end of August 8, only four weekly taggings were carried on over a similar period of time; July 18 to August 15. It was for this reason that twice the usual number of salmon were tagged on August 15.

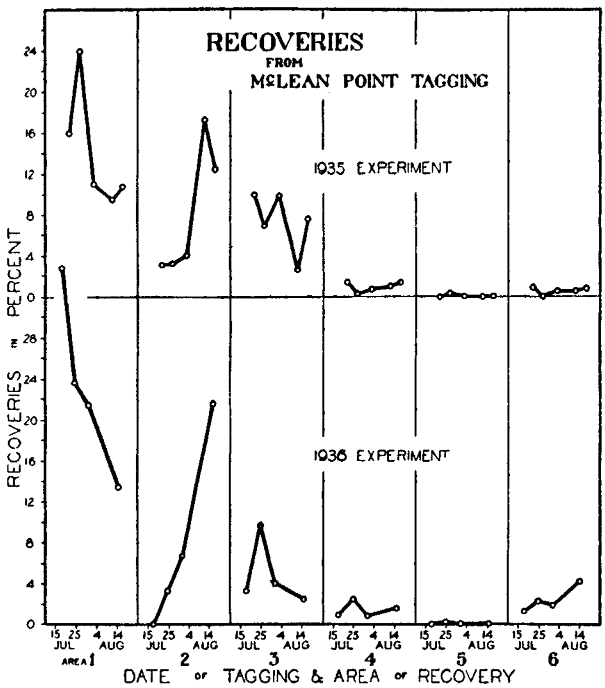

FIGURE 4.—Trends in the percentage recoveries of tagged pink salmon from the weekly tagging experiments in 1935 and 1936 at McLean Point.

Tables 4 and 5 also give the number and percent of tagged salmon recovered from each of the experiments and the localities in which they were captured. These localities, as stated in tables 1, 2, and 3, are listed under the geographic areas in which they occur. The average number of days the tagged salmon were en route before recapture are also reported but, owing to the extreme variability in the rate of travel, as indicated by the dates the salmon were recaptured, the authors do not feel justified in drawing definite conclusions about this phase of the salmon migrations. However, since this information is of general interest, it is reported in the tables. The seasonal trends in the percentages of salmon recovered in the geographic areas, as indicated by the results from the weekly taggings, are shown in figure 4 for both the 1935 and 1936 series of experiments.

TABLE 5.—*Pink salmon tagged at McLean Point in 1936* [1]

[Column headings indicate date and number tagged]

Locality of recovery	Salmon recovered and average time en route									
	July 18, 339		July 25, 625		Aug. 1, 493		Aug. 15, 984		Total, 2,441	
LOWER CLARENCE STRAIT.—AREA 1										
East of Cape Fox:										
Nakat Bay	2	18							2	18
Revillagigedo Channel and Tongass Narrows:										
Cape Fox	1	11			1	5	17	3	19	3
Tree Point					2	7			2	7
Foggy Bay	11	3	10	4	5	5	1	3	27	4
Duke Point			3	23	4	11			7	16
Slate Island	2	5							2	5
Black Island			2	11	1	3			3	8
Point Alava			2	16	3	8			5	11
Lucky Cove	1	14	5	7	2	9			8	8
Thorne Arm					1	13	5	4	6	5
Carrol Point	2	7	1	2			4	4	7	5
Annette Island, north and east shores	4	9							4	9
General	12	?	23	?	4	?			39	?
Behm Canal, south arm:										
Point Sykes					1	4			1	4
Smeaton Bay	1	7					2	3	3	4
Chickamin River	1	14							1	14
Behm Canal, north arm:										
Point Higgins	5	2							5	2
Bond Bay	3	6	5	7	4	9	3	4	15	7
Clover Passage					3	7			3	7
Betton Island							3	4	3	4
Traitors Cove	1	21			2	6			3	11
Belle Island	5	6	1	10	3	8			9	7
General					2	10			2	10
West and south shores of Gravina, Annette, and Duke Islands:										
Percy Islands	2	13							2	13
Annette Island, south shore			1	20			1	4	2	12
Annette Island, northwest shore	14	5	28	4	24	5	11	5	77	5
Point McCartey	3	3	2	4					5	3
Warburton Island	3	7	2	7	1	9	2	5	8	7
Seal Cove	1	21	1	3	1	3	12	5	15	6
Blank Point	1	5			1	11			2	8
Gravina Island, west shore	43	7	62	7	41	5	72	7	218	7
Total recoveries	118		148		106		133		505	
Percent recoveries	34.8		23.7		21.5		13.5		20.7	
LOWER CLARENCE STRAIT.—AREA 2										
Prince of Wales Island from Cape Chacon to Approach Point:										
Kendrick Bay			9	8	9	3	97	5	115	5
Polk Island, Scott Point, Rip Point, and Hidden Point			2	21	15	9	59	6	76	7
Moira Sound							2	6	2	6
Point Adams					3	3	10	6	13	5
Wedge Island			3	4	1	18	6	3	10	5
Chasina Point							21	4	21	4
Island Point							10	4	10	4
Patterson Island					1	21			1	21
Skowl Arm			4	10	7	8	1	4	12	8
Twelve Mile Arm			2	23			1	7	3	18
Kasaan Bay					1	22	5	4	6	7
Total recoveries			20		37		212		269	
Percent recoveries			3.2		7.5		21.6		11.0	
MIDDLE CLARENCE STRAIT.—AREA 3										
Approach Point, Caamano Point, to Narrow Point, and Ernest Point:										
Caamano Point and Grindall Island			21	8	3	6	15	8	39	8
Niblack Point	4	12	10	7	7	15	5	6	26	10
Ship Island and Street Island					1	9			1	9
Meyers Chuck			3	5	8	10	4	6	15	8
False Island	2	14	15	6					17	7
Ernest Sound:										
Vixen Point	5	5							5	5
Union Point and Watkins Point			11	6					11	6
Total recoveries	11		60		19		24		114	
Percent recoveries	3.2		9.6		3.9		2.4		4.7	

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647.

TABLE 5.—*Pink salmon tagged at McLean Point in 1936*—Continued

[Column headings indicate date and number tagged]

Locality of recovery	Salmon recovered and average time en route									
	July 18, 339		July 25, 625		Aug. 1, 493		Aug. 15, 984		Total, 2,441	
UPPER CLARENCE STRAIT.—AREA 4										
Narrow Point, Ernest Point to Point Harrington, and East Island:										
Ernest Point							3	10	3	10
Narrow Point	1	25	1	18	1	11			3	18
Olson Cove			2	16					2	16
Eagle Creek			5	9	1	25	4	11	10	11
Lincoln Rock					1	29	2	9	3	16
Marsh Island	1	26	3	12			5	7	9	11
Steamer Rock	1	32			1	12			2	22
Snow Passage and Stikine Strait:										
Snow Passage			4	7			1	2	5	6
Total recoveries	3		15		4		15		37	
Percent recoveries	0.9		2.4		0.8		1.5		1.5	
SUMNER STRAIT.—AREA 5										
Affleck Canal			1	7					1	7
Total recoveries			1						1	
Percent recoveries			0.2						0.1	
WEST COAST PRINCE OF WALES ISLAND.—AREA 6										
Nichols Bay					4	?	1	3	5	3
Brownson Bay	3	16	9	11	5	12	15	5	32	8
Hunter Bay			1	32			13	6	14	8
Point Webster							1	8	1	8
Klakas Inlet							5	5	5	5
Natkwa Inlet							1	7	1	7
Cordova Bay	1	36					4	3	5	9
Cape Muzon			4	6					4	6
Total recoveries	4		14		9		40		67	
Percent recoveries	1.2		2.2		1.8		4.1		2.7	
OUTLYING AREAS										
Kingsmill Point	1	10	3	7	1	0			5	6
Total recoveries	1		3		1				5	
Percent recoveries	0.3		0.5		0.2				0.2	
Summary of all recoveries	137		261		176		424		998	
Percent of all recoveries	40.4		41.8		35.7		43.1		40.9	

The percentage of recoveries in area 1, from the weekly taggings at McLean Point, tended to be highest in the early part of the season and lowest in the latter part, thus indicating a seasonal decrease in the portion of the run passing McLean Point that was bound for area 1. In reviewing the number of tagged salmon recovered in area 1 (see tables 4 and 5), it was found that very few were captured in the localities east of Cape Fox and in the south arm of Behm Canal. Considerable numbers were captured in Revillagigedo Channel and the north arm of Behm Canal. The largest numbers, however, were recovered consistently along the west shores of Annette and Gravina Islands.

The percentage of recoveries in area 2 from the weekly taggings tended to be lowest in the early part of the season and highest in the latter part. This is just the reverse of the seasonal trends in area 1. In other words, there was a very definite seasonal increase in the percentages of the pink salmon tagged at McLean Point that were recovered in area 2. The localities in which these recoveries were made were scattered along the east shore of Prince of Wales Island from Kendrick Bay to Kasaan Bay. During the first part of the season a large proportion of the salmon were recaptured just north of the point of tagging but, as the season progressed, more and more were reported from localities in the vicinity of Kasaan Bay.

The percentage of recoveries in area 3 from the weekly taggings was much smaller than those in areas 1 and 2. No doubt many of the tagged salmon bound for this area were intercepted in the latter regions. Nevertheless, there were sufficient recoveries in area 3 to give some indication of the time when these salmon migrated through Clarence Strait. Although the seasonal trends in area 3 are not very marked, there is indication that more of the recoveries were made in the early part of the season than in the latter part. In other words, more pink salmon bound for area 3, and the areas above it, migrate through Clarence Strait in the early part of the season than in the latter part.

The percentage of recoveries in areas 4 and 5 were so small that no definite trends occur in them. Many of the salmon bound for these areas were, no doubt, intercepted in areas 1, 2, and 3.

The percentage of recoveries in area 6 for the 1935 series of experiments was too small to indicate a definite seasonal trend. However, the percentage recovered from the 1936 series of experiments, although only slightly greater, indicates a possible upward trend in the latter part of the season. Since, in 1935, there was a misunderstanding on the part of the cannerymen in this area as to the method of reporting recoveries of tagged salmon, there is reason to believe the 1935 data are incomplete. This tendency toward an increase in the percentage of recoveries as the season progresses is in accord with the results from the experiments carried on near Cape Chacon during the second and third weeks of August in 1925 and 1926. In fact the whole distribution of the salmon tagged during the second and third weeks of August in the 1935 and 1936 experiments is in accord with the distribution of the salmon tagged in the 1925 and 1926 experiments.

In discussing the distribution of the recoveries from the early tagging experiments in Clarence Strait, evidence was pointed out which indicated that many of the pink salmon migrating along the west shores of Gravina and Annette Islands during the latter part of the season were bound for localities along the east shore of Prince of Wales Island in area 2. Further evidence in regard to this peculiar migration of the pink salmon in Clarence Strait may be found in the distribution of the recoveries from the 1935 and 1936 experiments.

In discussing the localities in area 1 in which the tagged salmon were recovered (see tables 4 and 5), it was pointed out that the majority were recovered from the west shores of Gravina and Annette Islands. The total numbers, by weekly taggings, recovered in area 1 in the localities east of Cape Fox, Revillagigedo Channel, and Behm Canal, as a group, and the recoveries from the west shores of Gravina and Annette and Duke Islands, as a group, are given in table 6.

TABLE 6.—*Pink salmon recovered in area 1 from tagging experiments at McLean Point in 1935 and 1936*

Date of tagging experiment	Recoveries in 1935						Recoveries in 1936					
	East of Cape Fox, Revillagigedo Channel, and Behm Canal		West shores of Gravina, Annette, and Duke Islands		Total		East of Cape Fox, Revillagigedo Channel, and Behm Canal		West shores of Gravina, Annette, and Duke Islands		Total	
	Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
July 18							51	43	67	57	118	100
July 22	29	48	32	52	61	100						
July 25							52	35	96	65	148	100
July 27	51	54	44	46	95	100						
Aug. 1							38	37	68	63	106	100
Aug. 3	20	45	24	55	44	100						
Aug. 12	14	38	23	62	37	100						
Aug. 15							35	26	98	74	133	100
Aug. 17	8	25	24	75	32	100						

The relation between these recoveries and the total recoveries in area 1, expressed in percentage, is also given in table 6. It will be noted that the weekly percentage of recoveries in area 1, from the localities east of Cape Fox, Revillagigedo Channel, and Behm Canal, are highest in the beginning of the season and lowest toward the end. The weekly percentage of recoveries along the west shores of Gravina, Annette, and Duke Islands is, on the other hand, lowest at the first part of the season and highest toward the last. In other words, there is a seasonal increase in the percentage of tagged salmon caught in area 1 along the west shores of Gravina and Annette Islands, whereas there is a seasonal decrease in the percentage of the tagged salmon caught in other localities of the area.

Since there are very few streams along the west shores of Annette and Gravina Islands in which salmon can spawn, most of the tagged salmon caught in this region were evidently bound either for other localities in area 1, or in one of the other areas. During the first part of the season considerable numbers of tagged salmon were recovered in the north arm of Behm Canal and in area 3. No doubt many of those recovered from the west shores of Gravina and Annette Islands during the first part of the season were bound for those regions. In the latter part of the season, however, very few were recovered from the north arm of Behm Canal and area 3, but there were still large recoveries from the west shores of Gravina and Annette Islands. Where were these tagged salmon going at this time of the season?

In discussing the percentage of recoveries of tagged salmon in area 2 from the weekly taggings it was pointed out that there was a seasonal increase in these recoveries and that larger numbers were reported from the localities in the vicinity of Kasaan in the last part of the season than in the first part. Hence, it is not at all improbable that many of the tagged salmon recovered from the west shores of Gravina and Annette Islands during the latter part of the season were bound for the localities in area 2 in the vicinity of Kasaan Bay and southward. These salmon no doubt migrated across Clarence Strait to the west shores of Gravina and Annette Islands and then turned back to the localities on the east shore of Prince of Wales Island in area 2. Whether or not the salmon make this journey may depend to some extent upon the prevailing winds. If a southeast wind is blowing there seems to be a greater tendency for the salmon to migrate northward along the east shore of Prince of Wales Island rather than to cross over to the west shores of Gravina and Annette Islands. If a southwest wind is blowing the opposite course is more apt to be taken. No definite conclusions may be drawn because of the lack of sufficient information, at the present time, concerning the influence of wind direction on migration.

SUMMARY OF CAPE CHACON EXPERIMENTS

1. The results from the tagging experiments in Clarence Strait, both past and present, indicate that the pink salmon migrating into the strait at different times of the season follow rather definite migratory routes to the localities for which they are bound.

2. Most of the first pink salmon to appear each season are bound for localities in Revillagigedo Channel, the north arm of Behm Canal, Ernest Sound, or the northernmost regions in Clarence Strait. These salmon enter Clarence Strait by way of Cape Chacon and, after migrating for a short distance northward along the east shore of Prince of Wales Island, leave this shore and either follow directly up the middle of the strait or turn eastward until they reach the west shores of Annette and Gravina Islands. From here they either continue northward into the north

arm of Behm Canal and the northern regions of Clarence Strait, including Ernest Sound, or they continue eastward and southward into Revillagigedo Channel.

3. This peculiar migration of the salmon along the west shores of Annette and Gravina Islands results in many of the salmon, bound for the north arm of Behm Canal and the northern regions of Clarence Strait, being intercepted by the traps and purse seines operated along these shores.

4. As the season progresses, more and more of the pink salmon entering Clarence Strait by way of Cape Chacon are destined for the localities along the east shore of Prince of Wales Island below Approach Point. Most of these salmon continue northward along the east shore of Prince of Wales Island instead of crossing the strait to the west shores of Annette and Gravina Islands. Many of those that do cross the strait turn back from the shores of these islands to the localities on the east shore of Prince of Wales Island.

5. At the very close of the season many of the salmon migrating into Clarence Strait are bound for localities in Cordova Bay on the extreme southwest shore of Prince of Wales Island.

The migration of the pink salmon along the west shores of Annette and Gravina Islands, especially the latter, makes these shores one of the most productive fishing areas in Clarence Strait. The fishing gear operated in this area intercepts the runs of pink salmon that are bound for practically all of the localities in Clarence Strait and its adjacent waters to the east. It is for this reason that so many of the pink salmon tagged in Clarence Strait were recovered along the west shores of these islands.

PINK-SALMON TAGGING EXPERIMENTS IN SUMNER STRAIT, 1924–36

It has long been known that the run of pink salmon in Sumner Strait appears earlier in the summer than the run in Clarence Strait. The time the salmon appeared in the commercial catches and the location of these catches in the strait indicated that most of these early migrants were bound for localities in the extreme eastern section and the adjoining waters of Zimovia Strait, Eastern Passage, Blake Channel, and Bradfield Canal. However, the extent to which this run penetrated the waters of Clarence Strait and other adjoining channels was not known. In order to determine more completely the distribution of the localities in which these pink salmon spawned, the Bureau laid plans for a number of tagging experiments to be carried on in various parts of Sumner Strait. This work began in 1924, was continued each year through 1927, and taken up again in 1935 and 1936. Since only one experiment was carried on in each of the latter seasons, their results will be discussed with those from the early experiments.

The locations where the salmon were tagged in Sumner Strait from 1924 to 1936 are shown in figure 1. The dots indicate the locations of early taggings and the triangle is that of the later ones. The early tagging was done at Cape Decision, Ruins Point, and Point Colpoys, and during 1935 and 1936 only at Point Colpoys. Although none of these experiments continued throughout the entire season of any year, they varied sufficiently in point of time so that, taken together, they give a picture of the movements of fish in this region over an entire season. Thus, experiments were carried on at Cape Decision and Ruins Point in 1924, 1925, and 1927, between July 12 and August 3; those at Point Colpoys on July 10, 1926, July 26 to 30, 1927, August 13, 1935, and August 16, 1936. A summary by geographic areas of the results from all experiments from 1924 to 1936 is given in table 7. The individual localities in the geographic areas, in which the tagged salmon were recovered from the 1935 and 1936 experiments at Point Colpoys, are given in table 8. The taggings at Point Colpoys were made from the trap operated at this location by the Pacific American Fisheries, Inc., and the Bureau of Fisheries wishes to express its appreciation for the cooperation of this company in furnishing these facilities, and the salmon that were tagged.

TABLE 7.—*Pink salmon tagged in Sumner Strait, 1924–36, and number recovered* [1]

[Column headings indicate locality and date of tagging]

	Point Colpoys, July 10, 1926	Point Colpoys, July 26–30, 1927	Point Colpoys, Aug. 13, 1935	Point Colpoys, Aug. 16, 1936	Total, Point Colpoys	Ruins Point, July 18–25, 1925	Ruins Point, July 12–Aug. 3, 1924	Cape Decision, July 30, 1927	Total, Ruins Point and Cape Decision
Number tagged	259	569	386	498	1,712	1,217	250	162	1,629
LOCALITY OF RECOVERY									
SUMNER STRAIT (ALL POINTS).—AREA 5									
Total recovered	2	6	9	9	26	295	20	8	323
Percent recovered	0.8	1.1	2.3	1.8	1.5	24.2	8.0	4.9	19.8
UPPER CLARENCE STRAIT.—AREA 4									
Point Colpoys						32	6	5	43
Snow Passage and Stikine Strait	3	13	19	84	119	36		2	38
Narrow Point, Ernest Point to Point Harrington, and East Island	8	34	47	66	155	30	3	2	35
Total recovered	11	47	66	150	274	98	9	9	116
Percent recovered	4.2	8.3	17.1	30.1	16.0	8.2	3.6	5.6	7.1
MIDDLE CLARENCE STRAIT.—AREA 3									
Ernest Sound	28	88	3	6	125	29	2	2	33
Approach Point, Caamano Point to Narrow Point and Ernest Point	11	39	20	7	77	15	2	2	19
Total recovered	39	127	23	13	202	44	4	4	52
Percent recovered	15.1	22.2	6.0	2.6	11.8	3.6	1.6	2.5	3.2
LOWER CLARENCE STRAIT.—AREA 2									
East shore of Prince of Wales Island from Approach Point to Brownson Bay:									
Total recovered	1	4	2	6	13	6	3		9
Percent recovered	0.4	0.7	0.5	1.2	0.8	0.5	1.2	0.0	0.6
LOWER CLARENCE STRAIT.—AREA 1									
West shores of Gravina, Annette, and Duke Islands	2	21	4	9	36	13	1		14
Behm Canal, *north arm*	4	6		2	12				
Behm Canal, south arm		1			1	1			1
Tongass Narrows and Revillagigedo Channel	1	8	2	3	14	7	2		9
East of Cape Fox	1				1	4			4
British Columbia		2			2	1		1	2
Total recovered	8	38	6	14	66	26	3	1	30
Percent recovered	3.1	6.7	1.6	2.8	3.8	2.1	1.2	0.6	1.8
OUTLYING AREAS									
Northwest coast Prince of Wales Island (all points)						27	7		34
Chatham Strait and Frederick Sound (all points)	2	1			3	7	3	16	26
Total recovered	2	1			3	34	10	16	60
Percent recovered	0.8	0.2	0.0	0.0	0.2	2.8	4.0	9.9	3.7
SUMMARY:									
Total recovered	63	223	106	192	584	503	49	38	590
Percent recovered	24.3	39.2	27.5	38.5	34.1	41.3	19.6	23.5	36.2

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647. The original records of the tagging experiments from 1924 to 1927 are given in the reports of Rich 1926, Rich and Suomela 1927, and Rich and Morton 1929.

TAGGING EXPERIMENTS AT RUINS POINT AND CAPE DECISION

Ruins Point is located on the east side and Cape Decision on the west side of the entrance to Sumner Strait. Point Colpoys is located in the central part of the strait where, through Snow Passage, Sumner Strait connects with the northern part of

Clarence Strait. Because of the rather wide geographic separation of these points, separate summaries were made of the Ruins Point-Cape Decision experiments and the Point Colpoys experiments.

TABLE 8.—*Pink salmon tagged at Point Colpoys in 1935 and 1936* [1]

Locality of recovery	Salmon recovered and average time enroute					
	Aug. 13, 1935, 386		Aug. 16, 1936, 498		Total, 884	
	Number	*Days*	*Number*	*Days*	*Number*	*Days*
SUMNER STRAIT.—AREA 5						
Kah Sheets Bay			2	5	2	5
Red Bay	2	1			2	1
Point Baker	1	?			1	?
Rocky Pass	2	7			2	7
Port Beauclerc	1	8	7	5	8	5
Calder Bay	1	3			1	3
Warren Channel	2	9			2	9
Total recoveries	9		9		18	
Percent recoveries	2.3		1.8		2.0	
UPPER CLARENCE STRAIT.—AREA 4						
Snow Passage and Stikine Strait:						
Snow Passage	19	2	65	2	84	2
Steamer Point			19	3	19	3
Point Harrington, East Island to Ernest Point, and Narrow Point:						
Steamer Rock			2	3	2	3
East Island	3	6			3	6
Whale Passage	7	6	9	12	16	9
Marsh Island			11	3	11	3
Screen Islands	3	13			3	13
Lincoln Rock			26	6	26	6
Lake Bay	3	7			3	7
Eagle Creek	29	5	12	9	41	6
Ratz Harbor	2	3	2	9	4	6
Olson Cove			4	7	4	7
Total recoveries	66		150		216	
Percent recoveries	17.1		30.1		24.4	
MIDDLE CLARENCE STRAIT.—AREA 3						
Ernest Sound:						
Ernest Point			4	5	4	5
Union Point and Watkins Point			1	8	1	8
Emerald Bay			1	6	1	6
Point Ward	3	6			3	6
Narrow Point, Ernest Point to Approach Point, and Caamano Point:						
Meyers Chuck	12	5	5	7	17	6
Wolf Creek	2	7			2	7
Ship Island	3	7			3	7
Niblack Point			2	7	2	7
Grindall Island	3	9			3	9
Total recoveries	23		13		36	
Percent recoveries	6.0		2.6		4.1	
LOWER CLARENCE STRAIT.—AREA 2						
East shore Prince of Wales Island from Approach Point to Brownson Bay:						
Chasina Point			3	5	3	5
Moria Sound	1	4			1	4
Ripp and Scott Points			2	7	2	7
Cape Chacon	1	4			1	4
Brownson Bay			1	7	1	7
Total recoveries	2		6		8	
Percent recoveries	0.5		1.2		0.9	
LOWER CLARENCE STRAIT.—AREA 1						
West shores of Gravina, Annette, and Duke Islands:						
West Shore of Gravina Island	3	7	6	6	9	6
West Shore of Annette Island			3	4	3	4
Seal Cove	1	7			1	7
Behm Canal and Revillagigedo Channel:						
Cape Caamano			2	6	2	6
Point Sykes			2	5	2	5
Foggy Bay	2	8	1	2	3	6
Total recoveries	6		14		20	
Percent recoveries	1.6		2.8		2.3	
Summary of all recoveries	106		192		298	
Percent of all recoveries	27.5		38.5		33.7	

[1] These data do not include recoveries reported from the point of tagging nor those doubtful as to location of capture. See text, p. 647.

Seven tagging experiments were carried on at Ruins Point in 1924 and 1925, and one at Cape Decision in 1927. Since these experiments were carried on at different times in the season, from July 12 to August 3, their results should indicate the destinations of the pink salmon that migrate through Sumner Strait at all times of the season. A total of 1,629 pink salmon were tagged, of which 590, or 36.2 percent, were recovered. Of these, 393, or 19.8 percent, were captured in Sumner Strait, area 5; 116, or 7.1 percent, in upper Clarence Strait, area 3; 9, or 0.6 percent, in lower Clarence Strait, area 2; 30, or 1.8 percent, in lower Clarence Strait, area 1; and 60, or 3.7 percent, along the northwest shore of Prince of Wales Island, Chatham Strait, and Frederick Sound. Hence it may be assumed that most of the pink salmon migrating into Sumner Strait are bound for localities in the strait and the northern regions of Clarence Strait, with only a small percentage migrating to localities in the lower regions of Clarence Strait. It is also important to note that of the 52 tagged salmon recovered in middle Clarence Strait, area 3, 33 were captured in Ernest Sound, indicating that many of the Sumner Strait pink salmon use the northern region of Clarence Strait only as a means of reaching Ernest Sound and its adjoining channels.

TAGGING EXPERIMENTS AT POINT COLPOYS

Further and more exact proof of this distribution of the Sumner Strait pink salmon in Clarence Strait and Ernest Sound may be found in an analysis of the results from the Point Colpoys taggings. A total of five tagging experiments were carried on at Point Colpoys; one on July 10, 1926, one each on July 26 and 30, 1927, one on August 13, 1935, and one on August 16, 1936. Thus, these experiments cover a period from July 10 to August 16 and represent both the odd- and even-year runs in equal proportion. The results were compiled in a manner similar to the procedure followed with the Clarence Strait data. In other words, they were used to show the seasonal differences in the distribution of the pink salmon to the spawning localities in the eastern section of Sumner Strait and its adjoining channels, and in Clarence Strait and Ernest Sound.

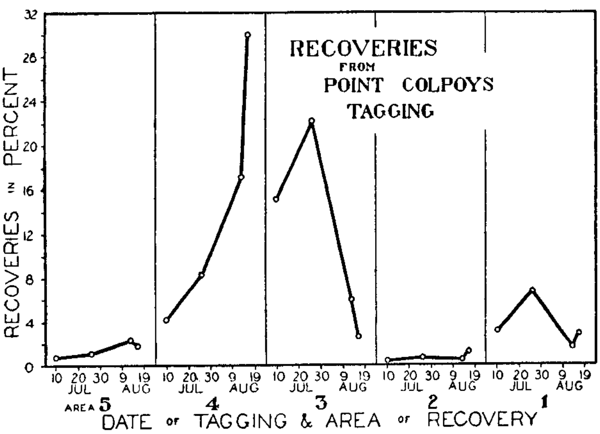

FIGURE 5.—Trends in the percentage recoveries of tagged pink salmon from the 1926, 1927, 1935, and 1936 tagging experiments at Point Colpoys.

The percentages of the tagged pink salmon recovered in the various geographic areas from each of the experiments are given in figure 5. From an inspection of this figure it will be noticed that very few of the salmon tagged at Point Colpoys were recovered in area 5 (Sumner Strait). The seasonal trend in the percentages of the recoveries in this area was not very definite and cannot be considered as indicative of any seasonal change in the number of pink salmon bound for the area. The seasonal trends in the percentages of recoveries in areas 3 and 4, on the other hand, were very marked and are certainly indicative of a seasonal increase in the number of pink salmon bound for the localities in area 4, and a definite seasonal decrease in the numbers bound for the localities in area 3. The percentage of recoveries in area 2, like those in area 5, was very small. The percentage of recoveries in area 1, although by no means as great as those in areas 3 and 4, did show some indication of a seasonal decrease. It is not improbable that the majority of the Sumner Strait pink salmon migrating as far south as area 1 in Clarence Strait come from the early, rather than the late, part of the run.

SUMMARY OF POINT COLPOYS EXPERIMENTS

In reviewing the distribution of the pink salmon tagged at Point Colpoys (see tables 7 and 8), it will be noted that the majority of the tagged salmon recovered during the early part of the season were captured in the Ernest Sound region of area 3. This region supports a large number of excellent spawning streams whose pink-salmon populations enter them during the early part of the season. The majority of the tagged salmon recovered during the latter part of the season, on the other hand, were captured in area 4. This region also supports a large number of excellent spawning streams whose pink-salmon populations are known to migrate into them during the latter part of the season. Hence it may be assumed that most of the pink salmon migrating through Sumner Strait as far as Point Colpoys are bound for the localities in Ernest Sound and its contiguous channels, and the localities in the northern region of Clarence Strait. Furthermore, the pink salmon destined for localities in Ernest Sound and its adjoining channels, which are the farthest from the sea, pass through Sumner Strait early in the season, whereas those bound for the localities in Snow Passage and the northern region of Clarence Strait, which are closer to the sea, migrate later in the season.

The results from both the Clarence and Sumner Straits experiments indicate that most of the pink salmon migrating through these channels in the early part of the season are bound for the inside localities farthest from the sea, and as the season progresses they tend more and more to migrate into the localities which are closer to the sea. In view of these results the authors do not feel that the contention of the salmon packers, that their catches of pink salmon in area 2 during the latter part of the season are made from the runs migrating through Sumner Strait, is well founded.

CONCLUSIONS

Cape Fox region.—The pink salmon migrating through Dixon Entrance to the shores near Cape Fox are either bound for localities east of the cape or those in Revillagigedo Channel and the south arm of Behm Canal.

Cape Chacon region.—Most of the pink salmon entering Clarence Strait by way of Cape Chacon, during the early part of the fishing season, are destined for localities in Revillagigedo Channel, the north arm of Behm Canal, and the more distant localities in the northern region of Clarence Strait. Most of those migrating by the same route later in the season are bound for localities on the east shore of Prince of Wales Island south of Approach Point. Thus, the early migrants are native to the streams farthest distant from the sea, whereas the later migrants are native to those in the more proximate localities.

Cape Muzon region.—The tagging experiments carried on near the entrance to Cordova Bay were all made during the latter part of the season. The results indicate that at this time the incoming pink salmon are bound for localities in Cordova Bay, with a small percentage continuing around Cape Chacon to the southeast shore of Prince of Wales Island.

Point Colpoys region.—Those pink salmon migrating through Sumner Strait which pass Point Colpoys early in the season are destined for localities in Ernest Sound and the central region of Clarence Strait with a few continuing as far south as Revillagigedo Channel. Those passing the point later in the season are destined almost exclusively for localities in Snow Passage and the northern region of Clarence Strait. Thus, again, we find a seasonal difference in distribution. The early migrants are destined for the localities remote from the sea, the later migrants for the more proximate localities.

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THE GEOGRAPHIC DISTRIBUTION AND ENVIRONMENTAL LIMITATIONS OF THE PACIFIC SALMON (GENUS *ONCORHYNCHUS*)[1]

By FREDERICK A. DAVIDSON, Ph. D., *Aquatic Biologist*, and SAMUEL J. HUTCHINSON, B. S., *Junior Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

There are five principal species of Pacific salmon, all of which are classified in the genus *Oncorhynchus*. They are chinook, or quinnat (*O. tschawytscha*); sockeye, or red (*O. nerka*); coho, or silver (*O. kisutch*); pink, or humpback (*O. gorbuscha*); and chum, or dog (*O. keta*). These fish are anadromous; they spend part of their lives in the sea and part in the streams. The eggs are deposited in gravel beds in the streams and lakes during the summer and fall and hatch out during the following spring months. The fry remain in fresh water for varying lengths of time, depending upon the species, but all eventually migrate to the sea where they make over 95 percent of their growth. Upon attaining maturity in the sea the adults return to the streams where they spawn and die. The studies of Gilbert (1913), Snyder (1921–24), Rich and Holmes (1928), Pritchard (1933), Davidson (1934), and Foerster (1936), on the life histories of the Pacific salmon show that they have a pronounced homing instinct and in general return to their parent streams to spawn.

The locations and depths at which the salmon feed while in the sea have not been definitely determined. Catches of chinook and coho salmon are made by the troll fishery as far as 100 miles offshore and at depths as great as 90 fathoms. Commercial and Government vessels operating in Alaskan waters have reported the presence of the salmon even farther out to sea. The continental shelf along the Pacific coast of North America averages less than 40 miles in width, thus it is evident

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that the feeding salmon frequent the waters of the open sea as well as those of the immediate coast. Bigelow and Welsh (1924), in discussing the habits of the pink salmon transplanted in the coastal streams of Maine, state that:

> During their first months in salt water the fry linger near the mouths of the home streams, where they feed chiefly on copepods and other small crustaceans, or pteropods, and on insects that drift down stream with the current, and occasionally on fish fry. After they are 5 or 6 inches long they move out into deep water, and very little is known of their habits and wanderings thereafter until they reappear on the coast as adults to breed.

Since the Pacific salmon live alternately in two distinctly different environments, fresh-water and marine, their geographic distribution is influenced by the limiting factors in each environment. This study was made for the purpose of determining the geographic distribution of the salmon and gaining knowledge of the environmental limitations to their occurrence.

GEOGRAPHIC DISTRIBUTION

NATIVE

The native distribution of the Pacific salmon is confined almost entirely to the temperate and arctic waters of the North Pacific. They are found in the streams along both the North American and Asiatic coast lines within similar geographic limits. On the North American continent O'Malley (1920), Cobb (1930), and Evermann and Clark (1931), give Monterey Bay, 70 miles south of San Francisco, Calif., as the southernmost limit of their common occurrence, although a few specimens have been taken at odd times as far south as the Ventura River, Calif. From here O'Malley (1920), Gilbert (1922), and Cobb (1930), report them inhabiting the coastal streams, in varying degrees of abundance, northward along the continent to Kotzebue Sound in Bering Strait.

Dymond and Vladykov (1933) give the probable occurrence of chum salmon in the Mackenzie River of northern Canada and the definite occurrence of this species in the Lena River of northern Siberia. These rivers flow into the Arctic Ocean. From the Lena River, the northernmost point of occurrence on the Asiatic continent, they are found to a limited extent southeastward along the Arctic shores to the Chukchee Peninsula in Bering Strait. From the Anadir River just south of the Chukchee Peninsula all species, according to Caldwell (1916), Lebedev (1920), Russian Economic Monthly (1920), Baievsky (1926), and Pravdin (1932), are present in varying degrees of abundance in the coastal streams southward along the continent to the Amur River. The range of the pink and chum salmon extends farther southward to the Tumen River in northern Korea which is given by Mori (1933) as the southernmost occurrence of these salmon.

All species other than the chinook salmon, according to Jordan, Tanaka, and Snyder (1913), Tanaka (1931), Handa (1933), Oshima (1933), and Tokuhisa and Ito (1933), are found in the coastal streams of Sakhalin, Hokkaido, and Kurile Islands and the northern shore of Honshu Island. The range of the pink and chum salmon extends farther southward on Honshu Island to the Tonegawa River near Cape Inuboye on the eastern shore, and to the Omonogawa River near Akita on the western shore. A report has also been received through correspondence from Dr. Fujita of the Hokkaido Imperial University, of the limited occurrence of the chum salmon along the west shore of Honshu Island as far south as the Joganjigawa River. The geographic distribution of the Pacific salmon on both the North American and Asiatic continents is shown in figures 1, 2, 3, and 4.

FOREIGN

In 1872 the United States Commission of Fish and Fisheries, later the United States Bureau of Fisheries, established an egg-taking station (Baird Station, Calif.) on a tributary of the Sacramento River for the sole purpose of collecting chinook or quinnat salmon eggs for transplantation in foreign waters.[2] This station formed the source of supply of millions of these eggs which were shipped to the Atlantic Coast States and to countries in many parts of the world. With the development of the Pacific coast, additional egg-taking stations were established in Oregon and Washington by the Bureau of Fisheries. Following 1900, these stations furnished eggs and young of the other species of the Pacific salmon that were likewise shipped to various parts of the world for transplantation. The introduction of salmon into foreign waters was continued actively through 1930. The number, by species of eggs and young shipped, and the States and foreign countries receiving them, are given by 10-year periods in tables 1 and 2.[3] Only those eggs and young that were transplanted in coastal streams for the purpose of developing natural sea-run populations are included in these tables. All transplantations in inland waters for the establishment of landlocked populations have been omitted.

TABLE 1.—*Foreign distribution of Pacific salmon eggs and young*

[By 10-year periods, 1872–1930]

CHINOOK SALMON (*O. tschawytscha*)

Localities of distribution	Periods and number distributed						Total
	1872–1880	1881–1890	1891–1900	1901–1910	1911–1920	1921–1930	
STATES							
Connecticut	1,410,000						1,410,000
Delaware	31,400						31,400
Georgia	79,000		40,000				119,000
Louisiana	43,400						43,400
Maine	215,000		3,450,000	100,000			3,765,000
Maryland	4,445,000	500,000	10,000		22,500	139,700	5,117,200
Massachusetts	640,000		400	10,100	117,500		768,000
Mississippi	43,400						43,400
New Hampshire	550,000	50,000	50,000	567,960	184,710	720,000	2,122,670
New Jersey	2,800,000	550,000					3,350,000
New York	975,000		7,097,400	114,240	985,550		9,172,190
North Carolina	1,150,000						1,150,000
Pennsylvania	2,545,000	150,000	100,000		10,000		2,805,000
Rhode Island	340,000						340,000
South Carolina	200,000	300,000					500,000
Vermont	40,000		304,070	50,750	122,000		516,820
Virginia	1,270,000		7,000	45,000			1,322,000
COUNTRIES							
Argentina				1,058,000			1,058,000
Australia	100,000	50,000					150,000
Canada	915,000	500,000					1,415,000
Chile						200,000	200,000
England	150,000						150,000
France	358,000	300,000	395,000				1,053,000
Germany	830,000		125,000				955,000

[2] For history of establishment and early development of this station see Stone (1878).

[3] For more detailed information on the data reported in these tables see United States Bureau of Fisheries reports on the propagation and distribution of food fishes (1871 to 1935).

TABLE 1.—*Foreign distribution of Pacific salmon eggs and young*—Continued

CHINOOK SALMON (*O. tschawytscha*)—Continued

Localities of distribution	Periods and number distributed						Total
	1872–1880	1881–1890	1891–1900	1901–1910	1911–1920	1921–1930	
COUNTRIES—continued							
Hawaii	30,000					99,000	129,000
Ireland			50,000				50,000
Italy			50,000				50,000
Mexico [1]		50,000	50,000				100,000
Netherlands (Holland)	500,000					400,000	900,000
New Zealand	1,175,000		775,000	1,600,000			3,550,000
Nicaragua [1]			20,000				20,000
Norway [2]		25,000					25,000
Tasmania				494,000			494,000
Total	20,835,200	2,475,000	12,523,870	4,040,050	1,442,260	1,558,700	42,875,080

[1] No information was secured on the disposition of these shipments.
[2] This shipment was refused in Norway and sent to one of the northern Europe countries (see Aagaard, 1930).

TABLE 2.—*Foreign distribution of Pacific salmon eggs and young*

[By 10-year periods, 1901–30]

SOCKEYE SALMON (*O. nerka*)

Localities of distribution	Periods and number distributed			Total
	1901–1910	1911–1920	1921–1930	
STATE				
Maine		17,500		17,500
COUNTRIES				
Argentina	397,500			397,500
Canada		30,700,000		30,700,000
Chile			314,000	314,000
Total	397,500	30,717,500	314,000	31,429,000

PINK SALMON (*O. gorbuscha*)

Localities of distribution	1901–1910	1911–1920	1921–1930	Total
STATES				
Maine	991,141	27,482,826	1,722,340	30,196,307
Maryland		15,000	6,350	21,350
New Jersey		18,000		18,000
New York	2,000			2,000
Total	993,141	27,515,826	1,728,690	30,237,657

COHO SALMON (*O. kisutch*)

Localities of distribution	1901–1910	1911–1920	1921–1930	Total
STATES				
Maine	1,317,387	69,800		1,387,187
Maryland			12,000	12,000
New Hampshire	315,000			315,000
New York	5,000	8,500		13,500
Pennsylvania	350,000		5,600	355,600
Vermont	5,800	41,875		47,675
COUNTRIES				
Argentina	377,180			377,180
Chile	225,040			225,040
Total	2,595,407	120,175	17,600	2,733,182

In this study a transplantation has been considered successful only when it survived to the extent of producing subsequent sea-run populations with migratory and spawning habits characteristic of the species in the native distribution. In other words, the mere hatching of the eggs or rearing of the young under landlocked conditions has not been considered as indicating the successful introduction of the species.

In order to secure complete and authentic information concerning the ultimate success or failure of the attempts to introduce these salmon into foreign waters, letters requesting this information were sent to the fish commissions and scientific fishery societies of the States and countries listed in tables 1 and 2. These letters, together with the replies that were received, are on file in the office of the Bureau of Fisheries, Washington, D. C.

The history to date of the attempts to introduce the Pacific salmon in foreign waters is not very encouraging. Only 1 State and 3 countries reported the development of natural sea-run populations in their coastal streams. The others reported that negative results or, to the best of their knowledge, no natural populations had developed from the transplantations. Maine is the only State in which natural runs of salmon have been definitely established. According to Bigelow and Welsh (1924), pink-salmon fry planted in the Dennys, Medomak, St. Georges, St. Croix, Pembroke, and Penobscot Rivers survived and developed populations having characteristics similar to those in their native distribution. However, adverse sentiment of the residents in this region has greatly contributed to their present lack of abundance.

Dymond, Hart, and Pritchard (1929) report the establishment of sea-run populations of chinook salmon in the St. John River, New Brunswick, and the Port Credit River, Ontario. These salmon have been taken in the St. John River by the hundreds and vary in weight up to 8 pounds. They are also quite plentiful in the Port Credit River where fish weighing up to 30 pounds have been taken. It is assumed that the Port Credit salmon migrate to and from the sea by way of Lake Ontario and the St. Lawrence River. Other streams tributary to these waters may maintain small runs of chinooks which to date have not been identified. The streams and coastal regions of Maine, New Brunswick, and Ontario are the only foreign waters on the North American continent in which natural populations of the Pacific salmon have been established.

Transplantations of Pacific salmon have been made in both Chile and Argentina in South America. Chile reports the presence of either coho or sockeye salmon running in the San Pedro River in the southern part of the country. Legislation has been promulgated by the Chilean Government which prohibits commercial fishing for these salmon until 1940. In Argentina none of the transplantations to date, according to Marini (1936), have been successful. However, final information in Chile as well as Argentina is not available owing to the lack of adequate scientific surveys throughout the sparsely inhabited regions in which the salmon have been introduced.

All European waters stocked with Pacific salmon, according to Bottemanne (1879), Behr (1882), Aagaard (1930), and correspondence received, have been unfavorable to the survival of the species. The countries acknowledged receiving the eggs but none could cite a single instance in which adult salmon had returned from the sea to spawn. Various methods of propagation were used but none proved successful. From the many unsuccessful attempts at introducing the Pacific salmon into European waters it may be concluded that the establishment of sea-run populations in them is very improbable. However, Finland is at present importing chinook eggs with the hope of establishing natural runs of this species. The possibility of successfully introducing the Pacific salmon into the coastal waters of Norway may never be determined since the Norwegian Government has always, with thanks, declined offers to plant these salmon in their waters.

Attempts to establish natural runs of Pacific salmon in the waters of Hawaii have been unsuccessful. The eggs were hatched successfully and the young reared to the migrant stage before planting but no adults have ever returned to the streams. Although recent shipments of eggs have been made to Hawaii it is not deemed advisable to continue this practice.

The waters of Australia and Tasmania, according to McCulloch (1927), Tasmania Fisheries Commission (1933 and 1935), and correspondence received, have all been unfavorable to the introduction of Pacific salmon. Many attempts have been made to establish natural runs in the coastal streams but all have been unsuccessful. No particular difficulty was encountered in hatching the eggs and rearing the young to the migrant stage, see Baird (1878), but no adults ever returned from the numerous plantings in the streams. The Tasmania Fisheries Commission (1933) states that in the confined waters of the Great Lake, chinook salmon thrive and grow rapidly to support a flourishing sport fishery. Other than to maintain landlocked populations for sport fishing it is considered that attempts to stock the streams for the establishment of sea-run populations would not justify the necessary expenditure of eggs and effort.

The introduction of the Pacific salmon into the waters of New Zealand has been successful only on South Island and even there, only within definite limits. The streams in which sea-run populations have been established, and those which have been stocked consistently with salmon but which have never developed sea-run populations, are shown in figure 5. The well-defined distributional range of the salmon on South Island will be explained in the discussion on environmental limitations to their occurrence.

The many attempts to establish runs of chinook salmon in New Zealand prior to 1900 were all unsuccessful. During this period the eggs and young were divided into small consignments and distributed to many rivers throughout the colony. Following the year 1900 this practice was discontinued and only one river system, the Waitaki, was stocked. In 1905 many adult salmon returned to this river to spawn, thus establishing the first natural run of chinooks on South Island. This run survived and through natural and artificial propagation has been spread to other rivers on the island.

Although the Bureau of Fisheries records show only the shipment of chinook salmon stock to New Zealand, shipments of sockeye salmon stock were also received from another source according to W. L. Calderwood (Fishery Board for Scotland, Salmon Fisheries, 1924, No. 2) who states:

> In operating with Sockeye, some curious results have appeared. Eggs were imported in 1902, and adult specimens of this fish began to appear in 1907. Dead examples were first noticed, and

these were found to have spawned and died in the usual way. A brief note in the last official year-book states that "a number exist in Lake Ohau, having acquired a landlocked habit. These fish run up creeks at the head of the lake and spawn there every season [year] in March and April."

Hatcheries have been constructed, and each year there is an abundant egg take. The eggs are hatched and the fry used to restock the parent stream or are planted in other streams on the island. Eggs collected and eyed in New Zealand have been sent to Tasmania for transplantation. Of the four successful foreign regions in the world to develop sea-run populations, New Zealand has been the most outstanding to date. The authors wish to acknowledge the kind cooperation of A. E. Hefford, Chief Inspector of Fisheries, New Zealand, in furnishing them with complete information concerning the history of the transplantation and development of the chinook salmon in the waters of New Zealand. Pictures of the chinook salmon and the streams in which they spawn, also scenes of the sport and commercial fisheries, are shown in figures 6–9.

The sea-run populations of Pacific salmon that have been established in both Chile and New Zealand have adjusted their life cycle to the change in occurrence of the seasons in the Southern Hemisphere. The spawning migrations of these salmon occur in January, February and March which are the seasonal equivalents of July, August, and September in the Northern Hemisphere. The foreign regions into which the Pacific salmon have been introduced are shown in figures 1–4. The solid black areas indicate the regions in which the salmon have been transplanted successfully, and the dots show the regions in which transplantations failed.

ENVIRONMENTAL LIMITATIONS TO OCCURRENCE

During the first years of the introduction of the Pacific salmon into foreign waters very little was known concerning the proper methods for shipping or propagating these species. The failure of many transplantations to survive during this early period may have been due to excessive mortality in the eggs or unsuccessful rearing and planting of the young. However, with the improvement in fish-cultural methods the mortality during shipment and early propagation declined in importance so that following the year 1900 a high percentage of eggs shipped survived and the young were reared and planted successfully. This information was secured mainly through correspondence received from the various States and countries participating in this work. In view of this fact it is believed that the ultimate success or failure of these latter transplantations was dependent, to a high degree, upon the favorable or unfavorable influences existing in the foreign waters in which they were made.

NORTH PACIFIC REGION

The environmental components of the fresh-water habitats in the native distribution of the salmon, which appear to be definite limiting factors, are temperature of water and character of stream bed. The degree of tolerance to temperature is much greater for the adults than for the eggs and young. The temperatures of the streams in which the salmon have been found spawning ranged from slightly above 0° to a maximum of 21°C. This range of temperature has been determined from recording thermographs operated yearly in Alaskan streams by the Bureau of Fisheries, and from stream surveys made by the Bureau's biologists, in both the Pacific Coast States and

Alaska. Records taken at the Bureau's hatcheries on the Pacific coast also show the range of temperature tolerated by the adult salmon. Adult salmon have also been found migrating through estuaries, and streams fed by hot springs, whose temperatures were as high as 27° C. The California Department of Public Works (1931) reports a temperature range of 16° to 26° C. in the lower reaches of the Sacramento River during the months the salmon are migrating into the river. In July and August it is not uncommon for the temperature of the lower estuary of the river to hover for days around 24° C. Although the temperature of the streams in the native range may fluctuate at a high level during the spawning period it rapidly decreases with the onset of the winter season during which time the eggs pass through the incubation period. The studies of Donaldson (1936) have shown that the eggs can withstand temperature below 4° and above 11° C. for short periods of time but that the optimum lies between these limits. The mortality was extreme in eggs maintained constantly at temperatures below 4° or above 11° C. After hatching, the optimum range of temperature in fresh water, which controls the rate of growth and survival of the young, shifts to a level of 13° to 17° C. Constant temperatures above 17° C. retarded growth and increased the mortality of the young and at 20° C. the mortality was excessive. Constant temperatures below 13° C. retarded growth and at 3° mortality was excessive. In view of the results from these studies it may be assumed that temperature in the fresh-water habitats becomes a limiting factor in the early developmental period of the salmon.

The eggs of the Pacific salmon are spawned free and, being of a higher specific gravity than water, sink to the bottom. Eggs of this type require a medium that will hold and cover them for protection and at the same time permit the free flow of well-aerated water for incubation. Such a medium is found in clean gravel beds, or in pockets among rocks, but not in mud or sand. The former conditions are invariably found in all of the native fresh-water habitats of the salmon. Spawning in the streams is usually confined to the comparatively shallow areas where the current is swift, and in the lakes to areas provided with flowing water from seepage or surface drainage. In the Pacific Coast States deforestation, agricultural developments, and mining operations have, in some areas, produced excessive erosion of the watersheds. This has always resulted in the silting of the streams and the subsequent destruction of their salmon populations. An excessive amount of silt in the water influences the normal respiration of the salmon and destroys the eggs by suffocating them with a blanket of mud. The character of the stream bed, therefore, becomes a very definite limiting factor in the distribution of the Pacific salmon.

The environmental components of the marine habitats in the native distribution, which appear to be limiting factors, are ocean currents and associated temperatures and salinities (salt content). The mean directional drifts in the North Pacific from June through September are shown in figure 1. This period was selected because it is during these months that the salmon are known to be definitely migrating in the ocean. The adults are migrating from the open ocean to the streams to spawn and the young are migrating seaward from the streams. The currents in figure 1 were determined from the limits of the directional drifts during this period as given by Dall (1880), Schulz (1911), McEwen (1912), Marmer (1926), Hatai and Kokubo (1928), Uda and Okamoto (1930), Uda (1931 and 1933), Schumacher (1932), Zeusler

(1934), Schott (1935), Thompson and Van Cleve (1936), and Wüst (1936). Since it is known that the salmon mature in the offshore waters and begin their spawning migration there, more emphasis was laid upon the general movements in these waters than upon the local and complex shiftings along the immediate shores.

The Japan, or Kuroshio Current; Bering Sea, or Oyashio Current; Okhotsk Sea Current, and other less perceptible currents form an intricate maze of water move-

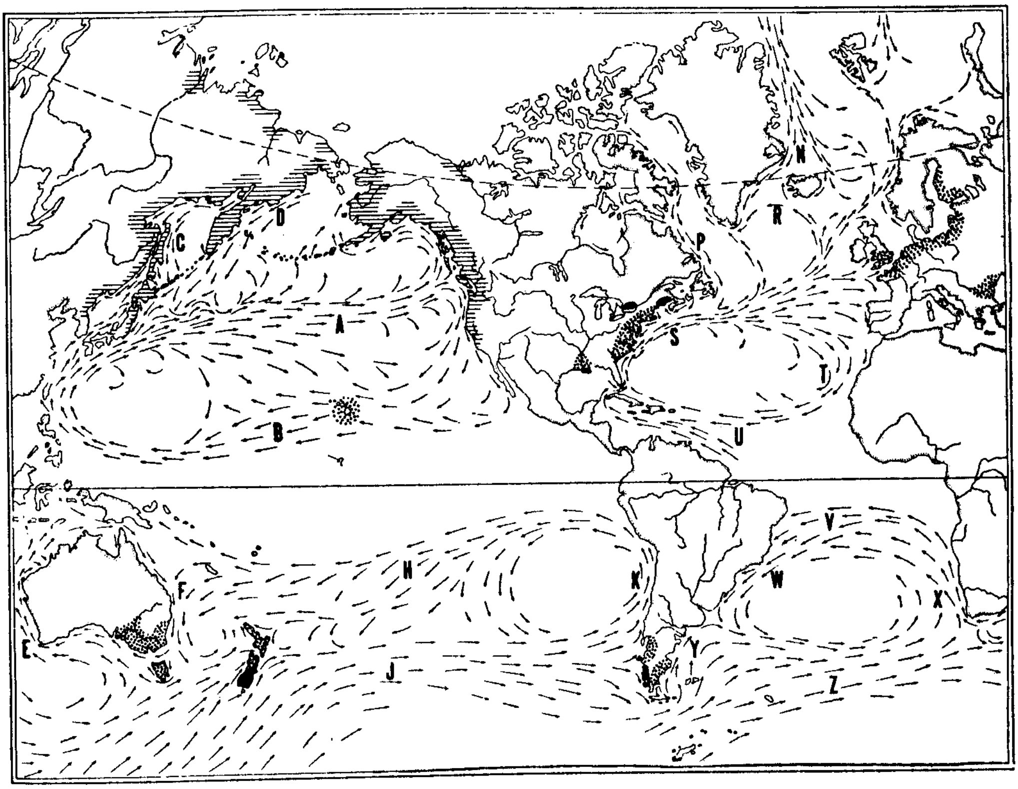

FIGURE 1.—The geographic distribution of the Pacific salmon and the directional drifts of ocean currents during the spawning migration period of the salmon. The bars indicate the native distribution of the salmon, the solid black areas indicate the regions in which the salmon have been transplanted successfully, and the dots indicate the regions in which the transplantations were unsuccessful. The directional drifts of the ocean currents in the Northern Hemisphere are means calculated from the monthly averages of June, July, August, and September, and in the Southern Hemisphere are means calculated from the monthly averages of January, February, and March. A, Japan or Kuroshio Current and West Wind Drift; B, North Equatorial Current; C, Okhotsk Sea Current; D, Bering Sea, Oyashio or East Kamchatka Current; E, West Australian Current; F, East Australian Current; H, South Equatorial Current; J, South Pacific Current and Antarctic Drift; K, Peruvian or Humboldt Current; N, East Greenland Current; P, Labrador Current; R, Irminger Current; S, Gulf Stream or Florida Current; T, Canaries Current; U, North Equatorial Current; V, South Equatorial Current; W, Brazil Current; X, Benguela Current; Y, Falkland Current; Z, South Atlantic Current and Antarctic Drift.

ments in the North Pacific. The Japan Current has the most outstanding circulation. It is a tropical drift originating from the North Equatorial Current off the east shore of the Philippine Islands. From here it flows northward and strikes the shores of the Islands of Japan. Part is forced to the west of the islands and enters the Japan Sea. The bulk, however, closely follows the east shore of Honshu Island to Cape Inuboye just east of Tokyo. Here it is met by the Bering Sea Current of arctic origin which flows southward along the island. The southern limit of occurrence of the Pacific salmon on this shore of the island is at Cape Inuboye near the point of confluence of these currents. A similar relation exists between the distributional limits of the salmon along the shores of the Japan Sea and the confluence of the Japan and Okhotsk Sea Current. The Okhotsk Sea Current, which is of arctic nature, flows southward along the continent and is dissipated in the waters off the northern shore of Korea. The Tumen River, which marks the distributional boundary of the salmon in this region, flows into these waters. After entering the Japan Sea the Okhotsk Sea Current influences the Japan Current flowing northward along the west coast of Honshu Island. The salmon are found on this shore of the island as far south as the Jogan-jigawa River which is near the southern point of confluence of these currents. There is a definite correlation between the distribution of the salmon and the influence of ocean currents in these regions.

The Japan Current, after encountering the Bering Sea Current off the east coast of Honshu Island, takes a northeasterly course across the Pacific to form a fan-shaped divergence commonly known as the West Wind Drift. During this course it is greatly tempered. Upon nearing the coast of North America, off Vancouver Island, it divides into two branches; the northern branch forming the Alaska Current and the southern branch the California Current. According to McEwen (1912), an upwelling of cold waters along the coasts of Oregon and California influences the California Current as it flows southward. The southern distribution of the salmon on the North American continent appears to be correlated with the region dominated by this cold upwelling current.

The adult salmon are subjected to the influence of surface temperatures in the ocean during their spawning migration to the streams, for it is definitely known that they frequent the surface waters at this time. Accordingly a study was made of the mean surface temperatures from June through September in relation to the distribution of the salmon. The mean temperatures rather than the limits of temperature during this period were used owing to the continuous character of the spawning migration which in some areas extends over the entire period from June through September. The mean surface temperatures in the North Pacific during this period are given by the isotherms in figure 2. These isotherms were determined from the seasonal and monthly surface temperatures given by Dall (1880), Rosse (1881), McEwen (1912), Uda and Okamoto (1930), Uda (1931), Kokubo (1932), Zeusler (1934), and Schott (1935). Along the coasts of Japan and Korea the mean 20° C. isotherm touches the shores near the southern limits of the native range of the salmon. According to Uda and Okamoto (1930), and Uda (1931), the surface temperatures of these coastal waters range from 15° C. in June to approximately 24° in September. On the North American continent the mean 15° C. isotherm touches the shores of California below the southern limits in the distribution of the salmon. According to Schott (1935), the surface waters along the coast of California have an annual range of only 3° C.

The northern distribution of the salmon on both continents is bounded by the mean 5° C. isotherm. However, the salmon migrating to and from the Mackenzie, Lena, and other streams tributary to the Arctic Ocean may be subjected to surface temperatures only a few degrees above freezing. It is, therefore, possible that the surface temperatures tolerated by the salmon during their spawning and seaward migrations approximate 0° C. at the minimum and are in the vicinity of 20° C. at the maximum.

Information thus far available indicates that the Pacific salmon, during their sojourn in the sea, frequent the subsurface waters to depths of 200 meters. Hence, the mean annual temperatures at 200 meters were studied in relation to the distribution of the salmon. These mean temperatures for the North Pacific are shown by the

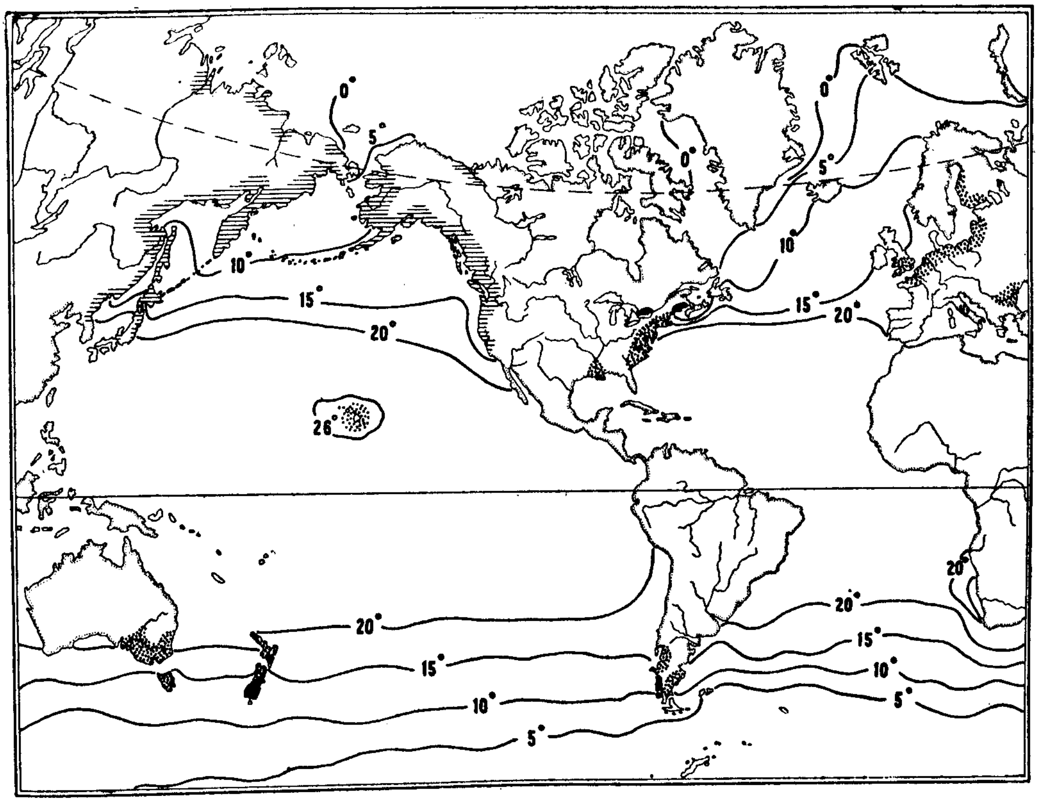

FIGURE 2.—The geographic distribution of the Pacific salmon and the mean surface ocean temperatures during the spawning migration period of the salmon. The bars indicate the native distribution of the salmon, the solid black areas indicate the regions in which the salmon have been transplanted successfully, and the dots indicate the regions in which the transplantations were unsuccessful. The isotherms in the North Pacific Ocean give the mean surface temperatures for the period of June, July, August, and September. Those in the North Atlantic Ocean give the mean surface temperatures for the period of July, August, and September, and those in the South Atlantic and South Pacific Oceans give the mean surface temperatures for the period of January, February, and March.

isotherms in figure 3. Schott (1935) gives a review of the oceanographic studies carried on in the North Pacific and describes the subsurface temperatures in this region. The isotherms in figure 3 were taken primarily from Schott's review.

Along the coasts of Japan and Korea the mean annual 10° and 5° C. isotherms, respectively, at 200 meters, describe the subsurface temperatures of the waters at the southern distributional boundaries of the salmon. The mean annual temperatures at 200 meters on the east coast of Honshu Island, Japan, decrease from 10° to 3° C. within the comparatively short distance from Cape Inuboye to the north end of the island.

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Uda and Okamoto (1930), and Uda (1931), give the monthly temperatures at 100 meters along these shores. The temperatures at 100 meters along the Korean coast do not differ appreciably from those at 200 meters and vary no more than 3° C. throughout the year. The temperatures at 100 meters along the east shore of Honshu Island average from 3° to 4° C. higher than at 200 meters and also vary no more than 3° throughout the season. In general the subsurface temperatures in this region do not fluctuate widely throughout the year.

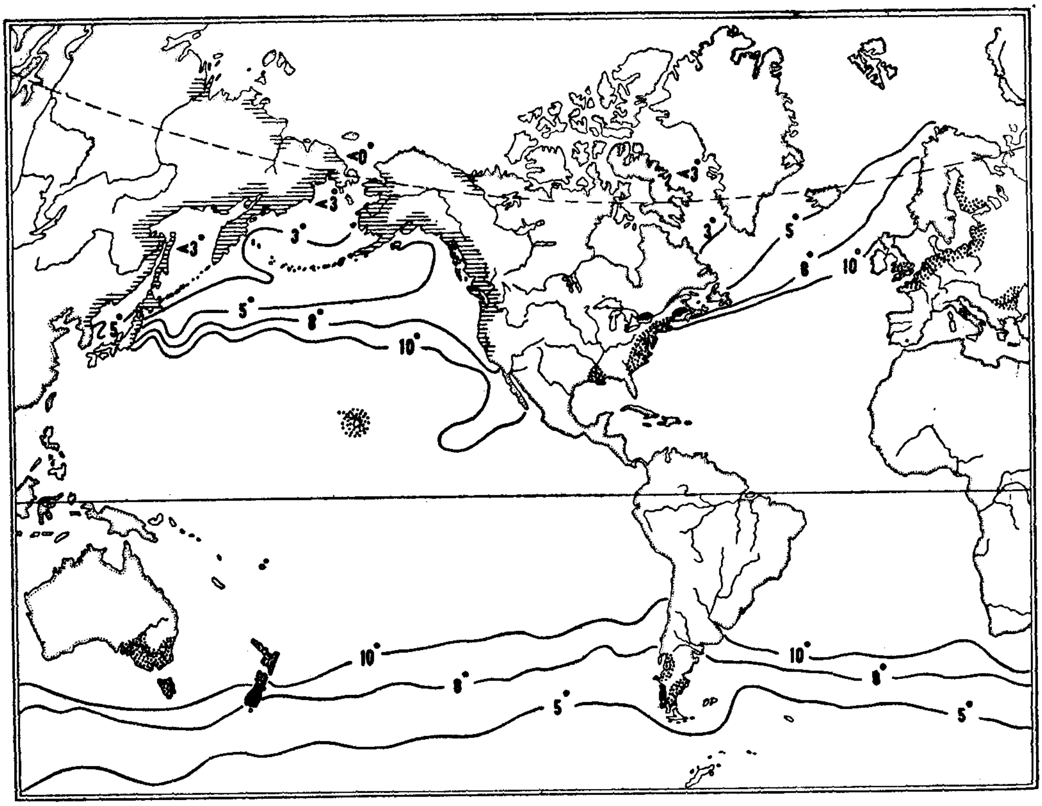

FIGURE 3.—The geographic distribution of the Pacific salmon and the mean annual subsurface ocean temperature at 200 meters depth. The bars indicate the native distribution of the salmon, the solid black areas indicate the regions in which the salmon have been transplanted successfully, and the dots indicate the regions in which the transplantations were unsuccessful. The isotherms give the mean annual subsurface temperatures at 200 meters depth.

The southern distribution of the salmon along the North American continent falls well within the region bounded by the mean 8° C. subsurface isotherm. Here again the subsurface waters vary only 2° to 3° C. throughout the year. In the Bering Sea the mean annual temperature at 200 meters is less than 3°, and in the Arctic Ocean it is less than 0° C. Hence, if the salmon frequent the subsurface waters to depths of 200 meters, they must be tolerant to temperatures ranging from slightly below 0° at the minimum to the vicinity of 10° C. at the maximum.

Donaldson (1936) has shown that the optimum range of temperature for growth of the young salmon in fresh water is between 13° and 17° C. Furthermore, he found that mortality was excessive at constant temperatures of 20° and 3° C. In view of the temperature data given in figures 2 and 3 it is obvious that the optimum range for growth in the sea must shift to a lower level. The mean annual temperatures of the ocean waters at 200 meters throughout almost the entire distribution of the salmon do not exceed 8° and in the northern half of the range they fluctuate close to 3° C. Even if the salmon frequented only the surface waters during their sojourn in the sea they would encounter temperatures of less than 15° C. throughout the greater part of the year, for it is only during the summer that the surface waters reach this temperature

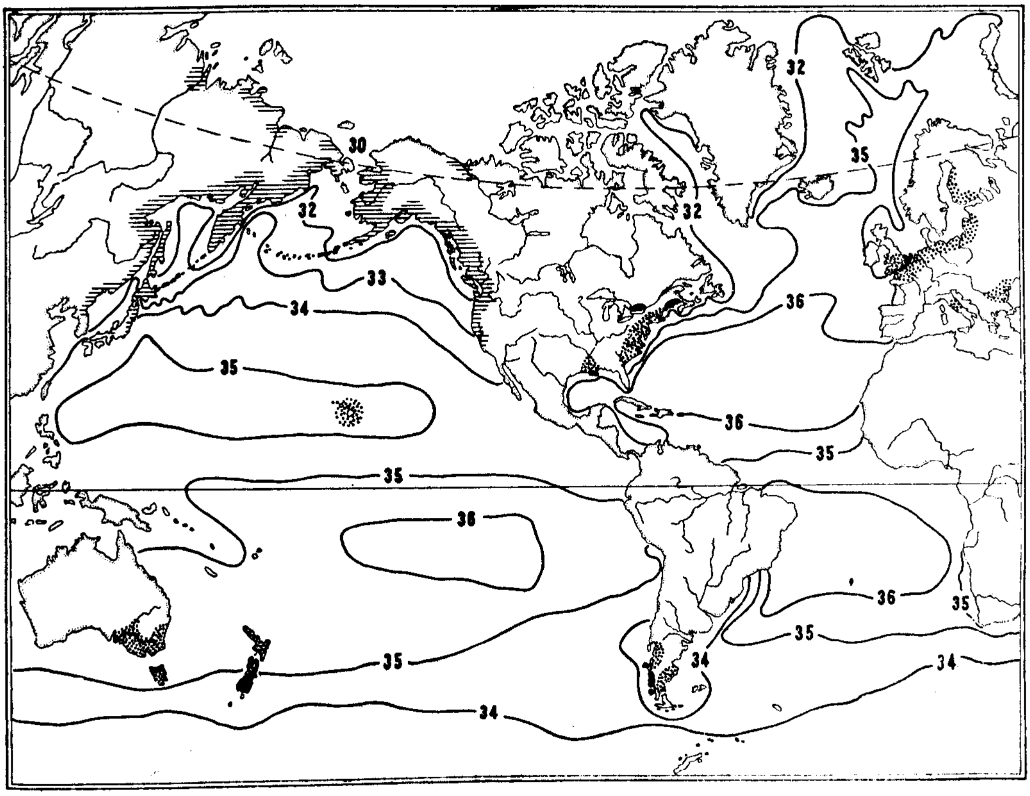

FIGURE 4.—The geographic distribution of the Pacific salmon and the mean annual surface salinities in parts per 1,000. The bars indicate the native distribution of the salmon, the solid black areas indicate the regions in which the salmon have been transplanted successfully, and the dots indicate the regions in which the transplantations were unsuccessful. The isohalines give the mean annual surface salinities in parts per 1,000.

and then only in the southern part of the range. In the northern part of the range the temperature of the surface waters at no time exceeds 10° C. Hence, the salmon must become acclimated to the colder waters of the ocean during their sojourn in them, and are able to grow and survive at lower temperatures than in fresh water.

Since the salinity of the water forms an important environmental component of marine habitats, it was likewise studied in relation to the distribution of the salmon. Although salinity data for the subsurface waters would have been more desirable it was found that only surface data were available for all of the oceanographic regions. The mean annual surface salinities in parts per thousand for the North Pacific are shown by the isohalines in figure 4. The data from which these isohalines were determined were taken from the works of Schott (1928 and 1935), Uda and Okamoto (1930), and Uda (1931).

The isohalines of 33 and 34 parts per thousand describe the mean annual salinities of the surface waters at the southern boundaries in the distribution of the salmon along the coasts of Korea and Japan. Owing to the direct contact of warm currents of high salinity with cold currents of low salinity, and the continuous shifting of these currents off the eastern coast of Honshu Island, the isohaline of 34 parts per thousand is not confined to any one district but shifts about over a broad area. Hence, the salmon frequenting the waters in this area may at times be subjected to surface salinities as high as 35 and as low as 33 parts per thousand.

The southern distributional limits of the salmon on the North American continent fall within an area whose coastal waters are characterized by mean surface salinities from 33 to 34 parts per thousand. In the northern range of the salmon the mean salinities of the surface waters do not exceed 30 parts per thousand. It is, therefore, quite possible that the salmon orient themselves in the open ocean to surface waters of salinities ranging from 30 to 35 parts per thousand.

The analysis of the marine habitats thus far has been confined mainly to the determination of the ranges in certain physical and chemical properties of the waters in the North Pacific Ocean within the limits of the native distribution of the salmon. Briefly, it was found that the occurrence of the salmon is associated with the presence of ocean currents bearing waters of low temperature and salinity. The mean surface temperatures during the spawning migration period of the salmon ranged from 0° to 20° C. The mean annual temperatures at 200 meters ranged from slightly below 0° to 10° C. and the mean annual surface salinities varied from 30 to 35 parts per thousand. Since the salmon frequent the ocean waters of these temperatures and salinities, it may be assumed that they are tolerant to them. In this analysis, however, it has not been possible to definitely determine if temperatures and salinities outside these ranges are also tolerated by the salmon or form definite limiting factors governing their survival. The further analysis of this relationship may be found in a similar study of the marine waters in the foreign regions where the salmon have been transplanted. In other words, if the foreign marine waters in which the transplantations have survived have physical and chemical properties similar to those in the native distribution of the salmon and if the foreign waters where the transplantations have failed have properties unlike those in the native distribution, fresh-water conditions being favorable to survival, then it is logical to assume that temperature and salinity values beyond the ranges of the native distribution may form limiting factors to the marine survival of the species.

SOUTH PACIFIC REGION

In discussing the foreign distribution of the Pacific salmon in this region it was pointed out that transplantations were made in Hawaii, Chile, New Zealand, Tasmania, and Australia, Natural sea-run populations developed from the transplantations in New Zealand and Chile but failed to develop from those planted in Hawaii, Tasmania, and Australia.

New Zealand is composed of two large islands, known as North Island and South Island. Some of the streams on each island were stocked with chinook salmon from the Sacramento River, Calif., but only those on South Island have developed natural sea-run populations and even here only within certain limits. The streams on both islands are shown in figure 5. The streams on South Island which support natural runs of chinooks are indicated by a solid circle, and those which have been stocked frequently from 1910 to 1929, but which have never developed natural runs, are indicated by a solid triangle. Does the explanation of this failure of the chinooks to develop natural runs in certain streams on South Island and in none of the streams on North Island lie in unfavorable conditions in the fresh-water or the marine environments?

The streams on both North Island and South Island are quite similar in origin and type. Most of the larger ones originate in mountain lakes and flow rapidly to the sea over gravelly and rocky beds, see figures 6–8. Percival (1932), in describing the streams of New Zealand, states:

> The geological youthfulness of the present land-surface of New Zealand accounts for the relative absence of slowly flowing rivers such as, in other countries, give shelter to a great variety of free-swimming organisms and allow of the growth of much vegetation on the bed.
>
> *　*　*　*　*　*　*
>
> Generally speaking the rivers of New Zealand are comparable with the portions of the European rivers called by Thienemann (28) "Aschenbach" (Grayling stream), where the bed is stony and liable to flooding through the accumulation of surface water.

The streams on North Island, owing to the milder climate, are somewhat warmer than those on South Island. At Rotorua, North Island, the mean air temperature for January is 18° C. and for July is 7.5° C., while at Queenstown, South Island, the mean air temperature for January is 15.5° and for July is 3° C. Phillips (1929) reports stream temperatures on North Island, during the winter and spring, as low as 8° C., and during the fall from 12.5° to 15.5° C. Hobbs (1937) reports the mean monthly temperatures of salmon-bearing streams on South Island as ranging from 3° C. in midwinter to 16.5° C. in midsummer. Percival (1932), in discussing the presence of fish food in the streams on both islands, states that it is sufficiently abundant in most of the streams to support trout and other fresh-water fishes. In view of these facts it may be assumed that the streams on both islands provide favorable environmental conditions for the survival of the salmon during their fresh-water existence.

An examination of the environmental conditions found in the coastal waters of the islands, however, gives an altogether different picture, for North Island is almost wholly bathed by a tropical current and South Island by an Antarctic current. The directional drifts of these currents are shown in figures 1 and 5.

Hefford (1929), in discussing the reasons why runs of chinooks have not been established in the Wairau and Hokitika Rivers on South Island, and in all of the rivers on North Island, makes the following statement:

> It is known that off the south-eastern coasts of South Island the water in the sea is of Antarctic origin. There is a general set or drift in a north-easterly direction of cold water from the south, and this water produces the prevailing conditions in the sea off the Otago and Canterbury coasts where the quinnat have been established for some years. The South Equatorial Drift, which sets from the eastward and impinges upon the east coast of North Island, may be said to dominate the conditions to the northward of East Cape; while between that point and Cook Strait there is a mixture of this subtropical water with water from the south. For a long time navigators have been familiar with these "sets" or surface movements of the sea, but it was not until the hydrographer of the Danish research steamer *Dana* had applied physical and chemical tests to the water sampled at intervals between the east coast of Auckland and the coast of Otago, in January 1929, that the significant differences in the character of the water along this line were ascertained. It seems clear from the *Dana's* observations that the present distribution of quinnat salmon off the New Zealand coasts coincides with the occurrence of practically unmixed Antarctic water, with its characteristic physical and chemical qualities. Not a single individual of the quinnat species has ever been

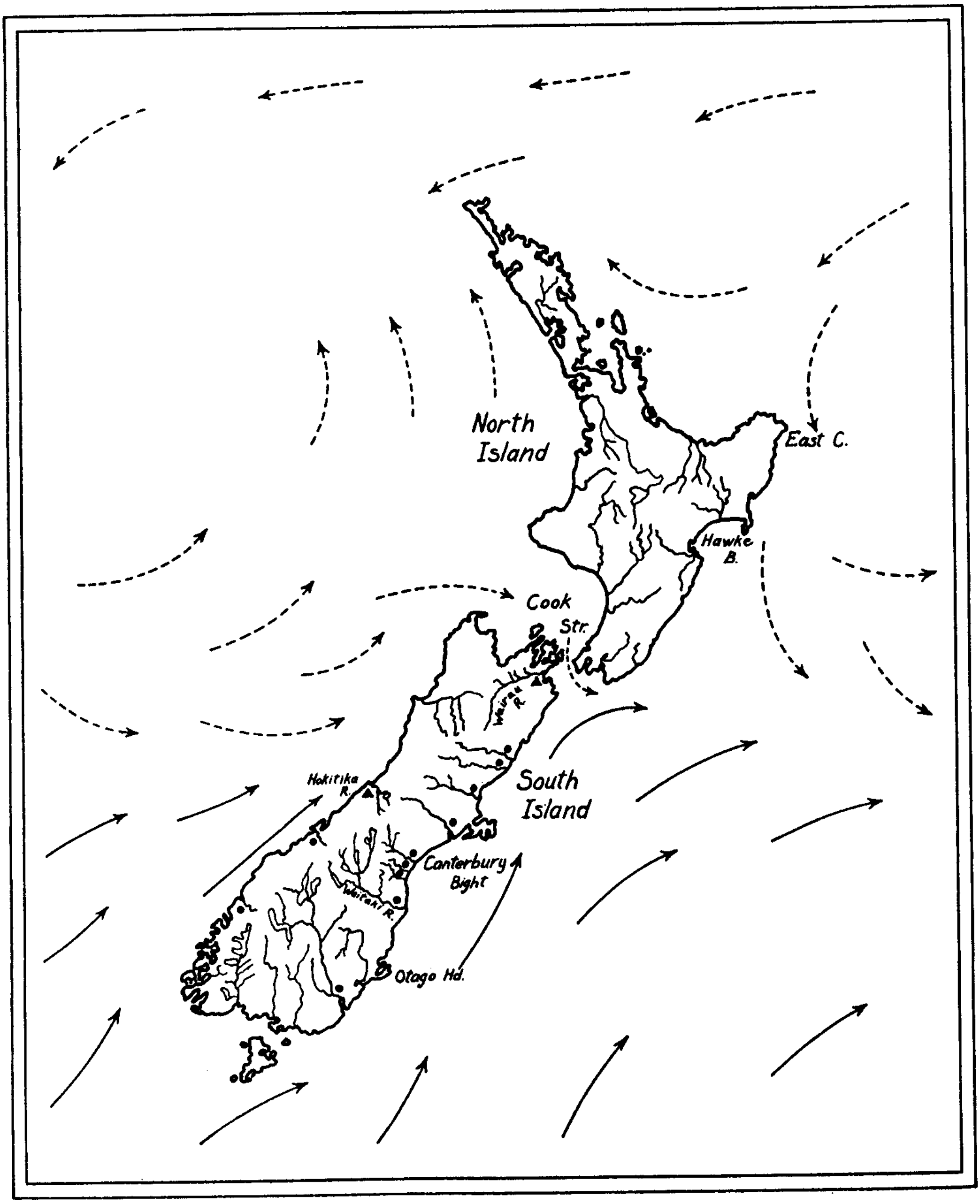

FIGURE 5.—The distribution of chinook salmon in New Zealand. The dots indicate the streams on South Island in which natural sea-run populations of these fish have been established. The triangles indicate the streams which have been stocked frequently from 1910 to 1929 with young chinooks but which have never developed natural runs. All of the streams on North Island have at some time or other been stocked with young chinooks but have also never developed natural runs. The solid arrows indicate the directional drifts of cold currents. The broken arrows indicate the directional drifts of warm currents.

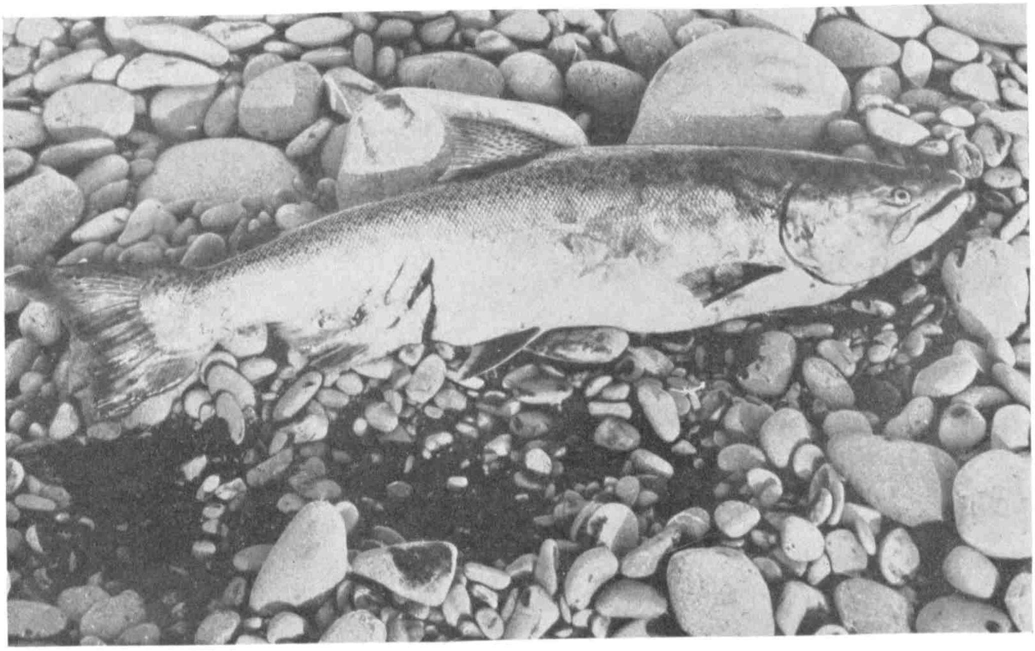

FIGURE 6.—A chinook salmon caught at mouth of the Rangitata River, Canterbury, New Zealand. The general form and markings, such as the spots on the back and fins, are typical chinook salmon color markings. Gashes on the body are due to attacks by predators, probably barracuda. New Zealand Government Publicity Photo.

FIGURE 7.—Fresh-water stream conditions as found in the Rakaia River, Canterbury, New Zealand. The clean gravel beds in the foreground and the snow-covered mountains in the background are prime factors in the fresh-water life history of the chinook salmon. New Zealand Government Publicity Photo.

FIGURE 8.—Sport fishery at mouth of the Rangitata River, Canterbury, New Zealand. Anglers in foreground landing a chinook salmon, while others fish the surf at the mouth of the river. New Zealand Government Publicity Photo.

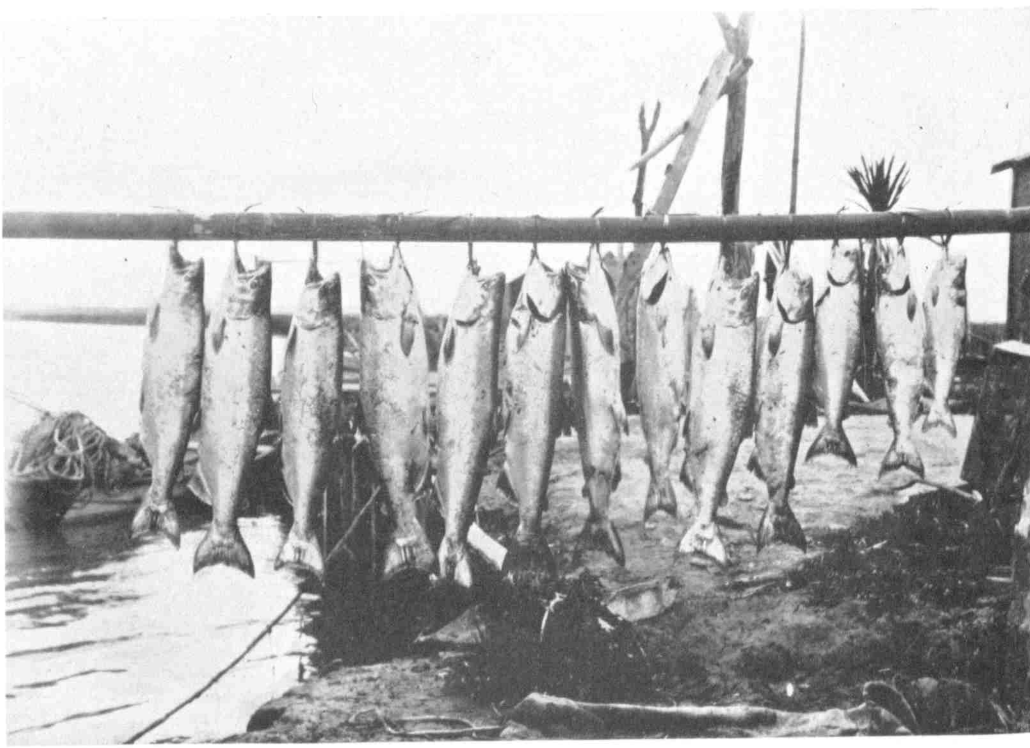

FIGURE 9.—Commercial fishery as carried on along the Waimakariri River, Canterbury, New Zealand. Note range in size of the chinook salmon that were netted with a small seine carried in skiff at left. New Zealand Government Publicity Photo.

planted in a Canterbury stream, yet the Canterbury rivers now provide the best quinnat fishing in the Dominion, the species having migrated to their mouths from the Waitaki, where the original fry were planted. The Wairau has been fairly generously stocked and yet shows no appreciable run of fish. The inference is that it is probably too far north—outside the influence of the purely Antarctic water which attracts the bulk of the species—though an odd few are known to run into the Wairau, and, in fact, into some of the southern rivers of the North Island. This season an indubitable quinnat was caught in the Tukituki River, Hawke's Bay. It does not follow that these parts are suitable for the permanent establishment of the species in abundance. The limit to which the influence of hydrographical factors pertaining to Antarctic waters extends will doubtless vary at different times, and it may be that in odd years the Cook Strait neighborhood, or even farther north, may provide suitable and congenial conditions for the quinnat salmon. But the indications afforded both by experience and by theoretical considerations seem to emphasize the probability of the fundamental relationship between the nature of the sea-water and the distribution of these salmon. There is also the case of the attempted acclimatization of the quinnat in the Hokitika River, on the west coast of the South Island. Our departmental reports show that between 1910 and 1924 the fry from over three million ova were planted in the head-waters of this river. The only apparent outcome has been a stock of lake-dwelling quinnat which has established itself in Lake Kanieri. As is well known, the west coast of the Dominion is washed by a warm current which has eddied across the Tasman Sea from the coast of eastern Australia, and which was originally a branch of a westerly-trending subequatorial current. Again it seems to be a case of the wrong sort of sea-water for a salmon species. Where the quinnat smolts, which have presumably entered the Tasman Sea to the number of thousands or hundreds of thousands, have disappeared to is a mystery which may never be solved. This discussion is admittedly somewhat speculative, but it seems necessary to ventilate these considerations in view of the frequent recommendations, based rather on what is desirable than on what is probably feasible, to stock this or that river with salmon.

The analysis of the physical and chemical properties of the coastal waters of New Zealand bears out Mr. Hefford's assumptions as to the unfavorable character of the marine waters off the north and west coasts of South Island and the entire coast of North Island. The directional drifts of the ocean currents, the mean seasonal surface temperatures, the mean annual subsurface temperatures at 200 meters, and the mean annual surface salinities are given in figures 1–4, respectively. These data were calculated in the same manner as those for the North Pacific and were taken from the studies of Buchan (1894) and Schott (1928 and 1935). Schott (1935) gives a complete summary of all the hydrographic data collected in this region.

The directional drifts of the ocean currents shown in figures 1 and 5 were calculated for the months of January, February, and March, which cover the spawning migration period of the Pacific salmon in this region. The South Pacific Current and the Antarctic Drift, which are so closely related that they may be considered as one current, carry waters of low temperatures and salinity. South of New Zealand a portion of this combined current divides. Part flows northward along the west coast of South Island and merges with a branch of the warm East Australian Current near the central coast of the island. Natural runs of California chinooks have been established only in the streams along this coast south of the point of confluence of these currents. The remainder flows northward along the east shores of South Island to Cook Strait where it is met by counter drifts from the warm South Equatorial Current. Natural runs of California chinooks have also been established only in the streams along this coast south of the point of confluence of the cold and warm currents. This shows a relationship between ocean drifts and the occurrence of natural runs of salmon similar to that found along the coasts of Korea and Japan.

The mean surface and subsurface temperatures, and mean surface salinities, given in figures 2, 3, and 4, all show that the coastal waters of North Island are warmer and more saline than those of South Island. The mean 15° C. surface and 10° C. subsurface isotherms and mean 35 parts per thousand surface isohaline all touch the shores of South Island near the upper limits of the range in which the salmon have established natural runs. Similar mean temperatures are also found in the coastal waters near the native limits of occurrence of these salmon in California. Hence, from these observations in New Zealand, it may be assumed that the California chinooks react unfavorably to temperatures beyond the ranges found in their native habitats, but that they tolerate surface salinities of higher values up to 35 parts per thousand which is the maximum found throughout the entire native range of the Pacific salmon.

Further demonstration of the unfavorable influence of coastal waters of high temperature and salinity on the marine survival of these salmon may be found in the failure of the attempts to introduce them into the streams of Hawaii, Australia, and Tasmania. The upper reaches of the streams in these countries have been favorable to the introduction of trout, whose fresh-water requirements are similar to those of the salmon. In fact, the salmon eggs shipped to these countries, according to correspondence received, Baird (1878), McCulloch (1927), and Tasmania Fisheries Commission (1933 and 1935), were hatched without considerable loss and the young reared successfully to the stage of seaward migration. Landlocked populations of chinooks have been established in the Great Lake of Tasmania but no adults have ever returned from the plantings in the rivers, although chinook eggs were also imported from New Zealand for stocking them. No adults have ever returned from the many plantings of salmon made in the rivers of Australia and Hawaii.

The mean directional drifts in figure 1 show that Hawaii, Australia, and Tasmania are completely surrounded by currents of tropical origin during the spawning and seaward migration periods of the salmon. Schott (1935) shows that this same condition also prevails throughout most of the year. The mean isotherms and isohalines given in figures 2, 3, and 4, show that in general the surface and subsurface temperatures and surface salinities of the coastal waters of these countries exceed the values found in the native marine habitats of the salmon. The mean surface temperature during the spawning migration period appears to be an exception in the case of Tasmania. This may indicate that all marine conditions must be favorable before survival of the salmon is possible.

The attempts to introduce sockeye and coho salmon from Washington and Oregon into the waters of southern Chile have been successful. The coastal streams of southern Chile are similar in origin and character to the streams of southeastern Alaska. The climates of the two regions are also quite similar, being characterized by heavy rainfall and comparatively mild temperature. The hydrographic conditions of the waters along the southern coast of Chile (see figs. 1–4) are also similar to those in the native marine habitats of these salmon. The returns, thus far, of adult salmon have been reported only in the most southern streams in which transplantations were made. This does not mean, however, that other streams in the region are not suitable for the establishment of natural runs, but merely that no returns have as yet been reported in them. It is for this reason that areas of both success and failure have been indicated on the distributional charts in figures 1–4. The successful transplantation of sockeye or coho salmon in Chile supports the conclusion that environmental conditions in both the marine and fresh waters of a foreign region must be similar to those in the native habitats of the salmon before successful introduction may be expected.

NORTH ATLANTIC REGION

Many attempts have been made to introduce the Pacific salmon into the streams along the eastern coast of North America and the countries of northern Europe (see tables 1 and 2). Of these many transplantations all but those in the streams of Maine, New Brunswick, and Ontario were failures. The origin and character of the streams and lakes along the North American coast, north of the State of Maryland, indicate that they originally provided the physical requirements essential to the fresh-water survival of these salmon. Kendall (1935) states that the original range of the Atlantic salmon (*Salmo salar*), which has fresh-water requirements similar to those of the Pacific salmon, probably extended from Delaware to Labrador. The establishment of natural runs of Pacific salmon in Maine, New Brunswick, and Ontario, as well as the development of landlocked populations in lakes throughout this region, gives further evidence of the suitability of these fresh waters for the introduction of these salmon.

Many of the streams in this region have been gradually altered, through the introduction of power dams and pollution, so that at present they may not provide the essential requirements for the fresh-water survival of the salmon. However, these hazards were not so serious from 1872 to 1900, during which time the majority of the transplantations of Pacific salmon were made (see tables 1 and 2). Mather (1887) states that natural runs failed to develop from the transplantations of chinook salmon in the Hudson River but that the runs of Atlantic salmon in the river could be greatly improved through the introduction of eggs and young from other coastal streams. Since the Pacific and Atlantic salmon have similar fresh-water requirements, the indications are that the Hudson River, in 1887, provided the essential fresh-water conditions for both species. The failure of these salmon to develop natural runs in the coastal streams from Maryland to the Gulf of Maine cannot be wholly attributed to the presence of unfavorable conditions in them. In fact, the streams of Maine would still support natural runs of Alaska pink salmon had they not been destroyed through adverse sentiment. The consistent lack of returns from plantings made in the coastal streams of Virginia, North Carolina, South Carolina, Georgia, and especially in the warm and muddy streams of Louisiana and Mississippi, may be in part attributed to their unsuitability for the fresh-water existence of the salmon.

The millions of California chinook eggs sent to the countries of northern Europe, according to Baird (1878), Bottemanne (1879), Behr (1882), Aagaard (1930), and correspondence received, were all hatched with little loss and the young reared successfully to the stage of seaward migration. Many of the young were also reared to the adult stage in natural or artificial ponds in France, Germany, and Holland. In France these landlocked fish were spawned artifically for propagation in inland waters. The rivers and lakes of northern Europe in which the chinooks were reared and liberated have in the past supported large populations of trout and Atlantic salmon, see Kendall (1935), all of which have fresh-water requirements similar to those of the chinooks. In fact, many of these rivers and lakes still support populations of Atlantic species. With the exception of artificial barriers and hazards introduced in these rivers through the progress of civilization, they all provide the essential conditions necessary for the fresh-water survival of the Pacific salmon.

The warm silt-bearing streams of southern Europe, in which efforts were made to establish natural runs of chinooks, do not provide the conditions essential to the survival of these fish. It is not surprising that the transplantations in these streams were unsuccessful. However, the failure of the chinooks to develop natural runs in the rivers of northern Europe cannot be logically attributed to this cause.

Figures 1–4, inclusive, give hydrographic data for the North Atlantic Ocean similar to those given for the other oceanographic regions. These data were calculated in the same manner as in the other regions and were taken from the works of Rathbun (1882), Townsend (1901), Nansen (1913), Bigelow (1917 and 1933), Sandström (1918), Bjerkan (1919), Huntsman (1921), Dawson (1922), Schott (1926), Zeusler (1926), Smith (1928), Church (1932, 1934, and 1936), Helland-Hansen (1933), and Parr (1933). The mean directional drifts in figure 1 show the general movements of the North Atlantic waters from June through September, the period during which the spawning migration of the salmon occurs in this zone. Three major currents dominate the waters of the North Atlantic; namely, the Gulf Stream or Florida Current, the Labrador Current, and the East Greenland Current.

The North Equatorial Current, banking up the waters in the Caribbean Sea and the Gulf of Mexico, gives rise to a strong current, the Gulf Stream, which flows out of the gulf through the straits between Florida, Cuba, and the Bahamas. This current follows the coast line of Florida and Southeastern United States until it reaches Cape Hatteras. Here it turns more to the eastward toward the banks of Newfoundland, thus allowing a cold current from the north to bathe the shores of Canada and the United States as far south as Cape Hatteras. However, the influence of this cold current is not appreciably effective south of Cape Cod. South of the banks of Newfoundland the Labrador Current meets the Gulf Stream. This cold current has only a minor influence on the Gulf Stream as it continues eastward toward the coast of Europe.

The cold current which bathes the Northeastern shore of the United States is not a continuation of the Labrador Current, but originates in the Gulf of St. Lawrence. As it leaves the gulf it turns southward and effectively carries waters of low temperature and salinity to the shores as far south as Cape Cod. It is interesting to note at this point that the Pacific salmon have not developed natural runs in the coastal streams south of Cape Cod. Here again, as in the North and South Pacific regions, the occurrence of natural runs of these salmon is associated with the presence of ocean drifts bearing waters of low temperature and salinity.

As the Gulf Stream follows its eastward drift toward the coast of Europe it branches into a number of lesser currents whose warm waters greatly temper the areas influenced by them (see fig. 1). The major branch passes to the northward of the Faeroes and flows toward and along the coast of Norway, where it divides and sends branches to Spitsbergen and the Barent Sea. A portion of the Gulf Stream also flows around Scotland and enters the North Sea. Other branches penetrate the English Channel and bathe the shores of France, Spain, and Portugal.

The North Sea, which averages considerably less than 200 meters in depth, is readily influenced by the warm and saline waters of the Gulf Stream. The Baltic Sea, being likewise very shallow, warms rapidly in the summer months, and the waters flowing from it during this period fluctuate around 17° C. Furthermore, all of the fish in the Baltic Sea area migrating to and from the open ocean must pass through the warm and saline waters of the North Sea. The failure of the California chinook salmon to develop sea-run populations in the streams tributary to these seas is consistent with their failure to develop natural populations under similar conditions in the South Pacific region.

The mean temperatures and salinities of the coastal waters in the areas of the North Atlantic (see figs. 2, 3, and 4), where the Alaska and California salmon have failed to establish natural runs, are beyond the ranges of temperature and salinity found in the native marine habitats of these salmon. The areas in which they have been successfully established all have coastal waters with temperatures and salinities similar to those in the native marine habitats of the salmon. In other words, the reactions of the Pacific salmon to both fresh-water and marine environmental conditions in the North Atlantic are consistent with their reaction to similar conditions in the South Atlantic and South Pacific regions.

SOUTH ATLANTIC REGION

The only attempts to introduce the Pacific salmon into the South Atlantic region have been those made in the waters of southern Argentina, which have apparently failed. The streams of Argentina, with the possible exception of those in southern Patagonia, receive a great deal of drainage from plateaus and are essentially alluvium-bearing streams with sandy and mud bottoms. Since it is known that the Pacific salmon do not spawn in sandy- or mud-bottomed streams, nor could the eggs survive under such conditions even if so spawned, it is not surprising that sea-run populations have failed to develop from the transplantations in these streams. Marini (1936) also reports unfavorable high temperatures in some streams in which the salmon were transplanted. Complete surveys have not as yet been made of all the streams in Patagonia in which the salmon have been introduced. There may still be streams in the southern extremity of this province that will support natural runs which are at present unknown.

The mean directional drifts of the currents, the mean seasonal surface temperatures, the mean annual subsurface temperatures (200 meters), and the mean annual surface salinities for the South Atlantic, are given in figures 1–4, inclusive. These data were taken from the oceanographical studies of Buchan (1894), Schott (1926), and Church (1934). The hydrographic conditions of the coastal waters of Patagonia, as given in these figures, are in every case similar to those found in the native marine habitats of the salmon. Hence, it appears that the failure of the attempts to introduce these salmon in Argentina lies in the unfavorable environmental conditions in its fresh waters.

SUMMARY

The native distribution of the Pacific salmon (genus *Oncorhynchus*) is confined almost entirely to the temperate waters of the North Pacific. They are found in varying degrees of abundance along the North American coast from Monterey Bay, Calif., to Kotzebue Sound, Bering Sea, and along the Asiatic coast from the Anadir River, Siberia, to the Tumen River, Korea, and Cape Inuboye, Honshu Island, Japan. They also occur in isolated streams along the Arctic coast.

From 1872 to 1930, millions of eggs and young of Pacific salmon from California, Oregon, Washington, and Alaska were shipped to the Atlantic Coast States and foreign countries for the purpose of establishing natural runs in their coastal streams. Transplantations were made in Hawaii, Australia, Tasmania, New Zealand, Chile, Argentina, Eastern United States, Eastern Canada, England, Ireland, France, Holland, Germany, Finland, and Italy. Of these many transplantations only those in New Zealand, Chile, the State of Maine, and the provinces of New Brunswick and Ontario have developed natural populations of these salmon with characteristics similar to those in their native distribution.

The environmental components, as considered in this study of the foreign streams and lakes and coastal waters in which these salmon have developed natural runs, have in every case been similar to the components of the waters frequented by the salmon in their native range. On the other hand the environmental components of the foreign waters in which these salmon have failed to develop natural runs have differed from those of the waters native to the salmon. The failures of the transplantations in some areas have been due to the lack of suitable fresh-water conditions; in others, to the lack of suitable marine conditions, while some areas provided neither fresh water nor marine conditions favorable to the introduction of the salmon.

Owing to the dependence of the Pacific salmon on particular environmental conditions, as shown in this study, there are no oceanographic regions in the world that can support populations of these fish as great as those supported by the North Pacific region.

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THE SALMON AND SALMON FISHERIES OF SWIFTSURE BANK, PUGET SOUND, AND THE FRASER RIVER

By GEORGE A. ROUNSEFELL and GEORGE B. KELEZ

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THE SALMON AND SALMON FISHERIES OF SWIFT-SURE BANK, PUGET SOUND, AND THE FRASER RIVER [1]

By George A. Rounsefell, Ph. D., and George B. Kelez, M. A.

CONTENTS

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INTRODUCTION

By George A. Rounsefell and George B. Kelez

The decrease in abundance of sockeye salmon in the waters of Swiftsure Bank, Puget Sound, and the Gulf of Georgia has been readily apparent, but no previous attempt has been made to measure accurately this change, nor has the decline of other species been previously demonstrated. The studies included in this report on the seasonal occurrence of each species, and the history and development of each form of gear, were necessary in arriving at logical conclusions as to the causes and extent of the changes in abundance that have occurred. The interrelations of the various species of salmon and the different types of gear in this region are such that the problem cannot be understood unless all of these factors are considered. Not since the general report in 1899, entitled "A Review of the Fisheries in the Contiguous

Waters of the State of Washington and British Columbia," by Richard Rathbun, has this region been considered as an entity.

The region is of considerable extent, including that portion of the high seas in the vicinity of Swiftsure Bank, the Strait of Juan de Fuca, and the narrow inland sea, over 200 miles in length, formed by Puget Sound and the Gulf of Georgia (see fig. 1). Of the numerous tributary streams, only the Fraser River penetrates the Coast Range into the interior. Many shorter rivers, however, such as the Skagit, Snohomish, and Squamish on the mainland, and the Cowichan and Nanaimo Rivers on Vancouver Island, together with a host of smaller streams, also furnish spawning grounds for the salmon of these waters.

THE PACIFIC SALMONS

The Pacific salmons (genus *Oncorhynchus*) inhabiting this region, like the Atlantic salmon (*Salmo salar*) and the steelhead trout (*Salmo gairdneri*), spend varying lengths of time in fresh water after hatching, before descending to the sea where most of their growth is attained. They differ from the Atlantic salmon and the steelhead in that all of the adults, upon returning to fresh water, die shortly after spawning. The adult salmon, returning from the ocean to spawn in the streams from whence they came, form the object of intensive fisheries on Swiftsure Bank, among the inlets and islands of Puget Sound, the Gulf of Georgia, and in the estuary and lower reaches of the Fraser River.

This region has five species of Pacific salmon: The sockeye (*Oncorhynchus nerka*), known as the red salmon in Alaska and as the blueback on the Skagit, Quinault, and Columbia Rivers; the coho or silver salmon (*O. kisutch*), also known as the silverside; the king or spring salmon (*O. tschawytscha*), known as the chinook on the Columbia River and the quinnat on the Sacramento River; the pink or humpback salmon (*O. gorbuscha*); and the chum or dog salmon (*O. keta*), also called keta or fall salmon. In addition to the confusing array of names given above, the immature king salmon are often called blackmouth, a term which is also sometimes applied to immature cohos. In the Gulf of Georgia the immature cohos taken early in their third summer are termed bluebacks.

In size the pinks are the smallest, averaging around 4 pounds. The sockeyes average under 6 pounds, the cohos about 7–8 pounds, and the chums about 9 pounds. The kings are by far the largest, averaging about 22 pounds, with occasional individuals of 60 pounds and upwards.

The pink salmon are unique in that they appear in abundance over the greater part of this region during the odd-numbered years, whereas only a few thousand are taken in the even-numbered years.

FISHING DISTRICTS

The region may be roughly divided into fishing districts, not only geographically, but also in accordance with the types of gear used and the abundance of the various species. Swiftsure Bank is unique in that the vast majority of the cohos and kings caught by trolling are taken there. Here the purse seiners meet the incoming schools of pinks, cohos, and sockeyes that are bound for the Strait of Juan de Fuca, and

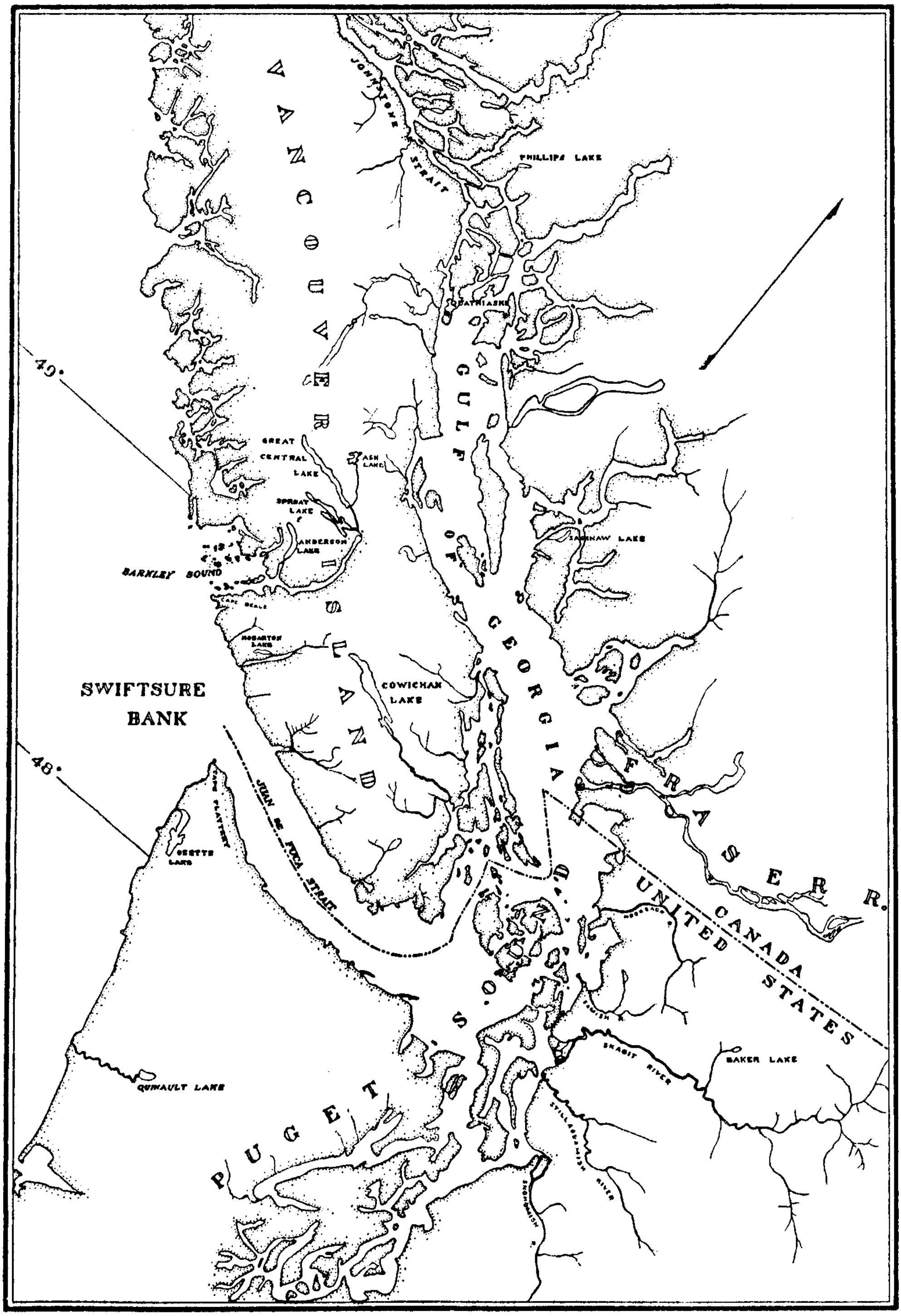

FIGURE 1.—General map of the region.

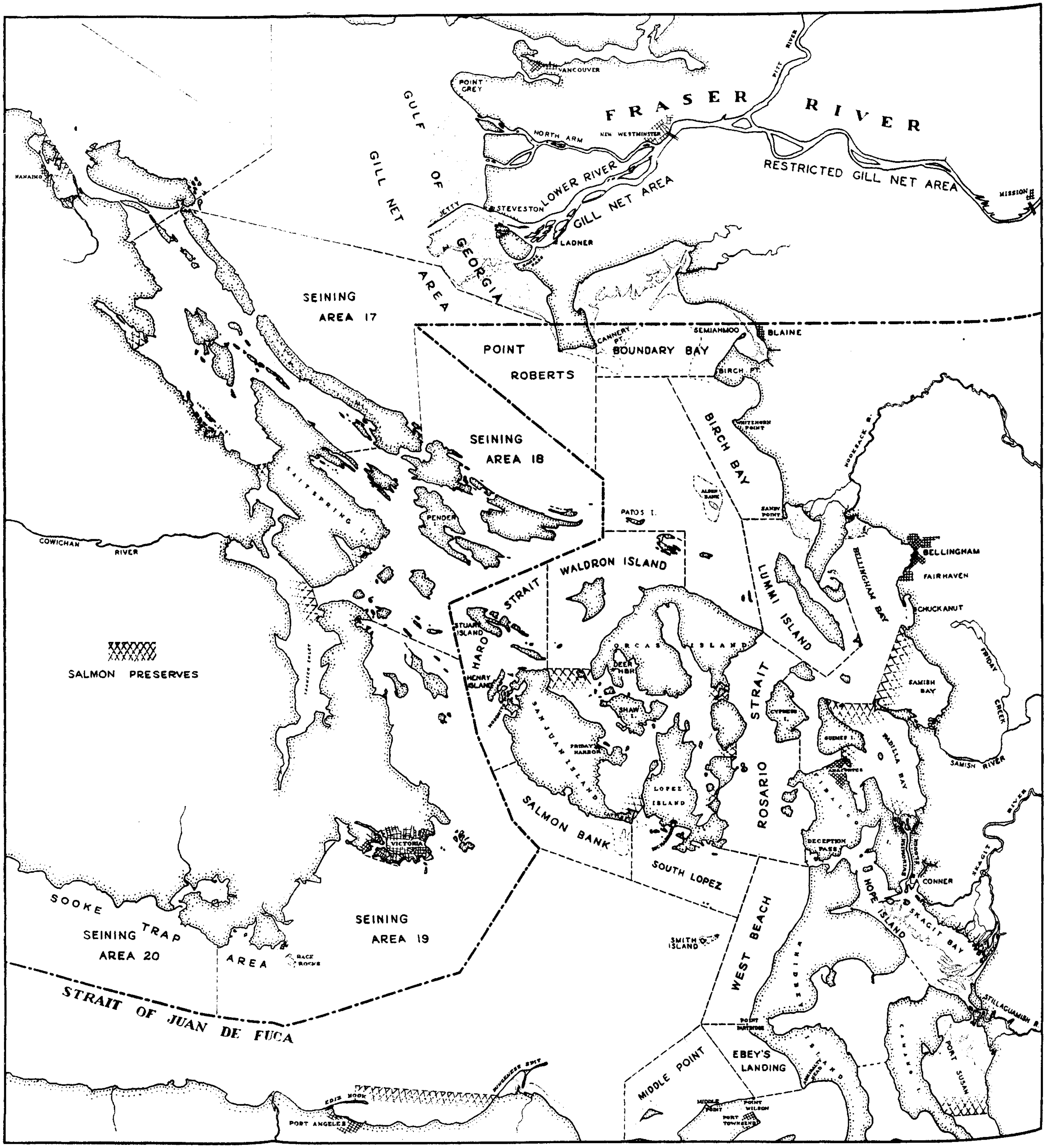

FIGURE 2.—Map of the portion of the region from the Fraser River to Point Wilson, showing the fishing areas.

thence to their spawning grounds in the myriad streams of the region. Here also, during the early summer, immature cohos and kings, actively feeding on this ocean bank, are taken in large quantities.

The waters inside of the strait, our so-called "inland sea," also fall into natural categories. The waters of Puget Sound east of Whidbey Island (see fig. 2), and south of Point Wilson (see fig. 3), are traversed almost entirely by salmon bound for local streams; the dominant species being the coho, chum, and pink. The only sockeyes taken are a few headed for the Skagit River. Traps, purse seines, and gill nets are employed.

The remainder of Puget Sound, north of Point Wilson and west of Whidbey Island, is often spoken of as the "outside" waters. In this district, which should include also the southern tip of Vancouver Island, the sockeye and pink salmon greatly outnumber the other species in the catches. The trap and purse seine are both employed to advantage and a few gill nets are used in Bellingham and Boundary Bays.

The last district is the Fraser River itself, from Mission Bridge to the mouth, and the adjoining waters of the Gulf of Georgia. Here the sockeye is the paramount species, although pinks are taken in abundance and fair catches of kings, cohos, and chums are made. The only gear permitted is the drift gill net, except late in the fall when portions of the district are opened to purse seining. The remainder of the Gulf of Georgia is fished by purse seines for cohos, chums, and pinks. A few sockeyes are taken near Quathiaski.

DEVELOPMENT OF THE FISHERIES

Exploitation of the salmon fisheries on a commercial scale began with the building of the first sockeye cannery at New Westminster in 1866 (see fig. 2). Since sockeye were plentiful and the fishing, conducted with gill nets, was easy, the industry flourished (see table 1). Some changes have occurred in the gear, the skiffs used at first were replaced by roundbottomed boats in the 1890's, and engines were installed in practically all of the gill-net boats between 1911 and 1913. Since 1914 the gear has not undergone any significant changes in this Fraser River district.

The second of the aforementioned districts to be commercially exploited was the inside waters of Puget Sound. Here the first cannery was built at Mukilteo (see fig. 3) in 1877, followed soon by canneries at Seattle and Tacoma. In these waters the early forms of gear were the gill net, set net, drag seine, and a primitive type of purse seine. Traps were used near Seattle as early as 1885–87, but were not successful in this portion of the district until about 1899, although east of Whidbey Island they were successful by the early 1890's. In later years the gill nets, set nets, and drag seines became of minor importance, while the power-driven purse seiners became a major factor in the fishery.

The northern or "outside" waters of Puget Sound were lightly fished until the erection of the first cannery in this district at Semiahmoo in 1891 (see fig. 2.) Canneries were built at Point Roberts (see fig. 7) in 1893 and at Friday Harbor in 1894. By 1900, 15 canneries were operating in the district, out of a total of 19 in Puget Sound (see table 1). The sudden expansion of the fishery here was due to the success-

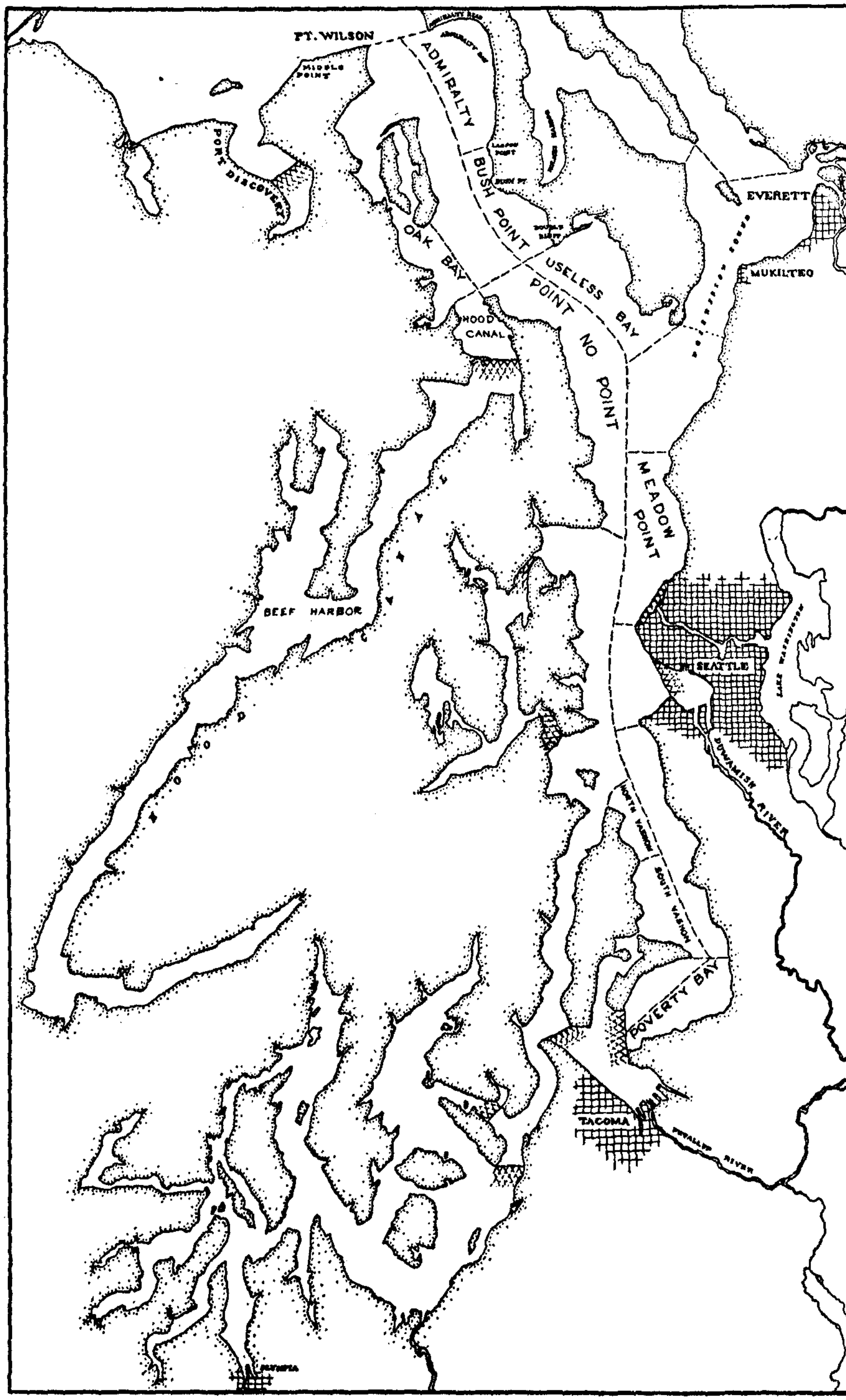

FIGURE 3.—Map of Puget Sound from Point Wilson to Olympia, showing the fishing areas.

ful use of traps in the capture of sockeye Purse seines did not become of great importance in this district until 1907 when power-driven vessels had come into general use.

In the Gulf of Georgia the fishery developed slowly, except for the area near the mouth of the Fraser River. The first cannery in this district was built at Quathiaski in 1904 and canned chiefly cohos, caught by troll in the northern end of the Gulf of Georgia, as well as small quantities of sockeye. Later pinks and chums were also utilized. Except for a small cannery at Pender Harbor in 1906 and 1907, this was the only cannery in this district for several years.

Swiftsure Bank was the last district to be exploited, as the development of this fishery in the open ocean depended upon the increased mobility of power-driven vessels. About 1908 trolling vessels were fishing in the Strait of Juan de Fuca as far as the open sea, and by 1912 the greater part of the fleet was fishing at the cape. Purse-seine vessels also began to fish here by 1911 and, since 1912, a fair share of the fleet has spent a portion of the summer there.

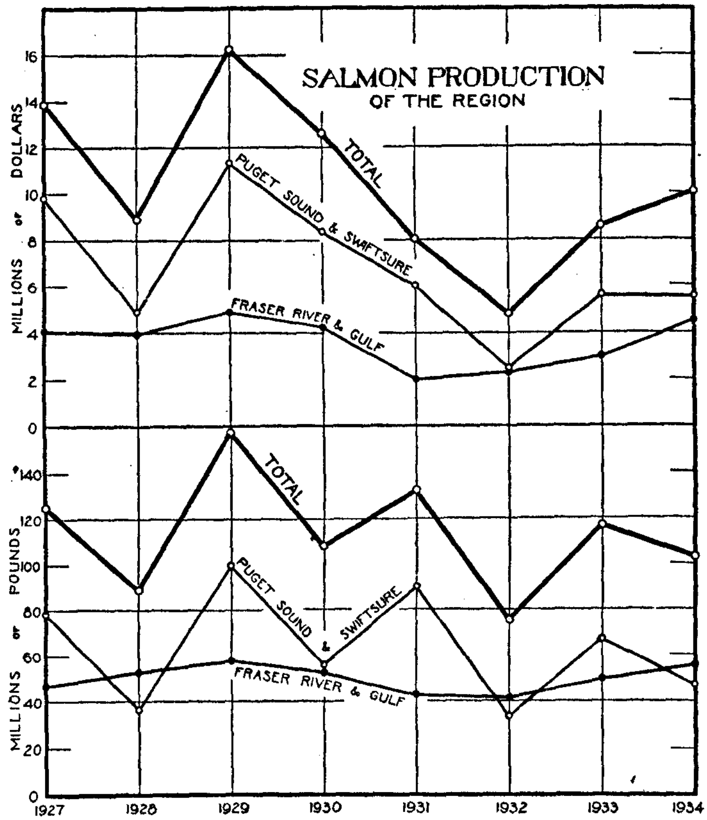

FIGURE 4.—Salmon production of the region in pounds of raw salmon, and wholesale value of the products.

PRODUCTION AND VALUE

Because of variations in economic conditions, and in the abundance of the various species, it is difficult to appraise the value of these fisheries. During the 8-year period, 1927–34, the average annual production was 113,450,000 pounds of raw salmon which had a wholesale market value of $10,400,000. If the 2 worst depression years, 1931 and 1932, are omitted, the averages are raised to 116,660,000 pounds and $11,720,000 (see fig. 4).

However, this region is capable of producing a great deal more wealth than it does at present. By way of illustration one need only refer to the reduced catches of sockeye. From 1898–1913, a 16-year period when the sockeye fishery was flourishing, the average pack of sockeye was 790,000 cases per year, worth on the average $4,930,000 (average price of just over $6.00 per case). During the 8-year period, 1927–34, the sockeye pack has averaged 229,147 cases, valued at $3,180,000 per year (average price just under $14.00 per case). At present prices the former sockeye pack would be worth $10,960,000 per year—as much as the present fishery for all five species combined—and yet the present sockeye catch only averages about 15,000,000 pounds, or 13 percent of a regional total of 113,000,000 pounds.

NEED FOR INVESTIGATION

Although the entire region should be considered in general as a biological unit, the fact that the salmon are taken on the high seas, and in both Canadian and American waters, has caused each governmental agency to keep only records of the catches landed under their own jurisdiction. Furthermore, during the period covered by this report, these agencies have usually collected only such records as have been necessary for purposes of taxation or general production statistics. Hence, only a few of the existing catch records were of any biological value.

In order to determine such relative factors as the seasonal progression of the runs, or changes in abundance of the various species, it was imperative that catch data be obtained which included the daily landings of individual units of fishing gear. Many valuable records of this type still exist in private hands, although, with the passage of time, a large part of various individual company records have been destroyed or lost when certain companies changed ownership or ceased operation. Accordingly, the authors gathered a vast quantity of these records from both American and Canadian companies which, together with total catch records from the publications of various agencies, have been analyzed in this report.

Such analyses were complicated by the many changes which have occurred during the long period of development of these fisheries. Not only were new fishing areas pioneered, and new types or radical improvements of the old forms of gear developed, but there has been a considerable shift in intensity of the fisheries for some of the species, both for economic reasons and because of changes in abundance. Because these changes directly influenced the exploitation of the resource, the history and development of the major forms of gear have been carefully traced. Differences in fishing locality, seasonal operation, and effectiveness in the capture of the various species of salmon have necessitated the separate consideration of each of the more important forms of gear.

The different species of salmon enter the fishery in varying abundance at certain parts of the season, hence it has been necessary to determine the curves of seasonal occurrence for each species. The changes in abundance that have occurred during the course of the fishery have in the past been measured largely from the total annual production of canned fish, a measure which is especially inaccurate in view of the influence of changing economic conditions, changes in fishing effort, and the obscuring of the decline in certain species by the increase in intensity of the fishery for others. The authors have endeavored to present, for each species, the best measure of abundance possible from the available data. The varying importance of the species in certain districts and in different types of gear, and the differences in production of the major spawning areas have also been treated. The complexity of these problems and the differences in their life histories have made it necessary to consider them, like the major types of gear, in separate sections of the report.

It has been the desire of the authors not only to make the above material available, but to present it in such a way as to provide a thorough understanding of the fisheries of the region and to establish a background which will form the basis for future conservation efforts in the region.

ACKNOWLEDGMENTS

The authors wish to express their appreciation for the splendid cooperation in the furnishing of information and statistics by the following companies: Anglo-British Columbia Packing Co.; The British Columbia Packers; The Canadian Fishing Co.; Francis Millerd; Greatwest Packing Co.; J. H. Todd & Sons; Johnston Fishing & Packing Co.; Kingcome Packers; Nelson Fisheries; Quathiaski Canning Co.; Queen Charlotte Fisheries; Sooke Harbour Fishing & Packing Co.; Alaska Packers Association; American Packing Co.; Anacortes Canning Co.; Astoria & Puget Sound Canning Co.; Beach Packing Co.; Bellingham Canning Co.; Booth Fisheries Corporation; Carlisle Packing Co. (S. P. Kelly); Everett Fish Co.; Farwest Fisheries; Fidalgo Island Packing Co.; Fishermen's Packing Corporation; Friday Harbor Canning Co.; W. A. Lowman; New England Fish Co.; Northwestern Fisheries Co.; Pacific American Fisheries; Puget Fisheries; San Juan Fishing & Packing Co.; Sebastian-Stuart Fish Co.; Icy Straits Packing Co.; Western Fisheries; Western Sea Foods Co. For valuable information and statistics of early fishing on the Fraser River the authors are indebted to Mr. Henry Doyle, of Vancouver. Capt. T. E. Eggers, of Seattle, supplied information of the early fishing on Puget Sound.

The officials of the Fisheries Departments of the Dominion of Canada, the Province of British Columbia, and the State of Washington have extended numerous courtesies, in addition to giving the authors access to their files and records.

GILL NET FISHERY

By George A. Rounsefell

FRASER RIVER

EARLY COMMERCIAL DEVELOPMENT

Gill nets were the first to be developed of the four main types of gear used commercially in this region. Since 1873 they have captured 46 percent of all of the sockeyes taken, as well as large quantities of the other species. The gill net fishery is so inextricably bound up with the Fraser River that its story is largely that of the Fraser itself.

The salting of salmon was begun soon after 1800 by the Northwest Company, later the Hudson Bay Company (Rathbun 1899), which exercised a monopoly of the fishing (Howay 1914), and by 1835 was shipping 3 to 4 thousand barrels of salt salmon each year to the Hawaiian Islands. These early trading companies depended very largely upon salmon for their food supply. Thus, in 1836, the supplies gathered for the upper Fraser River trading posts included 67,510 salmon, 11,941 smaller fishes, 781 sturgeon, and 346 trout (Morice 1904). In 1858 the Hudson Bay Company's license was revoked and its claim of monopoly fell.

The first salmon were canned on the Fraser River in 1863, when Mr. Annandale canned a limited quantity for local use (Doyle 1920). This pre-dates by 1 year the establishment of the first salmon cannery on the Pacific coast by Hapgood, Hume & Company, in 1864, on the Sacramento River. The first real cannery on the Fraser River was built in 1866 at New Westminster. The first cannery on the Columbia River was built the same year at Eagle Cliff. Thus, salmon canning on the Pacific coast started almost simultaneously on three of the largest salmon streams. The first recorded pack on the Fraser River, in 1873 (Rathbun 1899), was 8,125 cases.

Howay (1914), mentions the unsuccessful use of Scotch trap nets in 1864 by the Annandale saltery, and the change to drift gill nets. The gill netting during the earlier years was done by Indian fishermen from canoes and flat-bottomed skiffs. The packs were restricted because of the crudeness and inefficiency of the canning equipment, and because the necessary tinplate had to be shipped around Cape Horn in sailing vessels in advance of the season. Thus, in 1882, because of an unexpectedly large run of salmon, the supply of tinplate became exhausted in the middle of the season and the packers were forced to close down.

RELATIVE IMPORTANCE OF THE VARIOUS SPECIES

In the early development of the Fraser River fishery the sockeye was by far the most important species. The deep color and firmness of its flesh was most important for producing an attractive product with the crude canning methods then in use. Also, sockeyes were tremendously abundant, the run reaching its peak during the summer months when fishing conditions were at their best. So important were they to the canning industry that, for the period before 1900, when accurate records of the number of cases of each species canned were not always available, the total canned pack has often been used to represent the sockeye pack.

In seasons when sockeye were not abundant the canners would often, even during the earlier years, supplement their pack with coho and king salmon. However, when the packers were unable to handle all of the sockeye that the fishermen delivered they could not afford to waste time, effort, or their sometimes inadequate supply of tinplate, to put up a cheaper product. Thus, 1905 was the first of the "big" years of the quadrennial sockeye run to the Fraser River in which as many as 30,000 cases were canned of the other four species combined.

Meanwhile the fishery for king salmon began to attain importance after freezers were built on the Fraser River. The first of these appeared in 1886 and two others in 1887. In early years the canning of king salmon usually began before the sockeye runs made their appearance. Thus, one cannery, in the period from 1887–91, usually started canning king salmon during the latter half of April, more than 2 months before the sockeyes were due to appear. Gradually they commenced operations later in the season until, from 1900–1902, they did not start until after the sockeyes had arrived. There was much variation between individual canneries, however, as to their season of operation.

Since the 1880's a few canneries have remained open, after poor sockeye runs, for the fall fishing. For many years this fishing was confined largely to cohos, and the fall run of king salmon, which are inferior to those running in the spring.

The pink salmon were for a long time considered inferior in value for canning because of their light-colored, soft flesh. However, as the sockeyes became scarcer and a demand for cheaper grades of salmon increased, the pinks eventually became important. The first pack of any consequence on the Fraser River was in 1907 when 63,000 cases of pinks and chums were canned. In 1909, a big sockeye year, only 2,000 cases of pinks were canned, but in 1911, the next pink-salmon cycle, 142,000 cases were packed and the pink salmon had definitely become an important factor in the fishery.

TABLE 1.—*Number of canneries operated in the region*

Year	Fraser River [1]	Victoria and Gulf of Georgia [2]	Puget Sound and Neah Bay [3]	Total	Year	Fraser River [1]	Victoria and Gulf of Georgia [2]	Puget Sound and Neah Bay [3]	Total
1876	3	----------	----------	3	1906	23	4	17	44
1877	5	----------	1	6	1907	18	3	13	34
1878	8	----------	1	9	1908	10	2	11	23
1879	7	----------	2	9	1909	34	3	23	60
1880	7	----------	2	9	1910	21	2	15	38
1881	8	----------	3	11	1911	15	2	20	37
1882	11	----------	3	14	1912	15	2	20	37
1883	13	----------	3	16	1913	35	4	31	70
1884	6	----------	3	9	1914	20	3	22	45
1885	6	----------	3	9	1915	22	3	41	66
1886	11	----------	3	14	1916	21	5	32	58
1887	12	----------	3	15	1917	29	5	47	81
1888	12	----------	4	16	1918	18	5	37	60
1889	15	----------	2	17	1919	14	3	36	53
1890	17	----------	1	18	1920	11	3	11	25
1891	22	----------	2	24	1921	13	3	23	39
1892	22	----------	2	24	1922	10	4	15	29
1893	26	----------	3	29	1923	11	4	18	33
1894	28	----------	4	32	1924	9	4	12	25
1895	33	----------	6	39	1925	10	4	23	37
1896	35	----------	11	46	1926	10	3	14	27
1897	43	----------	12	55	1927	10	3	21	34
1898	49	----------	18	67	1928	8	3	14	25
1899	41	----------	17	58	1929	9	3	21	33
1900	45	----------	19	64	1930	8	3	13	24
1901	49	----------	16	65	1931	7	3	18	28
1902	42	----------	20	62	1932	8	3	10	21
1903	36	----------	19	55	1933	10	3	19	32
1904	25	1	12	38	1934	11	3	21	35
1905	38	2	24	64					

[1] Includes canneries in Vancouver and environs.
[2] Extending north to and including Quathiaski.
[3] Neah Bay is just inside of Cape Flattery. Number estimated from 1878 to 1887, inclusive, except for 1881, which is from Hittell (1882).

Chum salmon were long regarded as a nuisance by the fisherman, although the Indians always used them to some extent, especially in years of poor sockeye runs. In 1897 the Japanese commenced drysalting chum salmon on the Fraser River for the Japanese market, and for use in the Yukon for dog feed. The Report of the Department of Marine and Fisheries for 1899 (1900) says:

> A new feature in the fishing industry this season was the salting for shipment to Japan of 4,000,000 pounds of dog salmon (*O. keta*) by Japanese fishermen. The fish were mostly caught by fishermen when fishing for cohos for the canners, and bought by the Japanese. Formerly this class of fish, when caught, were allowed to go to waste.

In 1900 the canners commenced using chum salmon. The sockeye run was very small and a good price was being offered for lower grades of salmon, so 105,000 cases were canned. Difficulty was experienced in marketing, however, on account of a large production in other areas, and the chum-salmon pack remained small until 1910, when 52,000 cases were packed. The pack did not again exceed 100,000 cases until 1923.

NUMBER OF CANNERIES

Judging from the number of canneries in operation on the Fraser River or near its mouth each season since 1876 (see table 1), exploitation of salmon increased almost continuously from 1876–98. The great majority of the canneries were built during this 23-year period and the peak was reached when nine new canneries were built in 1897.

The decline in the number of canneries in 1884 was possibly due to unfavorable economic conditions at that time. The Annual Report of the Department of Fisheries for 1884 says:

> There is estimated to be over in Great Britain now—1st January, 1885—in an unsalable condition, . . . , over two hundred thousand (200,000) cases of fall salmon, that will not bring much more than freight, insurance and charges.

In 1901, the large packs both on the Fraser River and in Puget Sound again brought about an oversupply of salmon. The British Columbia Packers Association, which was formed at this time, included 29 of the 49 canneries on the river. The number of canneries in operation was considerably curtailed through this and other combines, especially during the "off" years when a few canneries were sufficient to handle all the catch. During the war years the number of canneries increased somewhat, but at the end of the war it dropped sharply, and there have been less than a dozen since 1921.

EVALUATION OF FISHING INTENSITY

Company Licensing System

In the early years of the fishery the majority of the fishing licenses were taken out by the canneries, who then hired men to fish them on whatever arrangement the company wished to make. At first they usually hired men to fish by the day or month, but later this custom was largely supplanted by the share system in which a certain percentage of the price of the fish, usually one-third, was deducted by the company, which supplied the net and rented a boat for a nominal charge. The independent fisherman was required to fish under his own license. The canneries often hired 2 gangs (2 men in each gang) for each of their boats. Thus, by working in shifts, the license and boat might be used day and night. For instance, Hittell (1882) says of the cannery of Laidlaw and Co. in 1881, "It has 25 boats, which run day and night, with 4 men to each boat."

Of a total of 1,174 gill-net licenses issued in 1893 the companies obtained 909, varying from 27 to 40 licenses per company. Apparently the companies were restricted as to the total number of licenses they might have for 1 company had 27, 7 had 30, 4 had 35, 7 had 36, and 7 had 40.

In 1894 the number of company licenses was reduced by law to a maximum of 20 each for canneries, and 7 for dealers in fresh, frozen, salted, cured or smoked salmon. By 1898 this limit was further reduced to 10, and after 1907 company licenses were abolished.

Nationality of the Fishermen

Because of differences in fishing ability it has been important to a study of the gill netting to note the changes in the nationalities of the fishermen. According to Henry Doyle the fishermen were practically all Indians as late as 1882. The first Japanese fishermen were engaged by English and Company at their Steveston cannery in 1888. Only a few were employed at first, however, and up to 1892 they were not given independent licenses. Doyle estimated that they formed at least one-third of the fishermen by 1895.

The statement by Doyle that in 1882 most of the fishermen, if not all of them, were Indians, is borne out by Hittell (1882) who says that the Delta Packing Company in 1881 had 36 boats and employed 200 Chinese, 150 Indians, and 30 white men. The Chinese, of course, were used as cannery labor, the white men were probably nearly all clerks and mechanics, and the 150 Indians would be about the number required to furnish 2 crews of fishermen (4 men) to each of the 36 boats.

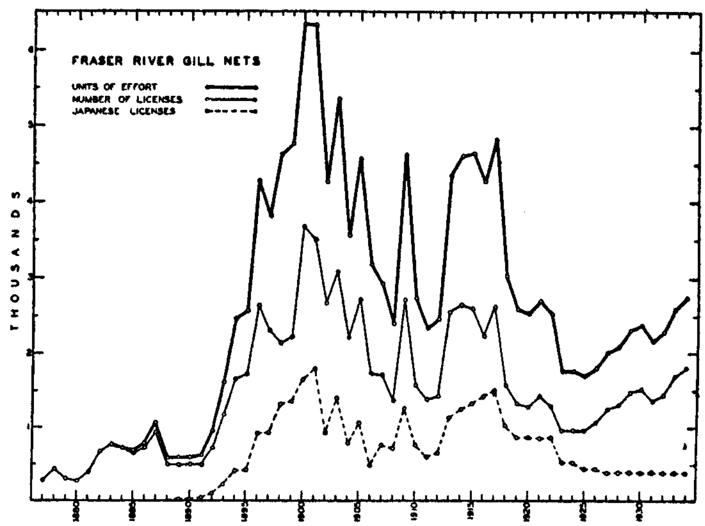

Figure 5.—Fraser River gill nets, showing for each year the total number of gill-net licenses issued, the number issued to Japanese fishermen, and the total units of fishing effort. For an explanation of units of fishing effort see text.

From 1900 to date the license registers for individual fishermen have been available at the New Westminster office of the Dominion Fisheries Department. Since 1915 these registers have given the nationality of each fisherman. For previous years we have divided them into three groups: Japanese, Indian, and white, being guided both by the name and residence of each fisherman.

Number of Licenses

The number of licenses issued to each of these three groups of fishermen, plus company licenses—which we have not attempted to segregate before 1900—and special licenses issued since 1908 permitting bona fide residents along the banks of the Fraser River between the New Westminster and Mission bridges to fish only in that area are given in table 2. The figures for the Fraser River, except the totals, for years previous to 1900 were empirically determined from available information.

Units of Fishing Effort

Having made an estimate of the number of each type of fishermen, it has been necessary, in order to obtain the best measure of the intensity of the gill-net fishery during each season, to determine the relative efficiency of each type. For one company we have records from 1905–16, inclusive, giving the catches of their individual fishermen. During this 12-year period the average annual catch of their Japanese fishermen was 1,782 sockeyes, their white fishermen 1,057 sockeyes, and their Indian fishermen 768 sockeyes (see table 3).

TABLE 2.—*Gill net licenses of the Puget Sound-Fraser River region, 1877–1934*

Year	Fraser River						Puget Sound			Grand total
	Type of license [1]					Total	Type of gill net		Total	
	Company	Individual			Between-bridges license		Drift	Set		
		Japanese	Indian	White						
1877			285			285				
1878			449			449				
1879			304			304				
1880			274			274				
1881			396			396				
1882			666			666				
1883			715	49		764				
1884			645	57		702				
1885			611	44		655				
1886			625	109		734				
1887			615	320		935				
1888		10	323	167		500				
1889		25	308	167		500				
1890		25	308	167		500				
1891		50	283	167		500				
1892		108	373	240		721				
1893		235	558	381		1,174				
1894		417	549	701		1,667				
1895		434	539	731	30	1,734				
1896		926	530	1,130	60	2,646				
1897		928	520	780	90	2,318	422	668	1,090	3,408
1898		1,321	511	690	120	2,642	281	460	741	3,383
1899		1,361	501	710	150	2,722	322	344	666	3,388
1900	393	1,659	555	1,076		3,683	380	330	710	4,393
1901	416	1,805	396	909		3,526	414	369	783	4,309
1902	381	929	583	781		2,674	353	361	714	3,388
1903	343	1,416	477	860		3,096	334	470	804	3,900
1904	232	795	446	742		2,215	438	540	978	3,193
1905	339	1,056	464	915		2,774	348	574	922	3,696
1906	200	494	392	660		1,746	310	618	928	2,674
1907	193	769	270	494		1,726	329	755	1,084	2,810
1908	3	717	175	273	195	1,363	362	836	1,198	2,561
1909		1,263	584	638	243	2,728	366	686	1,052	3,780
1910		766	236	426	148	1,576	403	666	1,069	2,645
1911		607	232	411	146	1,396	459	813	1,272	2,668
1912		655	217	486	72	1,430	377	829	1,206	2,636
1913		1,132	476	843	109	2,560	427	807	1,234	3,794
1914		1,250	333	842	231	2,656	544	458	1,002	3,658
1915		1,332	317	768	199	2,616	512	559	1,071	3,687
1916		1,435	211	437	157	2,240	449	541	990	3,230
1917		1,520	300	570	237	2,627	537	658	1,195	3,822
1918		1,025	106	303	149	1,583	417	646	1,063	2,646
1919		874	56	294	113	1,337	540	686	1,226	2,563
1920		875	36	275	102	1,288	364	439	803	2,091
1921		857	68	359	153	1,437	346	318	664	2,101
1922		871	32	277	116	1,296	119	37	156	1,452
1923		523	26	304	111	964	136	14	150	1,114
1924		523	40	289	117	969	181	10	191	1,160
1925		444	36	357	132	969	391	17	408	1,377
1926		444	53	429	137	1,063	361	11	372	1,435
1927		400	58	619	172	1,249	397	18	415	1,664
1928		400	57	695	151	1,303	353	22	375	1,678
1929		400	73	830	170	1,473	368	23	391	1,864
1930		400	60	863	200	1,523	398	20	418	1,941
1931		400	35	739	184	1,358	319	19	338	1,696
1932		400	26	840	180	1,446	254	8	262	1,708
1933		400	25	1,026	234	1,685	302	9	311	1,996
1934		400	31	1,105	267	1,803	318	12	330	2,133

[1] From 1877 to 1899 the nationalities have been estimated from various notes. The company licenses before 1900 are not separated from the total, and so are allocated amongst the other types. There were no special "between bridges" licenses prior to 1908, so the figures from 1895 to 1899 merely represent a rough estimate of the number of this type of resident up-river fishermen before 1900. From 1900–1907, inclusive, no estimate of these fishermen was made as it was impossible to segregate the nationalities accurately.

TABLE 3.—*Annual catches of sockeyes by white, Indian, and Japanese fishermen at a Steveston cannery, 1905–16, inclusive*

Year	Japanese		Whites		Indians		Cannery license [1]	
	Number	*Average*	*Number*	*Average*	*Number*	*Average*	*Number*	*Average*
1905	114	4,064	72	2,872	29	2,414	9	3,154
1906	46	1,537	77	860	50	550	8	717
1907	132	425	46	234	19	183	9	249
1908 [2]	132	788	42	545	27	370		
1909	122	2,393	34	1,437	31	1,102		
1910	94	1,270	28	852	10	527		
1911	69	824	58	328	11	412		
1912	62	1,283	56	611	15	660		
1913 [3]	85	3,588	62	1,832	13	1,204		
	21	3,546	14	2,365	10	1,142		
1914	138	1,053	92	517	29	476		
1915	141	435	106	164	27	122		
1916	168	178	30	63	20	53		
Total	1,324	21,384	717	12,680	291	9,215		
Unweighted average	110.3	1,782	59.3	1,057	24.25	768		

[1] From 1904–7, inclusive, out of 40 company licencees, 38 were white, 2 Japanese during the summer fishery, and a few Indians were employed for fall fishing.
[2] Includes a very few cohos and some kings.
[3] Two canneries.

From the averages shown in table 3, and the variations in the number of each type of fishermen, it is obvious that in order to obtain a true picture of the intensity of fishing the total number of licenses must be broken into component groups and each group weighted according to an estimate of its efficiency. This has been done by assigning to Indian licenses and "between bridges" licenses a weight of 1.00, to white and company licenses a weight of 1.375, and to Japanese licenses a weight of 2.32. From 1900–1907, inclusive, we have estimated that 150 of the fishermen not falling into other classifications, grouped as whites in table 2, were up-river resident fishermen of the same type that later used the special between bridges license. These are given the same efficiency weighting as the Indian licenses. The total units of effort for each year, estimated on the above basis, have been used in the sockeye section of this report to determine the average annual catch per unit of fishing effort on the Fraser River (see fig. 5 and table 33).

CHANGES IN GILL-NET BOATS

In addition to differences in the efficiency of each license holder, according to his nationality, there have been changes in the form of the unit of gear itself. The first of these to be considered is the change in type of boat used.

According to Greenwood (1917) the fishermen still used a two-oared skiff in 1896, 20 years after salmon canning began. Rathbun (1899, p. 307) says:

> The boats are mostly small skiffs, about 20 feet long, generally manned by two, occasionally by three persons. In recent years the Columbia River boat has been introduced and is now used to a considerable extent in the lower part of the river and outside. Its breadth and centerboard make it much safer for the more exposed places.

Greenwood also says the round-bottomed 30-foot sail boats were introduced "a score of years ago", when 20 were built for the Alliance cannery. This would place their introduction about 1897. However, Rathbun establishes their introduction in the early 1890's.

In 1903 the records for one cannery show that their 25 white fishermen all used round-bottomed boats while their 66 Indian fishermen used 36 round-bottomed boats and 30 skiffs. Since the Japanese all fished on contract no record was kept of their gear, but it is safe to assume that all of their boats were round-bottomed, as they were very progressive fishermen. Among 3,096 licenses issued in 1903 only 477 were for Indians,[2] and it is therefore evident that the transition from skiffs to Columbia River boats was almost complete. After 1905 the records of this company show no skiffs in use.

The introduction of motorpower in gill-net boats, to replace oars and sails, took place soon after the turn of the century. According to old-timers on the river, gasoline engines were used as early as 1902, although only a few were in use until a decade later. Thus records of one of the largest canneries on the river, located at Steveston, show very few gasoline boats in 1909 and 1910. From then on, however, the number increased rapidly and large numbers of engines were installed in 1911–13. By 1914 the change appears to have been almost complete. The data have been insufficient to measure the increase in efficiency brought about by the adoption of engines, but such an increase existed and should be remembered when comparing the catches of the earlier years with those made during and after the World War.

Changes in the Gill Net

The gill-net fishery on the Fraser River is remarkable for the few changes that have taken place in the net itself over a long period of years. There has been no change of any consequence in the length of the net, and the deep nets, used for only a few years, were confined to a small percentage of the fishermen.

In 1882, when the Richmond cannery was built on the North Arm, the nets used in that section of the river were 27 and 30 meshes in depth, 150 fathoms in length, and of 5⅞-inch mesh, according to Charles F. Todd.

The Government regulations that went into effect May 1, 1894, provided for a maximum length of 150 fathoms. Rathbun (1899) says that although there was no restriction upon their depth, custom fixed it at 50 to 55 meshes, though some were shallower. In the years 1903 and 1905, the men fishing on shares for the Imperial cannery used a total of 8 nets of 40-mesh depth, 101 of 45 meshes, 37 of 50 meshes and 1 each of 55 and 60 meshes, placing the average at less than 50 meshes. The records for these years do not give any indication of the depth of the nets used by the Japanese, who formed over 40 percent of the fishermen on the river.

Testimony as to the depth of gill nets is given in the Interim Report of the British Columbia Fisheries Commission (Report of the Fisheries Commission for B. C., 1906, pp. C18–C40), in which one witness, a canneryman, stated:

> This summer I had over 20 boats of Japanese fishing in the river, and there was not one of them with a net of less than 80 meshes.

The same witness says later:

> It is only 8 or 10 years ago that the fishermen commenced to use these extra deep nets * * * I think it is only 4 or 5 years ago since 80-mesh nets were common.

[2] This figure does not include Indians that may have fished on the 343 company licenses.

FIGURE 8.—Brailing crew lifting the spiller of a salmon trap preparatory to brailing. In this operation one side of the spiller is lowered sufficiently to permit a small pot scow to enter the spiller. The side is then raised. Starting at one side of the spiller the crew overhauls the web until the salmon are crowded enough for brailing.

FIGURE 9.—Brailing a salmon trap. The lower end of the heavy net, or brail, is attached to the side of the scow. The upper end is attached to a heavy pipe so that when the brail is lowered over the side of the spiller it sinks quickly. As soon as the brail sinks it is hauled under the densely schooled salmon by the men on the pot scow (in the background). The brail is then hoisted with a winch and the salmon are dumped into the large transporting scow.

From the foregoing it would appear that the depth of the gill nets commenced to increase somewhat after 1899, the last year for which Rathbun gives any information. In 1906 our records for the Imperial cannery give 4 nets of 40 meshes in depth, 52 of 45, 42 of 50, 4 of 72, 4 of 75, and 3 of 80 meshes, so that out of 109 nets only 11 were over 50 meshes in depth. The 1906 records included both share and contract white fishermen, and unless the Japanese fishermen were using radically different gear, our records do not support the viewpoint of the witnesses as to the preponderance of deep nets.

The British Columbia Fisheries Commission also stated:

> We favour the limitation of the length of salmon gill nets to 150 fathoms (300 yards). This was formerly the length of net universally used in the sockeye fishery, but for some years nets double the length, viz., 300 fathoms (600 yards) have been permitted outside the mouth of the Fraser River. To prevent all risk of abuse arising from the alleged use of long nets inside the Fraser River, a length of 150 fathoms is recommended as a maximum limit.

Their statement is at variance with a statement by Inspector C. B. Sword in the Dominion Fisheries Report for 1904, p. 214, in which he says the canners suggest that a gill net longer than the prescribed 150 fathoms should be allowed in the Gulf of Georgia, as the shallower nets in use there would permit handling of 300 fathoms. That the longer nets were not used in the Gulf of Georgia is also the opinion of the cannerymen.

From 1908–30 the size of gill nets in the whole area was restricted to a maximum length of 150 fathoms and a maximum depth of 60 meshes. Since 1930 a maximum length of 200 fathons has been permitted in the Gulf of Georgia.

The size of the meshes in the sockeye nets were restricted as early as 1882, and probably earlier, to a minimum of 5⅞ inches. In 1916 the minimum size of mesh was lowered to 5¾ inches and in 1928 the minimum was abolished.

Fishing Seasons

In studying changes in fishing intensity one must know not only the relative effectiveness of the gear used in different years, but also the length of time during which it was employed and the proportion of the run that occurred during that period. On the Fraser River the closed seasons had little effect on sockeye fishing, especially during the earlier years. At one lower-river cannery the earliest sockeye canning date was July 5, 1887 and 1890, and the latest was August 30, 1888. The shortest season was 26 days in 1885, and the longest was 50 days in 1888; averaging 39 days. The closing date of August 25, effective in most years, had little influence on the pack.

At another lower-river cannery, over the period 1887–1902, the sockeye pack was put up, on the average, in 52 days—from July 5 to August 25. The earliest start was made on June 27, 1896, and the latest on July 13, 1901. The season ended on August 12 in 1887 and on September 6 in 1902.

The sockeye fishing seasons, as far as we have been able to determine from available data, are given in table 4.

TABLE 4.—*Fraser River sockeye fishing regulations*

Year	Closing summer season [1]	Fall season		Week end closed season		Remarks
		Opening	Closing	General	Between bridges [2]	
				Hours	*Hours*	
Before 1878						No regulations.
1878-81	(?)	(?)	(?)	40		No gill netting above tide water—must not obstruct over one-third of channel.
1882-87	Aug. 25			40		Nets 5⅞-inch mesh, minimum.
1888	Aug. 31			40		Nets 150 fathoms maximum length.
1889-92	Aug. 25			40		
1893	Aug. 31			40		
1894-1900	Aug. 25	Sept. 25	Oct. 31	36		
1901	Aug. 31	Sept. 25	Oct. 31	36		
1902	Sept. 6	Sept. 25	Oct. 31	36		
1903	Aug. 31	Sept. 25	Oct. 31	36		
1904-07	Aug. 25	Sept. 25	Oct. 31	36		
1908	Aug. 25	Sept. 16	(?)	42	48	Nets 60 meshes maximum depth.
1909	Aug. 25	Sept. 16	Oct. 7	42	48	
1910	Aug. 25	Sept. 16	Sept. 31	42	48	
1911	Sept. 31			42	48	
1912-14	Aug. 25	Sept. 16	Sept. 31	42	48	
1915	Sept. 31			42	48	
1916	Aug. 25	Sept. 16	Oct. 31	[3] 42	48	Nets 5¾-inch mesh.
1917-20	Sept. 31			42	48	
1921	Sept. 6			42	48	
1922	Sept. 22			42	48	
1923-24	Sept. 30			42	48	
1925	Nov. 21			42	48	
1926-27	Sept. 30			42	48	
1928	Sept. 30			48	48	Mesh limitation abolished.
1929	Nov. 30			48	48	
1930	Sept. 20			48	48	Nets 200 fathoms permitted outside of river.
1931	Sept. 29			48	48	
1932	Sept. 30			48	48	
1933	Sept. 30			48	48	Purse seining Aug. 25-Sept. 30.[4]
1934	Sept. 15	Oct. 1	Oct. 31	48	54	Purse seining Sept. 1-8 and Oct. 1-27.

[1] Closing dates of summer season 1882 to 1903 partly from cannery pack records, opening date July 1 at least as early as 1894.
[2] Fraser River between New Westminster and Mission bridges.
[3] 54 hours weekly closed season during fall of 1916.
[4] Purse seining in area 17, see map.

CHANGES IN LOCATION OF THE CANNERIES

At first the gill-net fishing was conducted inside the river, chiefly from New Westminster to Sumas and beyond, a distance of over 50 miles from the river mouth. At times the canneries received shipments of sockeye that were caught by the Indians with dip nets in Yale Canyon, near Hope, a distance of nearly 100 miles from the river mouth. The first canneries, as a consequence, were located at New Westminster.

Meanwhile the fishermen had discovered that it was possible to make large catches in the lower river and the canneries found it advantageous to be closer to these fishing grounds. Consequently the first down-river cannery was built on Deas Island in 1876, followed by a second in 1878, and a third in 1880. In 1882 two more were built in this area, as well as one each at Steveston and in the North Arm.

The Indian fishermen did not have good boats for fishing outside the river, although they went out at least as far as the sandheads. In 1885 we find the Dominion Report suggesting that the distance between gill nets, while drifting over the sandheads outside the river, should be increased from 250 to 400 yards. That they did not, as yet, venture far from the river mouth is attested by the Dominion Report for 1887 which states that the fishermen go out only as far as the lightship, 4 or 5 miles from land.

Table 1 gives the number of canneries operated annually from 1876 to 1934. For nearly 20 years the proportion of the canneries located at New Westminster declined, while the proportion near Steveston and Ladner continued to rise. The few remaining canneries were either at the river mouth, in the North Arm, or entirely outside the river proper.

The canneries at Ladner reached their peak in 1885, when half the total number operating were located there, and have since declined steadily to a point of little consequence. Many ascribe much of this decline to the fact that the fish have entered the river through Canoe Pass in decreasing numbers since the driving of traps at Point Roberts. The decline may possibly be further ascribed to the silting up of Canoe Pass and the change in the main channel at Woodwards Slough, effected during the flood of 1894, which made it difficult to reach most of the canneries with large boats.

SEASONAL OCCURRENCE OF EACH SPECIES

Seasonal occurrence is of prime importance in any fishery wherein more than one species is taken, as the intensity of fishing for a species is not governed by its abundance alone, but by a combination of factors, such as the relative abundance of the several species at any time during the season, as well as the relative prices.

In determining the seasonal occurrence for sockeyes, data for 1,982,735 fish taken in 30,706 gill-net deliveries were used, covering 3 complete 4-year cycles, 1898–1909, inclusive. The occurrence shown in these early years was considerably different than that shown in the last three cycles, 1923–34. This difference is treated in the sockeye section of this report (see page 754).

The king salmon curve is derived from 102,123 fish taken in 26,193 deliveries over a 5-year period, 1929–33.

For pink salmon 8 years are represented, all of the odd-numbered years from 1915–33, except 1917 and 1921; the data totaling 597,774 fish in 15,581 deliveries.

The coho curve is also based on 8 years' data, 1904, 1905, and 1929–34, and represent 155,957 fish in 22,117 deliveries.

The chum-salmon curve represents only 3 years, 1932–34, but is quite representative of those particular years, comprising 263,703 fish from 10,608 deliveries.

In analyzing these data the average catch per delivery for each 7-day period was computed for each year and then given equal weight in determining the average curve for all years (see table 5).

Table 5 shows that the period over which one or more species can be taken in some measure of abundance extends from June 24 (week ending June 30) to November 17; 21 weeks, or 147 days. As mentioned above, in earlier years the season was very much shorter, corresponding largely to the more abundant portion of the sockeye run.

The sockeye and pink-salmon runs, which overlap to a slight extent, are both of short duration. Approximately 79 percent of the pinks are caught in 4 weeks, September 2–29, and 83 percent of the sockeyes are taken in the 5 weeks from July 22–August 25.

TABLE 5.—*Seasonal occurrence in Fraser River gill nets*

Week ending—	Percentage occurrence				
	Sockeye	King	Pink	Coho	Chum
June 30	--------	3.73	--------	--------	--------
July 7	--------	5.17	--------	.083	0.42
July 14	4.15	5.21	0.37	.92	.42
July 21	5.68	6.53	.46	.84	.42
July 28	9.90	5.24	.43	.87	.42
Aug. 4	18.24	5.36	.98	.84	.42
Aug. 11	24.95	7.45	1.42	.99	.42
Aug. 18	20.21	7.11	1.28	.87	.51
Aug. 25	10.12	8.06	2.66	1.11	.47
Sept. 1	6.75	10.04	5.65	2.65	.56
Sept. 8	--------	7.35	14.73	5.96	.58
Sept. 15	--------	8.40	31.40	14.64	.75
Sept. 22	--------	5.19	18.25	12.52	1.18
Sept. 29	--------	3.90	15.84	14.57	2.86
Oct. 6	--------	3.77	3.37	13.69	6.69
Oct. 13	--------	3.38	2.27	9.43	11.66
Oct. 20	--------	1.87	.54	6.72	13.01
Oct. 27	--------	2.24	.37	7.38	13.37
Nov. 3	--------	--------	--------	2.29	28.46
Nov. 10	--------	--------	--------	1.34	9.58
Nov. 17	--------	--------	--------	1.53	7.81
Number in sample	1,982,735	102,123	597,774	155,957	263,703
Number of catches	30,706	26,193	15,581	22,117	10,608

Week ending—	Cumulative percentage occurrence				
	Sockeye	King	Pink	Coho	Chum
June 30	--------	3.73	--------	--------	--------
July 7	--------	8.90	--------	0.83	0.42
July 14	4.15	14.11	0.37	1.75	.84
July 21	9.83	20.64	.83	2.59	1.26
July 28	19.73	25.88	1.26	3.46	1.68
Aug. 4	37.97	31.24	2.24	4.30	2.10
Aug. 11	62.92	38.69	3.66	5.29	2.52
Aug. 18	83.13	45.80	4.94	6.16	3.03
Aug. 25	93.25	53.86	7.60	7.27	3.50
Sept. 1	100.00	63.90	13.25	9.92	4.06
Sept. 8	--------	71.25	27.98	15.88	4.64
Sept. 15	--------	79.65	59.38	30.52	5.39
Sept. 22	--------	84.84	77.63	43.04	6.57
Sept. 29	--------	88.74	93.47	57.61	9.43
Oct. 6	--------	92.51	96.84	71.30	16.12
Oct. 13	--------	95.89	99.11	80.73	27.78
Oct. 20	--------	97.76	99.65	87.45	40.79
Oct. 27	--------	100.00	100.02	94.83	54.16
Nov. 3	--------	--------	--------	97.12	82.62
Nov. 10	--------	--------	--------	98.46	92.20
Nov. 17	--------	--------	--------	99.99	100.01

The chum season is of almost as short a duration, 76 percent being taken in the 5 weeks from October 7–November 10. The coho season is somewhat more protracted, only 65 percent being taken in the 5-week period from September 9–October 13, and 7 weeks being required, September 9–October 27, to take 79 percent of the catch. The king salmon run rather steadily over a long period, 11 weeks, from July 1–September 15, being required to cover 76 percent of the run.

Fifty percent of the sockeye catch has been made by about August 7 (see table 5). The pinks do not reach the 50 percent mark until about September 12, a difference of 36 days. This is followed about 2 weeks later by the cohos, which reach the 50-percent mark on September 26. Another month usually elapses before 50 percent of the chum run has passed. The king salmon run slowly but steadily and reach the halfway point about August 22.

PUGET SOUND

LOCALITIES FISHED

Gill nets have been employed in Puget Sound since the earliest days of the fishery, but have never attained the importance that they have on the Fraser River. There are two reasons for this: First, in the clear waters of Puget Sound gill nets can be used only at night, as the fish avoid them in daylight; and second, it is difficult to compete with other forms of gear.

The gill nets employed were of two kinds, drift and set, and, as their name implies, one was used adrift and the other anchored. They were used chiefly in a few localities such as Skagit Bay and Skagit River, the estuary of the Snohomish River, and off the mouths of the Nooksack and Samish Rivers. A few were used in other localities, especially south of Point Wilson, among the San Juan Islands and in Boundary Bay.

The addresses of the drift net licensees in 1899, from the State of Washington Fisheries Department files, showed that of 322 licenses issued, 154 were taken out in areas south of Point Wilson, 78 from Seattle, 38 from Tacoma, 26 from Hood Canal, and 12 from scattered localities. More than one fourth, or 86, were from Skagit Bay and the Snohomish River. Of the remainder 1 was from Port Angeles, 5 from the San Juan Islands, and 76 from Bellingham and Boundary Bays.

A second check was made, for the year 1901, of both drift and set gill nets, and it was found that out of 414 drift gill net licenses, only 63 were from Boundary Bay and the San Juan Islands. Out of 369 set net licenses 15 were from the San Juan Islands and none from Boundary Bay. It is evident that gill nets played a very minor role in the sockeye fishery in Puget Sound.

The set nets were employed chiefly in river mouths, and especially in the Skagit, Snohomish, Duwamish, and Puyallup. A few were used away from the river mouths at such places as Open Bay on Henry Island, Andrews Bay on San Juan Island, and along the northwest shore of Orcas Island.

There is some confusion as to the number of set nets operated, and as to their location during the earlier years. This is because a set net license was sometimes bought merely to hold a trap location during a year when it was not desired to drive the trap. The license fee for a trap was from 4 to 10 times as much as for a set net.

No accurate estimate of the numbers of the different species taken by the gill-net fishery is available for early years, but the fishery was essentially the same then as today, except for the areas around Seattle and Tacoma, and the head of Puget Sound, where the salmon runs declined several years ago.

RELATIVE IMPORTANCE OF VARIOUS SPECIES

The set nets, fishing chiefly in the river mouths, caught mostly cohos and kings. In the 4 years from 1917–20, inclusive, they caught, on the average, 5.8 percent of the cohos and 3 percent of the kings taken in Puget Sound. They took but 1.3 percent of the chums and negligible quantities of pinks and sockeyes. After the formation of the Washington State Fishery Board in 1921, set nets ceased to be a factor in the fishing because of their subsequent strict seasonal regulation and their removal, by law, from the rivers.

The drift gill nets, fishing in the more open waters, caught a greater variety of salmon than the set nets. During the 18-year period 1917–34, inclusive, they took, on the average, 12.1 percent of the kings, 8.9 percent of the cohos, 4.9 percent of the chums, 1.1 percent of the sockeyes, and 1 percent of the pink salmon caught in Puget Sound.

TRAP FISHERY

By George A. Rounsefell

REEF NETS

Reef nets, being the forerunners of the traps, will be considered first. They were used almost exclusively by the Indians, deriving their name from the kelp-covered reefs on which they were fished. Originally made from the fiber of cedar bark or roots, they were changed to cotton twine when it became available. According to Rathbun (1899) a reef net consisted of a piece of webbing, varying more or less in size, but averaging perhaps 36–40 feet long by 25–30 feet across, the mesh being about 3½ inches.

To fish a reef net a channel was cut through the kelp. The net was suspended between two canoes, anchored at both the sides and bows, with the forward end of the net sloping downward and the rear end curving back upward to the surface. In deep locations strands of rope were sometimes strung across in front of the net and below it, to lead the salmon closer to the surface. The nets were fished when the tide was running strongly, but a tide of over 5–6 knots per hour was considered too fast for fishing. Reef net crews often had two locations and fished them at different stages of the tide. A lookout was stationed in the bow of each canoe and when a school of salmon passed over the net they signaled for it to be lifted. The net crews immediately let go the side anchor lines and, since the bow anchors were placed close together, the canoes were swung toward each other by the current. At the same time the forward edge of the net was swiftly lifted, enclosing the salmon in a bag from which they were dumped into the canoes.

Because of the manner in which these nets were operated, only a few localities were well suited to this type of fishing. One of the principal reef-netting grounds was off the southeastern point of Point Roberts, before that region was disturbed by the introduction of traps. Another excellent ground was along the western shore of Lummi Island, but the introduction of traps here diverted the salmon from these reefs. Other grounds, of lesser importance, were along the south shore of Lopez Island, the west shore of San Juan Island, the east and west shores of Stuart Island, and at Point Doughty on Orcas Island.

The number of these nets in the earlier years of the fishery must have been considerable, as Rathbun says that 15 to 20 nets were formerly fished at Point Roberts, 16 operating there in 1889. By 1894 the string of traps had destroyed the advantage of this reef for nets. Wilcox (1898) lists 25 reef nets in Whatcom County and 14 in San Juan County in 1894. As late as 1901 there were 27 reef nets licensed, 15 to Lummi Island Indians and 12 to residents of the San Juan Islands. Because of the amount of labor involved, and the scarcity of favorable fishing locations, this gear was gradually supplanted, and only about a dozen have been used each year for the past 20 years.

According to Rathbun the reef-net fishermen confined their attention almost exclusively to sockeyes, taking only a few king salmon. However, in late years they have taken more of the other species, especially pinks and cohos. A day's catch has declined until, in recent years, it has rarely amounted to more than a few hundred salmon, but this decrease has been due largely to the fact that the more favorable locations have been rendered useless by traps.

CONSTRUCTION OF THE TRAPS

The trap fishery, which was abolished after 1934 in Puget Sound by the passage of an initiative measure in the State of Washington, was the second of the four main types of gear to attain prominence. From 1873–1934 they have taken 37 percent of the sockeyes caught in the region, as well as enormous numbers of the other species.

Trap nets were tried at Point Roberts some years earlier than at other places, the first trap being built in 1880 by John Waller at Cannery Point, Rathbun (1899), (see fig. 7). Several years elapsed before the fishermen discovered the most desirable

FIGURE 6.—Modern Fraser River gill-net boat. These round-bottomed motorized boats are very seaworthy, being relatively independent of the vagaries of the weather. They are more efficient than the skiffs in use during the earlier years, or the round-bottomed boats in use before motors were installed.

FIGURE 7.—View from Cannery Point, on Point Roberts, showing the cannery established there in 1893. Note the 10 traps in the background. The trap nearest the cannery is approximately on the original trap location in Puget Sound, first established by John Waller in 1880.

locations for intercepting the salmon runs, and before they learned to build their traps sufficiently strong to withstand the storms that occasionally swept all exposed locations.

The first traps consisted essentially of a barrier, or "lead" of webbing hung from a row of driven piling, which diverted the passing fish into a pen, or "crib," similarly constructed. Although patterned after the pound nets of the Great Lakes, with a crib, heart, tunnel, and lead, they were built with much heavier piling which was usually strengthened by having the pilings bound together with a capping of timbers, lashed on with cables. At first the heart was merely two rows of piling that formed a V with the lead pointed toward the bottom of the V. The fish followed the lead, which usually extended out from shore, until they found themselves between the lead and one of the outstretched arms of the heart. Continuing farther they swam through a narrow opening, or tunnel, into the crib.

By 1895 the traps were much improved. The heart was often partially closed at its base, so that if the fish failed to enter the tunnel into the crib, they would, on circling back, find themselves in a semienclosure pointing toward the tunnel. A few traps had double hearts to minimize the chances of escape, and some had a leadlike extension, the forerunner of the "jigger" often employed on later traps. The jigger was essentially a supplementary lead consisting of a row of pilings connecting at about a right angle with the arm of either side of the heart, depending on the direction from which the fish usually approached the trap, and extending out toward deeper water, with the pilings driven to form a hook on the far end. The purpose of the jigger was to direct back to the lead such fish as passed the opening into the heart.

The cribs in several traps measured by Rathbun were rectangular but not always square in shape, ranging from 35–80 feet on a side, and were driven in water from 3–9 fathoms in depth. The catches were sometimes much larger than could be handled by the canneries at once and, while a large catch might be held in the crib for several days, such accumulation prevented continuous fishing during a period when the salmon might be running best. To meet this contingency, an adjunct to the crib, called a "spiller," was devised and appeared to be coming into general use. It was, in fact, an additional crib, square in shape, and connected with the first by means of a tunnel, through which the surplus fish of any catch could be driven.

The netting on the earlier traps was cotton twine, usually of 3-inch mesh in the crib and heart and from 3½–4 inches in the lead. Galvanized wire netting, in place of cotton, was experimentally used for the hearts and leads at Point Roberts in the late 1890's, Rathbun (1899).

The modern fish trap differs from the majority of those described by Rathbun in several respects. All of the trap, except the lead, is now customarily capped. If no capping is used the piles are tightly connected with a heavy wire cable to which the netting is attached to prevent sagging. All netting, except the spiller, is of galvanized wire which is cheaper and much more easily kept clean of seaweed and floating debris.

All traps use a spiller of tarred cotton web. As a general rule the spiller is 40 feet square, and the pot is usually the same. If a trap fishes very well a second spiller is sometimes driven on the opposite side of the pot to take care of the surplus fish.

A spiller is so placed that the fish, which enter the trap with the tide and then turn and swim against it, are led into the spiller through a narrow web tunnel which can easily be closed when the current is running in the opposite direction. Two spillers thus have a big advantage over one in that each one can be filled in turn, unless the trap is in an eddy where the current does not reverse itself with the tide. The pot aids in the fishing as the fish would not readily pass from as large a chamber as the heart directly through the narrow tunnel leading to the spiller, but the salmon are removed only from the spiller.

The construction of the earlier traps was modified to some extent when certain regulations were put into effect. In 1897, the length of a trap lead was restricted to 2,500 feet, and it was further provided by law that there should be an end passageway of at least 600 feet, and a minimum lateral passageway of 2,400 feet, between all traps.

These regulations had the effect of preventing a complete blockade of a whole area. For instance, in 1895 a string of three traps, each one connected with its neighbor, extended in a southeasterly direction off Cannery Point, the southeast tip of Point Roberts, for a mile. Two other connected traps near the international boundary extended for four-fifths of a mile. Such long strings of traps were not uncommon, and the law advanced conservation by breaking them up.

Another law, passed in 1897, prohibited traps from operating in water over 65 feet in depth. However, this law was not observed for several years. In 1913, soundings by the State Fish Commissioner (Washington State, 24th and 25th reports, 1916, p. 36) revealed 11 traps operating in water exceeding the legal depth by 1½–27 feet, The owners admitted having driven these traps in the same locations for 12 years, but changed them to conform with the law.

NUMBER IN OPERATION

The total number of traps operated each year in Puget Sound has been rather difficult to obtain owing to the fact that a trap need be driven only once in 4 years in order to hold a location. Furthermore, where the driving of one trap would tend to lead fish away from another it has been the general practice among companies to drive the one location for fishing and to hold the other by driving a "dummy" trap there at least once every 4 years. A dummy trap was very poorly constructed, and hung chiefly with old, worn-out gear. The object was merely to comply with the law, the dummy not being expected to catch more than a few dozen fish.

In addition to these dummy traps there have always been some traps of an experimental nature, especially in years of abundant runs and good prices. Many of these locations have been driven but once, others have been tried from time to time.

The efficiency of the traps has not varied as much as the number in operation from year to year might seem to indicate, since the best locations are practically always fished, and many of the extra traps, added during years of abundant runs or high prices, are driven in inferior locations.

The number of traps in operation, exclusive of dummies, is given in table 6. Between 1895 and 1900 the traps doubled in number three times, reaching a peak of 163 in 1900. During this first great expansion many inferior locations were tried and later abandoned, as shown by the lessened number in all years except for those of the big sockeye runs. During the World War the number of traps remained high even during years of poor runs owing to the high prices of salmon, but immediately thereafter the number fell off sharply and never fully recovered.

The number of traps has been reduced to a slight extent by regulations closing certain areas to fishing. In 1921 the State fishery board set aside certain areas as salmon preserves, but they were areas that had been without regular traps for several years. The San Juan Island preserve had had a few traps at times, especially on Shaw Island, but none of them had been successful.

In 1924 the Hood Canal preserve, which was created in 1921 to protect the lower end of Hood Canal, was extended to take in nearly all of the canal. Two or three traps that had been operating in the fall, chiefly for chum salmon, were thus removed. In the same year traps were prohibited in the Hope Island area, thus removing about a dozen traps catching chiefly Skagit River salmon. However, this prohibition was modified the following year.

TABLE 6.—*Number of salmon traps operated from 1893–1934, exclusive of dummy traps*

Year	Traps operated in Puget Sound [1]			Traps with data before 1915	British Columbia traps	Total	Year	Traps operated in Puget Sound [1]			Traps with data before 1915	British Columbia traps	Total
	Regular	Experimental	Total					Regular	Experimental	Total			
1893	------	------	[2] 13	3	------	13	1914	------	------	116	71	[8] 10	126
1894	------	------	[3] 19	------	1	20	1915	121	27	148	------	[8] 10	158
1895	------	------	[4] 21	11	2	23	1916	96	14	110	------	4	114
1896	------	------	------	26	2	------	1917	121	32	153	------	7	160
1897	------	------	[5] 71	35	4	75	1918	98	11	109	------	[8] 11	120
1898	39	6	45	32	3	48	1919	101	13	114	------	[8] 8	122
1899	98	14	112	76	3	115	1920	71	8	79	------	[8] 8	87
1900	130	33	163	74	3	166	1921	91	5	96	------	8	104
1901	140	9	149	88	3	152	1922	62	1	63	------	4	67
1902	105	37	142	82	3	145	1923	90	6	96	------	6	102
1903	104	2	106	67	3	109	1924	68	3	71	------	4	75
1904	75	4	79	44	1	80	1925	• 104	13	117	------	5	122
1905	137	1	138	70	[7] 17	155	1926	86	5	91	------	6	97
1906	88	8	96	61	[9] 10	106	1927	97	3	100	------	5	105
1907	------	------	[6] 98	60	[7] 12	110	1928	86	2	88	------	5	93
1908	------	------	80	49	[7] 12	92	1929	116	14	130	------	6	136
1909	------	------	152	76	[9] 15	167	1930	102	9	111	------	6	117
1910	------	------	93	57	[9] 10	103	1931	93	5	98	------	4	102
1911	------	------	111	68	[9] 10	121	1932	47	1	48	------	4	52
1912	------	------	110	66	[8] 10	120	1933	80	3	83	------	5	88
1913	------	------	168	84	8	176	1934	84	8	92	------	5	97

[1] 1898–1906 partly from State license files at Auburn.
[2] At Point Roberts only, Rathbun (1899).
[3] Partly estimated from Rathbun (1899).
[4] Rathbun (1899).
[5] Fidalgo Island Packing Co. records.
[6] 1907–14 estimated. Number for which we had data estimated as 61 percent of traps operated, as from 1901–06 (except 1905), when it varied from 56–64 percent. In 1905 twice as many operated and this was used for 1909 and 1913.
[7] Partly from Pacific Fisherman.
[8] Number licensed.
[9] Estimated.

LOCATIONS FISHED

Because of the sketchy nature of the available data no attempt has been made to give accurately the number of traps operating in each area prior to 1898. Traps were first tried at Point Roberts in 1880, but could hardly be considered a success until 1891. In the few years from 1891–97 traps were driven in numerous localities throughout Puget Sound, but mostly without much success. The locations that proved successful were continued, and for the others only a few records are available.

The number of traps fishing in each locality since 1898 is shown in table 7.[3] It is apparent that while the trap fishery was widespread its use was emphasized only in those few localities where trap sites could be favorably situated to intercept the salmon runs, and where there was a depth and a bottom suitable for driving. Where these conditions were well satisfied, as in Boundary Bay, the number of traps was large. In some areas, like the Salmon Banks or Rosario Strait, the fish were present, but suitable places for driving were scarce, and few traps were constructed.

TABLE 7.—*Number of traps fishing in various localities, 1898–1934* [1]

Area	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915
Point Roberts	5	7	7	5	5	5	4	5	5	4	3	6	5	4	4	6	4	6
Boundary Bay (U. S. traps)	18	30	26	35	35	30	21	29	23	23	21	29	20	21	19	31	21	24
Birch Bay [2]	5	12	14	15	16	15	8	10	9	8	6	14	9	10	8	13	9	16
Lummi Island [3]	----	1	1	3	3	3	2	5	6	4	1	8	5	5	5	10	5	9
Rosario Strait [4]	1	5	1	1	2	2	1	2	2	2	1	3	1	3	4	5	5	12
South Lopez	----	----	----	----	----	----	----	----	----	----	----	----	----	2	----	----	3	4
Salmon Bank	----	5	6	6	7	5	4	4	4	4	3	5	5	4	4	4	4	5
Haro Strait	----	1	3	2	3	2	1	1	1	----	1	----	----	----	1	3	2	6
Waldron Island	----	----	----	1	1	1	----	1	----	----	----	1	----	1	----	1	----	2
West Beach	3	4	2	1	2	2	1	4	4	6	6	4	4	6	6	6	6	13
Ebeys Landing	----	----	----	----	----	----	----	----	1	----	----	----	1	1	----	1	1	----
Middle Point	----	----	----	----	----	----	----	----	----	----	----	----	1	2	1	1	2	4
Strait of Juan de Fuca [5]	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	2
Admiralty Bay and Bush Point	----	1	4	3	4	----	2	5	4	4	3	3	3	3	3	2	3	8
Oak Bay and Point No Point	----	----	1	1	1	----	----	1	1	2	1	----	1	1	1	----	1	3
Hood Canal	----	1	1	2	----	----	----	----	----	----	----	----	----	4	4	----	4	4
Useless Bay and Possession Sound	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1
Meadow Point and south	----	1	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	3
East of Whidbey Island	----	----	8	5	4	----	----	3	1	3	3	3	3	3	3	2	2	10
Total	32	70	74	80	83	65	44	70	61	60	49	76	58	70	63	85	72	132

Area	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Point Roberts	5	7	5	6	5	6	2	4	4	6	7	8	5	8	8	5	3	3	5
Boundary Bay (U. S. traps)	19	29	19	18	14	21	11	17	12	19	14	19	16	28	18	21	10	22	22
Birch Bay [2]	9	14	10	9	3	8	3	8	4	10	7	9	7	10	8	7	3	7	6
Lummi Island [3]	6	9	5	5	4	5	3	4	3	4	4	4	4	5	5	6	4	4	3
Rosario Strait [4]	7	13	8	5	6	7	1	2	5	9	5	3	4	10	6	7	1	5	8
South Lopez	2	5	4	6	3	5	4	4	5	4	4	4	3	5	3	3	3	3	4
Salmon Bank	5	7	6	8	3	6	3	8	5	7	5	8	6	9	8	5	3	5	8
Haro Strait	4	7	5	6	2	6	2	6	4	9	4	6	4	9	5	5	----	3	5
Waldron Island	----	2	1	1	1	1	----	----	----	----	----	1	----	1	1	1	1	1	1
West Beach	11	13	12	13	12	11	9	13	12	12	11	11	13	12	15	8	4	5	7
Ebeys Landing	1	2	2	2	1	----	1	1	1	2	1	----	3	2	2	2	1	1	1
Middle Point	2	2	2	3	1	1	2	3	1	2	2	2	2	2	3	2	----	1	1
Strait of Juan de Fuca [5]	2	1	1	2	1	1	1	1	1	1	2	2	2	2	1	1	1	----	1
Admiralty Bay and Bush Point	9	7	9	7	6	4	3	7	7	8	8	8	9	9	11	11	3	8	7
Oak Bay and Point No Point	3	4	4	3	3	2	3	3	3	3	3	2	2	3	3	2	----	1	----
Hood Canal	2	4	4	4	2	----	3	4	1	1	----	----	1	1	3	2	----	----	----
Useless Bay and Possession Sound	1	3	1	1	1	1	----	----	----	1	1	----	----	----	----	----	----	1	1
Meadow Point and south	2	1	1	2	2	1	1	1	3	5	2	2	2	4	3	2	3	3	2
East of Whidbey Island	7	8	7	9	8	8	11	10	----	14	11	11	5	9	8	8	8	9	10
Total	97	138	106	110	78	94	63	96	71	117	91	100	88	129	111	98	48	82	92

[1] Incomplete before 1915.
[2] Including Alden Bank.
[3] Including Bellingham Bay.
[4] Including Padilla Bay and Guemes Island.
[5] South side.

During the period from 1915–34, 33 percent of all the traps have been located north of Sandy Point—Point Roberts, Boundary Bay and Birch Bay areas; 27 percent south of Sandy Point and north of Deception Pass—Rosario Strait, Salmon Banks,

[3] These trap locations have been determined from charts made by the U. S. Army Engineer's Office in Seattle, 1919–34, from the files of the State of Washington Department of Fisheries, and from numerous records and maps obtained from various operators. This table is not complete for years before 1915, and a few minor traps have not been identified as to location since that date. Since table 7 is based only on traps for which locality data are available, the numbers of traps do not check with table 6 giving the total number operated.

Haro Strait, Lummi Island, etc.; 16 percent along West Beach, Ebeys Landing, and the south side of the Strait of Juan de Fuca; 9 percent east of Whidbey Island—chiefly Hope Island area; and 15 percent south of Point Wilson—Admiralty Bay, Hood Canal, etc.

CANNERY EXPANSION FROM THE TRAP FISHERY

After more than a decade of cannery operation in the southern portion of Puget Sound, 1877–90, during which time 3 or 4 small canneries were annually engaged in the industry, business had fallen off to such an extent that only 1 cannery operated in 1890.

The successful use of salmon traps at Point Roberts resulted in the building of a salmon cannery at Semiahmoo in 1891, one at Point Roberts in 1893, and another at Friday Harbor in 1894, the number quickly increasing to 19 by 1900. In 1901, a big sockeye year, the number dropped to 16, owing to overproduction the previous year, especially of the cheaper grades. In 1902, however, the number rose again to 20 (see table 1). In 1902, in addition to the original sockeye cannery at Semiahmoo, there were 2 at Point Roberts, 3 at Blaine, 3 at Fairhaven (now South Bellingham), 1 at Chuckanut, 1 on Lummi Island, 6 at Anacortes, and 1 each at Friday Harbor, Port Angeles and Seattle. The successful use of salmon traps near Sooke, on Vancouver Island (see fig. 2) caused the building of a cannery at Victoria in 1905.

SEASON

One very striking instance of the increased intensity of fishing in later years is furnished by changes in the season when the fish traps were operated. The season has been measured by the dates of the first and last lift of a trap. Since the traps usually fish from about two days to as much as a week before the first lift, all seasons mentioned are slightly less than the actual time fished. In Boundary Bay, the most important sockeye area, the date by which half the traps had been lifted for the first time was July 9 in the period 1897–1902, in the next 8 years, it advanced to July 7, in the following 16 years it averaged July 4, and in the last period, 1927–34, it had advanced to June 25, a total for the whole period of 14 days. (See fig. 10.)

The change at the end of the season is more striking. From August 23 the closing date became later and later until, in the last 8-year period, it was September 27. A 46-day season had changed to one of 95 days. The reasons for the change are best explained by comparing trap seasons with the curves for seasonal occurrence of each species. It is evident that the late spring fishing is to increase the catch of kings. In the early days the traps usually stopped fishing in the odd-numbered years before the sockeye run was quite over in order to avoid bothering with the tremendous pink runs which were of little value. In recent years the traps have usually fished until the pink runs are over.

A somewhat similar story is told of the traps in the area between Point Wilson and Point No Point (Admiralty Inlet). Admiralty Inlet was a fall fishing area for many years. The opening date for the period 1900–1910 averaged August 27, and for the next 8 years August 23. From 1919–26 it had advanced to June 14 and in the last 8-year period, 1927–34 it was May 30, a change in the opening date of 85 days.

During the earlier years this southern area was fished chiefly for cohos and chums and the pink run was usually in full swing before fishing commenced. Later the fishing was advanced to take in all of the pink run, and more recently a large proportion of the traps made their first lift about May 4; evidently fishing immediately after the cessation of the April closed season to catch the early run of king salmon.

In the areas east of Whidbey Island the season was always very long. The traps opened in late April and early May to take kings and steel heads, and to be in time to fish the June run of sockeye to the Skagit River. They then remained open for the coho run in the fall.

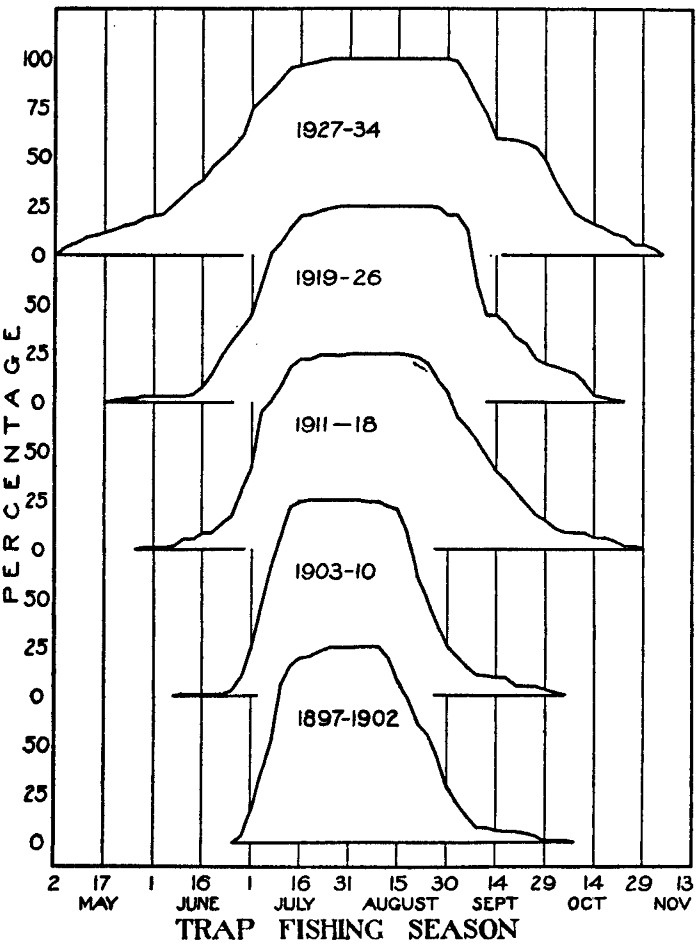

FIGURE 10.—Length of the trap-fishing season in Boundary Bay by groups of years from 1897–1934. The length of the season is gaged by the percentage of the traps that were actually in operation during the various parts of the season. Note the progressive increase in the length of the season during which they fished.

The season fished by the traps has been modified somewhat by regulation. The first of these was a law, enacted in 1905, imposing a weekly closed season of 36 hours. Our data do not indicate any observance of this law prior to 1908. This weekly closed season was modified in 1915 to apply only during July and August. Commencing in 1921 it was applied during the balance of the year to the districts east of Whidbey Island and south of a line from Point Wilson to Partridge Point.

A closed season was introduced in 1915 from January 18–April 15, inclusive. This affected some forms of gear but had almost no effect on trap fishing. In Hood Canal an additional closed season from November 16 to January 1, inclusive, probably had some effect on the few traps in that area. The area near Tacoma, including Poverty Bay, was also closed from November 16–30, inclusive. The closed periods from 1921–34 are given in the following table.

TABLE 8.—*Puget Sound closed seasons from 1921–34* [1]

Year	All districts		Southern district [2]		Middle district		Northern district [3]			
	From—	To—	From—	To—	From—	To—	From—	To—	From—	To—
1921	Oct. 26	Apr. 30	Sept. 6	Sept. 15	Sept. 6	Sept. 15	Sept. 6	Sept. 15		
1922	Nov. 6	do								
1923	do	do	Sept. 6	Sept. 15	Sept. 6	Sept. 15	Sept. 6	Sept. 15		
1924	do	do	Aug. 25	Sept. 3						
1925	do	do	do	do	Sept. 6	Sept. 15	Sept. 6	Sept. 15		
1926	do	do								
1927	do	do	Aug. 25	Sept. 3	Sept. 6	Sept. 15	Sept. 6	Sept. 15		
1928	do	do								
1929	do	do	Aug. 25	Sept. 3	Sept. 6	Sept. 15	Sept. 6	Sept. 15		
1930	do	do			do	do	do	do	Sept. 21	Sept. 30
1931	Nov. 11	do	Aug. 25	Sept. 3	do	do	do	do		
1932	do	do	do	do	do	do	do	do		
1933	do	do	do	do	Sept. 11	Sept. 20	Sept. 11	Sept. 30		
1934	do	do	do	do	Sept. 2	Sept. 11	Sept. 2	Oct. 1		

[1] All dates are closed days.
[2] East of Whidbey Island and south of line Point Wilson to Point Partridge.
[3] North of line Sand Point to Patos Island (Birch Bay, Boundary Bay and Point Roberts areas).

The closed periods were introduced largely for the protection of the pink salmon and so at first were confined to the odd-numbered years, except in 1924, when it was hoped that there might be a fair run of pinks from the fry liberated by the hatcheries from eggs taken in Alaska. Since 1930 this closed period has been extended to the even-numbered years for the protection of the sockeye. The fall closing date was inaugurated in 1921 and applied to all districts. This closing protects a considerable portion of the chum salmon runs, and a small percentage of the cohoes.

SEASONAL OCCURRENCE OF EACH SPECIES

The seasons during which each species migrates through the salt water toward the spawning grounds is of the utmost importance from a standpoint of conservation as it determines, to a great extent, the possibilities of so regulating the fishery as to allow the taking of the more abundant species, while protecting the less abundant. There is, of course, considerable variation from season to season in the time of run, although a general average may be obtained. The traps furnish the best measure of seasonal occurrence since a trap does not fluctuate from day to day in its fishing effort, but continuously samples the runs that are passing by.

For sockeyes data were used for 12 traps, all located north of Deception Pass. They fished in various years from 1896–1934, catching a total of 13,129,869 sockeyes. In making a seasonal curve (fig. 11), the total catch of each 7-day period was divided by the number of trap-fishing days. However, for sockeyes the trap-fishing days for each trap were weighted by the fishing efficiency of that trap. (Cf. page 768.) For species other than sockeye the traps were not weighted.

For king salmon the catches of 17 traps were employed; 7 were north of Deception Pass, 4 at West Beach, 2 at Middle Point, 2 in the Hope Island Area, and 2 in Admiralty Inlet. They caught a total of 580,698 fish from 1900–1934.

The pink-salmon curve was derived from 4,467,115 fish caught in 16 traps; 9 located north of Deception Pass, 1 at Ebeys Landing and 6 in Admiralty Inlet. Since little effort was made to take pinks during the earlier years of the fishery, the material used is from odd-numbered years from 1919–33. As 1919 is the only year in which a fall closed season was not in effect it was necessary to determine a small portion of the curve by empirical methods. The curves for the 9 northern and the 7 southern traps were each calculated separately and combined with equal weighting to obtain the final curve. (See fig. 11.)

To obtain the seasonal occurrence for coho salmon 26 traps were used; 15 located north of Deception Pass, 2 in the Hope Island Area, 2 in Middle Point Area, 1 at Dungeness Spit, and 6 in Admiralty Inlet. They fished from 1900–1934, taking 5,652,592 fish.

For the chum salmon, as for the pinks, a northern and a southern curve were each calculated and then combined. However, in the case of the chums, the southern curve was given double weight, as more chums are always caught in the southern areas. A total of 13 traps were used; 7 north of Deception Pass and 6 in Admiralty Inlet, catching 946,094 fish. The curves for all species are given in table 9 and shown in fig. 11.

TABLE 9.—*Seasonal occurrence in Puget Sound traps*

Week ending—	Percentage occurrence					Cumulative percentage occurrence				
	Sockeye	King	Pink	Coho	Chum	Sockeye	King	Pink	Coho	Chum
Apr. 21		0.425					0.425			
Apr. 28		1.353					1.778			
May 5	0.391	2.259		0.018		0.391	4.037		0.018	
May 12	.351	3.212		.035	0.001	.742	7.249		.053	0.001
May 19	.328	3.649		.059	.001	1.070	10.898		.112	.002
May 26	.149	3.780	0.002	.054	.002	1.219	14.678	0.002	.166	.004
June 2	.061	4.166	.002	.084	.006	1.280	18.844	.004	.250	.010
June 9	.018	4.770	.005	.080	.011	1.298	23.614	.009	.330	.021
June 16	.015	5.145	.006	.103	.008	1.313	28.759	.015	.433	.029
June 23	.087	5.921	.007	.175	.007	1.400	34.680	.022	.608	.036
June 30	.468	6.330	.010	.174	.013	1.868	41.010	.032	.782	.049
July 7	2.206	7.292	.017	.351	.026	4.074	48.302	.049	1.133	.075
July 14	4.495	6.696	.027	.393	.032	8.569	54.998	.076	1.526	.107
July 21	8.408	6.252	.170	.466	.063	16.977	61.250	.246	1.992	.170
July 28	16.098	6.188	1.463	.532	.172	33.075	67.438	1.709	2.524	.342
Aug. 4	26.344	6.072	3.660	.709	.450	59.419	73.510	5.369	3.233	.792
Aug. 11	20.911	6.149	6.875	.962	.816	80.330	79.659	12.224	4.195	1.608
Aug. 18	11.224	5.565	10.117	1.413	1.234	91.554	85.224	22.361	5.608	2.842
Aug. 25	5.542	4.456	21.120	2.717	1.863	97.096	89.680	43.481	8.325	4.705
Sept. 1	1.530	3.406	23.837	3.911	1.835	98.626	93.086	67.318	12.236	6.540
Sept. 8	.493	2.875	19.591	6.953	1.977	99.119	95.961	86.909	19.189	8.517
Sept. 15	.071	2.074	8.660	10.795	2.298	99.190	98.035	95.569	29.984	10.815
Sept. 22	.121	1.105	3.452	12.652	3.246	99.311	99.140	99.021	42.636	14.061
Sept. 29	.132	.451	.830	12.129	7.376	99.443	99.591	99.851	54.765	21.437
Oct. 6	.048	.167	.107	12.628	9.244	99.491	99.758	99.958	67.393	30.681
Oct. 13	.018	.069	.041	11.978	11.803	99.509	99.827	99.999	79.371	42.484
Oct. 20	.036	.041	.004	8.357	12.656	99.545	99.868	100.003	87.728	55.140
Oct. 27	.096	.038	.003	5.313	13.643	99.641	99.906	100.006	93.041	68.783
Nov. 3	.099	.064		3.108	10.335	99.740	99.970		96.149	79.118
Nov. 10	.258	.030		1.628	7.131	99.998	100.000		97.777	86.249
Nov. 17				1.502	5.747				99.279	91.996
Nov. 24				.667	3.282				99.946	95.278
Dec. 1				.051	1.865				99.997	97.143
Dec. 8				.005	1.097				100.002	98.240
Dec. 15					.431					98.671
Dec. 22					.669					99.340
Dec. 29					.553					99.893
Jan. 5					.066					99.959
Jan. 12					.015					99.974
Jan. 19					.006					99.980

The seasonal occurrence of each species is quite distinct from any of the others and the modes of the five curves are about a month apart; kings, sockeyes, pinks, cohos and chums following in that order.

The king-salmon run covers a long period of time, but averages much earlier than those of the other species. Thus 40 percent of the run is over by June 30, whereas no other species has reached 2 percent of its run by that date.

The next species to appear in abundance is the sockeye, overlapping the latter portion of the king-salmon run. On the average, over a long period of years, the sockeye runs have been practically over by August 25. By that date only 5 percent of the chums, and less than 10 percent of the cohos, have passed the traps. However, over 40 percent of the pink salmon run is complete.

The pink salmon run lasts for such a short period that it is practically over before the cohos appear in abundance, 85 percent having passed by the time 20 percent of the cohos are taken.

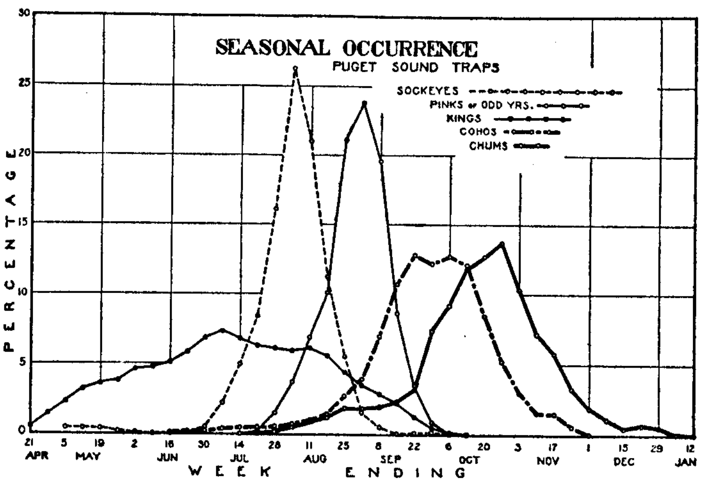

FIGURE 11.—Seasonal occurrence of all species of salmon as shown by Puget Sound trap catches. Each ordinate shows the percentage of the run occurring during the indicated 7-day period.

The coho and chum salmon are the backbone of the fall fishery. Neither species presents a well-defined mode, but the centers of the two distributions are between three weeks and a month apart. Since both species run for a considerable length of time there is a considerable degree of overlapping in their time of run. During the five 7-day periods, from September 23–October 27, inclusive, 54.7 percent of the chum and 50.6 percent of the coho runs occur.

RELATIVE IMPORTANCE OF EACH SPECIES AND DISTRICT

The relative importance of each species of salmon to the trap fishery is shown in figure 12 which illustrates the number of each species of salmon caught by traps in the 5 major areas during the past four decades. The areas shown are (1) North of Sandy Point, (2) Sandy Point to Deception Pass, (3) West Beach and Ebeys Landing, (4) the Strait of Juan de Fuca, and (5) the waters east of Whidbey Island and south of Point Wilson. For the past two decades the Puget Sound data are complete. Before that they represent only that portion of the trap catches for which original records could be secured. For sockeye this portion was about 80 percent of the trap catches in Puget Sound and practically all of the Canadian trap catches. For the other species the proportion represented is even higher than is the case for the sockeyes, as the data are more complete in the latter part of the period when more of the other species were used. For Canadian traps the other species are not included, as the data were not available.

From figure 12 it is to be noted that 53 percent of the entire catch came from the district north of Bellingham—Point Roberts, Boundary Bay, and Birch Bay Areas. The next largest district, from the standpoint of catch, was that south of Bellingham

(Sandy Point) and north of Deception Pass, which includes the San Juan Islands. The second district accounted for an additional 27 percent. In other words, 80 percent of the trap catches during the past 40 years have been from the areas north of Deception Pass. Of the remaining 20 percent, less than 11 percent came from the inside waters of Puget Sound—east of Whidbey Island and south of Point Wilson.

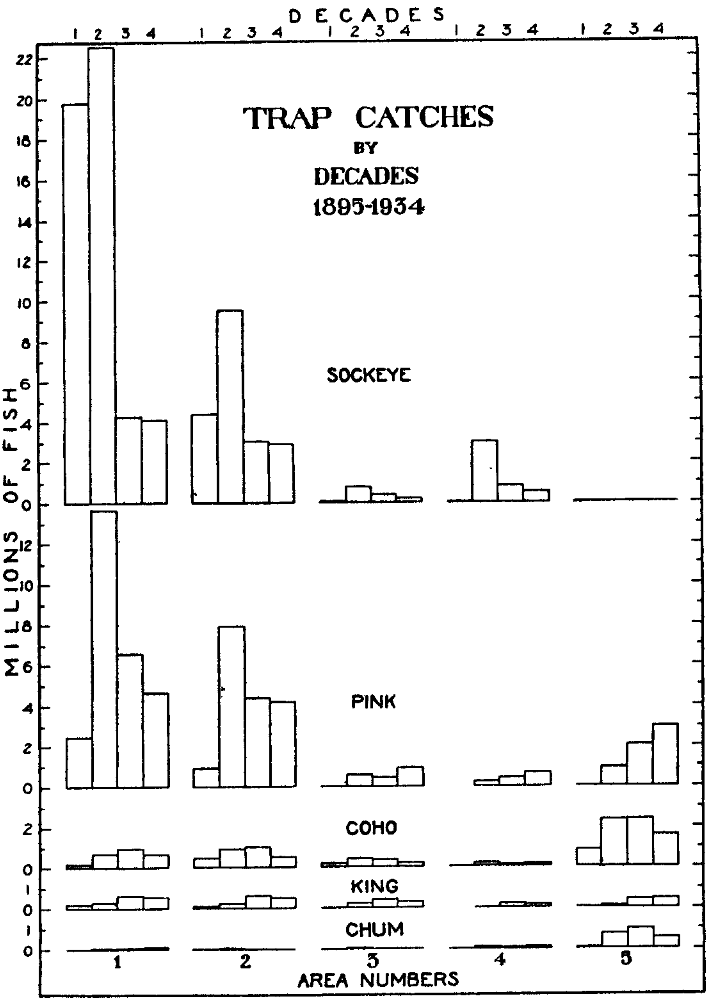

FIGURE 12.—Showing the number of each species of salmon caught by traps in the major areas during each of the past four decades.

Fifty percent of the trap catch were sockeyes, 34.9 percent pinks, 9.3 percent cohos, 3.6 percent kings, and only 2.2 percent chums. These figures, however, give only a general picture. If the catches are considered by districts it is found that the two districts north of Deception Pass caught 56.8 percent of the sockeyes, 36 percent of the pinks, 4.3 percent of the cohos, 2.6 percent of the kings, and 0.4 percent of the chums. That is, all but 7.3 percent of the catch consisted of but two species, sockeye and pink.

In the West Beach and Ebeys Landing district the catch was 32.2 percent pinks, 25.7 percent sockeyes, 20.8 percent cohos, 16.9 percent kings, and 4.4 percent chums; the sockeye and pink, the two dominating species north of Deception Pass, thus accounting for but 58 percent of the catch.

East of Whidbey Island and south of Point Wilson, except for the pinks, the catches are very different, being 43.5 percent cohos, 35.9 percent pinks, 13.9 percent chums, 6 percent kings, and only 0.8 percent sockeyes.

The changes in the catch by decades in each of the 5 districts are apparent. The catches of pinks, for example, after being subjected to exploitation in the second decade, 1905–14, fell off tremendously in the third and fourth decades in the two northern areas. In district 5, however, they have continued to rise.

THE PURSE-SEINE FISHERY

By George B. Kelez

The importance of the purse seines has varied considerably during the history of the salmon fisheries. Shortly after their introduction they surpassed the drag seine, their forerunner, and were in turn superseded by the traps. They again became an important factor when motor-driven vessels were employed. Since the use of traps has recently been prohibited in Puget Sound waters they are the only important gear operating in that district, and a knowledge of their effectiveness, the species taken, and the seasonal nature of operations in various areas, is of extreme importance to the administration of the fishery.

DRAG SEINES

One of the earliest forms of fishing gear to be used on Puget Sound was the drag seine. This was a long shallow net provided with cork floats on the upper edge and lead weights on the bottom, and was pulled by lines attached to each end.

In use the net was loaded into a skiff and one of the hauling lines passed to a man on shore. The skiff was pulled directly away from the beach until all the line was payed out, then turned parallel to shore and the net run out, after which the skiff returned to the beach with the second line. The lines were rapidly hauled in until the wings of the net were ashore and the fish concentrated in the center or "bunt" of the net, whereupon the remaining web was quickly hauled onto the beach, landing the catch. Since a beach free of large rocks or other obstructions was necessary for landing the catch, the drag seiners worked in unobstructed places where the fish were concentrated by favorable currents, or where their migration routes led them close inshore. The mouths of streams where the mature fish schooled before ascending to spawn were favorite locations prior to the passage of legislation protecting these areas.

The number of drag seine-licenses from 1897–1934 is shown in table 10. The greatest number of licenses was issued during the period from 1908–14, and that number steadily decreased thereafter.

Drag seines were commonly used in early years along the east shore of Vancouver Island and in Puget Sound near the cities of Seattle, Tacoma, and Olympia. They later appeared on the sands at the mouth of the Skagit River, the Nooksack River, and Lummi Slough, as well as at Point Roberts. They were also used extensively in the inlets and passages of the west shore of Puget Sound and in Hood Canal.

In early years the catch of this gear consisted chiefly of coho and pink salmon. Later, chum salmon became of considerable importance, and in some years large numbers of king salmon were caught. Subsequent to 1924 the total catch of the drag seines has been only a few thousand fish per year, consisting chiefly of pink salmon. Sockeye, which were caught only occasionally in former years, are now second in importance. These changes in the proportion of various species in the catch have been due in part to the competition of other forms of gear, but have resulted chiefly from the closure, by legislation, of many districts which were frequented by the drag seines. This gear is still used in the region, but it is now of very little importance.

TABLE 10.—*Puget Sound drag seine licenses, 1897–1934*

Year	Number	Year	Number	Year	Number
1897	59	1911	307	1923	111
1898	59	1912	243	1924	109
1899	125	1913	238	1925	144
1900	114	1914	354	1926	130
1901	74	1915	187	1927	135
1902	74	1916	189	1928	120
1903	171	1917	218	1929	123
1904	95	1918	185	1930	123
1905	69	1919	187	1931	104
1906	123	1920	144	1932	84
1907	176	1921	116	1933	109
1908	283	1922	108	1934	90
1909	242				
1910	247				

DEVELOPMENT OF THE PURSE SEINE

EARLY SEINES

The purse seine is a net not unlike the drag seine in shape, but much longer and deeper. Its chief characteristic is the purse line, a stout rope or cable, rove through metal rings attached to its lower edge. This net is used in deep water. When a school of fish have been observed the net is set around them, the two ends are brought together, and the purse line hauled in. This closes the bottom of the net, trapping the fish within it. Although the purse seine is inseparably associated at the present time with the highly specialized vessel from which it is fished, the seine itself has undergone but little change, except in size, whereas the vessel is the product of long years of development and experience.

The date this gear was originally introduced on Puget Sound is a matter of conjecture. Hittell (1882) reported it to be an important form of gear in 1882. He stated that the fishery was prosecuted almost entirely by Indians and that the nets were from 50–80 fathoms in length, and 4–8 fathoms in depth. These seines were set from large canoes from which they were also pursed when the set was complete. Other canoes cruised around the net, the crews beating the water with their paddles to keep the fish schooled. Coho, pink, chum, and king are listed as the species caught, and from two to five thousand fish might be taken at a single haul. Hittell offers no information as to the date of introduction or as to the number of years that these nets had been used.

SCOW SEINES

This type of fishing must have undergone a considerable development in a brief space of time. Collins (1892) reports purse seines to be "the most effective form of apparatus yet used in the salmon fishery," and states that they were introduced in 1886. They are described as being approximately 200 fathoms long and 25 fathoms deep. They were set from a four-oared skiff, the after 8-foot portion of which was decked to form a platform for stowing the seine. A scow 20 feet long and 8 feet wide, equipped with a hand winch, was used for pursing the net and carrying the catch. One end of the net was attached to the scow and the bulk of the seine was carried by the skiff, from which it was set around the school of fish. The free end was brought back to the scow where the two ends of the purse line were then hauled in by the means of the winch. A "plunger," consisting of a stout pole with a wooden box shaped like a truncated pyramid and attached to the lower end, was thrust repeatedly into the water at the opening between the purse lines to keep the fish from escaping there. This was necessary, since pursing the net was a very slow procedure. As high as 6,690 fish were taken in a single haul. At this time the principal fisheries on the Sound were at Seattle, which then had three canneries, at Tacoma, and at Port Townsend (see figs. 2 and 3).

Rathbun (1899) describes the purse seines in use about 1895 as essentially similar to those of 1888. He also dates their introduction to these waters as 1886, doubtless based on Collins' report, and gives their size as ranging from 150–250 fathoms in length, from 14–25 fathoms in depth, and being of 2½–3-inch mesh.

Rathbun states that in 1893 and 1894 several seines fished regularly at Point Roberts, some were employed at Port Angeles, and some in the San Juan Islands. The principal purse-seine fishery remained at Seattle, however, where the catches were sold to the fresh-fish markets as well as to the canneries. Eleven seines fished out of Seattle in 1895, and at least 20 in 1896. Individual hauls of from 1,500 to 2,500 fish were not uncommon, and one Seattle cannery received from 6 seines an average of 12,000 cohos a day during the height of the 1895 run. Although traps had become the chief source of salmon in other districts by 1895, the seines still supplied the greater part of all fish used in the Seattle area.

Purse-seine fishing in the San Juan Islands received considerable impetus from the location of a cannery at Friday Harbor in 1894, and three at Anacortes in 1896. Large shore camps, established at points close to the best fishing grounds, provided living quarters for the crews. The seine scows and skiffs were towed to these camps at the beginning of the run and remained there during the season. The individual seine outfits also had to be towed to various parts of the fishing grounds, for their own movements were limited to the distance that the boat-pullers could row the heavy skiff and attendant scow, and at the close of the day's fishing the whole apparatus had to be returned to the camp ground. Because of these limitations, fishing by purse seines was confined to a radius of a few miles from the base camps.

The first purse seines had been employed during the fall season in the southern districts of the Sound where the bulk of the catches consisted of coho salmon. Although large quantities of chum and pink salmon were available, the lack of a ready market curtailed the fishing for these species. A considerable increase in the number of canneries after 1895 furnished a better market for species other than coho, and the fishing season of the seines was considerably lengthened. The license records of the Washington State Department of Fisheries show that, during 1897, 22 licenses were issued during the month of June, 11 during July, 1 in August, and 13 in September. In 1898 approximately 31 licenses were issued up to and including July 6, and none thereafter until September 10. Nine licenses were issued after the latter date. It will be noted that the larger number of licenses were issued during the early summer, that few or none were issued during a slack period of several weeks, and that an additional number were issued in the later summer or fall. For convenience, the first group of licenses will hereafter be designated as "summer licenses," and the second group as "fall licenses" (see table 11). Although somewhat obscured by a general increase, the odd-numbered years show a larger number of licenses than do the even-numbered years. This is largely due to the greater availability in those years of the pink salmon, which by this time could be marketed in sufficient quantity to encourage their pursuit by the seine fleet.

TABLE 11.—*Puget Sound purse-seine licenses, 1897–1915*

Year	Summer	Fall	Total	Year	Total
1897	34	13	47	1907	64
1898	31	9	40	1908	69
1899	58	14	72	1909	95
1900	41	16	57	1910	120
1901	45	22	67	1911	133
1902	59	19	78	1912	169
1903	79	8	87	1913	252
1904	53	19	72	1914	288
1905	73	18	91	1915	308
1906	73	5	78		

DEVELOPMENT OF THE MODERN PURSE-SEINE VESSEL

INTRODUCTION OF POWER

Perhaps the most important single factor which influenced the development of the purse-seine fishery was the introduction of the internal-combustion engine for fishing vessels. The Pacific Fisherman Yearbook for 1919 states that the first gasoline-powered boat on Puget Sound, exclusively engaged in the fishing industry, was a 32-foot fish carrier, the Silverside, built in Tacoma about 1898 for T. E. Eggers, a pioneer operator of that city. In a few years the success of power in other fishing vessels encouraged the purse seiners to take advantage of this new development.

The complete change of the purse-seine fleet from oars to power was accomplished n a very few years. The Pacific Fisherman Annual Review for 1910 states:

> Skansie Brothers of Gig Harbor, pioneers in the use of gas engines, have ordered two new boats. They started six years ago (1904) with one boat powered with a 7 hp. "Frisco Standard". They have since bought 15 more.

The same publication, in the issue of 1907, includes in the caption of a picture of a power seiner the statement:

> Gasoline power is now universally used in seine boats.

From these statements we may conclude that the change to power in the seine fleet was completed in but little more than 3 years.

This change to power necessitated a revision of purse-seine fishing methods. The scow was replaced with a small open power boat and, although the skiff was retained, its function was reversed. The seine was now carried in the after part of the power boat. In setting, one end was made fast to the skiff while the seine boat circled the school of fish and payed out the net. The end of the net which had been made fast to the skiff was now brought aboard the seine boat and the purse line

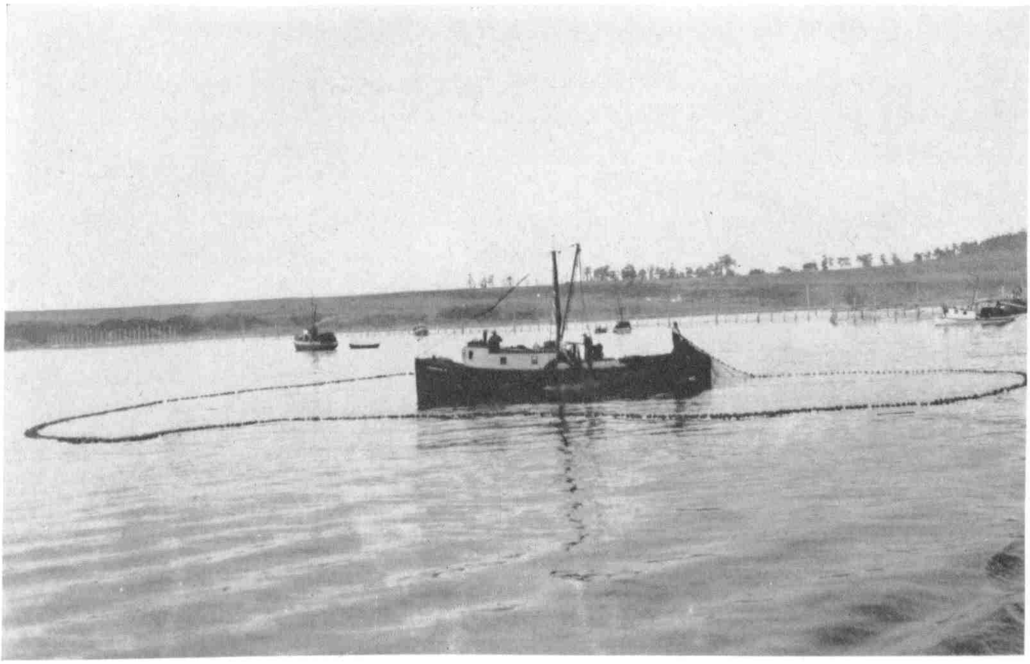

FIGURE 13.—An early Puget Sound purse-seine vessel, of 12 net tons, built in 1909. Note the large house on deck containing the crew's quarters, and the outside steering wheel in front of the house.

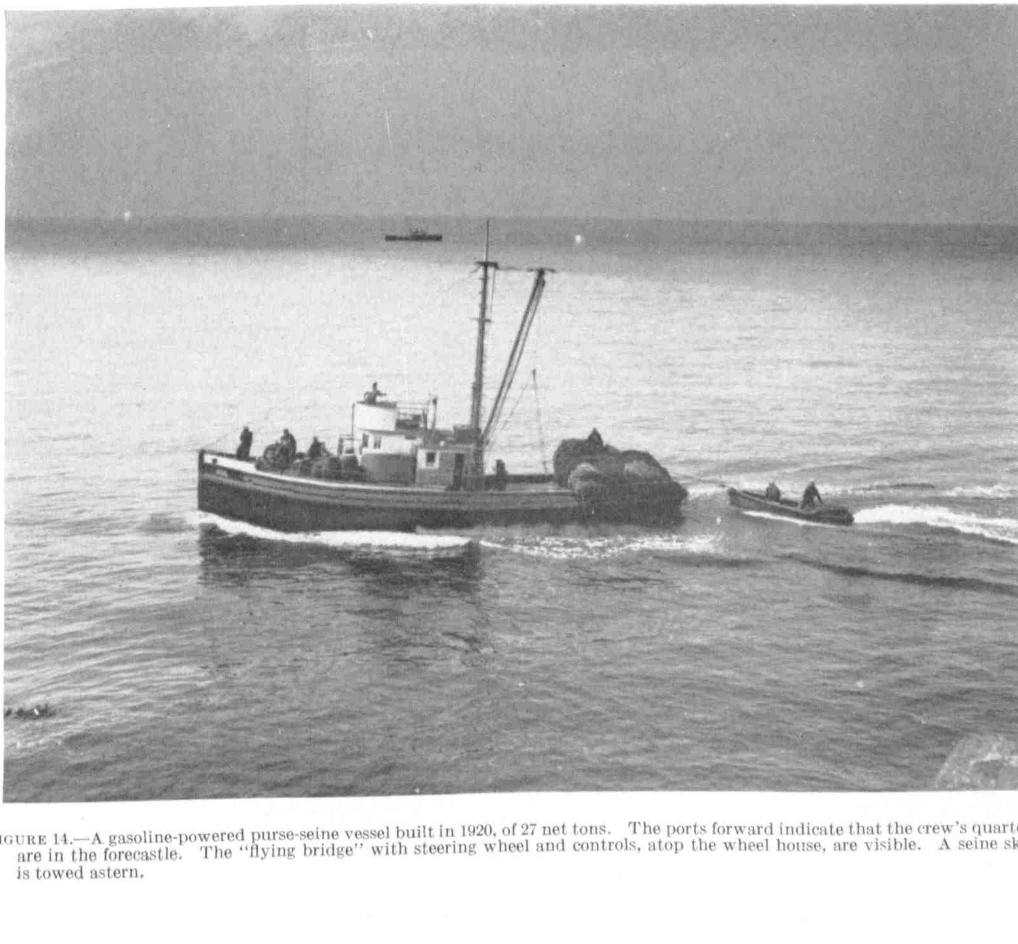

FIGURE 14.—A gasoline-powered purse-seine vessel built in 1920, of 27 net tons. The ports forward indicate that the crew's quarters are in the forecastle. The "flying bridge" with steering wheel and controls, atop the wheel house, are visible. A seine skiff is towed astern.

hauled in by means of a winch. The time necessary to reach and surround a school of fish was thus greatly decreased, with a corresponding increase in the efficiency of the seine.

It has already been noted that purse seines became the most important type of gear in use on Puget Sound shortly after their introduction, and that by about 1895 the successful development of the salmon traps had relegated them to a position of much less importance. The adoption of power by the purse-seine fleet, which was consummated by 1907, now altered this position of minor influence in the fishery to one of considerable consequence, for what had been a relatively fixed type of gear became an extremely mobile one when the seine scows were superseded by power boats. This newly acquired mobility, allowing rapid shifting of operations during the season to any district in which salmon were abundant, has remained the outstanding characteristic of the purse-seine fishery.

Improvements in Vessel Design

The introduction of power was followed by a gradual but positive change in the type of vessels used. As the fishermen moved farther afield, the unsuitability of the open boat under adverse weather conditions soon became apparent, and seaworthiness became the major consideration when the seiners began fishing far out in the Strait of Juan de Fuca. The first improvement in design, a compromise hull partially decked forward, appeared shortly after power was introduced. Later vessels were built with a full deck, and, at the same time, their depth was increased considerably, providing greater carrying capacity and increasing their seaworthiness. By 1912 most vessels were full-decked. This roving type of fishery was greatly impeded by the necessity of the crew sleeping ashore, and crew's quarters were soon placed on board. At first a long superstructure was built, but the quarters were later arranged in a forecastle under a slightly raised forward deck. The wheel house and galley were brought forward partially over the raised deck, which afforded more deck space and increased the seaworthiness of the vessel.

The speed and maneuverability of the vessels was increased considerably as engine efficiency improved. These developments, together with the use of larger seines, brought about the introduction of the "turntable" upon which the seine was stowed. This was a free-turning platform mounted above the gunwales of the vessel at the stern, and still retaining the roller at the after edge, which had been used for many years. The seine could be payed out freely and rapidly from this turntable and also stowed thereon with far greater ease than before. At about the same time engine power was further utilized to operate the pursing winch. This reduced the labor and increased the speed of pursing the nets, thus effecting an increase in their efficiency.

Figure 13, which was taken before 1913, shows that the outside wheel had been adopted by that date. The fishing captain was thus enabled to steer the vessel while standing on the forward deck where he was better able to observe the fish and set the net. Some 10 years later this outer wheel was moved to the top of the wheel house, allowing still greater range of observation (see fig. 14). At about the same time a power drive was applied to the turntable roller, allowing the net to be gotten on board for stowing far more rapidly and easily than before.

Although the first Diesel-powered vessel on Puget Sound, the cannery tender *Warrior*, which was built in 1914 at Seattle by Nilson and Kelez (Pacific Fisherman Yearbook for 1919), was successful in operation and very economical, the original cost of these engines was too great to encourage their ready acceptance. However, during the years of expansion of the fleet following 1925, the many advantages of Diesel engines encouraged their installation in a majority of the new vessels. In recent years there have been no further radical changes in type or design of purse-seine vessels.

Increase in Vessel Size

Improvements in vessel design were accompanied by a parallel increase in vessel size. It is impossible to determine the exact size of all vessels in the fleets of early years, since most of them were of less than 5 net tons and were not required to be officially registered. We may obtain some indication of the increase in vessel size, however, from records of the vessels large enough to be registered. The average size of vessels of this class, built in 1906, was only 6 net tons. That of 1907 was 7.5 net tons, that of 1908 was 8.92 net tons, that of 1909 was 9.43 net tons, and that of 1910 was 9.97 net tons.

This tendency to build larger vessels received great impetus with the beginning of the high-seas fishery at Cape Flattery and on Swiftsure Bank, where there were frequent storms, few harbors, and no protection. Practically no seiners had fished there prior to 1911, but the development of this fishery was very rapid. Several vessels were laid down during 1911 of more than 10 net tons, and in 1912 nearly 50 vessels of 15–25 net tons were constructed. The size of vessels has continued to increase since that time.

EVALUATION OF FISHING INTENSITY

SEASONAL FLUCTUATIONS IN FLEET SIZE

Factors Affecting Seasonal Intensity

Variations in number of licenses in odd- and even-numbered years, and the licensing of an additional amount of gear in the fall of the year, have been noted in the discussion of scow seines. The operation of these factors was intensified by the conversion of the purse-seine fleet to power vessels and by the increase in vessel size which followed.

The larger seine vessels were now able to run from their home ports on Puget Sound to southeastern Alaska with little difficulty, and some even voyaged as far as Bristol Bay. The termination of the fishing season in Alaska usually occurred early enough to allow them to return to Puget Sound and fish during the coho and chum runs in the fall.

Since about 1925 the development of Alaskan herring-reduction plants attracted a fleet of large, able seine boats which fished from June to August or September, and many of which then returned to the Sound to further swell the fall fleet. Other large seiners, which fished in the California sardine fleets during the winter months, often fished in this region later in the year. During seasons when heavy runs of salmon were anticipated, certain vessels from the halibut fleet, which were constructed with a low stern suitable for seining, also engaged in the purse-seine fishery.

In even-numbered years, when the pink salmon did not appear, the departure of the larger vessels to other fisheries was especially common, and when the decreasing abundance of sockeye rendered summer fishing even less profitable many smaller vessels followed suit.

Other factors have further intensified the annual change in the number of vessels. Prior to 1921, when regulations in waters of the State of Washington were undertaken by the State Fisheries Board, a considerable fishery for immature coho salmon was carried on in lower Puget Sound, especially off the southern end of Whidbey Island, in Possession Sound, and in Port Susan (see fig. 3). This fishery was pursued by a number of very small boats which fished during April and May of each year. When the regular seining season began, in June or July, most of these small boats transferred their licenses to larger vessels and engaged in gill netting during the remainder of the season. Closure to early fishing of a large part of these waters discouraged seining by the smaller boats.

These various factors have caused considerable fluctuations in the size of the Puget Sound seine fleets, but have not obscured the striking difference in the number of seiners operating in the summer fleets of alternate years, or the distinct difference between the total fleets of odd and even years.

Size of Summer and Fall Fleets on Puget Sound

During the period from 1909–15, the number of seine licenses issued increased from 95 to 308 (see table 11). However, the dates on which fishing licenses were issued are available for only a few of those years, and the number of vessels fishing during different parts of the seasons cannot be determined for this early period.

Beginning with 1916, the vessels fishing on Puget Sound in each year have been classified as summer or fall seiners; all those obtaining early licenses were tabulated as the summer fleet, and all vessels fishing after September 6 as the fall fleet. In most years there was a period of from one to four weeks preceding this date during which no licenses were obtained. A more detailed discussion of the time of change from summer to fall fishing will be presented later under a discussion of the fishing seasons of the fleets. The number of vessels in the summer fleets of each year from 1916–34 are presented as column totals in the bottom line of table 12; those of the fall fleet of each year are similarly presented in table 13.

Table 12.—*Summer purse-seine fleets on Puget Sound, 1916–34*

Registered net tonnage [1]	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Below 5	4	30	23	21	25	2	1	----	----	2	----	----	----	3	1	1	1	1	1
5–9	32	40	11	14	5	7	2	5	3	5	3	3	3	6	5	7	3	5	5
10–14	78	103	37	46	16	45	12	24	9	27	13	22	9	26	13	22	17	23	22
15–19	81	121	52	56	36	69	15	30	13	41	19	43	34	46	35	55	42	56	54
20–24	44	82	43	53	30	51	13	24	6	21	13	22	20	30	35	45	41	42	43
25–29	3	25	16	18	31	47	8	22	11	24	12	26	21	41	37	48	42	46	41
30–34	1	23	9	20	10	21	6	14	8	11	5	19	17	24	21	40	33	32	34
35–39	----	1	1	3	1	1	1	2	1	1	1	2	1	6	2	20	15	16	14
40–44	----	----	----	----	----	----	----	----	----	1	----	----	----	2	2	5	4	6	4
45–49	----	----	----	----	----	----	----	----	----	----	----	1	----	1	3	4	1	2	1
Total	243	425	192	231	154	243	58	121	51	133	66	138	106	194	154	247	199	229	219

[1] Vessels of 5 net tons and larger from official registers; boats below 5 net tons from State license applications.

TABLE 13.—*Fall purse-seine fleets on Puget Sound, 1916–34*

Registered net tonnage [1]	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Below 5	6	31	24	23	26	3	1	1	1	3	----	1	2	4	4	1	1	4	1
5–9	36	40	11	15	7	7	3	4	3	6	4	3	3	6	5	8	4	5	5
10–14	90	106	45	54	23	46	27	26	20	29	20	26	22	26	18	22	18	25	22
15–19	88	125	58	63	43	69	36	35	26	47	36	44	44	49	47	56	45	56	57
20–24	51	83	50	58	34	53	27	28	16	27	19	27	25	39	38	45	42	44	43
25–29	4	26	19	19	33	49	22	23	16	29	28	33	34	41	40	48	42	47	43
30–34	1	23	15	20	13	22	12	14	9	14	20	32	31	27	30	40	34	34	36
35–39	----	1	1	3	1	1	2	2	2	2	2	8	6	10	8	20	15	17	15
40–44	----	----	----	----	----	----	----	----	----	1	1	----	----	3	2	5	4	8	4
45–49	----	----	----	----	----	----	----	----	----	----	----	1	1	1	4	3	1	2	----
Total	276	435	223	255	180	250	130	133	93	158	130	175	168	211	196	248	206	242	226

[1] Vessels of 5 net tons and larger from official registers; boats below 5 net tons from State license applications.

The data given in tables 12 and 13 are presented in graphical form in the top section of figure 15. The dotted line represents the size of the unallocated fleets from 1909–15. The size of the summer fleets from 1916–34 is represented by the solid line, and that of the fall fleets of the same years by the broken line.

A general consideration of the number of licenses indicates a continuous increase in numbers from 1909–15, an extremely high point in 1917, very small numbers during the years of post-war depression, and a considerable increase thereafter. The year 1917 stands apart as the peak in number of vessels during the entire history of purse-seining in this region; 425 vessels fished during the summer season and 435 during the fall. Pink salmon were abundant, the appearance of a big run of sockeye was anticipated, and a war-created demand for food had caused the price of raw fish to increase enormously. As a result, 122 new vessels were built that year, and almost every vessel on the Sound large enough to carry a net, including tow boats and pleasure craft, was engaged in purse seining. Although the regular seiners enjoyed a successful season, the sockeye run did not reach expectations, nor was the fall fishing especially profitable. Newcomers to the fleet found that purse seining was a most arduous vocation and that successful fishing was largely dependent upon the ability and experience of the vessel captain. These factors, coupled with the fact that 1918 was an off year for the summer fishery, caused the fleet of that year to shrink to more normal proportions, even in the face of a continued demand for fish. Except for the alternate rise and fall in odd-numbered years, the fleets remained approximately constant in number from 1918 to 1921. The abundance of most species of salmon had diminished considerably and this, together with the financial depression of 1921, resulted in a marked decrease in the number of vessels fishing in 1922.

Only three more vessels fished in the fall fleet of 1923 than in that of the previous year. This was the first year since the period of early development that the odd year showed so small a rise in number. The year 1924, when only 51 vessels fished during the summer season and 93 in the fall, was the first since 1909 in which less than a hundred vessels were licensed on the sound. However, beginning in 1925, the fleets again began to increase steadily in number. Although expansion ceased during the depression years following 1929, there followed no such decline as appeared in the period from 1922–24. The fleets of the 1930's, were of approximately the same size as were those immediately following 1917.

Size of Cape Seine Fleet

The purse-seine fishery in the waters off Cape Flattery and in the vicinity of Swiftsure Bank, which has long been called the "cape" fishery in this region, experienced a development similar to that of Puget Sound. For years the cape fleet has consisted of the larger vessels of the Puget Sound fleet, which fished there before the salmon runs began in inside waters, together with a few large vessels which have proceeded to other fisheries when the season was over.

During the years immediately following its development, tremendous catches encouraged many seiners to engage in this fishery. Most of the catch, however, consisted of immature fish which spoiled quickly, and the refusal of the canneries to accept them reduced the size of the cape fleet. This situation was met temporarily by butchering the fish at Neah Bay, and by icing the catches. Somewhat later the canners employed a fleet of fast tenders or "buying-boats", to which the seiners transferred their catches, and which then returned immediately to the canneries. This not only enabled the seine boats to remain at sea for longer periods of time, but insured the delivery of the fish ashore soon after they were caught. This development again encouraged the increase of the fleet.

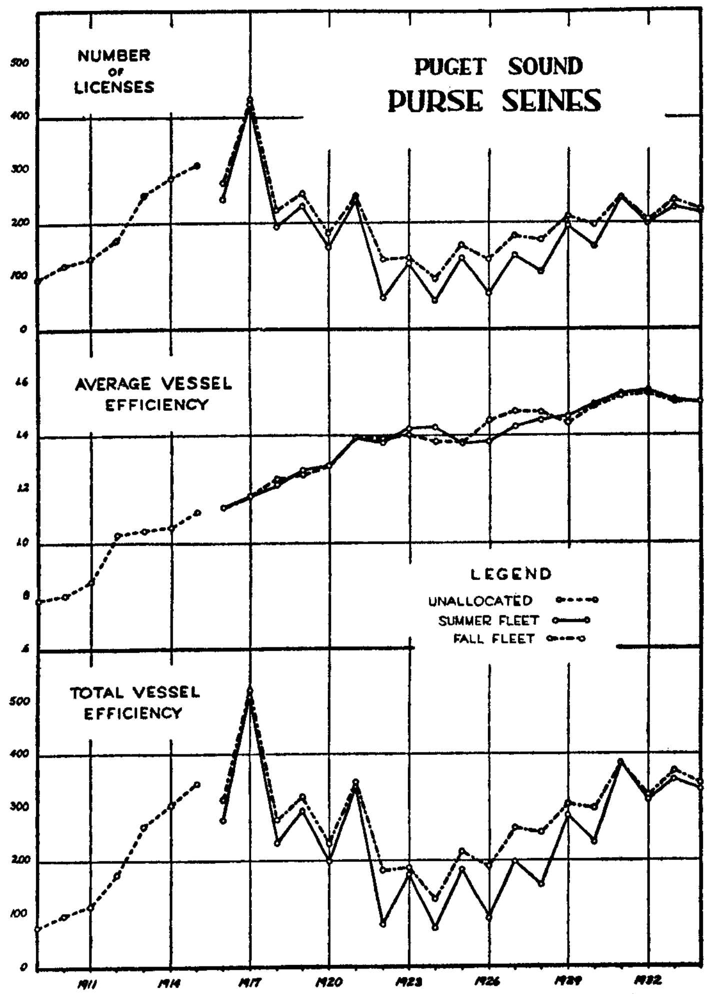

Figure 15.—Changes in numbers and efficiency of the Puget Sound purse-seine fleets. The early increase in size of the fleets, the decrease following the World War, and the increase during recent years may be seen, together with the general rise in efficiency throughout.

Since this fishery was conducted in waters outside the jurisdiction of the State of Washington, the vessels were not licensed and no record is available of the size of the annual fleets. Gilbert (1913) reported 22 vessels fishing at the cape in 1911, and more than 100 in 1912. Data furnished by the major part of the fishing companies in the region, which include the greater part of the landings from the cape, are quite complete for the period from 1927–34. These figures indicate that the numbers of vessels fishing there during these years were 64, 88, 122, 75, 163, 117, 104, and 142, respectively.

CHANGES IN COMPOSITION OF THE FLEET

The size-composition of the annual purse-seine fleets was essential to a determination of fishing intensity, for vessel size is an important aid in the calculation of vessel efficiency.[4]

The changes in size that have taken place during the history of the purse-seine fishery are partially indicated in figure 16, which shows the size distribution of vessels fishing on Puget Sound during the years 1911, 1917, 1925, and 1933. Of the entire fleet fishing during 1911, there were only 6 vessels of 15 or more net tons. By 1917 vessels of this larger size constituted the major portion of the fleet, although a considerable number of smaller vessels were still fishing. A number of vessels of 24 or more net tons fished for the first time that year.

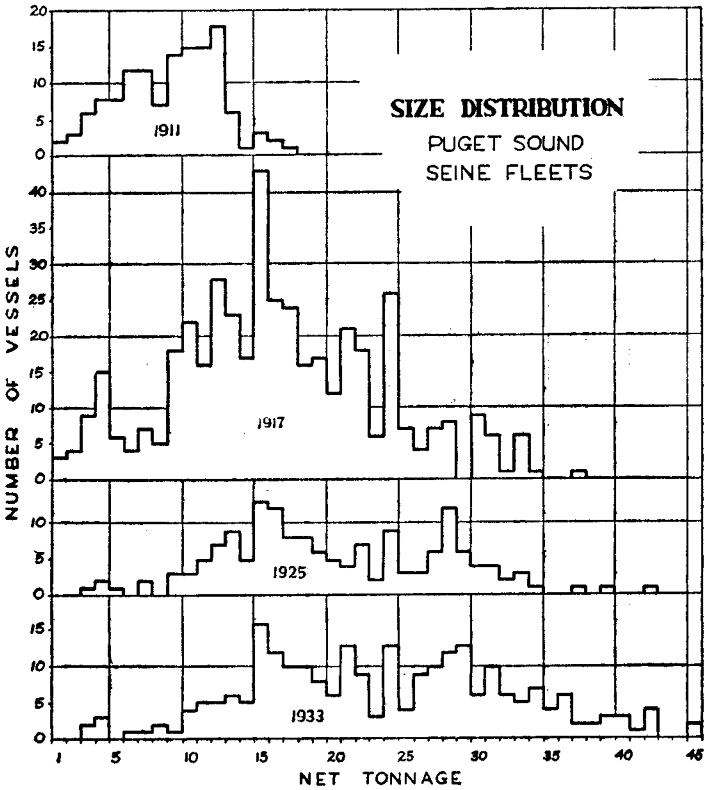

FIGURE 16.—Size distribution of vessels in the Puget Sound seine fleets at various intervals of development. The first histogram pictures the fleet shortly after the introduction of power; the second that of the exceptional year, 1917; the third the resumption of building after the post-war depression; and the fourth that of a recent year.

By 1925 vessels of less than 9 net tons had become scarce and the remaining fleet showed almost a bimodal size distribution, somewhat obscured by the presence of several vessels of 22 net tons built in 1915, and several of 24 net tons built in 1917; there is a mode at about 16 net tons, and another some 12 tons greater. Three vessels of more than 35 net tons fished in 1925.

In 1933 the small vessels had become even less numerous, and the remainder of the vessels, although similar in distribution to the fleet of 1925, show a considerable increase in the number of large vessels.

Because we are especially concerned with the fleets of the past 18 years, the year of building the vessels fishing during that time, and their size, are shown in table 14. The persistence of old vessels in the fleet is noteworthy, even though most of the smaller ones of early years have disappeared.

[4] In order to establish the size of vessels composing the fleets of various years, it was necessary to identify as many as possible of the individual vessels which had engaged in the purse-seine fishery of the region. By means of the license applications in the files of the Washington State Fisheries Department, the Fireman's Fund register of vessels documented on the Pacific coast, and the official Merchant Vessels Register of the United States Bureau of Navigation, the identity of 924 vessels was established, and the net tonnage, horsepower, and the year of building of each was recorded.

The increase in larger vessels in 1912, which resulted from the development of the cape fishery, is very apparent. These larger craft had been underpowered and not particularly successful, and smaller vessels were more popular during the next few years. The two large vessels, built in 1909 and 1911, were not built as purse seiners but were converted in later years.

The second abrupt size increase, beginning in 1916, was terminated by the depression in 1921. Building was resumed in 1924, but construction never reached the proportions of earlier years, for the declining abundance of salmon discouraged sustained building. It was at this time, however, that Diesel-engined vessels began to appear in the fleet. The depression following 1929 sharply curtailed the number of vessels under construction, and a recession in size similar to that in the years following 1921 is evident.

TABLE 14.—*Relation of size and year of building for vessels in the Puget Sound purse-seine fleet from 1915 to 1934* [1]

Net tonnage	Year built																	
	1895 to 1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921
1.							1	2	1			2						
2.						1	2	1			2	1	1	2				
3.						1			2	3	1		1	5	1	1		
4.	1	1	1	1			1	1	2	2	2	1	1	1		2		
5.		1			2		1	1		1	1			1	1			
6.		3	1	1	1			1			1		1		3			
7.	1	1		2			1	2	1	4		1				1		
8.	1		2		2	1	1				3							
9.	1	1		1	1	6	1			4		2	1		1	1		
10.				1	1	6	6	2		7	2	1		1	1	1	1	1
11.						1	10	2		3	2	2		2				
12.		2	1		2	1	3	7	3	5	2	4	1			1		1
13.	1			1	1	1	2	1	4	6	5	4		2		1		
14.										10	4	1		1				
15.								3	13	13	3	9	1	8	2			
16.								1	5	4	6	8		4				
17.									2	4	8	8	1	4				
18.									4		4	5		6	1			
19.									5	2	5	3		5			1	1
20.									3		2	5		6				
21.									3		5	8	2	5		1	1	
22.									3		1	18		3		2		
23.									4		1	2		2		1		
24.									5	1		3		17	1	4		
25.									1				1	5	1	1		
26.						1								4	1		3	1
27.													1	6		1	7	
28.										1				10	1	3	10	
29.								1								2	11	
30.													1	8		1	2	
31.														6	2	1	2	
32.														1	1	2	2	
33.													2	5	1	1		
34.														1		2		
35.																		
36.															1	1		
37.														1				
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49.																		
Total	5	9	5	7	10	19	29	25	61	70	60	88	15	122	19	31	41	4
Total tonnage	41	67	38	56	88	189	270	262	1,012	884	871	1,507	258	2,665	359	702	1,141	67
Average	8.20	7.44	7.60	8.00	8.80	9.95	9.31	10.48	16.59	12.63	14.52	17.13	17.20	21.84	18.89	22.65	27.83	16.75

[1] All vessels powered with gasoline engines prior to 1925, gasoline and Diesel ("oil") powered vessels listed separately thereafter.

TABLE 14.—*Relation of size and year of building for vessels in the Puget Sound purse-seine fleet from 1915 to 1934*—Continued

Net tonnage	Year built																	
	1924	1925		1926		1927		1928	1929		1930		1931		1932	1933	1934	
		Gas	Oil	Gas	Oil	Gas	Oil	Oil	Gas	Oil	Gas	Oil	Gas	Oil	Gas	Gas	Gas	Oil
1																		
2																		
3																		
4						1												
5																		
6																		
7																		
8																		
9											1					1		
10									1									
11				1					1									
12																		
13													1					
14									1									
15		1											1		1			
16																	1	
17																		
18	1									1		1						1
19	1					2	1											
20		1																
21						2	1		1									
22									1	2								1
23									1		1							
24			1							1	1							
25														1				
26		1								1				3				
27			1				2		1	1								
28	1	1	1		1													
29		1		1	3		1		1									
30				1		1	2											
31					3	1	2		1									
32		1			1	2	1											
33			1		3	1				1								
34					3	2	3	1				1	1					
35							2	2				1						
36					1		6	1						1				
37							2			2								
38							1			3								
39										2								
40							1	1		1								
41												1						
42			1							2		2						
43																		
44										1								
45												3						
46																		
47							1	1										
48																		
49								1										
Total	3	6	5	3	15	12	30	7	9	18	3	9	3	5	1	1	1	2
Total tonnage	65	150	154	70	477	276	854	256	188	564	55	347	62	139	15	9	16	40
Average	21.67	25.00	30.80	23.33	31.80	23.00	28.47	36.57	20.89	31.33	18.33	38.56	20.67	27.80	15.00	9.00	16.00	20.00
Average (combined)		27.64		30.39		26.90			27.85		33.50		25.13				18.67	

RELATION OF VESSEL SIZE TO EFFICIENCY

Any comparison of the number of vessels fishing in recent years to the number in any early year is of little significance unless consideration is given to the efficiency of the individual vessels of these respective periods. Many reasons may be offered for variation in vessel efficiency, but the greater number of these may be either directly or indirectly ascribed to the size of the vessel itself.

With the exception of two brief periods of unfavorable economic conditions, the size of the new vessels added to the fleet each year has been gradually increasing. The newer vessels have been fitted out with better engines and equipment, and in recent years Diesel engines have been used almost exclusively by the larger vessels. These engines, allowing a far greater range of operation and greater economy than had been possible with gasoline engines, contributed much to the efficiency of the larger vessels.

The average horsepower of engines has also gradually increased. For example, the average power of vessels in the 10–14 net-ton class has increased from 22.4 hp. in 1915 to 30.9 hp. in 1934. Larger vessels show a lesser increase in the case of gasoline engines, but the many Diesel engines are of much greater power. The maximum power of the largest vessels prior to 1918 was 55 hp., whereas vessels above 45 net tons now average 132.5 hp. The present averages for the 7 size-classes of vessels between 10 and 40 net tons are 36.5, 46.0, 56.6, 68.1, 88.1, 97.0, and 109.8 hp., respectively. The relatively greater power of the larger vessels undoubtedly adds to their efficiency.

An important difference in earlier years existed in the size of the seine carried. In general, the larger seines were more efficient than the smaller ones and, since the size of the seine was necessarily limited by the space available for handling and stowing, it was generally proportional to the size of the vessel.

Throughout the years the human factor, although difficult of measurement, has always been of great importance. The most successful fishermen have constantly built larger and better vessels, while the older, smaller craft have usually been manned by less active men or by newcomers to the fishery. For these reasons the present analysis of vessel efficiency has been confined to a study of the relation of vessel size to size of catch.

In order to facilitate vessel-catch comparisons, the fleets of all years from 1916 to 1934 have been divided into size classes of 5 net tons each. The annual numbers of vessels in each class, for the summer and fall fleets, are given in tables 12 and 13.

Theoretically, any difference in efficiency between vessels of varying size should be reflected in a proportional difference in the average size of their catches. In order to determine such differences and to measure their degree, the average catches, over a considerable period of time, of vessels of different size classes were compared. Catch data used were from the years 1916–19, 1922–25, and 1928–34, in order to include the various building periods of the vessels and the fluctuations in fleet size. The size class of vessels from 10 to 14 net tons was selected as the unit of relationship since this class was well represented throughout the period of years covered.

Direct comparisons of annual average catches could not be used because of the seasonal fluctuations in abundance of the various species of salmon, with the resultant influence that the presence of one species might have on the size of the catch of another. Therefore, data for different species were used for comparison during different parts of the fishing season. Sockeye catches were used for determining averages for the summer fishery of even years, pink-salmon catches for that of odd years, and coho and chum catches for the fall fishery in all years.

Data for individual species were limited to the part of the season when they were sufficiently abundant to warrant fishing, and when other species were less numerous than the one sampled. Pink-salmon catches for most years were those from a period between July 29 and September 15. This period was shifted one week earlier in 1929 and one week later in 1933 in accordance with the time of appearance of the runs. Catches of coho salmon used were those taken during a period between September 16 and October 27; this period was decreased by one week in both 1929 and 1930. The period used for chum salmon was from October 13 to November 6, except in years when the season was extended beyond the latter date. The periods for sockeye salmon were necessarily more varied than those for other species because of greater fluctuations in the time of run. Catches used were generally from the period between July 15 and August 15, although these dates were shifted when necessary, for example, to the period from July 29–September 8, in 1930, when the run was very late.

For each species the average delivery by vessels of each size class was determined by dividing the total number of fish caught, during the period selected, by the total number of deliveries made. No class was used in which less than 5 vessels fished with a minimum of 10 catches. For years in which the 6 size classes between 10 and 39 net tons were represented, the average catches of the individual classes were determined as percentages of the average catch of all classes. For early years, when data were available for only the smaller classes, the average catches were determined as percentages of the average catch of the total class range represented. In order to make the data for early years comparable with those for later ones, the percentages of the individual size classes were proportionately reduced so that their sum was equal to the average sum of the percentages of an equal class range in the years when all classes were represented. The sums of the percentages in all years were divided by the number of years to determine the average percentage for each class, and the ratio of these averages to that of the class from 10 to 14 net tons was calculated for each species.

These relative-efficiency ratios for each species, and for the average of all species, are presented in table 15. The sockeye salmon show the smallest and least consistent differences between vessel classes. Large catches of this species have frequently been made by vessels of all sizes fishing in certain limited areas on the Salmon Banks, near Lummi Island and at Point Roberts (fig. 2). Here peculiarities of winds and tides, or advantages of geographical location in relation to migration channels, have caused dense schooling for brief periods of time, and disproportional catches have been made by many vessels.

TABLE 15.—*Relative efficiency of Puget Sound purse-seine vessels* [1]

Species	Vessel size in five-ton classes [2]							
	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40 and larger
Sockeye [3]	0.66	1.00	0.99	1.46	1.56	1.43	1.55	1.59
Pink [4]	.92	1.00	1.27	1.64	1.85	2.02	2.33	2.25
Coho	.83	1.00	1.16	1.69	2.19	2.27	2.37	2.12
Chum	.79	1.00	1.21	1.43	1.70	1.78	1.91	1.98
All species	.80	1.00	1.16	1.56	1.82	1.88	2.08	1.99

[1] Proportion of the average annual catch of each species taken by each size class, calculated on basis of 10–14 class as unity.
[2] Size in net tons, official register.
[3] For even years only.
[4] For odd years only.

The ratios of the other species show a consistent increase with vessel size except in the group of vessels of 40 or more net tons. In this particular class, two species show increases and two decreases as compared with the next smaller class. The average ratios of all species were used as the final measure of relative vessel efficiency. The efficiency of boats of less than 5 net tons was arbitrarily set at 0.5, since sufficient data were not available from which a ratio for this class might be calculated.

The average vessel efficiencies of the Puget Sound fleets from 1909–34, based upon these ratios, are shown graphically in the center section of fig. 15. The abrupt increase in the efficiency of the 1912 fleet is due to the construction of large vessels in that year. Efficiencies of the summer and fall fleets are quite similar, with the exception of the period after 1923. The divergence shown here is due to considerable variations in the number of small boats fishing. The general trend of the average efficiency is upward, with a slight decline in 1933 and 1934. It is evident that the fleets of recent years are, boat for boat, about twice as efficient as were those of 1909 and 1910.

The total efficiency figures for the fleets from 1909–34 are presented in table 16. The same data are shown graphically in the bottom section of fig. 15. The great increase in efficiency in early years, as well as the considerable rise during recent years, is obvious. Judging from the actual number of licenses issued, as shown in the top section of the figure, there were 7 years between 1913 and 1921 in which the number of vessels fishing was greater than the average number fishing between 1931 and 1934. However, it is apparent from the figures of total vessel efficiency that the average of the last 4 years has been exceeded only once, in 1917, and approached closely in only 2 other years, 1915 and 1921. It is thus evident that, with the exception of the abnormal year 1917, the intensity of the purse-seine fishery on Puget Sound has been potentially greater during recent years than at any previous time in the history of the fishery.

TABLE 16.—*Relative efficiencies of Puget Sound purse-seine fleets, 1909–34* [1]

Year	Summer fleet	Fall fleet	Unallocated	Year	Summer fleet	Fall fleet
1909			74.58	1922	79.70	180.54
1910			96.68	1923	172.84	186.32
1911	112.06	113.86		1924	72.98	128.22
1912			174.22	1925	181.75	217.19
1913			263.10	1926	91.04	189.31
1914			304.30	1927	197.79	260.91
1915			343.48	1928	154.30	250.07
1916	275.54	312.60		1929	284.69	304.62
1917	509.10	520.62		1930	233.63	295.58
1918	232.82	275.94		1931	384.17	384.14
1919	294.02	319.48		1932	312.21	320.93
1920	198.36	231.10		1933	351.06	369.32
1921	338.30	348.44		1934	333.83	344.80

[1] For years 1909, 1912, 1913, and 1914, actual sizes of all boats unknown; efficiencies calculated from proportionate sizes of identified boats, which were 84, 70, 42, and 45 percent of the respective fleets of those years.

SEASONAL OCCURRENCE OF EACH SPECIES

PUGET SOUND FISHERY

In certain areas several species of salmon may be present in considerable numbers at the same time, and during parts of the season a single purse-seine haul usually contains all five species. The seiners are able to make a certain amount of selection as to the species they wish to catch, however, by operating in different localities.

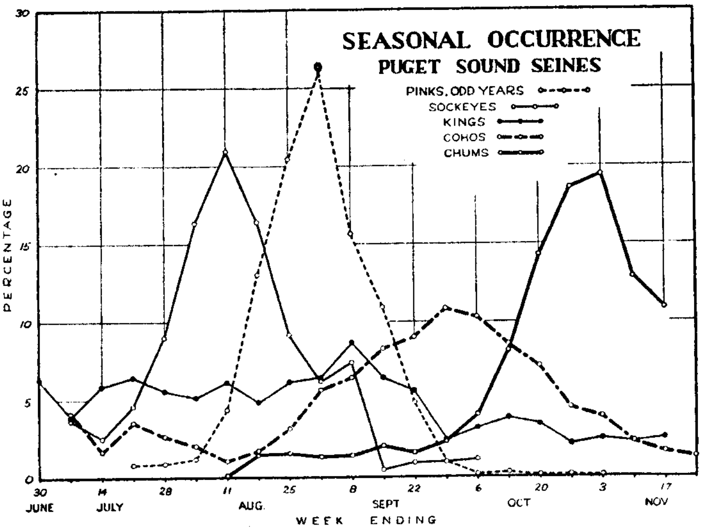

FIGURE 17.—Seasonal occurrence of the various species in the catch of Puget Sound purse seines.

In order to determine the seasonal progression of the various species in the fishery, the average daily delivery, by 7-day periods for each year from 1911–34, was calculated for each of them; data from all vessels of 10–39 net tons being used. The 7-day averages over the 24-year period were then calculated, and determined as percentages of their sum (see table 17 and fig. 17). The curves do not show the relative abundance between species, but indicate for each species the average proportion appearing in the catches of successive weeks during the fishing season. The pink-salmon curve represents occurrence only in odd-numbered years.

Although there is considerable overlapping in the time when the various species appear, a distinct progression throughout the season is apparent, and the peaks of the runs of all species, except king salmon, occur at intervals of 3–4 weeks. These curves correspond closely to those from the trap fishery. The more prolonged periods of abundance of the various species indicated by these data may be attributed to the ability of the seiners to move with the fish, making their catches in whatever region that affords the greatest abundance at any particular part of the season.

TABLE 17.—*Seasonal occurrence in Puget Sound purse seines*

Week ending—	Percentage occurrence					Cumulative percentage occurrence				
	Sockeye	King	Pink	Coho	Chum	Sockeye	King	Pink	Coho	Chum
June 30	---	6.314	---	---	---	---	6.314	---	---	---
July 7	3.685	3.966	---	4.181	---	3.685	10.280	---	4.181	---
July 14	2.534	5.864	---	1.709	---	6.219	16.144	---	5.890	---
July 21	4.629	6.466	0.805	3.561	---	10.848	22.610	0.805	9.451	---
July 28	9.070	5.542	.847	2.690	---	19.918	28.152	1.652	12.141	---
Aug. 4	16.352	5.136	1.189	2.055	---	36.270	33.288	2.841	14.196	---
Aug. 11	20.914	6.110	4.393	1.020	0.102	57.184	39.398	7.234	15.216	0.102
Aug. 18	16.481	4.847	13.066	1.738	1.437	73.665	44.245	20.300	16.954	1.539
Aug. 25	9.199	6.119	20.484	3.162	1.536	82.864	50.364	40.784	20.116	3.075
Sept. 1	6.142	6.398	26.069	5.602	1.297	89.006	56.762	66.853	25.718	4.372
Sept. 8	7.437	8.737	15.539	6.396	1.391	96.443	65.499	82.392	32.114	5.763
Sept. 15	.488	6.432	10.895	8.282	2.017	96.931	71.931	93.287	40.396	7.780
Sept. 22	.916	5.576	4.843	9.043	1.602	97.847	77.507	98.130	49.439	9.382
Sept. 29	.994	2.449	.999	10.834	2.324	98.841	79.956	99.129	60.273	11.706
Oct. 6	1.158	3.212	.204	10.286	4.076	99.999	83.168	99.333	70.559	15.782
Oct. 13	---	3.873	.291	8.564	8.138	---	87.041	99.624	79.123	23.920
Oct. 20	---	3.449	.128	7.147	14.272	---	90.490	99.752	86.270	38.192
Oct. 27	---	2.169	.142	4.522	18.593	---	92.659	99.894	90.792	56.785
Nov. 3	---	2.508	.106	3.948	19.487	---	95.167	100.000	94.740	76.272
Nov. 10	---	2.288	---	2.279	12.866	---	97.455	---	97.019	89.138
Nov. 17	---	2.542	---	1.672	10.860	---	99.997	---	98.691	99.998
Nov. 24	---	---	---	1.311	---	---	---	---	100.002	---

CAPE FISHERY

The seasonal occurrence of the various species in the cape fishery has been determined in the same manner as that for Puget Sound. Adequate data, however, were not available prior to 1927. These data are presented in table 18.

The sockeye and pink-salmon runs at the cape reach their seasonal peaks at about the same time as in the inside fishery (see fig. 17), but the former species is more concentrated at the time of the peak of the run. The king salmon run is generally similar to that of the inside fishery. The coho season at the cape differs considerably from that on Puget Sound. Large numbers of fish are taken during the first part of the season and the early cessation of fishing obscures what undoubtedly would be a fall run similar to that in Puget Sound waters. Occurrence of chum salmon has not been calculated because they form only a very minor part of the cape catches.

TABLE 18.—*Seasonal occurrence in cape purse seines*

Week ending—	Percentage occurrence				Cumulative percentage occurrence			
	Sockeye	King	Pink	Coho	Sockeye	King	Pink	Coho
June 23	0.192	2.526	---	13.959	0.192	2.526	---	13.959
June 30	.635	7.629	0.805	7.319	.827	10.155	0.805	21.278
July 7	.947	6.134	1.206	8.831	1.774	16.289	2.011	30.109
July 14	.939	8.296	2.511	5.275	2.713	24.585	4.522	35.384
July 21	2.021	6.114	4.101	5.828	4.734	30.699	8.623	41.212
July 28	6.048	9.176	6.003	6.536	10.782	39.875	14.626	47.748
Aug. 4	12.496	7.528	6.540	5.531	23.278	47.403	21.166	53.279
Aug. 11	30.768	10.075	12.880	3.799	54.046	57.478	34.046	57.078
Aug. 18	30.368	12.096	9.886	3.526	84.414	69.574	43.932	60.604
Aug. 25	8.561	11.449	18.723	4.988	92.975	81.023	62.655	65.592
Sept. 1	3.151	10.570	22.554	4.905	96.126	91.593	85.209	70.497
Sept. 8	3.341	6.265	14.145	8.884	99.467	97.858	99.354	79.381
Sept. 15	---	2.142	.484	10.930	---	100.000	99.838	90.311
Sept. 22	.531	---	.163	3.038	99.998	---	100.001	93.349
Sept. 29	---	---	---	1.863	---	---	---	95.212
Oct. 6	---	---	---	4.788	---	---	---	100.000

FISHING SEASONS IN DIFFERENT DISTRICTS

PUGET SOUND

Purse seining on Puget Sound usually begins in the early summer in the region of the San Juan Islands, the greater number of vessels fishing on or near the Salmon Banks (see fig. 2). As the season progresses the vessels work farther inside to Rosario Strait, Lummi Island, and Point Roberts, and, especially in years when pink salmon are abundant, in Haro Strait. In even years there is a slack period between the summer and fall seasons in which little fishing is done. In the odd years the pink-salmon run extends to the late summer closed period (see table 8).

Fall fishing begins shortly after this slack period. In odd-numbered years some vessels may remain in the northern districts for the last of the pink-salmon run, but the remainder of the fleet will shift to the eastern part of the Strait of Juan de Fuca from Ediz Hook to Middle Point, and the southern shores of the San Juan Islands. A short time later most of the vessels will move to Admiralty Inlet. Much of the late fall fishing is in the inlets and passages of lower Puget Sound. In even years the fall fishery is similar, except that such vessels as fish during the slack period between the summer and fall fisheries usually operate in the lower part of the strait at an earlier date.

Seining is carried on by Canadian vessels along the eastern shore of Vancouver Island and in seining areas 17–20 (see fig. 2), except that the portion of area 17 which is adjacent to the mouth of the Fraser River has, until recent years, been open to fishing only during the time of the pink and chum runs.

The intensity of the seine fishery during different parts of the season is dependent largely upon the abundance of fish. However, the number of fish caught does not truly represent the effort expended by the fleet for fishing intensity may be very high, even though only moderate catches are made. The best measure of effort which may be determined from present records is the average number of deliveries made in a uniform period of time. During the greater part of the season buyers pick up fish at fairly regular intervals, and the number of deliveries made to them should closely approximate the intensity of the fishery.

The number of deliveries in each week of odd- and even-numbered years from 1916–34, except 1920 and 1930, were calculated as percentages of the total number of deliveries made in each year. The year 1930 was omitted because of unusual differences in the time when the run of certain species occurred, and because of the curtailment of fishing in certain areas by administrative orders; 1920 was omitted because of inadequate data. The average percentage of the season's deliveries, of the Puget Sound fleet, made in each week for both odd and even years were then determined, and are shown in the first two columns of table 19.

TABLE 19.—*Average proportion in each 7-day period of the total annual deliveries of the Puget Sound and cape seine fleets*

Week ending—	Puget Sound fleet, 1916 to 1934 [1]			Cape fleet, 1927 to 1934		
	Odd years	Even years	Even years weighted [2]	Odd years	Even years	Even years weighted [2]
June 9				0.032		
June 16				.021	0.051	0.041
June 23				.615	2.933	2.361
June 30	0.020	0.005	0.003	3.705	10.765	8.665
July 7	.324	.143	.091	5.934	9.858	7.935
July 14	.906	.728	.463	7.570	10.432	8.397
July 21	2.462	2.882	1.833	13.474	15.043	12.108
July 28	3.836	5.586	3.553	9.193	11.546	9.293
Aug. 4	4.841	5.945	3.781	16.971	10.795	8.689
Aug. 11	5.470	5.583	3.551	18.926	4.942	3.978
Aug. 18	6.768	4.873	3.099	11.812	9.011	7.253
Aug. 25	10.303	4.153	2.641	4.870	3.084	2.482
Sept. 1	10.461	2.402	1.528	4.616	2.189	1.762
Sept. 8	7.425	1.504	.957	.473	4.328	3.484
Sept. 15		2.431	1.546	.235	3.552	2.859
Sept. 22	4.324	3.926	2.497	.667	.664	.534
Sept. 29	4.771	5.956	3.788	.541	.247	.199
Oct. 6	5.753	7.708	4.902	.028	.180	.145
Oct. 13	6.767	8.846	5.626	.266	.088	.071
Oct. 20	7.367	10.401	6.615	.050	.138	.111
Oct. 27	7.432	11.095	7.056		.064	.052
Nov. 3	7.077	10.458	6.651		.076	.061
Nov. 10	3.178	4.449	2.829		.013	.010
Nov. 17	.416	.875	.556			
Nov. 24	.099	.050	.032			
Total	100.000	99.999	63.598	99.999	99.999	80.490

[1] 1920 and 1930 omitted.
[2] Percentages in even years weighted by ratio of average number of deliveries in even years to average number of deliveries in odd years.

The week ending September 15 has been omitted from the odd years, since in all years except 2, 1917 and 1919, a closed period has been enforced. The catches made during this week in these 2 years were not included when the percentages for these years were calculated. The last 3 days of the preceding week were also included in the closed period. The catches for this week have been estimated on the basis of the daily average for the 4 days of the week during which fishing was permitted, and the percentages calculated from the estimated figures. Because a similar closed period has been enforced in the last 2 even years, the percentages for the closed weeks during these years were estimated on the average of the same weeks of the remaining 6 even years in which this closure was not operative.

Because the fleets in odd years have been larger than those in even years it was necessary, in order to show the proportionate intensity of the fishery, to reduce the even-year percentages in the same proportion that the average number of even-year deliveries bore to the average number of odd-year deliveries. From these weighted figures, appearing in the third column of table 19 and shown in the lower section of figure 18, it is immediately apparent that the increased intensity in odd years is confined largely to the summer fishery, and that the relative size of the summer and fall fisheries is reversed in odd and even years.

In both odd and even years deliveries start shortly before July 1. In even years they increase rapidly to a peak during the last part of July and the early part of August, begin to decline about the middle of August, and by the first week in September have almost ceased. Shortly after this the fall fishery begins, with a gradual increase each week until a peak is reached in the last week of October. From this point the fishery declines abruptly.

Fishing in odd years also increases during July, but, whereas the even years show a decline in August, the odd-year fishery continues to increase during that month to the highest point in the season. The slack season between summer and fall fishing follows, but is not so accentuated as in even years, even though the closed period terminates fishing entirely for a short time. After September 15 the fall fishing begins, increases to a peak about the middle of October, and then declines rapidly; the mode is more protracted than in even years.

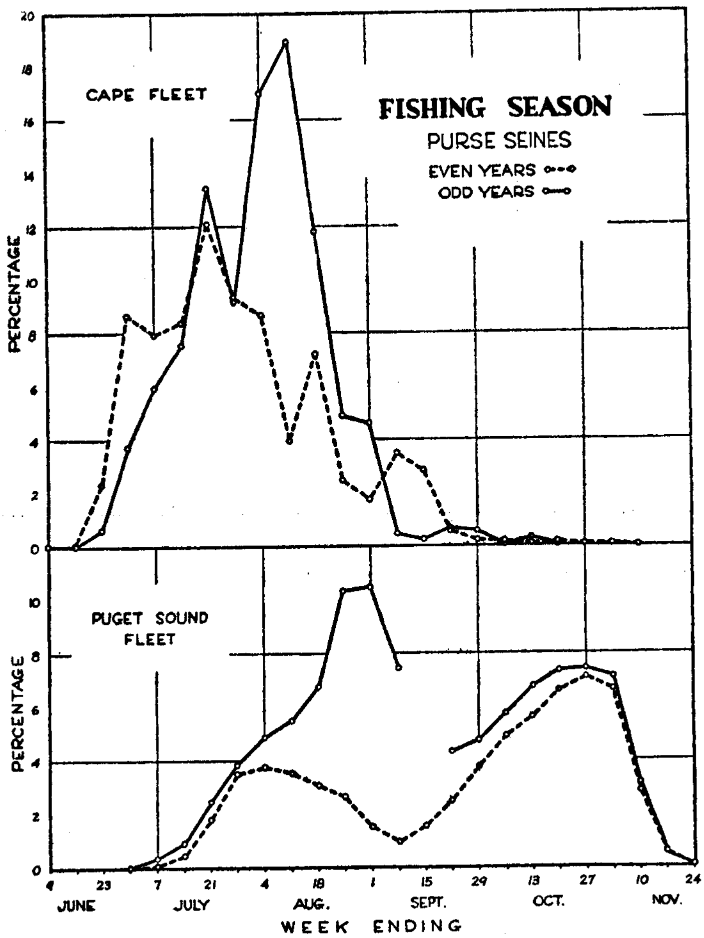

FIGURE 18.—Fishing seasons of the cape and Puget Sound fleets in odd and even years. The early season at the cape, the influence of the large runs of pink salmon in odd years in both districts, and the summer and fall fisheries on Puget Sound are indicated.

CAPE FLATTERY

This fishery is generally carried on during the early summer, after which most of the vessels move to the inside waters where better protection from adverse weather is afforded, and where there is a greater concentration of fall-running fish.

The average proportion of deliveries made during each week of the season was calculated for odd and even years in a manner similar to that for the Puget Sound fishery. These data are presented in the last three columns of table 18. The even-year percentages have again been weighted by the proportion of the average total numbers of even- and odd-year deliveries. These data are less smooth than those of the Puget Sound fishery because of the small number of years, 4 odd and 4 even, for which records are available.

The curves of proportional intensity in odd and even years are presented in the upper section of figure 18. It will be noted that in both cases fishing begins during the latter part of June and is generally concluded early in September. In even years more than 60 percent of the deliveries have been made before the first of August, the catches being largely taken from the coho populations feeding on the banks.

In the odd years a considerable number of catches are made throughout July, but the peak of the season is reached during the pink run in the month of August. Fishing terminates rather abruptly thereafter, the bulk of the vessels moving to the inside waters.

RELATION OF FISHING INTENSITY TO SEASONAL OCCURRENCE

Both seasonal occurrence and fishing intensity determine the proportion of the annual catch made at different intervals in the season. In order to portray the seasonal distribution of the catch, the percentage taken in each 7-day period was calculated, for vessels of 10–39 net tons, for each year from 1916–34. The years 1920 and 1930 were omitted for reasons previously explained. The average percentages, by 7-day periods, were calculated for both odd and even years.

These weekly percentages differ from the previously calculated figures for fishing intensity in that they show the relative number of fish caught during uniform parts of the season, whereas the intensity figures represent the fishing effort during similar periods.

Since it is also important to know the contribution of the individual species, their proportionate representation in the weekly catches of each year from 1916–34 were calculated and the average weekly proportions for odd and even years determined.

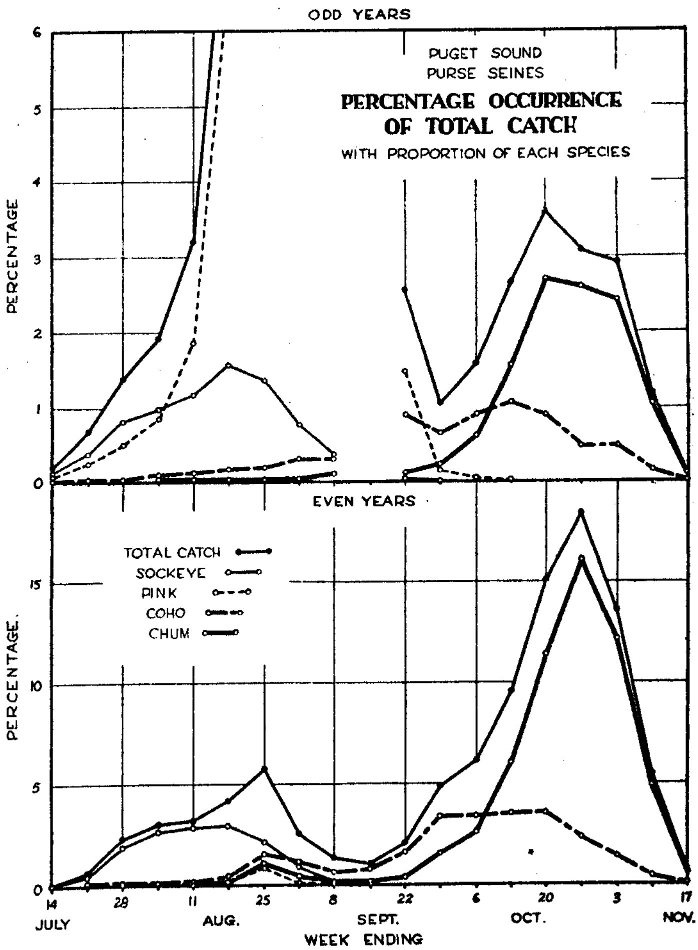

FIGURE 19.—Seasonal distribution of the catch of Puget Sound purse seines and the proportional contribution of the various species. The striking difference of the importance of the summer and fall fisheries in odd and even years is readily apparent.

Corrections were made for closed periods in a manner similar to that described in the calculation of seasonal fishing intensity. The average proportion of the catch taken by weeks, and the average representation of the individual species are presented, for both odd and even years, in table 20 and in figure 19.

TABLE 20.—*Average proportion of each species in the weekly catch of Puget Sound purse seines and percentage occurrence of total catch, 1916–34*

Week ending—	Sockeye	Pink	Coho	Chum	King	Percentage total catch
	Odd years					
July 7	71.766	19.500	7.018	0.577	1.140	0.091
July 14	56.546	34.241	5.767	1.761	1.685	.196
July 21	57.659	37.819	3.069	.250	1.203	.674
July 28	58.108	35.618	3.165	1.833	1.275	1.390
Aug. 4	59.657	44.138	4.082	.163	.960	1.918
Aug. 11	36.438	58.393	3.767	.450	.953	3.187
Aug. 18	19.450	77.595	2.132	.149	.675	8.007
Aug. 25	6.588	92.098	.965	.091	.258	20.568
Sept. 1	2.790	95.650	1.116	.119	.324	27.791
Sept. 8	2.013	95.096	1.769	.650	.472	17.446
Sept. 15 [1]	----	----	----	----	----	----
Sept. 22	1.673	58.246	35.109	4.540	.432	2.548
Sept. 29	1.142	14.147	62.718	21.447	.546	1.034
Oct. 6	.371	2.811	57.527	39.046	.245	1.580
Oct. 13	.138	.882	39.625	59.077	.278	2.631
Oct. 20	.002	.076	24.294	75.298	.329	3.608
Oct. 27	----	.054	15.315	84.447	.184	3.081
Nov. 3	.006	1.179	16.236	82.408	.172	2.931
Nov. 10	----	.721	11.909	87.219	.151	1.191
Nov. 17	----	----	6.210	93.440	.349	.102
Nov. 24	----	----	11.584	88.331	.085	.026
	Even years [2]					
July 7	78.415	1.453	19.094	----	2.038	.011
July 14	77.125	1.734	15.074	.328	5.739	.057
July 21	75.982	1.863	16.738	.288	5.388	.682
July 28	85.061	3.669	6.949	.028	4.264	2.289
Aug. 4	86.776	5.072	4.746	.082	3.324	3.070
Aug. 11	87.745	3.527	4.426	.181	4.121	3.197
Aug. 18	71.489	3.964	11.527	4.215	8.805	4.174
Aug. 25	37.173	13.813	26.204	17.536	5.274	5.753
Sept. 1	31.253	2.252	42.864	18.214	5.416	2.566
Sept. 8	13.785	1.251	56.441	22.021	6.503	1.316
Sept. 15	.217	1.410	75.811	20.243	2.319	1.035
Sept. 22	.296	.392	78.907	18.978	1.428	2.081
Sept. 29	.397	.072	67.506	31.576	.449	4.920
Oct. 6	1.086	.155	55.412	43.137	.209	6.114
Oct. 13	.002	.015	36.479	63.319	.184	9.529
Oct. 20	.033	.035	23.647	76.066	.219	15.052
Oct. 27	.011	.028	12.412	87.285	.265	18.367
Nov. 3	----	.010	9.996	89.816	.178	13.625
Nov. 10	----	.012	7.475	91.544	.970	5.423
Nov. 17	----	----	12.802	87.149	.049	.680
Nov. 24	----	----	2.807	97.126	.067	.058

[1] Omitted because of closed period. [2] 1920 and 1930 omitted.

The curves for even years are presented in the lower section of the figure, and those for odd years in the upper section. The curves for kings were omitted, since the highest point in any one week in even years was less than 0.4 percent, and in odd years was less than 0.1 percent. The scale for odd years was increased so that the proportion of the run afforded by all species other than pinks should be equal in odd- and even-numbered years. Because of the extreme peak the odd-year curve was truncated, hence the percentage occurrence of the total catch and the proportion represented by pink salmon are not shown for the weeks from August 18 to September 8. These curves vary most from those of fishing effort in the more extreme differences between the summer and fall fisheries. It is evident that the number of fish per delivery is much greater during the height of the run of pink salmon in odd years and during that of chum salmon in even years.

It is apparent that the late summer fishing for pink salmon in odd years in the northern districts of the sound has caused some extension of sockeye catches, and this is further demonstrated by the absence of chum salmon in the catches. In even years, although the summer fishery begins to decline much earlier, such vessels as are fishing are operating in districts where the early chum runs are found, and increased catches of chums appear more than a month earlier than in odd years.

The predominance of chum salmon in the fall fishery of even years indicates a greater effort to take this species when the lack of pink salmon has resulted in a poor season for the seiners. The peak of the fall fishery is reached during the week ending October 27. In odd years the peak of the total catch is reached a week earlier, shortly after the coho run has reached its maximum, and the curve begins to decline while chums are still abundant.

RELATIVE IMPORTANCE OF EACH SPECIES

PUGET SOUND

The sum of the Puget Sound purse-seine catches from 1917–34 was 64,978,888 salmon, of which 37,559,326 were pink salmon, 12,653,382 were chum salmon, 9,121,238 were sockeye, 5,383,438 were coho, and 261,504 were king salmon. Large and small runs of pink salmon appear in alternate years. In years of abundance, odd years, they have averaged over 4 million fish a year and have provided approximately 75 percent of the catch, in the even years they have averaged little more than 6,000 a year and have furnished less than 1 percent of the catch. Their average for all years is 37.44 percent (see table 21).

The average chum-salmon catch over 18 years has been approximately 700,000 fish per year. Seven of the 9 even-year totals are considerably above this figure, reflecting the more intense even-year fishery. During this period the average proportion of chums in the annual catches was 32.07 percent.

Although over 9 million sockeyes have been taken during this period, nearly 6 million were caught during only 3 years; almost 2 million in 1917, nearly 2¼ million in 1930, and over 1¼ million in 1934. The remaining 15 years averaged approximately 226,000 fish. The annual average for sockeyes was 15.63 percent over the 18-year period.

The catches of coho salmon show smaller fluctuations than do those of the above species; their average has been approximately 300,000 fish per year during this period. They averaged 14.16 percent of the annual catches.

King salmon are a negligible factor in the purse-seine catches, averaging less than 15,000 fish per year. This species has provided an average of only 0.7 percent of the total catches during the 18-year period.

TABLE 21.—*Proportion of various species in total annual catches of Puget Sound purse seines, 1917–34*

Year	Sockeye	King	Pink	Coho	Chum	Total catch [1]
1917	14.31	0.29	62.99	3.71	18.70	11,804,026
1918	2.35	2.13	.26	32.35	62.91	1,376,757
1919	4.10	.93	47.25	10.64	37.08	4,349,421
1920	3.05	.66	.03	22.82	73.44	775,421
1921	5.06	.39	78.18	11.86	4.51	3,079,015
1922	9.88	.79	.43	45.51	43.39	875,233
1923	4.39	.12	82.10	4.80	8.59	4,042,288
1924	10.35	.52	1.11	17.91	70.10	1,127,020
1925	3.32	.21	83.85	5.38	7.25	5,656,515
1926	13.69	.47	.36	28.33	57.15	1,168,848
1927	11.12	.43	78.64	5.04	4.76	4,549,007
1928	6.65	2.08	1.53	27.06	62.68	1,164,682
1929	6.79	.21	72.72	4.19	16.09	6,359,144
1930	81.24	.61	.80	4.25	13.10	3,567,442
1931	5.28	.39	81.44	4.23	8.66	5,468,739
1932	24.43	1.32	.36	17.40	56.49	1,716,772
1933	9.93	.34	81.64	2.77	5.32	5,531,318
1934	65.43	.61	.30	6.61	27.05	2,367,240
Average	15.63	.70	37.44	14.16	32.07	-------------

[1] Total catch of all species in numbers of fish.

Although approximately 58 percent of the total number of fish caught during this period have been pink salmon, they have been abundant only in odd-numbered years. In the alternate years chums have provided approximately half the catch, with cohos and sockeye next in importance.

CAPE FLATTERY

The contributions of various species to the purse-seine catch at the cape differ considerably from those on Puget Sound. Records are not available for the numbers of seine-caught fish taken at the cape before the period from 1927–34, during which 14,166,769 salmon were caught. Of these, 10,395,194 were pink salmon, 2,305,290 were cohoes, 1,348,553 were sockeye, 69,433 were kings, and 48,299 were chums.

Pink salmon have averaged 84.56 percent of the catch in odd years and 8.53 percent in even years. Their average for all years is 46.54 percent. During the period for which accurate figures are available, more than 73 percent of the total number of fish landed at the cape have been pink salmon (see table 22).

TABLE 22.—*Proportion of each species in the total annual catches of Cape Flattery purse seines, 1927–34*

Year	Sockeye	Pink	Coho	Chum	King	Total catch [1]
1927	2.10	89.66	7.92	0.03	0.29	2,382,838
1928	6.81	23.73	67.48	.57	1.40	290,222
1929	2.60	85.96	11.01	.07	.35	3,924,375
1930	23.49	6.85	66.33	1.89	1.43	614,170
1931	4.97	89.37	5.16	.17	.32	4,367,412
1932	5.44	1.66	87.60	3.38	1.92	359,900
1933	10.50	73.25	15.15	.71	.40	1,153,429
1934	62.80	1.87	34.01	.35	.98	1,074,423
Average	14.84	46.54	36.83	.90	.89	-------------

[1] Total catch of all species in number of fish.

Coho salmon are next in importance, furnishing the greater part of the early-season catch in all years. During the even years they averaged 63.86 percent of the catch, and during the odd years, 9.81 percent. Their all-year average is 36.83 percent.

The sockeyes show the same heavy catches in 1930 and 1934 noted in the Puget Sound fishery, providing 23.49 percent and 62.80 percent of the catch, respectively. Their average for the even years is 24.64 percent, for the odd years 5.04 percent, and over the 8-year period 14.84 percent.

King salmon, although taken throughout the season, provide only a very small proportion of the cape landings. The catch figures are somewhat reduced, however, by the practice of buying small kings as pink salmon, and occasionally as cohoes. The average in the even years is 1.43 percent, in odd years 0.34 percent, and over the 8-year period was 0.89 percent.

Chum salmon are caught infrequently in the offshore waters. Their average is 1.55 percent in even years, 0.25 percent in odd years, and was 0.90 percent over the 8-year period.

THE TROLL FISHERY

By George B. Kelez

Fishing with hook and line was engaged in by natives of the region long before commercial salmon fishing began, but this gear never became of significance until the introduction of power boats. As was true of the purse seine, little change has taken place in the gear itself, whereas a considerable improvement has been made in the boats from which it is fished. Although individuals of all five species of salmon are landed occasionally, only the coho and king salmon are readily taken by trolling.

The early Indian gear consisted of lines twisted from bark or animal sinews, a stone weight, and a hook of bone or of wood with a bone point. Although "spoons" (lures) of shell were in use, the principal Indian fishery was with baited hooks, herring being chiefly used for this purpose. According to Rathbun (1899) the fishing season at Neah Bay was during the months of June, July, and August.

Another interesting but little-known type of native gear, which developed from the trolling line, is shown in fig. 20. It consists essentially of a bladder float to which is attached a line of twisted sinew suspending a stone weight. A second line is fastened to the weight, and the free end is attached to a shank of whalebone bearing a double hook of bone lashed with bark. As many as thirty of these units were attached together, each hook was baited with a whole herring, and the string was drifted from a canoe. Both types of gear were fished close to the surface, and the principal catch was coho salmon, preferred by the natives because of its suitability for drying.

DEVELOPMENT OF THE FISHERY

For many years commercial trolling was of little importance. Collins (1892) did not include it among the commercial fishing methods listed for the region, but stated:

> The Indians employ trolling hooks and spears in the Sound and small streams tributary thereto, and parties fishing for pleasure also use spoon hooks and trolling lines. Also, the Indians at Neah Bay use trolling lines, and in 1888 took 7,000 pounds of salmon valued at $140. A much larger catch could, no doubt, be made at this place. . . .

Rathbun (1899) included trolling gear among commercial methods, but stated that its use was restricted both as to locality and number of men employed, and that it was still chiefly fished by Indians. The principal catch was king and coho salmon. Kings were fished from November to February, and sometimes to April, in the Gulf of Georgia, both in the region of Nanaimo and off the mouth of the Fraser River (see fig. 2). They were also taken in the vicinity of Victoria, in the San Juan Islands, off Port Townsend, in the upper part of Admiralty Inlet, and in Hood Canal. Cohos were taken in smaller numbers, although good catches were made in Boundary Bay and in the waters of lower Puget Sound. Rathbun also stated that the catch of trolling gear was much less than that of the gill nets in the region. Fishing was conducted from canoes or skiffs, and by one or not more than two men to a boat. Spoons and hooks baited with herring were in general use.

The introduction of power, which had almost as great an effect on trolling as it did on fishing with purse seines, eliminated the rowing or paddling of the skiff or canoe, and thus greatly reduced the labor of fishing. The fishermen were now able to cover greater distances, were less subject to the force of the tides, and could attend to more lines. Larger, more able boats soon came into use, and the fishing area was extended over the entire inner waters of the region, while the size of the catch of the boats was increased remarkably.

By 1908 the trollers were fishing well out into the Strait of Juan de Fuca, and by 1911 they were operating on the open ocean in the vicinity of Cape Flattery. With the development of the offshore fishery, still larger boats appeared in the trolling fleet. These carried a small cabin which housed the engine and provided cramped quarters for the crew when at anchor.

Although the greater part of the trolling boats remained at some base, such as Neah Bay, and fished during the early hours of the day, the larger boats, which were of 30–35 feet in length, made trips of 2 or 3 days duration. These were designated as "overnight" boats, in contrast to the majority, which were "day" boats.

The gear fished by these boats now consisted of as many as six lines, often carrying from two to three spoons and hooks each. The lines were suspended from poles of varying lengths hung outboard over the sides of the boat, one pair usually at the bow and one amidships. Metal spoons were almost universally used, but herring bait was still favored by a few single-liners. The power gurdy, which was introduced in 1918, was a multiple reel, driven off the motor, by means of which the lines could be hauled in whenever a fish was hooked. This greatly increased the speed of handling the lines. Figure 21 illustrates the mounting of this device, together with the lead-in blocks by means of which the lines are brought from the poles to the gurdy reels. The fish hatch is forward of the gurdy, and the cockpit, from which the boat is steered and the lines handled while fishing, is immediately aft of it. With the exception of the adoption of the Diesel engine, giving greater cruising radius and more economical operation, there has been little further change to the present time.

IMPORTANCE

It is difficult to obtain accurate records as to the number of trollers operating in the region during most of the past years. Some of these boats fished entirely on the high seas and were not licensed by the State of Washington, while others roved from Monterey Bay in California to Southeastern Alaska, fishing for varying periods along the coast according to the abundance of the fish.

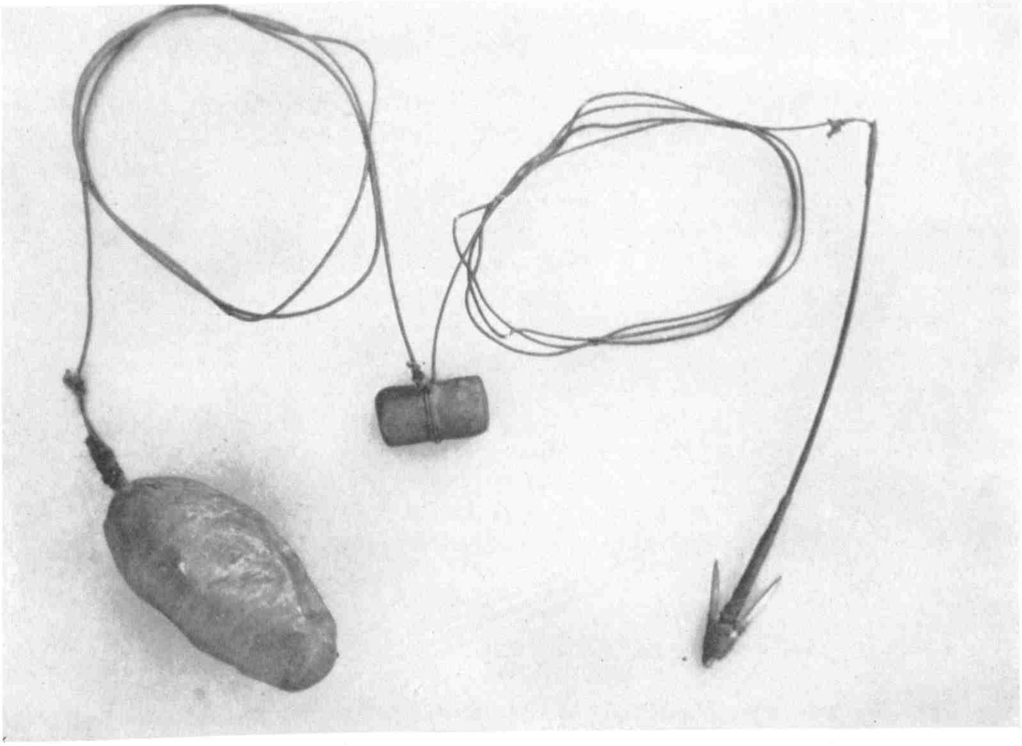

FIGURE 20.—Modified floating hook-and-line gear used for coho salmon by the natives at Neah Bay before white fishermen operated in that district. The bone hook was baited with a whole herring. From the collection of Captain T. E. Eggers.

FIGURE 21.—Stern view of trolling boat. Note the two hand-operated gurdies and the lead-in blocks directly over them and on both gunwales. The two main poles may be seen at the sides of the mast.

Records of licenses issued between 1917 and 1934 by the Department of Fisheries of the State of Washington for the Puget Sound district, which also embraces the territorial waters in the vicinity of Neah Bay, are presented in table 23. Boats fishing exclusively offshore did not have licenses prior to 1917 as none were issued. Gilbert (1913) reported 250 trollers in the cape region in 1911 and stated that this was an "unprecedented number." He estimated more than 400 there the following season. Smith and Kincaid (1920) reported more than 500 boats fishing at the cape in 1918.

We may assume that the fishery was of little importance prior to about 1910, and that the number of boats increased thereafter to a maximum in 1919, the last 3 years of this period being included in table 25. There was a marked decrease in licenses during the period of economic depression following 1921, and again in the similar period after 1931.

TABLE 23.—*Puget Sound trolling licenses, 1917–34*

Year	Number	Year	Number	Year	Number
1917	782	1923	221	1929	656
1918	982	1924	374	1930	784
1919	1,032	1925	438	1931	599
1920	611	1926	684	1932	259
1921	415	1927	820	1933	220
1922	165	1928	672	1934	478

During recent years practically all the boats have fished in the region of the cape, some as far as Forty-mile (La Perouse) Bank. A few of those fishing in Puget Sound operate in the San Juan Islands, but most of them fish the waters south and east of Point Wilson. A large fleet of Canadian trollers operates off the west coast of Vancouver Island, and a small fleet fishes in the upper part of the Gulf of Georgia for coho salmon. Some boats work off the southeastern part of Vancouver Island for kings.

The catches of the cape and Puget Sound fleets for recent years may be found in the sections on coho and king salmon. For the 8-year period from 1927–34, Puget Sound trollers took 104,692 cohos and 18,285 kings. During the same period, the cape fleet took 2,411,312 cohos and 1,545,178 kings. In addition, a few thousand pink salmon are taken at the cape in years of abundance, and occasional catches of the other species are made.

SEASONAL OCCURRENCE OF COHOS AND KINGS

Species other than coho or king appear so infrequently in trollers' catches that their occurrence may be disregarded. In the early part of the season kings are taken almost exclusively, but after the first of May both species appear in most of the catches. Seasonal occurrence is not so well defined in the troll catches as in other gear, for landings at any station, such as Neah Bay, may contain fish caught at a considerable distance from the landing point. In the early season the trollers fish longer, more heavily weighted lines, thus increasing their chance of taking the deeper-swimming king salmon. In the latter part of the season they fish closer to the surface in order to take cohos. Many fishermen shift during the fall from the plain metal spoons used in early summer for kings to ones which have been painted red on one side and which seem to be more efficacious for cohos. For these reasons the occurrence of the species in the troll catches do not reflect their relative runs as accurately as do those from less selective gear.

Catches were available for from 174–261 trolling vessels landing at Neah Bay during the years from 1922–28. Because of the extreme difficulty in identifying the boats, no attempt was made to treat their catches individually. For both kings and cohos the average daily delivery per boat during each week of the season was calculated for the individual years, and from these data the averages over the 7-year period were calculated. These were then determined as percentages throughout the season. The percentage occurrence of both species by weeks is presented in table 24.

TABLE 24.—*Seasonal occurrence in cape trolling gear*

Week ending—	Percentage occurrence		Cumulative percentage occurrence		Week ending—	Percentage occurrence		Cumulative percentage occurrence	
	King	Coho	King	Coho		King	Coho	King	Coho
Apr. 21	1.523	----------	1.523	----------	July 28	4.960	5.255	61.046	45.604
Apr. 28	3.600	----------	5.123	----------	Aug. 4	5.036	4.547	66.082	50.151
May 5	4.787	1.846	9.910	1.846	Aug. 11	4.494	5.212	70.576	55.363
May 12	3.320	.761	13.230	2.607	Aug. 18	4.846	6.585	75.422	61.948
May 19	2.905	2.867	16.135	5.474	Aug. 25	4.477	5.840	79.899	67.788
May 26	4.543	2.072	20.678	7.546	Sept. 1	2.932	4.608	82.831	72.396
June 2	6.519	3.139	27.197	10.685	Sept. 8	2.448	5.515	85.279	77.911
June 9	4.152	2.182	31.349	12.867	Sept. 15	4.304	6.227	89.583	84.138
June 16	3.669	3.186	35.018	16.053	Sept. 22	3.493	6.713	93.076	90.851
June 23	4.114	3.861	39.132	19.914	Sept. 29	3.882	3.427	96.958	94.278
June 30	3.347	4.717	42.479	24.631	Oct. 6	2.046	2.450	99.004	96.728
July 7	4.184	3.813	46.663	28.444	Oct. 13	.949	2.038	99.953	98.766
July 14	4.859	5.520	51.522	33.964	Oct. 20	.047	.740	100.000	99.506
July 21	4.564	6.385	56.086	40.349	Oct. 27	----------	.494	----------	100.000

There is a short period of heavy catches of king salmon in early May, followed by the main period of occurrence lasting from June to the latter part of August. There is a third small run in the latter part of September which decreases immediately after the first week in October. The coho catches build up slowly during a period of about two months prior to the middle of July, remain, with some fluctuations, at that level until the third week in September, and decrease thereafter to the last week in October.

A comparison of the cumulative percentage occurrence figures from trolling gear (see table 24) with those for cohos and kings in cape purse seines (see table 18) indicates some of the differences in these two fisheries. The first troll-caught kings are taken in the week of April 15–21, 25 percent of the catch is made by the end of May, 50 percent by July 14, 75 percent by August 18, and 100 percent by October 20. Seine-caught kings do not appear before the middle of June, 25 percent are taken by July 14, 50 percent by August 6, 75 percent by August 22, and 100 percent by September 15. The trollers will have been operating for about two months before the seiners begin, and slightly more than 50 percent of the troll catch has been made by the time that 25 percent of the seine fish are landed. The two curves cross during the latter part of August, and the seine season is over before 90 percent of the troll-caught fish are landed.

Trollers begin landing cohos about the first of May, 25 percent of the catch is taken by the first of July, 50 percent during the first week in August, 75 percent by the first week in September, and the season ends during the latter part of October. The seiners begin fishing cohos about the middle of June, and 25 percent of the catch is made by July 4, 50 percent by August 3, 75 percent by September 4, and 100 percent by the first week in October.

It will be noted that the differences in time of the king catches are due mainly to the length of season fished, and that there is little similarity in the time of the 25th percentiles. In the case of cohos, however, the 25th, 50th, and 75th percentiles of both types of gear coincide. The heavy catches of immature cohos by the seiners allow them to take the first quarter of their catch in some two weeks; the trollers require approximately two months to take 25 percent of their catch, since they are fishing primarily for king salmon during the early part of the season. During the remainder of the coho run, the curves of both types of gear are very similar.

SPORT FISHING

King and coho salmon have provided popular sport fishing in the region for many years. With the exception of fly-fishing in a few restricted localities, this fishery has been carried on entirely by trolling, or by modifications of this gear, hence catches of other species of salmon are rare.

Collins (1892) referred to trolling for salmon as a recreation, saying:

> In autumn, when salmon are most numerous in the Sound, Seattle Bay is literally covered with pleasure boats for days in succession.

Rathbun (1899) mentions sport trolling for king and coho, either with spoons or bait, and also refers to good fishing in the spring for king salmon in the pools of such rivers as the Nanaimo and Cowichan. At the present time the Campbell River is best known for fly-fishing for kings, and many cohos are taken by this method at the mouth of the Cowichan River.

Throughout the southern part of the region the greater part of the spring and summer king-salmon catches, and a considerable number of coho catches, are made with "spinning" gear. This is a highly specialized development of trolling, and consists of fishing from an anchored boat with a rod, light line, and small hook. The bait is a spinner which is usually cut from fresh herring. In use, the line is cast from the boat, allowed to sink almost to the bottom, and then recovered by drawing it in with successive pulls, allowing the recovered line to coil in the bottom of the boat. The largest kings are landed in a few favorable places by trolling with "plugs" somewhat similar to those used in bass fishing.

The bulk of the sport catches on the sound consist of coho salmon, and these are most frequently taken by trolling with spoons, although many fishermen use cut herring or candlefish. Mature cohos are taken in the fall on copper spoons which are nickelplated on one side.

Although sportsmen fish in nearly all the inner waters of the region and as far out in the Strait of Juan de Fuca as Port Angeles and Victoria, the most heavily fished waters are in the region of Whidbey Island and the lower part of Puget Sound. Many resorts located in this region have 50 or more boats available for rental, and several thousand sportsmen fish from early spring to fall. Fishing is conducted in places such as Elliot Bay at Seattle throughout the entire year.

This sport has become increasingly popular in recent years, and the outfitting of fishermen, together with the rental of boats and sleeping quarters, may now be ranked as one of the fishing industries of the region.

SOCKEYE SALMON

By George A. Rounsefell

INTRODUCTION

The Fraser River, with its numerous tributary streams and chains of lakes, is potentially the best sockeye river in the world. Over a period of 24 years, six generations, from 1894–1917, it produced 195,740,000 sockeyes; an annual average of 8,160,000. The Kvichak River, flowing into Bristol Bay, ranked next, producing, during the same period, 155,330,000 sockeyes, an annual average of 6,470,000. The production of the Nushagak River, also flowing into Bristol Bay, was 78,010,000, with an annual average of 3,250,000. The river ranking fourth in North America was the Karluk, on Kodiak Island, with a production of 47,700,000 fish and an annual average of 1,990,000.

This comparison cannot be made over a longer period of time because in the earlier years none of these rivers were fished with sufficient intensity for the catch to be any measure of the size of the run, and in later years the Fraser River runs were so depleted by the blocking of the river at Hell's Gate in 1913 and 1914, and the intense fishing of the War years, that the catches have no longer given any measure of the productive capacity of the river.

From an annual average catch of 8,160,000 sockeyes for the 24-year period from 1894–1917, the production of the Fraser River, for the 17-year period from 1918–34, has fallen to an annual average of 1,830,000. The consequent annual loss to the fishermen of several millions of sockeye, through the failure of sufficient adult salmon to reach the spawning grounds, is a waste of the potential capacity of this great river. Such a waste of a natural resource, although less obvious, is just as real as the needless burning of thousands of acres of forest.

GENERAL LIFE HISTORY

SPAWNING

The sockeye, unlike the other four species of Pacific salmon in this region, rarely spawns elsewhere than in a tributary of a lake, or in gravel provided with spring seepage within a lake. Sockeyes spawn in one or another of the vast Fraser River lake systems from August until December, spawning, in general, being earlier in the Nechako River and Stuart-Trembleur-Takla lake systems and later below Hell's Gate and in the tributaries of the Thompson River, although a lake system may have both an early and a late run of sockeyes during the same season, forming two spawning peaks.

The fry, after absorption of the yolksac, wriggle free from the gravel, usually during the spring and summer months. Those that are hatched in the tributaries of the lakes find their way downstream into the lakes. In some localities a considerable portion of the adult run may occasionally spawn in the sluggish outlet stream of a lake. Whether or not the fry, upon hatching, ascend the slow-moving stream into the lake is not known, but it would appear probable that such may be the case.

Young sockeyes spend varying lengths of time in lakes before descending to the sea. In the Fraser River the majority of the young migrate in their second year.

From scale reading (Clemens, 1934) it appears that approximately 91 percent of the returning adults had left the lakes in their second year, 5 percent in their third year, and 4 percent in their first year. Foerster (1929b, 1934) shows that from the 1925 spawning at Cultus Lake, 6.2 percent of the migrants were in their first year (fry), 92.9 percent were in their second year (yearlings) and 0.9 percent were in their third year.

AGE AT MATURITY

The majority of the sockeyes of this region reach maturity and return from the ocean to their spawning grounds in their fourth summer. From 1920–33, inclusive, a period of 14 years, the ages of the sockeyes taken by the traps near Sooke, on Vancouver Island, (Clemens, 1934) have averaged as follows: 3-year-olds, 3.2 percent; 4-year-olds, 76.4 percent; 5-year-olds, 19.6 percent; and 6-year-olds, 0.6 percent. Since the proportion of the fish at each age varied considerably in different parts of the season, these figures are only an approximation of the number of fish at each age composing the catch, but they show the preponderance of 4-year-olds.

The cycle, or generation of sockeyes occurring quadrennially in the year following leap year (1909, 1913, 1917, etc.) was, as is shown below, tremendously abundant up to 1913, and fairly abundant in 1917, but much less abundant in 1921 and later years. Gilbert (1914) showed that the sockeyes running in 1913 were 99.5 percent 4-year-olds. In 1917 they were 94 percent 4-year-olds. In the past 4 years of this cycle (Clemens 1934) they have averaged but 77.4 percent 4-year-olds.

There is reason to believe that the change in the proportion of sockeyes 4 and 5 years of age is caused, at least in part, by changes in the proportion of the runs coming from different lake systems. This was pointed out by Gilbert (1917), who said that the runs to the various tributaries did not show the same proportions of 4- and 5-year-olds as did the samples of the run as a whole, the 5-year-olds being especially prominent in many localities below Hell's Gate.

During May and early June a run of sockeyes occurs that contains a large proportion of 5-year-old fish. This run is too small to be of any importance, as can readily be seen from the trap curve of seasonal occurrence (fig. 11), and is distinguished by the small size of the individuals, the lack of oil, and light-colored flesh. Since these fish lose most of their color in the canning process, they are usually sold as cohos.

Some of these very early sockeyes may be Skagit River fish, which are taken in late June along West Beach, but the larger part are probably bound for the Fraser River, as the traps in Rosario Strait, Lummi Island, Boundary Bay, and Point Roberts Areas all take them, and in about the same amount as the traps in the Salmon Banks and South Lopez Areas.

A third group of sockeyes that merit attention are the "grilse." These fish, usually males, have migrated to the ocean at the usual time, in the second year, but have matured precociously, returning after only 1 year in the sea, instead of the customary 2 years. On the years that preceded the former big years grilse were always numerous. Gilbert (1913, 1916) estimated them at 21.5 percent of the run in 1912, and 10 percent in 1916. The presence of these small sockeyes on such years was well-known to the cannerymen. On years preceding the off years the percentage of grilse in the run was quite small; very often negligible.

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SOCKEYE RIVERS OF THE REGION

OUTER COAST STREAMS

In order to determine whether or not one is justified in regarding practically all of the sockeyes caught on Swiftsure Bank, in Puget Sound, and in the Gulf of Georgia as originating in the Fraser River, it has seemed advisable to show the extent of the runs to other sockeye streams in the region and to discuss the probability of any of these sockeyes being included in the records as Fraser River fish.

The largest run of sockeyes on the outer coast, immediately south of Puget Sound, is that of the Quinault River, which enters the ocean 65 miles south of Cape Flattery. The runs appear to fluctuate from about 50,000 to 500,000 sockeyes, as shown in table 25.

The Indians commence catching a few sockeyes at the mouth of the river as early as January, the bulk of the run reaching Quinault Lake between May 20 and July 7, and the mode occurring in the week ending June 9. In the 1922–24 runs, for which accurate weir counts by the Bureau of Fisheries are available, 77 percent had entered the lake by June 30. Of the remaining 23 percent there is reason to suppose that most of them were already in the river by this date, as fishing at the mouth of the river is usually practically over by July 1. The sockeyes run considerably later, however, on Swiftsure Bank, the seiners taking almost none before July 1 and the season not reaching its height until early in August.

TABLE 25.—*Quinault River sockeye (blueback) run, 1908–34*

Year	Pack in cases [1]	Actual catch	Escapement	Year	Pack in cases [1]	Actual catch	Escapement
1908	----	[2] 75,000	----	1921	2,590	----	[4] 20,000
1909	----	----	----	1922	19,213	265,649	248,935
1910	4,350	----	----	1923	10,454	138,148	174,602
1911	2,031	----	----	1924	8,473	104,571	136,774
1912	4,700	----	----	1925	3,313	54,000	19,395
1913	712	----	----	1926	1,729	----	----
1914	12,274	----	----	1927	5,260	----	----
1915	24,484	[3] 355,007	----	1928	2,000	----	----
1916	10,315	----	----	1929	4,449	----	----
1917	4,608	----	----	1930	21,536	----	----
1918	2,490	----	----	1931	8,476	----	----
1919	1,244	14,947	----	1932	14,263	----	----
1920	235	----	----	1933	6,754	----	----
				1934	4,960	----	----

[1] 1910–28 from Cobb (1930, pp. 559–560), 1929–35 from Pacific Fisherman.
[2] New York Sun, July 19, 1908. It also states: "This is 27,000 more fish than have ever been caught in any previous season."
[3] From Cobb (1930, p. 426).
[4] Only 11,786 counted, balance estimated.

The Ozette River (fig. 1) empties into the ocean 12 miles south of Cape Flattery. The Bureau of Fisheries placed a weir across this river in 1926, discovering that the run, which is nearly over by July 1, amounted to only a few thousand fish.

The Hobarton River empties into Nitinat Inlet, which reaches the ocean just north of the entrance to the Strait of Juan de Fuca. The Nitinat Inlet sockeye catch is given in the Fisheries Reports of the Dominion of Canada as follows: 12,000 in 1928, 20,130 in 1930, 16,487 in 1931, and 56,000 in 1932.

Barclay Sound, (fig. 1) a little farther to the north, has two runs of sockeyes, one ascending the Anderson River, which is 18 miles from Cape Beale, and the other the Somass River at the head of Alberni Canal, a northeasterly extension of Barclay Sound that cuts deeply into Vancouver Island.

The Anderson River spawning escapement has been estimated from 1925–34 in the Dominion Reports. The lowest escapement was 7,500 in 1933, the highest 135,000 in 1929, with an average for the 9 years of 55,000 sockeyes. In the only 2 years for which figures are given, 1928 and 1932, the catch was 15,000 and 28,000 respectively. The total annual run may therefore be considered as approximately 75,000.

The run to the Somass River appears to be larger. The Stamp River falls were formerly difficult for sockeye to ascend, most of the run to the Somass River spawning in Sproat Lake. In 1927, a permanent fishway was constructed, so that the run now spawns in Sproat Lake, Great Central Lake and Ash Lakes; all of considerable extent. The Reports of the Dominion give the catch of Somass River sockeyes as 24,000 in 1928, 47,860 in 1930, 77,000 in 1932, 60,000 in 1933, and 75,000 in 1934. The escapement is unknown but, if we assume it was 50 percent, the run since 1932 has been close to 150,000.

The annual run then to Barclay Sound appears to total in the neighborhood of 225,000 sockeyes. That a few of these fish may be captured on Swiftsure Bank is not impossible and it is unlikely that this can be adequately determined until such time as sockeyes are tagged on the bank.

PUGET SOUND STREAMS

The Skagit River, the only sockeye stream in the Puget Sound area, is no longer an important producer of sockeye salmon although it once supported a fair run. The Baker Lake sockeye hatchery, built in 1896 by the State of Washington on the Baker River, tributary to the Skagit, was bought by the Bureau of Fisheries in 1899 and has operated continuously since. The records of this station previous to 1916 were burned, but the remainder have been available.

The annual escapement to Baker River from 1898–1901 was estimated at 20,000 sockeyes. Within a few years the run had become somewhat reduced, and by 1916 the escapement was about 5,000 sockeyes per year. The escapement of 14,558 in 1924 was due to the closing of the salmon traps in the waters east of Whidbey Island during that season. The building of the Baker River dam destroyed all but 40 fish of the 1925 run, but since then the greater portion of those reaching the dam has been caught and hoisted over.

This small run of sockeyes is distinguished from that of the Fraser River by the season of its migration. The traps east of Whidbey Island, which catch only Skagit River sockeye, commence taking them by the first of June. The run, which reaches its peak during the last week in June or occasionally the first week in July, and is practically over by July 20, averages about a month earlier than that to the Fraser River. The traps on West Beach usually show two modes in their sockeye catches; a small early mode due to Skagit River fish and a later one when the bulk of the Fraser River sockeyes are migrating.

GULF OF GEORGIA STREAMS

The only sockeye stream in the Gulf of Georgia proper is Saginaw Creek (see fig. 1). The 1926 catch, mentioned as being very small, was reported as 3,000 sockeyes, while the escapement was estimated as between 18,000 and 19,000 fish.

Just north of the Gulf of Georgia proper, there are small runs of sockeyes to several streams, the chief being the run to Phillips Arm, which is practically over before the run of Fraser River fish makes its appearance.

MIGRATION IN SALT WATER

Tagging experiments (O'Malley and Rich, 1919) have shown that the sockeyes entering through the Strait of Juan de Fuca strike the Salmon Banks and pass along the southern shore of San Juan and Lopez Islands, and, to a slight extent, the western shore of Whidbey Island, thence past Lummi Island, Whitehorn Point, Boundary Bay and Point Roberts to the mouth of the Fraser River. A few migrate north through Haro Strait

Another tagging experiment (Dominion Report for 1929–30, p. 155; 1930), indicates that the run of sockeyes which enters the northern end of the Gulf of Georgia through Discovery Passage is bound chiefly for the Fraser River. Out of 519 sockeyes tagged at Deepwater Bay in Discovery Passage, 107 were recaptured. The 17 recaptured at the point of tagging must be disregarded. Out of the remaining 90 a total of 82 fish, or 91 percent, were recaptured either in the Fraser River or at Point Grey (7 fish) just at the mouth of the river.

TOTAL PACK OF THE FRASER RIVER SYSTEM

The first real sockeye cannery was built at New Westminster in 1866 but no pack records are available for the first 7 years of the industry. The pack of 1873 was 8,125 cases (Rathbun 1899). The packs of 1874 and 1875 are unknown, but figures are available since 1876. The annual sockeye packs of the Fraser River system are given in table 26.[5]

The Canadian fishery is much older than the American, reaching 100,000 cases by 1878 and 300,000 cases by the big sockeye year of 1889. By 1896 the Canadians had packed a total of 3,209,000 cases against 254,000 cases by the American operators. However, the introduction of traps in the early 1890's gave a great impetus to the industry in Puget Sound. From 1898–1934, a 37-year period, the Canadian pack was larger than the American in only 6 years: 1903, 1905, 1906, 1915, 1922, and 1926.

Up to the end of 1934 the packs of both countries aggregated the amazing sum of 21½ million cases of sockeye, of which the Canadians had packed 10,773,000 cases, the Americans, 10,721,000 cases.

[5] In compiling these data several sources have been used: The Dominion of Canada reports (1882–1934), the reports of the British Columbia Commissioner of Fisheries (1901–34), the Washington State reports (1890–1934), the Pacific Fisherman annual numbers (1903–34) and reports by the U. S. Bureau of Fisheries in various years from 1893 to 1934; as well as much unpublished material including printed tabulations of the pack by companies, prepared by R. P. Rithet & Co., Ltd., Victoria, B. C. for 1900; Fraser River Canner's Association (1904–8); British Columbia Salmon Canners Association, and since 1923 by the canned salmon section of the Canadian Manufacturers' Association. Material for recent years has been supplied by the Office of the Chief Supervisor of Fisheries for British Columbia and by the State of Washington Fisheries Department. In the earlier years the published reports of the packs are not segregated according to species and for these years we have made use of very extensive and careful notes kept by Henry Doyle of Vancouver, B. C. In addition, original records of various operators have been available.

TABLE 26.—*Sockeye pack of Fraser River system, in 48-pound cases*

Year	Cases canned			Year	Cases canned		
	Fraser River [1]	Puget Sound [2]	Total		Fraser River [1]	Puget Sound [2]	Total
1873	8,125	------	8,125	1906	185,440	182,241	367,681
1876	9,847	------	9,847	1907	65,061	96,974	162,035
1877	64,387	------	64,387	1908	79,211	170,951	250,162
1878	100,000	------	100,000	1909	585,935	1,102,399	1,688,334
1879	50,000	------	50,000	1910	151,595	248,041	399,636
1880	25,000	------	25,000	1911	64,470	127,761	192,231
1881	142,516	------	142,516	1912	124,967	184,680	309,647
1882	175,000	------	175,000	1913	739,601	1,673,099	2,412,700
1883	100,000	------	100,000	1914	201,498	335,230	536,728
1884	25,000	------	25,000	1915	95,407	64,584	159,991
1885	89,617	------	89,617	1916	35,070	84,637	119,707
1886	36,000	------	36,000	1917	154,415	411,538	565,953
1887	125,000	------	125,000	1918	21,598	50,723	72,321
1888	40,000	------	40,000	1919	38,854	64,346	103,200
1889	303,875	------	303,875	1920	49,184	62,654	111,838
1890	225,000	------	225,000	1921	41,731	102,967	144,698
1891	131,000	12,000	143,000	1922	54,829	48,566	103,395
1892	59,000	15,000	74,000	1923	34,574	47,402	81,976
1893	455,000	47,852	502,852	1924	39,732	69,369	109,101
1894	360,000	41,300	401,300	1925	36,954	112,023	148,977
1895	360,000	65,143	425,143	1926	86,765	44,673	131,438
1896	325,000	72,979	397,979	1927	65,154	97,594	162,748
1897	850,000	312,048	1,162,048	1928	30,128	61,044	91,172
1898	216,000	252,000	468,000	1929	60,823	111,898	172,721
1899	486,409	512,500	998,909	1930	103,662	352,194	455,856
1900	172,617	229,800	402,417	1931	40,947	87,211	128,158
1901	974,911	1,106,643	2,081,554	1932	69,792	81,188	150,980
1902	295,679	372,301	667,980	1933	54,146	128,518	182,664
1903	204,848	167,211	372,059	1934	139,276	349,602	488,878
1904	73,175	123,419	196,594				
1905	838,813	837,122	1,675,935	Grand total	10,772,638	10,721,425	21,494,063

[1] Includes packs at Victoria, Quathiaski, and points in the Gulf of Georgia. Quathiaski packs not available for 1931 and 1934.
[2] Includes 4,495 cases packed at Grays Harbor and the Columbia River in 1909 (see Cobb, 1930).

Some idea of the former abundance of the sockeyes can be gained by noting that in 4 years of the former big-year cycle the pack was in excess of 1,675,000 cases, and, in 1901 and 1913, it was over 2,000,000 cases.

METHOD AND LOCALITY OF CAPTURE

INDIAN FISHING IN THE FRASER

The Indians fishing in the Fraser River, except commercially, have depended largely on dip nets, gaffs, set nets, and spears. Dip nets are used chiefly in the larger rivers at points where the salmon have difficulty in ascending, such as Hell's Gate canyon; the canyon of the Fraser just above the mouth of Bridge River; Fish Canyon, Hanceville and Indian Bridge on the Chilcotin River, and at Fort George on the Nechako River above its confluence with the Fraser River (fig. 25). The fishing at both Hell's Gate and Bridge River canyons is much more successful during seasons of low water when the salmon have greater difficulty in passing. Set nets are used but slightly, not being practical in swift water. Spears are for use in the smaller tributaries, especially on the spawning grounds. Gaffs are mentioned in the 1917 report of the B. C. Commissioner of Fisheries as being used, along with dip nets, at Bridge River canyon.

At one time the salmon were also taken by barricading the streams. The fishing in the streams near Stuart Lake in 1830 is thus described by John McLean (Wallace, 1932) who says that the natives built weirs of stakes and brush and caught the salmon in wicker baskets as they swam through openings in the weirs.

In addition to catching the adult salmon the Indians formerly caught large quantities of the young sockeyes on their migration from the lakes to the sea. John P. Babcock (Report of the Fisheries Commissioner for British Columbia for the year 1903) describes how the Indians had built a dam of rocks and brush across a stream in the form of a great funnel with a basket trap at the lower end. Besides those caught in the trap many thousands were destroyed by becoming entangled in the brush.

EXTENT OF THE INDIAN FISHERY

Salmon fishing on the Fraser River was always carried on by the Indians, who consumed large quantities of fresh salmon and dried larger quantities for their own use and for barter with the tribes of the hinterland. Those living near the mouth of the river obtained some of all species of salmon, but the Indians dwelling nearer the headwaters depended chiefly on sockeye, and a few king salmon. The extent of this fishing is rather difficult to determine. At some points, such as Bridge River, Kamloops, Stuart Lake, Hell's Gate, Pemberton, and the Chilcotin River, large catches were made in good years (see fig. 25).

Fishery officials have made many estimates of the Indian catch at the chief fishing camps by counting the numbers of salmon on the drying racks. According to their reports the sockeye catch at Bridge River in big years averaged 40,000. For the Chilcotin River system the catches of 1905 and 1909 were also estimated at 40,000, the catch of 1908 at over 20,000, and that of 1913 at 25,000. Of the Lillooet River, Crawford (13th Annual Report of the State Fish Commissioner (Washington) 1902) says:

> Every year the Indians gather here to secure their salmon for the winter and thousands of sockeyes are taken and dried every season. One Indian speared seventy sockeyes in two hours, the first day I was there.

A toll of between 400,000 and 500,000 sockeyes in the former big years is a conservative estimate of the Indian catch. Even as late as 1929, with a greatly reduced abundance, as well as a much smaller Indian population, an accurate estimate showed that they caught 48,000 sockeyes, 20,000 kings, 25,000 cohos, 4,500 pinks, and 6,500 chums (Dominion Report, 1930). During years of poor sockeye runs the Indians living on tributaries where the runs failed were often on the verge of starvation, so complete was their dependence on the salmon for their livelihood. This was the case at Stuart Lake in 1841 and at Alexandria, on the Fraser River between the mouths of the Chilcotin and the Quesnel Rivers, in 1855 (Morice, 1904).

CATCH BY COMMERCIAL GEAR

In determining the number of sockeyes captured by the various methods in the different localities, the records of the actual number of sockeyes taken have been used wherever possible, and where these have not been available the number of cases canned has been converted into number of fish.[6]

[6] The number of sockeyes required to fill a 48-pound case of cans varies considerably from year to year, so that the use of the same conversion factor year after year would not give the best results. From two Canadian and two United States canneries we have obtained records covering 23 years, of the number of sockeyes required to fill a case. This varies from about 10 to 13 fish per case, tending to be higher in the earlier years, especially on the years of the big run. For years in which no conversion data were available we have used the average conversion factor of the other years of the same 4-year cycle, as the size tends to be the same from one cycle to the next. This is probably on account of the differences in size of the sockeyes spawning in the different lake systems, as the various lakes do not contribute equally to the runs of each cycle.

Table 27 shows the annual catch by the principal forms of gear. The total commercial take of sockeye from 1873–1934 comes to 253½ million, of which 116½ million, or 46 percent, have been caught by gill nets in, or off the mouth of the Fraser River. The traps, both Canadian and American, account for 94 million, or 37 percent, and of the remaining 17 percent, 14 percent were taken by purse seines and 3 percent by miscellaneous gear. The miscellaneous included most of the fish caught at Quathiaski, as well as fish taken by minor Puget Sound gear such as gill nets, set nets, drag seines, and reef nets. Approximately 5 million of the trap fish and one-half million of the purse seine fish were taken by Canadian gear, so that, if the miscellaneous gear is ignored, the catches total 122 million by Canadian gear and 124 million by United States gear.

The slight difference in pack in favor of the Canadians was due largely to shipments of fresh sockeye from Puget Sound waters to the canneries on the Fraser River, outweighing shipments in the other direction. In the early days the canning facilities on Puget Sound were too limited to handle the catch, and the Fraser River canneries were much closer to the sockeye fishing grounds. In 1894 the Canadians placed an embargo on the shipment of fresh sockeye out of the Province. This embargo, however, was not always in effect. In 1905, for instance, over 2 million pounds of late-run sockeyes were shipped from the Fraser River to Puget Sound canneries.

TABLE 27.—*Sockeye catch of the Fraser River system by various types of gear*

Year	Fraser River gill nets	Purse seines		Traps	Miscellaneous gear	Total
		Territorial waters	High seas [1]			
1873	100,839					100,839
1874	(?)					(?)
1875	(?)					(?)
1876	107,332					107,332
1877	799,107					799,107
1878	1,077,000					1,077,000
1879	571,350					571,350
1880	272,500					272,500
1881	1,768,766					1,768,766
1882	1,884,750					1,884,750
1883	1,142,700					1,142,700
1884	272,500					272,500
1885	1,112,257					1,112,257
1886	387,720					387,720
1887	1,428,375					1,428,375
1888	433,000				3,000	436,000
1889	3,651,393				120,000	3,771,393
1890	2,263,250				160,000	2,423,250
1891	1,296,937			[2] 344,000	[2] 200,000	1,840,937
1892	543,100			300,000	[2] 100,000	943,100
1893	5,397,005	[2] 100,000		371,356	[2] 372,535	6,240,896
1894	3,737,200	[2] 150,000		[2] 200,000	[2] 194,801	4,282,001
1895	4,033,720	6,002		903,852	207,183	5,150,757
1896	3,120,523	[2] 200,000		[2] 694,314	[2] 283,134	4,297,971
1897	9,959,350	[2] 600,000		[2] 3,128,486	[2] 734,342	14,422,178
1898	2,293,715	[2] 300,000		2,230,143	[2] 216,502	5,040,360
1899	4,514,385	804,681		5,610,418	438,759	11,368,243
1900	1,873,981	[2] 400,000		[2] 1,722,508	[2] 389,856	4,386,345
1901	11,792,692	[2] 1,000,000		[2] 12,457,957	[2] 509,382	25,760,031
1902	3,142,814	[2] 800,000		[2] 2,736,657	[2] 499,784	7,179,255
1903	2,338,987	[2] 400,000		[2] 1,252,012	[2] 261,620	4,252,619
1904	742,081	254,657		1,239,069	163,264	2,399,071
1905	10,143,517	[2] 1,374,745		[2] 8,662,974	[2] 500,000	20,681,236
1906	1,983,698	[2] 500,000		1,505,854	107,602	4,097,154
1907	584,033	[2] 200,000		[2] 903,807	[2] 33,729	1,721,569
1908	707,011	[2] 325,574		[2] 1,667,295	[2] 50,000	2,749,880

[1] High seas catch 1925–1934 from U. S. Fishery Industry reports, before that from our data, plus sockeye canned at Neah Bay. Some taken before our records.

[2] Estimated: From 1900 to 1912 the U. S. trap catch equals our data plus 20 percent, from 1896 to 1898 plus 50 percent, 1894 purely an estimate, and 1891 equals our data times 2.

TABLE 27.—*Sockeye catch of the Fraser River system by various types of gear*—Continued

Year	Fraser River gill nets	Purse seines		Traps	Miscellaneous gear	Total
		Territorial waters	High seas			
1909	4,869,134	3,484,799		12,026,263	546,278	20,926,474
1910	1,459,297	[2] 1,060,558		[2] 1,905,962	[2] 30,000	4,455,817
1911	659,496	[2] 392,300		[2] 1,101,837	[2] 25,000	2,178,633
1912	1,185,746	[2] 269,603		[2] 1,877,945	[2] 30,000	3,363,294
1913	8,761,249	10,049,295		12,493,687	38,808	31,343,039
1914	2,035,630	1,344,004		2,276,554	36,879	5,693,067
1915	1,050,672	244,693		456,542	73,556	1,825,463
1916	311,196	150,446		768,369	56,305	1,286,316
1917	1,402,327	1,989,191		3,292,193	199,690	6,883,401
1918	197,352	45,073	2,495	538,903	27,546	811,369
1919	368,395	286,365	25,365	539,618	29,125	1,248,868
1920	486,118	53,083	828	656,917	12,783	1,209,729
1921	433,852	221,152	35,820	915,313	80,104	1,686,241
1922	514,249	88,277	5,157	436,848	49,461	1,093,992
1923	300,115	142,355	5,717	370,874	37,892	856,953
1924	372,333	99,098	25,931	680,554	36,390	1,214,306
1925	397,386	287,329	142,224	975,252	26,525	1,828,716
1926	891,045	90,523	14,286	355,848	30,764	1,382,466
1927	648,254	435,693	50,000	586,944	62,596	1,783,487
1928	267,457	61,716	19,770	566,280	26,460	941,683
1929	605,170	368,155	102,134	926,939	56,780	2,059,178
1930	964,987	2,504,978	144,278	908,066	65,723	4,588,032
1931	450,532	316,141	217,015	444,366	5,585	1,433,639
1932	657,222	353,849	19,579	510,113	46,378	1,587,141
1933	546,026	541,505	121,061	1,198,887	42,957	2,450,436
1934	1,230,986	1,716,055	674,716	1,391,104	7,497	5,020,358
Total	116,543,814	34,011,888	1,606,376	94,132,880	7,226,576	253,521,533
Percent	46	13	1	37	3	100

[2] Estimated: From 1900 to 1912 the U. S. trap catch equals our data plus 20 percent, from 1896 to 1898 plus 50 percent, 1894 purely an estimate, and 1891 equals our data times 2.

LOCALITY OF TRAP CATCHES

In addition to the locality segregation given in the foregoing table, the following detailed analysis of the locality of capture of the trap fish shows the relative importance of each fishing district in Puget Sound. Since records were obtained for about 82 percent of all of the trap-caught sockeyes, 100 percent from 1915 to 1934, inclusive, the figures given in table 28 may be considered representative of all of the 94 million taken by this method.

LOCALITY OF PURSE-SEINE CATCHES

Of the 35½ million taken in purse seines, 1½ million are definitely assigned to extraterritorial waters off the mouth of the Strait of Juan de Fuca. The locality of capture of the remainder cannot be as easily established as in the case of those caught by traps. The principal sockeye seining grounds are the Salmon Banks and Point Roberts Areas, with lesser amounts from Rosario Strait, Haro Strait, Lummi Island, Birch Bay and Boundary Bay Areas, and a very few from West Beach.

Data from companies buying purse seine fish show that during the 4-year period covering a year of each sockeye cycle, from 1931–1934, about two-thirds of the seine-caught sockeyes were taken on the Salmon Banks. This includes the Salmon Bank and South Lopez Areas. Of the remainder the larger share were caught at Point Roberts, with lesser amounts from Rosario Strait, Lummi Island, and Haro Strait Areas.

TABLE 28.—*Sockeye catch by traps in different areas, 1893–1934* [1]

Year	Areas in which caught						
	North of Sandy Point [1]	Sandy Point to Deception Pass	West Beach and Ebeys Landing	Strait of Juan de Fuca [1]	East of Whidbey Island and south of Point Wilson	Undetermined	Total
1893	185, 678						185, 678
1894							
1895	600, 957						600, 957
1896	454, 831	8, 045					462, 876
1897	1, 904, 593	208, 191	2, 873				2, 115, 657
1898	1, 482, 549	15, 081					1, 497, 630
1899	3, 247, 248	832, 680					4, 079, 928
1900	1, 098, 886	324, 505	7, 148		6, 142		1, 436, 681
1901	7, 931, 801	1, 864, 905	21, 925		6, 411	595, 388	10, 420, 430
1902	1, 573, 961	687, 050	19, 907		4, 089		2, 285, 007
1903	775, 692	245, 923	22, 214				1, 043, 829
1904	728, 780	205, 141	5, 119	50, 000			989, 040
1905	5, 039, 241	1, 517, 262	238, 906	524, 535	2, 897		7, 322, 841
1906	832, 147	338, 049	20, 348	72, 357	4, 037		1, 266, 938
1907	455, 356	208, 059	27, 749	70, 822	2, 990		764, 976
1908	1, 004, 494	253, 066	22, 485	128, 218	2, 519		1, 410, 782
1909	5, 789, 782	2, 306, 825	212, 033	725, 736	1, 377		9, 035, 753
1910	991, 026	391, 156	21, 819	218, 461	2, 250		1, 624, 712
1911	572, 511	287, 167	6, 541	59, 212	2, 635		928, 066
1912	911, 978	488, 636	24, 118	164, 536	3, 109		1, 592, 377
1913	6, 011, 680	3, 080, 543	100, 027	881, 123	1, 350		10, 074, 723
1914	968, 885	683, 530	153, 991	171, 078	1, 213		1, 978, 697
1915	240, 670	149, 264	27, 572	26, 506	11, 046	1, 484	456, 542
1916	386, 446	278, 566	39, 765	55, 550	6, 581	1, 461	768, 369
1917	1, 584, 230	1, 091, 186	164, 683	437, 175	4, 197	10, 722	3, 292, 193
1918	220, 785	233, 426	33, 382	48, 312	2, 938	60	538, 903
1919	284, 714	142, 805	17, 136	86, 608	8, 331	24	539, 618
1920	307, 707	258, 877	34, 496	45, 416	9, 441	980	656, 917
1921	476, 128	347, 135	38, 713	46, 508	6, 208	621	915, 313
1922	220, 710	152, 200	24, 203	38, 393	1, 342		436, 848
1923	168, 851	161, 238	9, 115	28, 365	3, 305		370, 874
1924	382, 755	232, 610	17, 410	45, 933	1, 846		680, 554
1925	543, 310	338, 279	34, 279	52, 897	6, 594		975, 309
1926	192, 818	129, 592	6, 389	25, 324	1, 720	5	355, 848
1927	322, 282	203, 828	7, 853	51, 383	1, 598		586, 944
1928	308, 092	204, 315	18, 156	33, 812	1, 905		566, 280
1929	488, 018	328, 918	54, 851	46, 564	4, 062	4, 526	926, 939
1930	488, 386	323, 461	35, 503	58, 184	2, 532		908, 066
1931	206, 338	184, 492	18, 332	31, 150	4, 054		444, 366
1932	236, 248	202, 470	19, 716	48, 843	2, 836		510, 113
1933	510, 053	539, 848	25, 137	122, 349	1, 500		1, 198, 887
1934	821, 737	469, 463	27, 507	69, 751	2, 646		1, 391, 104
Total	50, 952, 364	19, 917, 787	1, 561, 401	4, 465, 101	125, 701	615, 271	77, 637, 615

[1] North of Sandy Point includes Canadian traps in Boundary Bay; the Strait of Juan de Fuca includes Canadian traps near Sooke and American traps west of Point Wilson. From 1915–34 our data include all trap-caught sockeye. All but portions of the Sooke data are actual numbers of fish, not converted figures.

During the late sockeye run of 1934, seining was permitted from September 1–8 in the portion of seining area 17 directly off of the mouth of the Fraser River, and 328,000 fish were taken. Small amounts of sockeyes are sometimes seined around Pender Island in seining area 18. In 1930 this area produced 31,000 sockeyes, in 1931, 3,000, and in 1934, 45,000.

CHANGES IN ABUNDANCE OF DIFFERENT PORTIONS OF THE RUN

The gill nets have been used as giving the best measure of the change in the time of the run. The average gill net delivery for each 7-day period was derived by combining the averages for each year and dividing by the number of years with data (see table 29).

The curves for the 12 early years, 3 sockeye cycles, and for the 12 late years are shown in figure 22. For the 12 early years sockeye fishing usually terminated on August 25, although considerable fishing was carried on during the heavy fall runs of 1905 and 1909. No data are available for the fall of 1905, but those for 1909 are shown in figure 22.

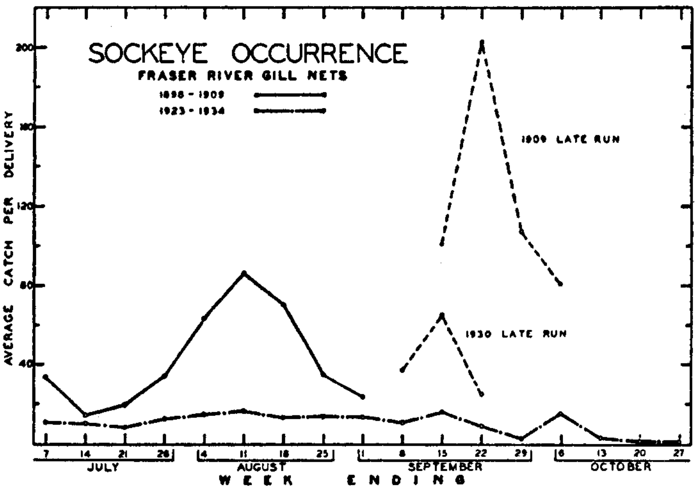

FIGURE 22.—Occurrence of sockeye as shown by Fraser River gill-net catches. Note the peak in the week ending August 11 in the three early cycles (1898–1909), which is entirely missing in the three late cycles. The late runs of 1909 and 1930 are also shown. The big years of 1901, 1905, 1909, and 1913 were characterized by a second heavy run coming late in the fall.

Because of the lack of fall fishing during most of the earlier years it is often thought that there were no abundant late runs in those years, but the figure shows plainly that the late run of 1909 was many times as abundant as that of 1930, the most abundant of the late runs during the last 12 years.

That some sockeye were ordinarily present in the river after the usual cessation of fishing on August 25, during the years before we have accurate records, is indicated by Rathbun (1899, p. 270) who says:

> . . . the average fishing season ends somewhere about the 20th to the 25th of August, and years are recalled when nothing could be done after the first week of that month. Small numbers usually continue present during more or less of the early part of September, but with the near approach of the spawning period the fish rapidly deteriorate in appearance and condition and lose their commercial value.

TABLE 29.—*Change in seasonal occurrence of sockeyes between early and late years in Fraser River gill nets*

Week ending	1898 to 1909		1923 to 1934	
	Number of years with data	Average catch per gill net delivery	Number of years with data	Average catch per gill net delivery
July 7	3	33.34	5	10.83
July 14	9	14.40	6	10.41
July 21	10	19.73	12	8.44
July 28	12	34.37	12	13.09
Aug. 4	12	63.31	12	15.15
Aug. 11	12	86.58	12	16.98
Aug. 18	12	70.13	12	14.06
Aug. 25	12	35.14	12	14.54
Sept. 1	4	23.41	12	14.17
Sept. 8	-------	----------	12	11.10
Sept. 15	1	101.52	12	16.60
Sept. 22	1	202.90	7	9.03
Sept. 29	1	107.32	4	3.09
Oct. 6	1	80.93	3	15.64
Oct. 13	-------	----------	3	2.77
Oct. 20	-------	----------	2	1.63
Oct. 27	-------	----------	2	1.44
Number of fish	-------	1,982,735	-------	1,469,746
Number catches	-------	30,706	-------	87,514

What has happened to the early runs is clearly shown by table 30, giving the average catches during the period from July 15–August 25, which embraces almost all of the period usually fished during the earlier years. The decrease in abundance is astounding, the average of 14.85 sockeye per delivery during the later years being but 24 percent of the earlier average. Even if the former big-year cycle is omitted from both periods, the deliveries in the later period are only 32 percent of the earlier.

TABLE 30.—*Average catch per gill net delivery of sockeye on the Fraser River*

Years	Number caught July 15 to Aug. 25, inclusive	Number of deliveries	Average delivery	Years	Number caught July 15 to Aug. 25, inclusive	Number of deliveries	Average delivery
1898	38, 636	1, 240	31. 16	1923	8, 823	783	11. 27
1899	76, 910	1, 201	64. 04	1924	18, 266	1, 018	17. 94
1900	38, 208	1, 172	32. 60	1925	17, 005	1, 183	14. 37
1901	186, 797	1, 345	138. 88	1926	22, 134	1, 172	18. 89
1902	45, 736	607	75. 35	1927	18, 600	2, 386	7. 80
1903	164, 058	3, 640	45. 07	1928	37, 873	3, 282	11. 54
1904	64, 867	2, 845	22. 80	1929	85, 811	3, 512	24. 43
1905	724, 000	4, 901	147. 72	1930	81, 557	6, 181	13. 19
1906	128, 484	2, 237	57. 44	1931	57, 064	6, 101	9. 35
1907	71, 292	3, 062	23. 28	1932	152, 847	7, 389	20. 69
1908	129, 662	3, 872	33. 49	1933	104, 944	7, 677	13. 67
1909	201, 467	2, 598	77. 55	1934	141, 932	9, 427	15. 06
Sum			749. 38	Sum			178. 20
Average			62. 45	Average			14. 85
Average of "off" years			42. 83	Average of "off" years			13. 86

The most unfortunate feature in the depletion of the earlier-running sockeyes is the accompanying fall in the quality of the pack as a whole. Not only have the sockeyes been depleted, but worse, the depletion has been much heavier during the early run when the quality is of the best.

The late-running sockeyes have been encouraged by several circumstances; first, during the earlier years the late run was seldom fished on account of its inferior quality; second, the Fraser River closed season, which began on August 25 during most years, was a protection; third, the 10-day fall closed season in odd-numbered years from 1921–29, and in all years since 1930 in Puget Sound waters, has enlarged the escapement of the late-running fish. This serves to emphasize the fact, common to nearly all fisheries, that the most valuable portion of a population is usually the first to be destroyed.

CHANGES IN ABUNDANCE

Because the sockeye has always been the chief object of the gill net and trap fisheries, its abundance may be more accurately measured than that of the other species. The abundance of a salmon run cannot be measured in the same manner as that of a marine species for which each unit of gear may fish throughout the season upon the same general population. The salmon are running a gauntlet, each school avoiding capture as it approaches closer to its goal. Therefore, because variations in temperatures, currents, winds and tides cause changes in the rate and exact route of migration, the productivity of the different fishing areas may exhibit annual variations independent of those produced by the actual numbers of migrating sockeyes.

Conditions often favor one form of gear more than another, so that the availability of the schools to one method of fishing must not be accepted as the final criterion of abundance without comparing it with the availability to other forms of gear. Also, the number of sockeyes caught on Swiftsure and Salmon banks is bound to influence the catches in Boundary Bay, and they aid in influencing the catches in the Fraser River.

The gill nets in the Fraser River, covering a restricted area, undoubtedly sample the portion of the run that escapes thus far more thoroughly than the traps and seines can hope to do. If the number and efficiency of the gill nets remained constant they might then give an adequate picture of the escapement, but, unfortunately, their number varies considerably.

To work out these complexities so as to allow for the difference in seasonal availability to different gear, the effect of one form of gear on the catch of another, the amount of competition between units of gear according to their numbers, and, finally, the changes in abundance of some races due to the difference in fishing intensity at different parts of the season, is beyond the scope of this report. General indices of abundance are presented for the major forms of gear and such general conclusions drawn as appear justified.

AVERAGE CATCH PER UNIT OF EFFORT WITH GILL NETS

The number of sockeyes actually captured by gill nets in the Fraser River, taking into consideration, whenever possible, fish shipped to and from the Fraser River, is given in table 31. This has been divided by the number of units of fishing effort and the results shown in figure 23.

In the earlier years the catch was often limited by the capacity of the canneries, and this continued in the big-year cycle up to 1913. Under these conditions the curve does not give a true picture of the actual early abundance which was undoubtedly somewhat higher.

TABLE 31.—*Catch per unit of effort by gill nets, 1877–1934*

Year	Number gill-netted	Total units of effort	Catch per unit of effort	Year	Number gill-netted	Total units of effort	Catch per unit of effort
1877	799,107	285	2,804	1907	584,033	2,942	199
1878	1,077,000	449	2,899	1908	707,011	2,410	293
1879	571,350	304	1,879	1909	4,869,134	4,634	1,051
1880	272,500	274	995	1910	1,459,297	2,745	532
1881	1,768,766	396	4,467	1911	659,496	2,350	281
1882	1,884,750	666	2,830	1912	1,185,746	2,476	479
1883	1,142,700	782	1,461	1913	8,761,249	4,369	2,005
1884	272,500	723	377	1914	2,035,630	4,621	441
1885	1,112,257	672	1,655	1915	1,050,672	4,663	225
1886	387,720	775	500	1916	311,196	4,299	72
1887	1,428,375	1,055	1,354	1917	1,402,327	4,849	289
1888	433,000	576	752	1918	197,352	3,049	65
1889	3,651,393	596	6,126	1919	368,395	2,600	142
1890	2,263,250	596	3,797	1920	486,118	2,545	191
1891	1,296,937	629	2,062	1921	433,852	2,702	161
1892	543,100	954	569	1922	514,249	2,548	202
1893	5,397,005	1,626	3,319	1923	300,115	1,768	170
1894	3,737,200	2,481	1,506	1924	372,333	1,768	211
1895	4,033,720	2,580	1,563	1925	397,386	1,689	235
1896	3,120,523	4,291	727	1926	891,045	1,810	492
1897	9,959,350	3,832	2,599	1927	648,254	2,010	323
1898	2,293,715	4,642	494	1928	267,457	2,092	128
1899	4,514,385	4,785	943	1929	605,170	2,312	262
1900	1,873,981	6,369	294	1930	964,987	2,375	406
1901	11,792,692	6,350	1,857	1931	450,532	2,163	208
1902	3,142,814	4,278	735	1932	657,222	2,289	287
1903	2,338,987	5,362	436	1933	546,026	2,598	210
1904	742,081	3,571	208	1934	1,230,986	2,745	448
1905	10,143,517	4,582	2,214				
1906	1,983,698	3,178	624	Total	116,335,643		

On account of economic conditions only six canneries operated in 1884 and 1885; but the number of licenses issued was as great as in years when double the number of plants were busy. Therefore, the low points of 1884 and 1885 should be regarded with suspicion, as the catch per net was obviously lowered by the inability of the canneries to utilize their full catching capacity. Eliminating these doubtful years, 1886 appears to be the low point of the early period.

Since about 1897 the whole curve is lower than would be the case were the whole sockeye population to have reached the river, as it did before the expansion of fishing in Puget Sound. Regardless, however, of all the factors that presumably affect the level of the curve to some extent the fall is far too pronounced to mean anything but depletion.

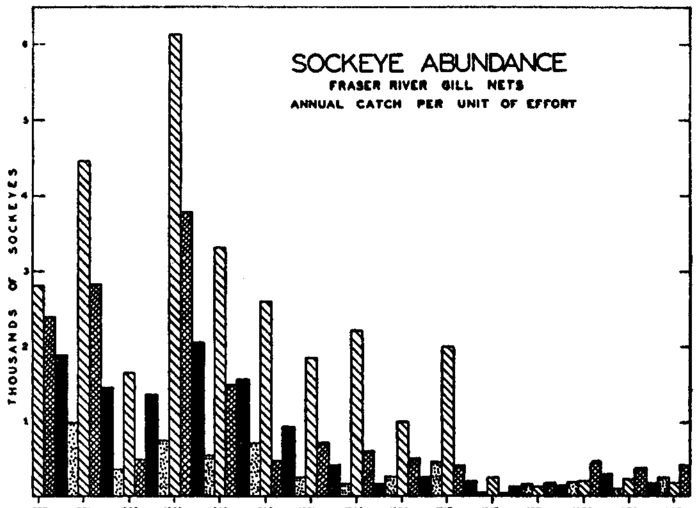

FIGURE 23.—Annual catch per unit of fishing effort of Fraser River gill nets for the 58-year period from 1877–1934. Note the decrease in the catch in each of the four cycles. These cycles are caused by the sockeye maturing predominately at 4 years of age.

INDEX OF ABUNDANCE FROM TRAPS

The salmon traps form a very reliable means of determining the abundance of the sockeye, inasmuch as they were driven year after year in the same location; and, although the fishing ability of the individual trap may have varied somewhat from year to year, on account of weather or tides, yet the decrease in the catch of one trap is apt to be compensated for by the increase in another if a sufficiently large sample is utilized.

In making this index traps were selected from various localities so as to discount the effect of any slight changes in migration routes or any diminution of the numbers migrating past any one locality, which might be caused by hydrographic conditions or by sockeyes of different lake systems using different migration routes through the salt water channels leading to the mouth of the river. Of the 43 traps selected, 3 were from the Point Roberts Area, 12 from Boundary Bay, 5 from Birch Bay, 4 from Lummi Island, 6 from Rosario Strait, 3 from the South Lopez Area, 4 from Salmon Banks, 1 from Waldron Island Area, and 5 from Haro Strait. No trap selected fished less than 10 years and 5 of them fished from 1898 to 1934, or 37 years, without a single break. They averaged 27 fishing years each between 1896 and 1934. The use of more traps would have given too much weight to the Boundary Bay Area which was already well represented. In most of the other areas all available traps were used to aid in compensating for changes in the route followed. No traps were used from West Beach as they also catch sockeyes bound for the Skagit River, but, as this area is a small producer of sockeyes, its omission can be of no consequence in determining the trend.

As not all of these traps fished every year during the period under consideration, it was necessary to determine the relative efficiency of each trap, especially since no two traps are exactly alike in their potential capacity to catch fish. In determining these efficiencies it was, of course, necessary to use a base.

The use of any one year as a base could not give a very accurate picture of their relative efficiencies, so a 28-year period was employed, from 1902–31; with the exception of 1908 and 1922. Fifteen traps were found that had fished every year during this period, of which 1 was from the Point Roberts Area, 10 from Boundary Bay, 2 from Birch Bay and 1 each from the Lummi Island and Salmon Bank Areas. For these traps an average annual catch per trap was computed. Using these average annual catches as a standard, or base, the proportion that the total annual catches of each of the 43 traps formed of the same annual catches of the standard was found. Instead of using these proportions as weights, each trap was assigned an efficiency weighting which was the calculated average annual catch it theoretically would have caught had it fished for the whole 28 years represented by the standard, or base, curve. This was done for each trap by merely multiplying the average annual catch of the standard curve for the 28 years by the above-mentioned proportion.

Having determined the relative efficiency of each of the 43 traps, the index was made by dividing for each year the total catch of such of the 43 traps as were driven by the total efficiency weightings of the same traps. The index figures are not actual numbers of fish but, as with most other indices, are to be considered in relation to one another. However, they give roughly the percentage that each year's catches are of the average of the 28 years represented in the standard curve.

Even though the trend of the base curve for the 15 traps rose or fell at a different rate than did the trend of the traps as a whole, this method of determining the efficiencies would prevent this difference in the trend from having any effect on the final index unless a large share of the traps selected fished for only a short number of years at one end of the period of time. Since this condition does not obtain, the index is believed to be a reliable measure of the changes that have occurred in the trap catches.

TABLE 32.—*Sockeye index of abundance from traps, 1896–1934*

Year	Catches	Efficiency weights	Number of traps	Index of abundance	Index from standard curve	Year	Catches	Efficiency weights	Number of traps	Index of abundance	Index from standard curve
1896	259, 512	157, 152	6	165. 134	--------	1917	1, 777, 158	1, 361, 590	43	130. 521	139. 225
1897	843, 303	349, 089	10	241. 572	--------	1918	350, 451	1, 316, 830	39	26. 613	23. 548
1898	821, 677	381, 254	11	215, 520	--------	1919	306, 114	1, 161, 984	35	26. 344	29. 226
1899	2, 663, 376	755, 475	21	352. 543	--------	1920	499, 406	932, 553	27	53. 553	52. 306
1900	942, 721	868, 394	26	108. 559	--------	1921	621, 190	1, 310, 431	42	47. 403	47. 050
1901	5, 095, 464	833, 241	26	611. 523	--------	1922	328, 554	802, 564	20	40. 938	--------
1902	1, 403, 869	983, 037	30	142. 809	132. 035	1923	276, 658	1, 180, 625	36	23. 433	24. 950
1903	703, 336	983, 037	30	71. 547	70. 728	1924	555, 636	972, 745	27	57. 120	65. 769
1904	609, 681	912, 297	25	66. 829	68. 660	1925	679, 459	1, 302, 442	38	52. 168	59. 422
1905	4, 273, 212	1, 033, 479	31	413. 478	424. 986	1926	272, 170	1, 171, 431	33	23. 234	24. 999
1906	875, 782	990, 361	29	88. 431	90. 637	1927	392, 468	1, 263, 574	39	31. 060	36. 742
1907	512, 369	976, 475	28	52. 471	53. 652	1928	418, 199	1, 121, 823	32	37. 279	35. 085
1908	907, 670	824, 243	23	110. 122	--------	1929	552, 836	1, 310, 431	42	42. 187	47. 686
1909	4, 621, 094	1, 095, 853	31	421. 689	406. 717	1930	629, 889	1, 195, 611	36	52. 683	48. 720
1910	1, 058, 917	1, 042, 569	28	101. 568	98. 828	1931	298, 260	1, 169, 332	36	25, 507	23. 957
1911	657, 770	1, 232, 865	33	53. 353	56. 610	1932	338, 576	743, 919	21	45. 513	--------
1912	1. 082, 917	1, 198, 760	32	90. 336	86. 775	1933	753, 311	1, 115, 144	32	67. 553	--------
1913	5, 790, 820	1, 226, 629	35	472. 092	492. 264	1934	921, 829	1, 076, 915	33	85. 599	--------
1914	1, 282, 777	1, 294, 252	35	99. 113	96. 928						
1915	244, 628	1, 342, 578	40	18. 221	20. 320	Total	45, 110, 330	--------	--------	--------	--------
1916	487, 271	1, 106, 225	33	44. 048	42. 167						

The index would appear to be extremely reliable for trap-caught sockeyes, as, during the period from 1896–1934 the 43 traps caught 45 million sockeyes while the total trap catch since the beginning of the fishery totals but 94 million. During the past 20 years, when complete figures for trap catches are available, our sample comprised as high as 82 percent of the trap catch in 1924, and fell only as low as 54 percent, in 1915 and 1917.

The index (table 32 and fig. 24) shows a marked decline in abundance in all four age cycles, comparing favorably with the average catch per unit of gill net effort, except in a few years. In 1897 the abundance shown by the trap index is decidedly lower than that shown by the gill net averages, but a large part of this discrepancy may be due to the fact that a great many of the traps were driven for the first time in 1897 and so had not yet been efficiently located. The details of the levels of abundance shown will be discussed under the various cycles.

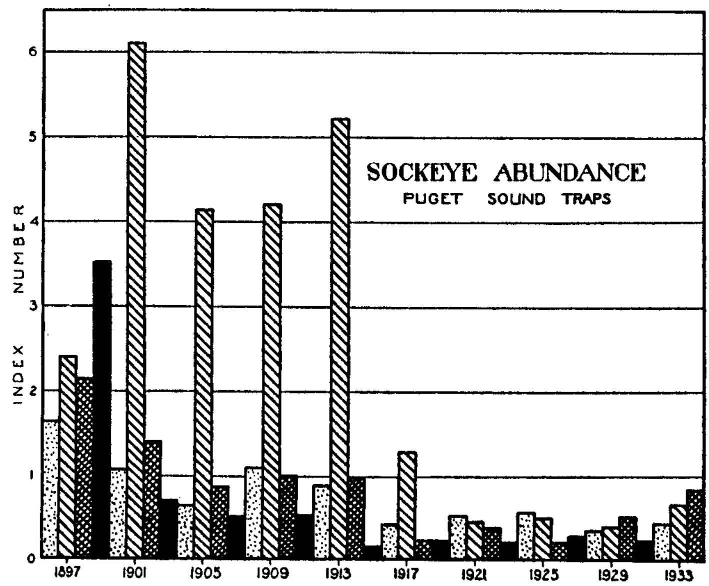

FIGURE 24.—Sockeye index of abundance calculated from the catches of Puget Sound traps for the 39-year period from 1896–1934. A decrease in abundance has occurred in all cycles.

PURSE SEINES

In the 26 years since 1909 when purse seines became an important factor in the sockeye fishery, their catch has exceeded that of the traps in only 3 years: 1930, 1931, and 1934. Their success in 1930 was due to the heavy schooling, especially at Point Roberts, of the abundant late run which, massed in the shallows off the river mouth, were easily seined. The 1931 catch exceeded that of the traps because the seines had their second most successful season on Swiftsure Bank. In 1934 the purse seiners were prepared for a repetition of the abundant late run of 1930 and, although they did not do as well in the inside waters, they caught over three times as many sockeyes on Swiftsure Bank as in any previous season. In 7 of the 26 years their catch in both inside and offshore waters totaled less than 150,000 sockeyes per year. Six of these were even-numbered years when no pink salmon were running. The seiners fished during the early season for cohos in the offshore waters, and during the late season for both cohos and chums in the inside waters.

In the odd-numbered years, which have abundant pink salmon runs, usually three or four times as many sockeyes are seined as in even years, because there are more seine boats fishing, and they are largely concentrated during the late summer in the areas where the pink salmon are migrating on their way to the Fraser River and other streams in the Gulf of Georgia.

The average size of the purse-seine delivery is not a good measure of sockeye abundance. In the even-numbered years it tends to be high, as the boats fish only during the height of the run. In the odd-numbered years it tends to be low, as the boats often made a large number of catches, containing few sockeye per catch, while fishing primarily for pink salmon. The purse seine catches are thus not as reliable as a measure as either the trap or gill-net catches, but they do show how the purse seines have fared under varying conditions of abundance.

In making this index the number of sockeye taken each year during each 7-day period was divided by the weighted number of deliveries. The weights were given according to the size of the boats making the catches in accordance with the efficiency weighting for all species described in the purse seine section of this report. Data were available for every year, except 1920, from 1911–34. Of the 23 years remaining, the data for 1918 cover such a short period of time that they were not used in computing a normal curve for each week From the other 22 years a normal average daily delivery was made for each of the 6 weeks between July 15 and August 25, by merely dividing the sum of the averages for all years by the number of years. No week had less than 19 years data.

For each year the sum of all the average daily deliveries for the six 7-day periods between July 15 and August 25, or as many of these six periods as there were data for, was divided by the sum of the average daily deliveries for the same periods for the normal. The resulting index then is a measure of the annual abundance expressed as a percentage of the normal.

The purse-seine index of abundance differs from the trap index in a number of years, but before deciding on the meaning of these differences several factors must be considered. Thus the actual catch of sockeye in 1918, 1922, 1924, 1926, and 1928 by purse seines in Puget Sound was less than 100,000 fish. In 1918 it was only 45,000 and in 1928 it was but 62,000. In such years the total quantities caught by purse seines were very low in relation to the actual abundances.

In certain other years the purse-seine index is very high in relation to that for traps, as the purse seines may make catches out of all proportion to the abundance when the fish are heavily concentrated, as they were at Point Roberts in 1930. Although it has seemed unwise to lay any stress on the purse-seine index as an accurate measure of abundance, yet, considered in relation to the trap and gill-net indices, it portrays the fluctuations in availability of sockeyes to the purse seines, and is thus necessary to an understanding of the fishery.

TABLE 33.—*Sockeye index of abundance from Puget Sound purse seines, 1911–34*

Year	Number of fish	Number of catches	Weighted number of catches	Average size of delivery for week ending—				
				July 14	July 21	July 28	Aug. 4	Aug. 11
1911	25, 634	262	238. 52		55. 92	138. 72	178. 85	134. 93
1912	80, 955	442	452. 16	29. 24	53. 54	180. 21	201. 96	286. 11
1913	1, 312, 188	799	904. 26	39. 48	196. 42	555. 81	1, 999. 39	2, 938. 88
1914	405, 937	1, 176	1, 308. 00	35. 81	87. 31	230. 62	555. 60	261. 75
1915	60, 644	1, 815	2, 184. 32		9. 12	30. 27	40. 35	40. 13
1916	36, 645	513	590. 52	15. 99	55. 15	71. 77	65. 22	55. 73
1917	180, 477	890	1, 181. 70	22. 36	88. 20	243. 28	460. 00	120. 46
1918	7, 708	153	192. 20		47. 63	36. 31	40. 15	42. 20
1919	22, 229	212	311. 22				72. 20	138. 27
1920								
1921	59, 340	1, 174	1, 668. 70		81. 19	72. 67	53. 17	38. 89
1922	19, 954	149	137. 54			46. 06	69. 78	113. 51
1923	80, 279	1, 253	1, 780. 62			12. 83	32. 36	32. 87
1924	26, 253	184	247. 76		52. 23	160. 78	131. 59	113. 68
1925	61, 764	837	1, 220. 70	17. 24	99. 59	115. 38	87. 20	40. 41
1926	74, 904	504	666. 34		18. 09	62. 57	115. 05	194. 10
1927	257, 741	1, 714	2, 483. 58		12. 30	16. 74	21. 47	53. 06
1928	54, 603	1, 212	1, 755. 96		45. 21	54. 44	45. 58	34. 65
1929	349, 740	4, 031	5, 958. 18	33. 88	78. 01	89. 51	73. 98	102. 54
1930	1, 503, 026	2, 451	3, 921. 71		10. 55	31. 52	82. 94	76. 52
1931	235, 864	4, 206	6, 516. 87	10. 15	16. 82	35. 72	38. 12	74. 45
1932	364, 018	3, 711	5, 832. 54	24. 15	26. 50	55. 70	102. 86	74. 97
1933	495, 126	7, 368	11, 375. 44	34. 39	49. 88	58. 09	72. 40	97. 41
1934	1, 227, 634	2, 758	4, 222. 36	18. 60	21. 74	33. 36	50. 02	164. 51
Sum [1]	6, 942, 663	37, 814			1, 057. 77	2, 296. 05	4, 550. 09	5, 187. 83
Number of years					19	21	22	22
Normal average					55. 67	109. 34	206. 82	235. 81

Year	Average size of delivery for week ending—Continued				Sum of weekly averages July 15 to Aug. 25	Sum of normal averages for same weeks	Index
	Aug. 18	Aug. 25	Sept. 1	Sept. 8			
1911	73. 55	53. 83			635. 80	905. 79	70. 19
1912	97. 43				819. 25	787. 13	104. 08
1913	2, 119. 56	468. 27	274. 85	128. 86	8, 278. 33	905. 79	913. 93
1914	24. 04	111. 30			1, 270. 62	905. 79	140. 28
1915	21. 98	30. 51	16. 20	6. 56	172. 36	905. 79	19. 03
1916	36. 82				284. 69	787. 13	36. 17
1917	93. 31	40. 29	28. 05	9. 50	1, 045. 54	905. 79	115. 43
1918					166. 29	607. 64	27. 37
1919	106. 18	73. 33	35. 25	29. 34	389. 98	740. 78	52. 64
1920							
1921	32. 88	23. 03	8. 70	6. 36	301. 83	905. 79	33. 32
1922	144. 11	133. 17			506. 63	850. 12	59. 60
1923	67. 44	65. 02	42. 79	13. 96	210. 52	850. 12	24. 76
1924	48. 07				506. 35	787. 13	64. 33
1925	44. 22	32. 16	21. 22	18. 37	418. 96	905. 79	46. 25
1926	114. 32	51. 09			555. 22	905. 79	61. 30
1927	54. 07	125. 09	147. 26	152. 07	282. 73	905. 79	31. 21
1928	24. 73	10. 26	4. 56	1. 37	214. 87	905. 79	23. 72
1929	90. 01	50. 41	27. 74	9. 01	484. 46	905. 79	53. 48
1930	147. 00	413. 27	603. 17	673. 61	761. 80	905. 79	84. 10
1931	56. 95	33. 90	26. 77	13. 78	255. 96	905. 79	28. 26
1932	65. 59	24. 41	19. 31	21. 72	350. 03	905. 79	38. 64
1933	56. 09	27. 75	17. 94	9. 15	361. 62	905. 79	39. 92
1934	430. 36	487. 49	296. 52	690. 08	1, 187. 48	905. 79	131. 10
Sum [1]	3, 948. 71	2, 254. 58					
Number of years	22	19					
Normal average	179. 49	118. 66					

[1] Excluding 1918.

COMBINED INDEX OF ABUNDANCE

In years when fishing conditions favored the traps the gill net measure of abundance was usually lower owing to the toll exacted by the traps, but when conditions were reversed, as in 1915 and in 1926, the gill net index was the higher. Since the two measures are thus somewhat interdependent, neither one gives as clear a picture of the actual abundance as the two considered together. Therefore, the two have been combined.

In making the combination each index was, from 1896 to 1934, expressed each year as a percentage of its average over the whole 39-year period. In each year each percentage was then weighted in accordance with the percentage of the combined trap and gill net-caught sockeyes that had been taken by that form of gear. The weighted percentages were then combined to form the final index, which is given by 4-year cycles in table 34.

EXPLANATION OF CHANGES IN ABUNDANCE

Having reviewed briefly some of the causes of changes in the sockeye fishery, the question arises as to the present state of the fishery and the present state of abundance. In order to arrive at any reasonable conclusions account must be taken of the changes that have occurred within each cycle of 4 years—four years, as mentioned above, is the age at which the majority of the Fraser River sockeye mature—in regard to the size of the spawning escapements, and the extent of the areas seeded.

TABLE 34.—*Abundance by cycles of Fraser River sockeyes*

Year	Combined index of abundance	Year	Combined index of abundance	Year	Combined index of abundance	Year	Combined index of abundance
		1896	134.1	1897	411.7	1898	132.4
1899	236.0	1900	69.4	1901	421.4	1902	126.4
1903	72.6	1904	48.3	1905	374.7	1906	96.4
1907	40.2	1908	78.8	1909	299.3	1910	89.2
1911	46.5	1912	79.1	1913	377.5	1914	80.8
1915	33.4	1916	29.3	1917	90.1	1918	19.0
1919	23.3	1920	39.9	1921	35.6	1922	35.4
1923	24.5	1924	43.7	1925	42.6	1926	70.3
1927	43.2	1928	28.1	1929	39.8	1930	59.3
1931	29.6	1932	45.9	1933	49.8	1934	75.6

The providing of a large number of spawners, while of importance, cannot achieve permanent rehabilitation unless these spawners are members of several different "races" or "colonies" of sockeye, so that they will migrate to many different lake systems. Such a distribution of spawners will insure ample spawning gravel for the adults, will guard the fishery against failure when on occasion unfavorable conditions of weather or enemies destroy the spawning of any single lake system, and will give a greater stability to the fishery as it is far better to have successive waves of migrating adults passing through the gear, than to have the whole season's migration occur in a very few weeks, as may easily happen when the total migration is to one lake system. A clearer conception of these waves of migration may be gained by thinking of the main river merely as an extension of the salt water channels up which different races of fish migrate to their spawning grounds on several independent lake systems. The principal lake systems of the Fraser River, the tributaries of which are sockeye spawning grounds, are shown in figure 25.

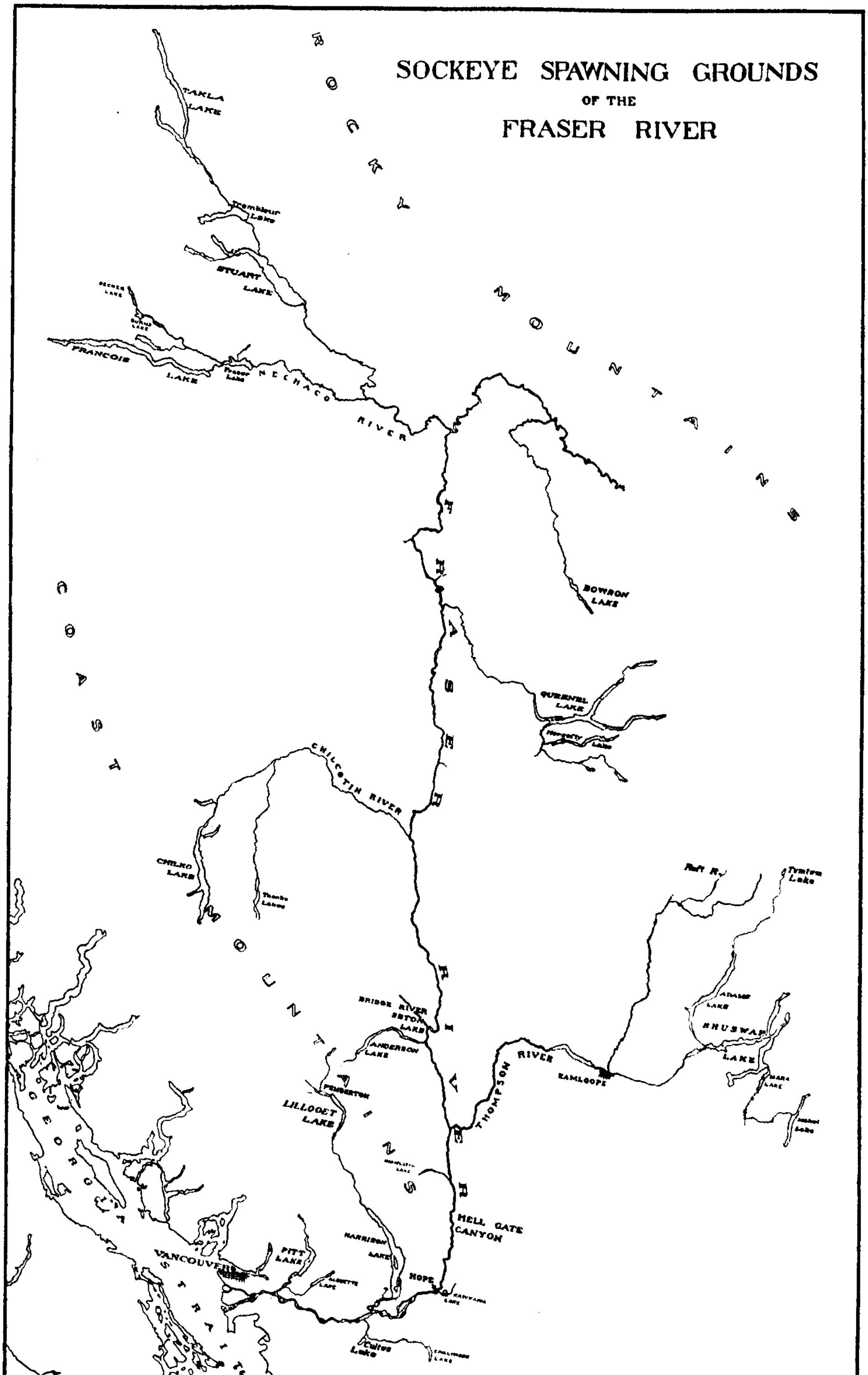

FIGURE 25.—Sockeye spawning ground of the Fraser River. All of the lakes shown are mentioned as sockeye lakes either in the reports of the British Columbia Commissioner of Fisheries or in the reports of the Department of Fisheries of Canada. Other lakes in this river system have been omitted. The sockeye spawn chiefly in the streams tributary to these lakes. The sockeye fry descend into these lakes and spend some time there, usually about a year and a half, before migrating to the sea.

ABUNDANCE OF CYCLE ENDING IN 1934

The cycle of years—1934, 1930, 1926, etc.—immediately following the big years showed a decline from 1898–1914 amounting to 39 percent from the 1898 level. The catch of 5,000,000 sockeyes in 1898 did not appear to be unduly heavy at the then existing level of abundance, only a 4 percent drop, which may not be statistically significant, occurring between 1898 and 1902. In 1902, however, the catch was increased to over 7,000,000 fish, resulting in a drop of 23 percent in the abundance of the 1906 run. Catches of over 4,000,000 in 1906 and 1910 were both too heavy for these lower levels of abundance and the catch continued to decline.

In 1914, the lowest level of abundance the cycle had thus far experienced, the fishing was very intense. One hundred traps fished in the sockeye areas, the most in any off year since 1903, and the gill net effort was exceeded only by 1900, 1901, and 1903, resulting in a catch of 5,700,000 sockeyes. The spawning ground reports for 1914 indicated the poorest escapement on record, which was amply borne out by the run of 1918, the next year of this cycle, which was the poorest in the whole history of the Fraser River fishery.

The intensive fishery of 1914 was doubtless instrumental in causing this remarkably low escapement, but there is little doubt that at least a small portion of the blame must be laid on the blockade of Hell's Gate in 1914. The report on this blockade stated that no salmon were able to ascend through the canyon from August 10 to 25, and that the fish had great difficulty in passing at other times, some 20,000 being put over the rapids with dipnets.

Although a fair amount of gear was employed in 1918 the catch of just over 800,000 was relatively much less than that of 1914, considering the very low level of abundance. However, the remarkable increase in abundance between 1918 and 1922 cannot be explained in terms of catch or escapement. The survival rate of the sockeyes being influenced to a great extent by conditions in the lakes, and probably, to a lesser extent, by conditions in the ocean, is subject to occasional violent fluctuations. In this case the result was a doubling in the level of abundance between 1918 and 1922.

In 1922, with the sockeyes much more numerous than in 1918, the catch was only slightly over 1,000,000 fish. The number of sockeye traps was the lowest since 1898 and the gill net effort had fallen considerably since the war years, permitting the best off year escapement for several years, possibly since 1912. One feature of the 1922 run was a fair escapement to the Shuswap-Adams Lake system.

The relatively good escapement of 1922 was reflected in an improved run in 1926. The run was exceptionally late, and, in addition, appeared not to have followed its usual migration routes through the salt-water channels leading to the mouth of the Fraser River. As a result, neither the traps nor the purse seines in Puget Sound caught many sockeyes, and the gill net operators on the Fraser River received the full benefit of the run, catching more per unit of fishing effort than in any year since 1913. However, the number of gill nets was so small that the escapement was relatively very high in proportion to the catch, which was slightly under 1,400,000.

The results of the 1926 escapement are shown in the catches of 4,600,000 and 5,000,000 in 1930 and 1934, respectively.

Abundance of Cycle Ending in 1933

The big year cycle, ending in 1933, 1929, 1925, etc., was tremendously abundant from the earliest records of the commercial fishery in 1877 up until the cycle following the Hell's Gate disaster of 1913. In earlier years the catch was so strictly limited by the capacity of the canneries that the index of abundance was always too low. All one can say is that the cycle was far more abundant than the others. In 1897 the trap index is considerably lower than in 1901, due largely to the fact that many of the traps were driven for the first time in 1897. That the big-year cycle was somewhat higher, as indicated by the combined index of abundance, in 1897 and in 1901 than in any of the succeeding years is undoubtedly true. In 1901, for instance, one trap in Boundary Bay caught 680,000 sockeyes between July 10 and August 29, which is as much as the entire trap catch of sockeyes for 11 out of the 21 years since 1913.

The 1901 catch of 25,800,000 sockeyes was, next to 1913, the largest in the history of the fishery. The trap catch in 1901, with less gear, was equal to that of 1913, and the gill net catch of 11,800,000 was 3,000,000 higher than that of 1913. In 1913 the power purse-seine fleet, which was nonexistent in 1901 (only hand-propelled seine boats were then in use), took 10,000,000 fish.

However, the difference in the catches of 1901 and 1913 was not due in any measure to a difference in the amount of gear, but rather to the great increase, by 1913, in the canning capacity of the plants. The number of sockeye wasted in 1913 was as nothing compared to the squandering of a natural resource that took place in 1897 and 1901. Rathbun (1899) says:

> The run of 1897 was one of the largest, if not the largest, in the history of the region. Preparations had been made in anticipation of a good year, both on the Fraser River and in Washington. The great body of sockeye first made its appearance about the middle of July and continued until about the end of the first week in August, a relatively short season, but during this period the cannery pack was completed and in addition an immense amount of fish was thrown away, the daily catch being often much larger than could be disposed of. It has, in fact, been claimed, though this is probably an exaggeration, that more fish were caught and wasted than were utilized.

Concerning the waste of sockeyes in 1901 the Report of the British Columbia Commissioner of Fisheries for 1909, page I 11, says:

> The catch that year (1901) was so great that every one of the canneries on both sides of the international line filled every can they had or could obtain; and in addition to the millions of fish which they packed that year, many millions more were captured, from both the Canadian and American waters of the Fraser River District, which could not be used, and were thrown back dead into the water. The waste of sockeye of our own catch and of that of the Americans in 1901 is believed to have been greater than the number caught and packed by all the canners on the waters mentioned in any year since, with the exception of 1905 and this year.

Despite catches averaging 24,700,000 sockeyes per year in the big years from 1901 to 1913, huge numbers escaped to the spawning grounds. The spawning ground surveys made by the Provincial Fisheries Department estimated millions in 1901 and 1905. In 1909 estimates made by counting, for a portion of each day, the number of sockeyes ascending the fishway at Quesnel Dam showed that over 4,000,000 fish entered the lake. The sockeyes were thicker in the Chilco River than the observer had ever seen them in any unobstructed stream. Fully 1,000,000 were estimated to have entered Seton and Anderson Lakes. Shuswap and Adams Lakes were better seeded than in 1905, when most of the very heavy late run went to that lake system. The runs to Lillooet and Harrison Lakes, below Hell's Gate, were practically a failure.

The fact that tremendous numbers of sockeyes escaped to the spawning grounds on the big years, despite the huge catches, may have occurred because of the presence in all of the big-year cycles from 1901–13 of very abundant late runs, appearing after most of the fishing had ceased. The extent of this late run on the big years is indicated in the following quotation from the British Columbia Commissioner of Fisheries Report for 1909:

> On September 16, 1905, there appeared in the channels at the mouth of the Fraser a run of sockeye so numerous as to lead many competent observers to state that it equalled that which appeared during the first two weeks in August. This late run continued until the first week in October. None of these fish were observed in Juan de Fuca Strait, or in the American channels leading to the Gulf of Georgia and the Fraser River. During the first week of this movement several of our canners packed the fish, and a considerable number of them were purchased for and shipped to American canneries . . . Nothwithstanding the fact that there had been a similar run in the Fraser in September and October of 1901, the claim was made that the late run of 1905 was most unusual. The same claim was again advanced as to the late run this year (1909). It appears evident, however, from the numbers of sockeye which ran in the lower Fraser in September and October of 1901 and 1905, and again this year, that a late run is characteristic of the big years.

Whether the huge catch of 1913 had enough effect on the spawning escapement to have affected the abundance of the 1917 run will never be definitely known, as a portion of the sockeye ascending the Fraser River in 1913 were prevented from reaching the spawning grounds on account of rock slides, incidental to the construction of a railway at Hell's Gate in the canyon near Yale. The spawning-ground estimates of 1913 show 552,000 entering Quesnel Lake, contrasted to 4,000,000 in 1909, the previous year of the cycle. Chilco Lake was likewise estimated to have had about one-eighth as many as in 1909. Anderson and Seton Lakes had an estimated escapement of 30,000 against 1,000,000 in 1909. Lillooet and Harrison Lakes, below Hell's Gate, had poor runs. However, large numbers were seen in Adams River; and in Little River, connecting the outlet of Shuswap Lake with Little Shuswap Lake, the spawning sockeyes appeared as thick as in 1905 or 1909. The run at Stuart Lake was reported to be one-twentieth as large as on most big years, and that at Fraser Lake about 50 percent as large.

From the foregoing it is evident that, whether due chiefly to the obstruction at Hell's Gate, or to the tremendous catch, the spawning escapement of 1913 was considerably curtailed. In spite of this curtailment, the run of 1917 was of such size that, had the fishing effort been sufficiently reduced to allow an escapement even comparable to that of 1913, the big-year cycle might have continued to dominate. However, the total fishing effort was probably as great as in any of the preceding big years, a relatively large portion of the run being taken before it even reached the river, as is shown by the small gill-net catches.

Spawning-ground surveys in 1917 showed 26,000 spawners arriving at Quesnel Lake as against 552,000 in 1913. The Chilcotin Indians caught but 15,000 in the Chilcotin River compared with 25,000 in 1913. Seton Lake had not to exceed 200 fish caught by actual weir count. Shuswap and Adams Lakes had much less than in 1913. Harrison and Lillooet Lakes had the poorest spawning escapement that they had known.

The returns from this spawning brought a run in 1921 only two-fifths as abundant as that of the parent year. The catch of 1,700,000 in 1921 was relatively a great deal less, for the abundance level, than that of 6,800,000 in 1917. Since 1921 this cycle has been very slowly recuperating, increasing about 25 percent in abundance by 1933, according to the combined index. Besides producing the best pack of the last 4 years of this cycle, 1933 also had the best spawning escapement since 1917. Especially worthy of note was the good escapement to the headwater lakes as compared to other recent years. For instance, over 100,000 are estimated to have reached Chilco Lake. A fair number reached the lakes of the Stuart system. The escapement to the Fraser-Francois Lake system was twice that of 1929 and for the first time in years numbers of sockeyes reached Burns Lake.

Abundance of Cycle Ending in 1932

The cycle of years, 1932, 1928, 1924, etc., immediately preceding the big years was the poorest of the 4 throughout the early years of the fishery, and in common with the other off years, this cycle commenced to decline before the beginning of the century.

In 1900, while still at a fair level of abundance, this cycle was fished with extreme intensity, the gill-net effort being the highest in the whole history of the fishery and the number of sockeye traps as great as in the big year of 1901. The resulting catch of 4,400,000 was too great a proportion of the run, the abundance declining over 30 percent by 1904. In 1904 the fishing intensity was greatly reduced, only 2,400,000 sockeyes being taken, and the cycle recuperated. In 1908 the fishing intensity was again dropped, yet a larger catch of 2,700,000 was made.

The abundance in 1912 was apparently as great as in 1908, as is shown both by the combined index and by the catch of 3,400,000 which was made with slightly more traps and about the same gill-net effort as the catch of 2,700,000 in 1908. Furthermore, the proportion taken by the gill nets was much greater in 1912 than in 1908 which might indicate a better escapement. This is confirmed by spawning-ground estimates that would certainly place 1912 ahead of 1908.

The index of abundance fell 63 percent between 1912 and 1916. In 1916, although the number of traps was fairly low, the gill-net fishery was very intense, yet only 1,300,000 fish were taken, and the unusually small proportion taken by the large number of gill nets would indicate a small escapement. The estimates show that it was probably the smallest escapement in the history of the fishery.

Because the spawning of 1912 produced a run so very far below the average expectation for such a relatively good escapement, we are forced to conclude that the failure in 1916 was not caused by overfishing, but by some natural condition, possibly connected with spawning, that greatly reduced the rate of survival. It is impossible, at this date, to know what all of the spawning-ground conditions were, but we have noted that the early months of 1913, when the eggs would have been incubating in the gravels of the spawning beds, were extremely cold.

Average monthly temperatures from 1888–1930 at Barkerville and from 1891–1930 at Kamloops were studied. These two points were chosen for having long series of observations and for being close to the spawning grounds. For each locality the average monthly temperatures for January, February, and March were added for each year, and the sum subtracted from the mean average of the sum of these 3 months for the whole series of years. The two series of temperature deviations were added for each year and divided by two (see table 35). It will be noted that in both series the winter of 1913 was the second coldest in 42 years. That this long protracted cold spell might well have had a deleterious effect on the success of the 1912 spawning is obvious, but the point cannot be pressed until information on the effect of severe cold upon spawning has been collected.

Although the escapement was reported as very poor in 1916, the abundance was somewhat higher in 1920, a much less intense fishery producing about the same catch as in 1916. The abundance was at practically the same level in 1924 as in 1920.

The cycle fell off slightly in 1928 but recovered in 1932 owing probably to the very small catch that was made in 1928 in proportion to the abundance.

TABLE 35.—*Winter temperatures of the upper Fraser River valley, 1888–1930*

Year	Barkerville		Kamloops		Average deviation in degrees	Year	Barkerville		Kamloops		Average deviation in degrees
	Sum of average temperatures, Jan., Feb., and Mar.	Deviation from average in degrees	Sum of average temperatures, Jan., Feb., and Mar.	Deviation from average in degrees			Sum of average temperatures, Jan., Feb., and Mar.	Deviation from average in degrees	Sum of average temperatures, Jan., Feb., and Mar.	Deviation from average in degrees	
1888	70.0	+8.9				1912	63.1	+2.0	82.0	−5.6	−1.80
1889	72.4	+11.3				1913	43.7	−17.4	63.8	−23.8	−20.60
1890	64.1	+3.0				1914	63.7	+2.6	94.9	+7.3	+4.95
1891	53.8	−7.3	86.9	−0.7	−4.00	1915	77.2	+16.1	105.3	+17.7	+16.90
1892	65.0	+3.9	94.3	+6.7	+5.30	1916	35.4	−25.7	65.5	−22.1	−23.90
1893	55.1	−6.0	73.2	−14.4	−10.20	1917	49.0	−12.1	70.1	−17.5	−14.80
1894	60.7	−.4				1918	63.4	+2.3	89.2	+1.6	+1.95
1895	66.8	+5.7				1919	59.3	−1.8	91.1	+3.5	+.85
1896	58.9	−2.2	95.0	+7.4	+2.60	1920	63.4	+2.3	89.9	+2.3	+2.30
1897	56.4	−4.7	83.5	−4.1	−4.40	1921	64.2	+3.1	96.3	+8.7	+5.90
1898	68.8	+7.7	91.7	+4.1	+5.90	1922	46.5	−14.6	69.3	−18.3	−16.45
1899	53.1	−8.0	80.8	−6.8	−7.40	1923	59.1	−2.0	84.4	−3.2	−2.60
1900	74.5	+13.4	103.5	+15.9	+14.65	1924	71.8	+10.7	99.4	+11.8	+11.25
1901	63.4	+2.3	91.1	+3.5	+2.90	1925	65.8	+4.7	93.0	+5.4	+5.05
1902	68.8	+7.7	100.8	+13.2	+10.45	1926	85.0	+23.9	111.0	+23.4	+23.65
1903	60.6	−.5	84.7	−2.9	−1.70	1927	58.0	−3.1	89.0	+1.4	−.85
1904	49.6	−11.5	81.0	−6.6	−9.05	1928	73.0	+11.9	96.0	+8.4	+10.15
1905	68.8	+7.7	97.7	+10.1	+8.90	1929	52.0	−9.1	71.0	−16.6	−12.85
1906	70.1	+9.0	101.2	+13.6	+11.30	1930	49.0	−12.1	76.0	−11.6	−11.85
1907											
1908	61.7	+0.6	88.9	+1.3	+.95	Sum	2,565.1		3,241.6		
1909	49.1	−12.0	82.2	−5.4	−8.70						
1910	60.6	−.5	94.7	+7.1	+3.30	Number of years	42		37		
1911	50.2	−10.9	73.2	−14.4	−12.65	Average	61.1		87.6		

ABUNDANCE OF CYCLE ENDING IN 1931

The cycle of years containing 1931—1931, 1927, 1923, etc.—has been the least abundant since 1899. The gill-net index shows that for six consecutive cycles, up to and including 1899, it was more abundant than the cycle following it. In 3 of the 6 years, 1887, 1895, and 1899, it was also more abundant than the cycle preceding it. Between 1899 and 1903 this cycle fell 69 percent according to the combined index of abundance—the largest drop in abundance in recent years with the exception of that of the big-year cycle after 1913.

In 1899 both the trap and gill-net fisheries, especially the latter, were quite intense, resulting in a catch of 11,400,000 sockeyes. This catch does not appear to be excessive in relation to the index of abundance when compared to the catches of the big years. On the other hand, there is a possibility that the escapement in 1899 (no surveys were made of the spawning grounds) was much less than the mere comparison of the catch with the level of abundance would indicate, as neither the trap nor the gill-net data point to any late run in 1899, although the evidence is not conclusive. This same cycle had a late run in 1887, mentioned in the Dominion Report for that year, which states that many sockeyes were caught as late as October, which was very unusual. In all of the big-year cycles, from 1901–1913, very abundant late runs appeared after most of the fishing had ceased and provided heavy escapements. Since there is no evidence of a late run in 1899, it is quite possible that the catch was too heavy to allow a sufficient escapement.

Some have ascribed this fall in abundance to the blocking of the Quesnel River by a dam at the outlet of Quesnel Lake, built in 1898, which caused the majority of the sockeyes reaching the dam to die below it without spawning, until after the construction of a fishway in 1904. That some of the sockeyes could not ascend the race is quite possible but that the majority did not enter the lake would seem to be refuted by the run of several millions that passed into the lake in 1905. If none spawned there in 1901, the run of 1905 cannot reasonably be accounted for.

The dam and fishway are thoroughly described in the British Columbia Commissioner's Report for 1904. The dam was 18 feet high and the race was 124 feet wide and 382 feet long, with a drop of only 6 inches. At the head of the race there were 9 gates, each 12 feet wide. At the time of the sockeye run the water in the race was said to average 4 or 5 feet in depth, with a velocity of 12–14 feet per second. The fishway was merely a walled-in section along one side of the race. It was 26 feet wide and every 25 feet timbers 2 feet high were placed on the bottom to form an inverted V pointing upstream. The fishway led to two of the gates, one of which was kept open during the sockeye run.

The dam was constructed for the purpose of shutting off the waters of Quesnel Lake in the fall of the year in order that mining operations could be carried on in the bed of the Quesnel River. Obviously the lake was permitted to become as low as possible during the summer so that the gates were merely openings through which the lake water flowed into the race.

In 1905 the wall separating the fishway proper from the race was washed out, but the fish continued to ascend, and a low wall was substituted for the former high one. It is obvious that the problem was not passage through the gates but merely that of getting the sockeyes through the race. There would appear to be little doubt but that the majority of the sockeyes passed this obstruction. That a matter of some thousands could not, should be regarded as of no greater moment than the residue that fail to negotiate any fall or rapid of any consequence in a natural stream.

Since the first great decline in this cycle, between 1899 and 1903, there has been a further decrease. From 72.6 in 1903 the combined index fell to 40.2 in 1907, due, as before, to overfishing. Remembering the good pack of 1899, large preparations were made in 1903, resulting in a catch of 4,300,000. The traps were numerous and the number of gill nets was exceeded only in 1900 and 1901. It is not surprising therefore that so large a catch was made at so low a level of abundance, or that the abundance had declined an additional 47 percent by 1907.

In 1907 only three-quarters as many traps and one-half as many gill nets were employed as in 1903. The catch of 1,700,000 doubtless permitted a larger escapement than in 1903. This is reflected by a slightly increased abundance in 1911. In 1911 the number of traps remained about the same as in 1907 and the gill-net intensity was slightly lower, yet the yield was larger, being 2,200,000.

According to the combined index of abundance there was a fall of 39 percent between 1911 and 1915, but this figure is undoubtedly too large. The trap index for 1915 was the lowest of the whole 39 years, but that it was so low chiefly on account of the failure of the run to pass by the traps is shown by the gill-net catch. This was nearly twice that of 1911, or about what one would have expected if the number of sockeyes reaching the gill nets in 1915 had been somewhat comparable to the number reaching them in 1911, as the gill-net fishing effort was about twice that in 1911. Since the number removed by the traps before reaching the gill nets was much greater in 1911 than in 1915 it is probably true that the 1915 level of abundance was slightly lower than that of 1911.

Between 1915 and 1919 the abundance declined another 30 percent, according to the combined index, and probably more if the 1915 level were higher than shown. The spawning ground reports claim that in 1915 fewer sockeyes passed through Hell's Gate to the spawning grounds of the upper Fraser than in any year since observations were started in 1901. On the other hand, the number spawning in the tributaries below the canyon, Lillooet Lake, Harrison Lake, Cultus Lake, Pitt Lake, etc., was estimated as being the largest for some years, even including 1913. Because of the failure of the traps to take many sockeyes, the total catch of 1915 was but 1,800,000.

Considering the catch of 1915 in relation to the abundance, it does not appear to have been sufficiently large to have been the sole cause of the drop in 1919. Rather, it would appear that the extremely cold weather early in 1916, when the eggs deposited in 1915 were incubating (see table 35), had some part in it. The temperatures prevailing early in 1916 were even colder than in 1913. The reason for this second instance not showing as great a fall in abundance as in the first instance, when the temperatures were not quite as low, probably lies in the fact that in 1912 by far the larger portion of the spawning escapement went to the lakes above Hell's Gate, in 1915 most of the spawning was below Hell's Gate where it would not be affected by the cold temperatures of the upper Fraser.

This is borne out by the 1919 escapement estimates, which for the region below the canyon were as high as in 1915, whereas practically none were found above the canyon. The survey was more thorough than usual and the dearth of up-river fish was very marked.

In 1923 the abundance level was about on a par with 1919. There were only two-thirds as many traps and slightly fewer gill nets than in 1919, resulting in a catch of 850,000 compared to 1,250,000 in 1919. Since 1919 was able to bring back a comparable run in 1923 with a larger catch it is not surprising that 1927 showed a much improved condition.

In 1927 both the trap- and gill-net fisheries were slightly more intense than in 1923. The purse seine boats were also more numerous. The net result was a catch of 1,800,000 in 1927 against 850,000 in 1923, and, as might be expected, the level of abundance fell off somewhat in 1931.

COHO SALMON

By George B. Kelez

INTRODUCTION

Ascending almost every stream and river of the region on their spawning migrations, cohos are the most widely distributed salmon present in these waters. Although suffering a severe decrease in numbers in recent years, they have formed a considerable portion of the catch throughout the history of the salmon fishery.

This species provided the bulk of the pack of the first Puget Sound cannery and of the establishments which immediately succeeded it in that district. They formed the major portion of the catch of the natives resident at Neah Bay when fishery operators first visited that region in quest of new supplies of salmon. The catches of the early type of purse seines were composed almost entirely of cohos, and they have provided the chief source of the seiner's income in off years up to the present time. This species is also the principal salt-water catch of summer vacationists and recreational fishermen throughout the region.

The first coho catches of the season are made during the early summer by the troll and purse-seine fleets operating in the waters off Cape Flattery, and on Swiftsure Bank. Great schools of immature fish feed there at that time, and large catches are common for a period of several weeks. In late summer the adult cohos begin their migration through the inner waters of the region to the tributary rivers where they will spawn, and the major part of the commercial catch is made during the period of this migration by traps, seines, and gill nets.

LIFE HISTORY

SPAWNING

The majority of the mature fish enter fresh water during the months of October and November, although some may run as early as September, and a few individuals may tarry in salt water until the latter part of January. Actual spawning usually begins a week or two after the fish first enter the streams, and often extends throughout the winter months. Some of the salmon hatcheries in the region have continued to strip eggs up to the middle of March, but most of the natural spawning has terminated before that date. In general, late spawning is confined to the smaller, shorter streams.

Active and highly adaptive to different conditions, coho salmon may spawn on suitable gravel beds only a few miles from salt water, or may ascend the larger rivers to tributary streams in the mountains which surround the region. Such variations in time and locality of spawning cause considerable differences in the time of hatching of the eggs and in the growth of the fry.

GROWTH

The time of hatching of the eggs depends on temperature conditions, but usually occurs during the early spring. The greater part of the young fish remain in the streams throughout the summer and the following winter, and usually migrate to salt water early in their second year.

Growth in fresh water is quite rapid, especially in the streams of southern Puget Sound where temperatures are favorable and food is plentiful. In these streams the fry usually have attained a length of approximately 30 mm by early March, whereas those in the more northerly part of the region may not reach this size until the latter part of May. By September the size range of the southern fingerlings is from 60–70 mm. Collections of fish in their second year, taken in early March, show a size range of from 80–95 mm. By early May these fingerlings measure from 100–130 mm.

During spring and early summer the fingerlings migrate from the upper reaches of the rivers to the estuaries, and finally into salt water. Scale collections from these populations indicate that the majority of the fingerlings migrate to salt water during the early spring freshets, but that many remain in the streams for a much longer period of time.

After reaching the inner waters of the region, young cohoes may be found in large schools for a period of several weeks. At this time they have reached a size of from 14–20 cm. The greater part of these young fish gradually migrate to the waters of the Pacific Ocean. Clemens (1935) states that tagging experiments have indicated that some of the cohoes never leave the Strait of Georgia. Sport-fishing catches in the lower sound confirm the presence of cohoes there throughout all stages of their life in salt water.

These fish remain in salt water during the second winter of their life, and throughout the following summer, during which time they experience a remarkable increase in size. Gilbert (1913) reported the cohoes at the cape to average 13.35 fish per case on July 23 and 7.56 fish per case on September 2. Smith (1921) stated that the average weight of cohoes taken by trollers in the same region increased from 5.63 pounds on July 8 to 9.75 pounds on September 2. Recent samples from the commercial catches taken in the inside waters of Puget Sound during October indicate a size range from 5.13–14.90 pounds, and an average weight of 9.47 pounds at this time. Individual fish of more than 20 pounds in weight have been taken by sport fishermen in this region.

Some indications of the migrations of cohoes in inside waters are given by tagging experiments reviewed by Clemens (1930). Recoveries were made of forty-seven immature cohoes tagged in 1927 at Deep Bay, in the northern part of the Gulf of Georgia. Of these, 29 were recovered north of the point of tagging, or on the lower coast of Vancouver Island, 3 were recovered in the Fraser River, and 1 in the nearby Capilano River. Approximately 30 percent were recovered in Puget Sound, some being taken as far south as Whidbey Island.

From a similar experiment at Nanaimo in 1928, 163 recoveries were made. Of these, 34 were taken north of Nanaimo and 34 in the general vicinity of the tagging, 43 were taken in the Fraser River and vicinity, 8 were taken in the Strait of Juan de Fuca, or west of it, while 44, approximately 27 percent, were taken in Puget Sound.

Of these latter recoveries, 15 were in the vicinity of Whidbey Island and in the Skagit River. These results would indicate that some individuals of the southern runs must either remain in the Gulf of Georgia during their life in salt water, or migrate inside of Vancouver Island on their return from the sea to the streams where they will spawn.

AGE AT MATURITY

Pritchard (1936) reported that commercially caught fish, secured for tagging experiments along the British Columbia coast during the years 1927–31, ranged in age from 2 to 4 years, but that 97.89 percent of these fish were in their third year.

A small number of grilse, almost entirely precocious males, returned to the streams in the fall of their second year. Fraser (1920) reported that, of 2,000 cohoes examined from the Gulf of Georgia in 1916, all but 28 were in their third year, and that these 28 fish were all males in their second year. Gilbert (1912) reported a very few "sea-type" scales, from fish which have descended to salt water during their first summer, in his collections from Puget Sound. Pritchard reported 0.35 percent of this type of scale in his collections.

It is reasonable to expect considerable fluctuations in the size of the runs of any species of which a high proportion of the individual fish mature at the same age. For those salmon which descend to salt water shortly after hatching, a considerable spawning escapement, combined with favorable conditions on the spawning grounds, often results in an extremely high return at maturity of that particular brood.

That coho salmon, which mature almost entirely at 3 years of age, have not experienced any sudden increase in numbers may be largely due to the fact that they have a long stream residence during their early life history. Because the carrying capacity of streams is physically limited, and there exists a considerable competition between the young stream-dwelling salmon and resident trout or other species, the numbers of fingerlings surviving until they begin their seaward migration cannot be increased beyond a certain point, even in very favorable years. Although this factor has doubtless had considerable influence in preventing large increases in numbers of coho salmon, the existence of so many populations in various streams has conversely aided in averting any sudden decrease in abundance, hence fluctuations in the numbers of this species have never been violent.

INDIVIDUALITY OF POPULATIONS

That the populations of different streams tend to be individual in nature is supported by some experimental evidence. Gilbert (1913) reported the return in the fall of 1911 at Scotts Creek, California, of several coho salmon grilse from fingerlings marked there during the preceeding winter; no data as to returns of mature fish from this experiment were published. Fraser (1921) reported the recovery in Cowichan Bay, on October 11, 1917, of 1 coho salmon from 1,000 fry marked at the Cowichan Lake hatchery in March 1915. Pritchard (1936) reported the recovery in 1927 of 19 adult cohos in Cultus Lake, B. C., from 72 fish marked there during the spring of the same year. These fish were in the early part of their third year when marked. and returned as adults after having remained only a few months in the sea.

During the spring of 1934, 26,000 coho fingerlings, averaging 47.4 mm in length, which were made available through the cooperation of the Washington State Department of Fisheries, were marked by the author at Friday Creek, a tributary of the Samish River. During the same month, 9,800 coho fingerlings, averaging 49.2 mm in length, were transferred from the Skykomish River and were marked and liberated in Friday Creek. In November of that year an additional 26,000 fingerlings from the same brood as the fish used in the first experiment were also marked and liberated at Friday Creek. This lot averaged 101.6 mm in length at the time of marking. Complete data on returns to the Samish River of six grilse from the third marking experiment were obtained during the spawning run of 1935, and the capture of two additional marked grilse was reported from a reliable source.

The run of normally maturing three-year-olds appeared during the winter of 1936–37, and 480 marked fish were recovered from the Samish River, 7 from the first experiment, 11 from the second, and 462 from the third. No recoveries have been made from nearby streams or from the Skykomish River. From these results it would appear that mortality is much higher for the smaller fish, and that there is a definite tendency for mature cohos to return to spawn in the stream from which they migrated to the sea.

LOCALITY OF CAPTURE BY DIFFERENT TYPES OF GEAR

CATCHES IN VARIOUS DISTRICTS

Cohos have been second in demand only to kings for consumption as fresh fish, and large quantities have always been used in local markets. Because of their suitability for freezing they have surpassed all other species as a supply for the considerable demand of cold-storage units which have maintained an active market since the earliest years of the present century. For these reasons the canned-pack figures for this species are an unreliable measure of the commercial catch in past years. Although they have been the mainstay of the cape purse-seine fishery throughout its history, Gilbert (1913) reporting over 850,000 cohos taken there as early as 1911, and have formed the major part of the offshore catch of trollers, no records of the high-seas catches have been kept for other than very recent years.

It is impossible without thorough tagging experiments to determine the proportion of the cape catch provided by the populations of the Puget Sound-Fraser River region. Because of their widespread range of operation, part of the troller's catch landed in Washington may well be drawn from other sources. The purse seiners, however, are usually concentrated in the area off the entrance to the Strait of Juan de Fuca, and their catch doubtless consists mainly of the populations from the region. We may infer, from the far greater size of the runs entering the Strait of Juan de Fuca than of those conceivably passing the Banks en route for any other nearby district, that the major portion of the catch there is drawn from the regional populations.

In Puget Sound the trap fishery usually suspended operations in early years before the coho run had begun, except in the inside waters where the catch consisted mainly of this species. However, from the time that the fishing season of the northern traps was increased to include the fall runs up to the last decade, traps took the major part of the cohos caught in Puget Sound waters. In late years purse seines have become the chief source of this species.

The major part of gill-net catches in the estuaries of such rivers as the Skagit and the Snohomish have been coho salmon. Although considerable catches of coho salmon have been made on the Fraser River, especially in years when sockeye were not abundant, fall fishing has never been prosecuted as strenuously in that district as in the Puget Sound region.

Except for recent years data are not available for catches other than in a portion of the region, hence it is not possible to present complete figures for coho salmon production prioi to 1926. During this latter period the catch has been considerably smaller than in previous years. The total catch of coho salmon for Swiftsure Bank, Puget Sound, and the Fraser River, by various types of gear from 1926–34, is presented in table 36.

LOCALITY OF TRAP CATCHES

Because of the mobile nature of the purse-seine fleet, the determination of the particular district of the region in which their catches were made is not possible from past records. The best indication of the coho production of specific localities may be had from a consideration of the catches of the traps located therein. The total catches of traps in restricted areas are presented for the period from 1896–1934 in table 37.

Most of the areas in this table may be readily located from figures 2 and 3. "Lower sound" includes the water south of Useless Bay on Whidbey Island. "Miscellaneous" includes such inner bays as Bellingham, Padilla, and Samish, as well as Possession Sound and Hood Canal, but four-fifths of these fish were from the waters south of Point Wilson.

TABLE 36.—*Catch of coho salmon, 1926–34*

Year	Fraser River catch [1]	Puget Sound traps	Purse seines		Trollers		Puget Sound gill nets	Minor Puget Sound gear	Total, all gear
			Puget Sound	High seas	Puget Sound	High seas			
1926	120,663	384,600	232,721	375,000	22,269	325,000	57,436	6,266	1,523,955
1927	226,710	536,937	354,976	188,750	23,491	400,000	108,360	5,051	1,844,275
1928	203,580	436,819	236,085	195,844	18,538	339,311	65,092	4,163	1,499,432
1929	334,467	397,381	319,847	432,095	19,331	329,026	61,757	8,655	1,902,559
1930	71,280	285,310	204,692	407,405	15,589	355,040	65,228	4,125	1,408,669
1931	79,254	241,873	449,081	225,798	6,655	267,916	40,527	1,099	1,312,203
1932	160,452	102,727	331,565	315,290	3,457	281,686	22,240	1,262	1,218,679
1933	125,883	244,755	248,686	174,728	4,922	176,529	35,421	2,194	1,013,118
1934	113,382	164,504	233,418	365,380	12,709	261,804	40,038	507	1,191,742
Total	1,435,671	2,794,906	2,611,071	2,680,290	126,961	2,736,312	496,099	33,322	12,914,632

[1] Converted from cases at 9 fish per case, does not include cohos caught elsewhere in the Gulf of Georgia and canned on the Fraser River, or Fraser River cohos used for purposes other than canning.

TABLE 37.—*Annual catch of coho salmon by traps, in different areas, 1896–1934* [1]

Year	Area												Total
	Point Roberts and Boundary Bay	Sandy Point to Boundary Bay	Lummi Island and Rosario Strait	Haro Strait and Waldron Island	Salmon Banks and South Lopez	Hope Island and Skagit Bay	West Beach	West of Point Wilson	Admiralty Inlet	Lower Sound	Miscellaneous	Unidentified	
1896	1,632						13,062					265	14,959
1897	2,170		31,000				54,361						87,531
1898	61,753						26,628						88,381
1899	1,270	27,938	42,107	1,607	32,832		25,587	15,459	43,329	9,621	13,163	1,034	213,947
1900	20,095	22,375	6,893	20,909	46,204	38,378	13,499		152,757			4,048	325,158
1901	3,181	19,913	22,171	33,588	52,919	41,600	24,405		211,079		29,846	13,340	452,042
1902	1,020	2,185	19,576	24,811	52,756	39,710	18,566		142,348				300,972
1903	5,540	6,570	3,841	5,476	27,486		15,272					65	64,250
1904	751	655	409	49,113	16		9,544		127,130				187,618
1905	7,708	8,457	8,622	10,696	29,087	28,181	27,432		221,547				341,730
1906	9,296	16,093	10,421	66,102	23,065	27,818	45,012		266,710		878		465,395
1907	33,559	15,135	14,919		38,533	33,952	51,321		234,528		16,047		437,904
1908	18,096	12,835	18,496	49,020	14,446	27,065	43,073		165,302				348,333
1909	226	51,504	61,876	155	70,061	42,785	52,952		258,668				538,227
1910	62,782	65,523	82,728		64,552	35,329	37,215	31,894	148,860		11,467	32,052	572,402
1911	49,647	107,906	105,140	690	46,124	54,815	64,693	83,830	254,102		20,148	60	787,155
1912	64,851	52,223	54,671	12,529	35,583	7,768	47,249	55,274	190,532		38,064		558,744
1913	7,808	35,299	42,682	1,134	3,871	1,659	18,802	36,590	143,723		10,584	11,080	313,232
1914	18,355	21,169	49,846	6,611	9,711	34,963	31,881	13,398	64,539		24,629		275,102
1915	67,608	45,389	64,972	60,516	16,642	38,730	51,921	27,289	205,632	10,500	32,061	20,621	641,881
1916	36,093	27,046	38,741	30,035	21,317	52,355	39,015	9,163	118,047	14,914	31,332	6,792	424,850
1917	80,524	38,972	37,671	40,062	19,278	34,634	31,106	12,761	117,263	5,310	40,132	4,190	461,903
1918	85,164	64,159	100,167	40,382	66,632	46,614	46,467	10,190	173,963	22,752	51,516	1,635	709,641
1919	86,545	52,551	62,028	42,307	46,442	61,023	50,982	15,796	184,763	15,517	23,617	443	642,014
1920	31,581	5,214	20,693	7,759	14,970	22,457	20,845	1,667	99,898	16,465	17,534	1,500	260,583
1921	31,550	11,213	25,821	24,308	9,548	44,639	14,553	3,295	103,691	22,741	7,338	192	298,889
1922	53,589	22,400	69,311	16,857	9,407	99,831	17,377	9,612	105,081	27,083	35,498		466,046
1923	48,621	24,171	50,049	22,478	10,502	49,884	21,680	4,059	186,609	11,400	16,169		445,622
1924	63,090	27,432	46,974	18,290	20,142		36,097	6,171	203,304	64,422	19,215		505,137
1925	60,440	25,616	32,738	17,231	15,301	41,222	13,452	13,825	186,083	6,041	11,865		423,814
1926	55,973	16,808	33,617	17,993	12,172	30,144	16,232	37,683	134,455	19,619	11,672	21	386,389
1927	76,058	34,756	47,234	17,772	19,334	59,197	31,764	21,895	211,748	16,981			536,739
1928	75,948	43,134	48,130	9,270	22,203	19,470	23,469	17,382	130,361	12,527	6,034		407,928
1929	66,880	32,631	56,387	10,574	11,814	28,431	21,198	12,536	129,908	13,579	9,289	524	393,751
1930	19,047	9,549	20,581	6,708	5,372	49,278	27,784	11,896	102,317	21,844	8,464		282,840
1931	28,247	31,146	23,354	6,165	4,594	32,895	17,883	10,256	72,879	6,948	14,939		249,306
1932	2,693	3,199	12,374	2,015	3,717	22,652	2,869	6,390	36,107	6,992	3,490		102,498
1933	15,845	14,874	17,421	6,411	14,908	16,292	14,590	23,829	108,676		12,837	5	245,688
1934	15,170	3,184	22,162	3,710	6,508	16,380	8,442	8,354	47,019	11,677	8,729		151,335
Total	1,370,406	999,224	1,405,823	683,284	898,049	1,180,151	1,128,280	500,494	5,282,958	336,933	526,557	97,867	14,410,026

[1] Incomplete before 1915.

Out of a total catch in all areas of nearly 14½ million fish, approximately 4½ million were taken in the northern part of the region, 2½ million in areas through which the populations of both northern and southern districts migrate, and more than 7 million in the southern areas of the region. Of the latter total, more than 5¼ million fish were taken from Admiralty Inlet alone.

SEASONAL OCCURRENCE IN VARIOUS AREAS

The general seasonal occurrence of coho salmon from different types of fishing gear has already been presented. However, as might be anticipated in the case of migrations of populations from widely scattered streams, occurrence varies considerably in different districts. These variations do not seem to be correlated with the distances which the fish must travel along their migration routes, but appear to depend largely upon the characteristics of the individual populations. Because the traps sample individual runs in exact localities, their catches were used as the best measure of seasonal occurrence in various portions of the inner waters of the region.

Data were available from 26 traps which fished throughout the duration of the coho run in most of the years from 1911–34. Districts selected (see figs. 2 and 3) and number of traps were as follows: Point Roberts 2, Boundary Bay 4, Birch Bay 5, Rosario Strait 4, Dungeness Spit and Middle Point 3, Admiralty Bay 3, Bush Point 3, and Hope Island 2. The total number of fish included in the catches of these traps was 5,652,592. From these data the average proportions of the season's catch taken in each 7-day period by the traps in various districts were calculated. These figures are presented in table 38. Because of the essential similarity in occurrence, Point Roberts and Boundary Bay have been grouped, as have Admiralty Bay and Bush Point.

TABLE 38.—*Seasonal occurrence of coho salmon from traps; proportion of total catch taken in each 7-day period*

Week ending—	Area										
	Point Roberts	Boundary Bay	Point Roberts and Boundary Bay	Birch Bay	Rosario Strait	Dungeness Spit and Middle Point	Admiralty Bay	Bush Point	Admiralty Bay and Bush Point	Hope Island	All districts
May 5	--------	--------	--------	--------	--------	0.062	0.002	0.056	0.044	--------	0.018
May 12	--------	--------	--------	--------	0.090	.038	.202	.024	.056	--------	.035
May 19	0.822	--------	0.871	0.046	.124	.105	.216	.034	.071	--------	.059
May 26	.554	--------	.588	.024	.100	.077	.138	.041	.073	--------	.054
June 2	.496	--------	.526	.327	.077	.068	.157	.072	.107	--------	.084
June 9	.265	--------	.281	.348	.073	.070	.131	.069	.094	--------	.080
June 16	.148	0.162	.154	.297	.121	.072	.224	.103	.151	--------	.103
June 23	.143	3.703	1.207	.396	.114	.086	.494	.158	.298	--------	.175
June 30	.461	1.058	.627	.343	.132	.127	.494	.132	.302	0.001	.174
July 7	.277	.649	.414	.695	.174	.261	1.273	.227	.757	.003	.351
July 14	.207	1.944	.937	.676	.370	.451	.867	.447	.667	.003	.393
July 21	.526	1.460	.946	.940	.636	1.214	.730	.465	.601	.057	.466
July 28	.451	1.610	1.001	1.210	.784	1.781	.599	.565	.583	.081	.532
Aug. 4	1.053	1.358	1.171	1.367	1.127	2.600	.613	.745	.681	.421	.709
Aug. 11	.518	1.464	.962	1.810	1.484	3.684	.796	.817	.808	1.825	.962
Aug. 18	.517	1.512	.985	1.880	1.915	3.563	1.269	1.540	1.412	3.178	1.413
Aug. 25	2.018	2.373	2.132	2.997	3.998	4.938	2.853	2.809	2.829	4.457	2.717
Sept. 1	5.068	5.117	4.950	6.393	6.091	7.840	3.732	4.026	3.891	5.366	3.911
Sept. 8	11.926	6.476	9.020	7.805	10.671	8.335	6.955	6.191	6.495	7.853	6.953
Sept. 15	12.540	14.586	13.173	13.341	13.462	7.360	10.041	9.459	9.689	10.329	10.795
Sept. 22	15.238	16.145	15.262	10.382	13.845	11.857	13.724	13.382	13.485	14.373	12.652
Sept. 29	15.194	11.935	13.513	9.271	11.967	12.869	13.004	13.411	13.200	12.789	12.129
Oct. 6	9.737	8.276	9.127	9.126	9.950	11.686	14.033	14.038	13.991	14.159	12.628
Oct. 13	8.501	9.454	8.819	10.385	10.211	10.076	12.091	12.479	12.279	12.351	11.978
Oct. 20	4.209	7.579	5.221	9.648	6.339	4.894	6.894	9.025	8.091	6.629	8.357
Oct. 27	6.042	2.681	5.315	7.727	4.149	4.041	3.897	4.862	4.441	2.993	5.313
Nov. 3	2.631	.459	2.314	1.756	1.553	1.845	2.256	2.290	2.270	1.362	3.108
Nov. 10	.457	--------	.484	.810	.441	--------	1.262	.939	1.061	.914	1.628
Nov. 17	--------	--------	--------	--------	--------	--------	1.053	1.000	1.000	.546	1.502
Nov. 24	--------	--------	--------	--------	--------	--------	--------	.547	.528	.301	.667
Dec. 1	--------	--------	--------	--------	--------	--------	--------	.044	.043	.008	.051
Dec. 8	--------	--------	--------	--------	--------	--------	--------	.003	.003	--------	.005
Total	99.999	100.001	100.000	100.000	99.998	100.000	100.000	100.000	100.001	99.999	100.002

Comparing the data for the Point Roberts-Boundary Bay area with those for Birch Bay, occurrence in both areas is slight until the latter part of August, when the runs increase abruptly in size. The run at Point Roberts and Boundary Bay increases steadily to a peak in the week ending September 22, and abundance decreases materially thereafter, with minor fluctuations, to the end of the season. Birch Bay clearly shows the presence of the same run as that of the former area, but occurrence is distinctly bimodal. The peak of the main run occurs in the week ending September 15, after which there is a definite decrease in numbers. A second run of smaller proportions follows, reaching its peak between October 6 and October 20, the run falling off abruptly thereafter. The main portions of the runs of both areas are probably contributed by the Fraser and other northern rivers, but the second peak in the Birch Bay area may be composed largely of populations of such rivers as the Nicomekl and the Serpentine.

A comparison of the data for the Point Roberts-Boundary Bay area with those from Rosario Strait indicate that the run in the latter area corresponds closely with that of the more northern districts; the somewhat earlier appearance here is probably due to the lesser distance of migration from the sea. There is a strong indication that a large part of the runs passing through Rosario Strait continues to Boundary Bay without entering Birch Bay. The Rosario Strait data are shown graphically in the lower section of figure 26.

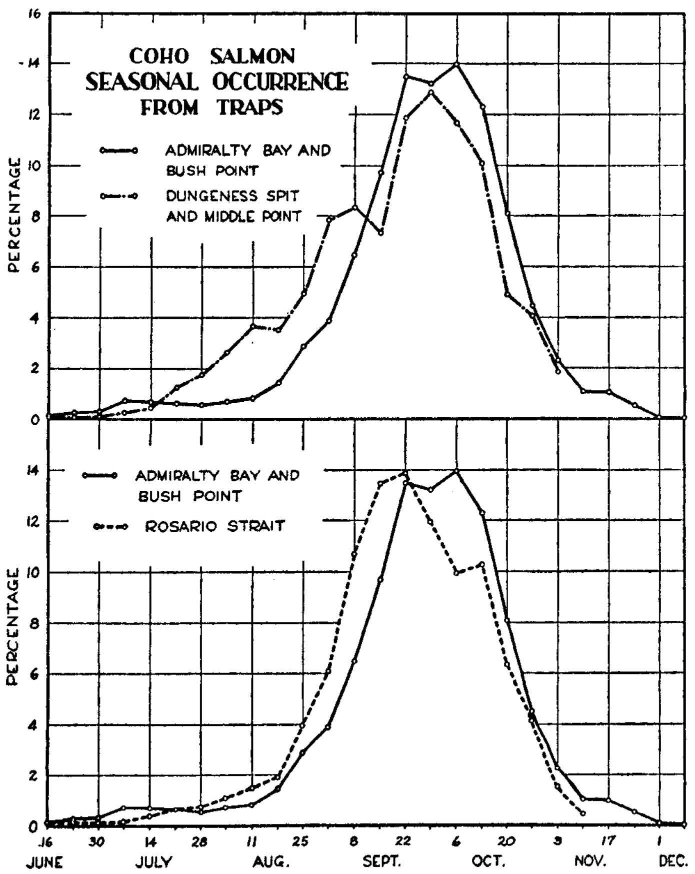

FIGURE 26.—Seasonal occurrence of coho salmon in trap catches from the southern part of Puget Sound. In the lower section of the figure occurrence in the principal southern area is compared with that of one of the northern areas.

A comparison of seasonal occurrence of the Dungeness Spit-Middle Point area with that of the Admiralty Bay-Bush Point area indicates that the early appearance of cohos in the former area is consonant with its more seaward location. In this area a relatively heavy run follows the first group of fish, appearing during late August and early September, after which the intensity slackens. This is followed by the main run, which reaches its peak in the last week in September and drops abruptly after the second week in October. It is evident that traps in this area fish a mixed population, but that the main run consists of fish bound for the southern areas.

The Admiralty Bay-Bush Point run increases steadily from the last week in August to the third week in September, remains at a high level for three more weeks, and decreases steadily thereafter to the middle of November. Unlike the other areas, the run does not terminate here, but continues at a low level until early December. The data for seasonal occurrence in these areas is presented graphically for comparison in the upper section of figure 26.

In the lower section of figure 26, occurrence in the Rosario Strait area is compared with that of the Admiralty Bay-Bush Point area. Although both of these areas are immediately adjacent to waters in which their individual runs mingle, seasonal occurrence of cohos in Rosario Strait is considerably earlier than in the southern area, in fact the run in the former area has begun to decrease almost at the time that the southern run has first reached its peak. The Admiralty Bay-Bush Point runs also show a more prolonged peak of occurrence, and continue much later in the season.

From table 38 it is evident that the Hope Island run is almost identical in occurrence with that of the Admiralty Bay-Bush Point area, although the small catches in the early and late portions of the season appear only in the latter area. It is apparent that a large proportion of the Skagit River runs must pass around the southern end of Whidbey Island in the course of their migration.

CHANGES IN ABUNDANCE

CALCULATION OF TRAP INDICES

It is apparent, from both trap and purse-seine catches, that there has been a considerable diminution in abundance of cohos in recent years. Inasmuch as traps and purse seines have been the principal types of gear catching coho salmon in this region, trends of abundance were determined from catches by both types of gear, and are presented together for comparison.

In measuring abundance from traps, several difficulties are encountered which arise from the lateness of the coho runs in relation to those of other species taken by this type of gear. During early years, in certain areas where other species formed the principal catch, the traps were often removed from the water after fishing during only part of the coho season. Closed periods, which were imposed through legislation in many of the years after 1920, also prevented the traps in certain areas from fishing during the entire coho run. Years in which these closures were enforced cannot be compared directly to those in which fishing was not restricted unless some provision is made to offset the shorter fishing period. In most early years the traps were permitted to fish well into the winter months, while in later years legislation has often terminated the season before the entire run has appeared. For these reasons it was impossible to use the catches of any trap unless the opening and closing dates of its annual fishing seasons were known. This requirement sharply curtailed the available amount of data.

In order to make the annual catch data comparable for both early and late years, they were weighted according to the length of the period fished. Inasmuch as the coho runs in the various districts are quite uniform in time from year to year, the average seasonal occurrences already presented were used as a basis for determining the time period of the runs in their respective districts.

November 10 was arbitrarily selected as the end of the fishing season. The catches of traps which fished later in the year were reduced in proportion to the percentage occurrence of the run after that date, and catches of traps which ceased fishing before that date were similarly increased. For 1921, and for other late years in which closed periods have been in force, trap catches were increased by the average percentage occurrence during the closed periods in their respective areas. Catches of traps which fished for a lesser period of time than that in which 75 percent of the run for their district normally occurred were not included in the analysis.

A certain amount of error is unavoidably introduced by empirically increasing or decreasing catches for particular years to compensate for irregular length of fishing season. However, catches which were decreased in size were confined almost entirely to early years when fishing was less restricted, and nearly all increases in catches were made in later years when closed periods were imposed and fishing seasons were shortened by legislative action. Such error as may have accompanied these necessary corrections would tend to reduce the apparent level of abundance in early years and to increase it in later years. Any decline shown in the trend of abundance would thus be given added validity.

Three particular districts were selected for analysis. The first was that extending from Sandy Point to the international boundary, and included the Birch Bay, Boundary Bay, and Point Roberts areas (see fig. 2). Because of the size of the district and the large number of traps situated therein, catches were used from all traps for which suitable data were available. Prior to 1910 the data were meager, for sockeyes were of such importance in this region that catches of other species were often not recorded. After the tremendous sockeye run of 1913 most of the traps were removed before the coho run. In 1932, unfavorable economic conditions sharply reduced the number of traps fishing. During the remaining years, suitable data for from 7–12 traps were available. These traps, although but a small part of the total number fishing in the area, represent a considerable portion of those which were fished late enough in the season to intercept the coho migration. The number of traps available in this area, and their total catch for each year, are tabulated in the first two columns of table 39.

The second area selected was Rosario Strait. Although the runs in this district are largely composed of the same populations which pass through the northern areas, fishing conditions differ considerably, for the area of water through which the runs must pass is much more restricted and the number of traps is very small. Three of these traps, located in strategic positions, have taken the bulk of the catch in this area. Data for the 16-year period, from 1919–34, when at least two of these traps fished every year, all three of them for fifteen years, are tabulated in the third and fourth columns of table 39. It is evident that the efficiency of Rosario Strait traps is greater than that of those in the northern area, and their index of abundance should provide a useful check on that calculated from the larger group.

TABLE 39.—*Indices of abundance of coho salmon from traps*

Year	Data by areas						Index figures		
	North of Sandy Point		Rosario Strait		Admiralty Inlet		North of Sandy Point	Rosario Strait	Admiralty Inlet
	Number of fish	Number of traps	Number of fish	Number of traps	Number of fish	Number of traps			
1900	----------	----------	----------	----------	122, 723	2	----------	----------	2. 166
1901	----------	----------	----------	----------	201, 962	2	----------	----------	3. 544
1902	----------	----------	----------	----------	113, 063	2	----------	----------	2. 071
1903	----------	----------	----------	----------	----------	----------	----------	----------	----------
1904	----------	----------	----------	----------	140, 004	2	----------	----------	2. 558
1905	26, 353	2	----------	----------	195, 469	4	4. 409	----------	1. 806
1906	33, 066	3	----------	----------	248, 189	4	3. 923	----------	2. 036
1907	50, 087	6	----------	----------	180, 145	4	3. 828	----------	1. 466
1908	47, 856	5	----------	----------	165, 054	3	5. 431	----------	1. 644
1909	31, 174	1	56, 871	2	294, 398	3	9. 888	8. 288	3. 195
1910	99, 579	10	64, 779	2	163, 185	4	4. 009	9. 238	1. 548
1911	54, 261	10	77, 585	3	277, 837	4	2. 278	7. 813	2. 472
1912	113, 122	12	56, 977	3	205, 888	4	4. 083	5. 798	1. 701
1913	36, 503	5	47, 753	3	159, 062	3	2. 598	4. 787	1. 449
1914	58, 640	10	32, 398	2	68, 166	3	2. 328	4. 551	. 718
1915	56, 881	12	30, 114	3	131, 229	4	1. 835	2. 988	. 992
1916	50, 375	10	25, 440	3	70, 722	4	2. 245	2. 507	. 517
1917	53, 562	12	23, 418	3	94, 769	4	1. 838	2. 403	. 754
1918	108, 710	12	69, 690	3	116, 083	5	3. 433	6. 812	. 811
1919	73, 488	12	44, 131	3	122, 723	5	2. 461	4. 473	. 862
1920	44, 597	10	21, 485	3	69, 010	4	1. 852	2. 199	. 731
1921	59, 820	12	14, 844	2	78, 967	3	2. 143	2. 330	1. 297
1922	86, 589	7	46, 791	2	61, 253	2	5. 332	6. 740	1. 715
1923	76, 529	12	32, 619	2	166, 608	6	2. 672	4. 950	1. 017
1924	92, 276	10	25, 802	2	166, 520	6	3. 978	3. 748	1. 044
1925	57, 501	12	21, 950	3	165, 477	5	1. 852	2. 191	1. 078
1926	49, 163	11	20, 396	3	99, 946	5	1. 898	2. 066	. 690
1927	56, 853	12	26, 584	2	186, 117	6	1. 879	3. 907	. 906
1928	51, 430	10	23, 784	2	104, 412	6	2. 009	3. 510	. 561
1929	63, 629	12	29, 402	2	115, 487	7	2. 291	4. 122	. 608
1930	26, 169	11	10, 108	2	81, 478	7	. 933	1. 434	. 443
1931	28, 659	11	13, 470	3	58, 381	4	1. 182	1. 381	. 722
1932	1, 184	3	19, 919	3	33, 155	2	. 175	1. 951	. 710
1933	23, 828	7	14, 026	3	106, 083	7	1. 342	1. 350	. 578
1934	21, 781	8	19, 317	3	54, 639	5	1. 151	1. 847	. 388
Total	1, 633, 665	----------	869, 653	----------	4, 618, 204	----------	----------	----------	----------

The third area selected was Admiralty Inlet (see fig. 3). Here, as in Rosario Strait, the runs are concentrated while migrating through a restricted passage, and the effectiveness of most of the traps is correspondingly great. Catches of from two to seven traps were available each year from 1900–1934, with the exception of 1903. The number of traps, and their corresponding total catches by years, are tabulated in the fifth and sixth columns of table 39.

The calculation of index figures from these data is complicated by the fact that only a few traps in each district have fished continuously throughout this period of years. There is a wide variation in the fishing effectiveness of different traps, and any determination, such as the average annual catch per trap, must be affected considerably by the proportions of efficient and inefficient traps fishing each year. In order to minimize this variation it was necessary to weight the catches in such a manner that the relative annual change in the average catch of each trap might be measured irrespective of the actual sizes of the catches from which the average was derived. Such weighting was accomplished for each district by selecting a group of traps which had fished in the same years over a long period of time, and from which the relative effectiveness of all traps in that district might be measured. From the sums of the annual catches of these traps the average annual catches were calculated;

each of these was then determined as a proportion of the average annual catch of the base group. The average annual catch of any trap which fished for a lesser period of years than did the standard traps was determined as a proportion of the average of the total catches of the base group for the same years as those in which that particular trap fished.

The annual catches of the traps were then divided by the proportional weights of the same traps, and the average of the resultant figures for any 1 year is the index figure for that year. The index figures for the three areas, tabulated in the last three columns of table 39, are not directly comparable as they now appear, but measure only the degree of change from year to year in the individual areas. The relative changes in the different areas will be considered in conjunction with the index derived from purse-seine catches.

CALCULATION OF PURSE-SEINE INDEX

Inasmuch as a considerable portion of the coho salmon taken in Puget Sound waters have been caught by means of purse seines, a determination of changes in abundance of the species based on purse-seine data provides a valuable comparison with the indices from trap catches.

The purse-seine index is similar to those derived from traps in that it is a measure of relative variation, from year to year, in the average catch of a unit of fishing effort. However, its construction is materially different in that the total seasonal catches of individual vessels are unknown, hence the size of the average delivery was used as the unit of measurement instead of the annual catch.

In order to eliminate the influence of deliveries made by the vessels fishing for other species of salmon than coho, only such deliveries as were made between September 2 and October 20 were included. Data were also limited to vessels of more than 9 net tons and less than 40 net tons. This restriction excluded both the very small vessels, which were not regular purse seiners, and the largest vessels, which fished on Puget Sound only occasionally in the fall.

Since the average delivery of the small vessels operating in early years could not be compared directly to that of the large-sized, modern vessels, the catches necessarily were weighted to compensate for the changes in efficiency. In determining the weighted average delivery of the fleet, the vessels of 10–14 net tons were considered as unity, and the weighted number of deliveries of vessels in larger size-classes were the product of their actual number of deliveries and the vessel efficiency of that particular size-class, taken from table 15. For each year from 1911–34 the sum of the number of fish in the catches of all vessels in the fleet was divided by the weighted number of deliveries. The weighted average delivery figures represent the average catch in terms of one size-class of vessels, hence they are directly comparable throughout the series of years. These figures are presented in the last column in table 40. The other columns in the table show the same data broken down according to groupings of vessels of various sizes.

TABLE 40.—*Index of abundance of coho salmon from Puget Sound purse seines*

Year	Indices from individual size classes							
	10-14 net tons			15-24 net tons				
	Number of fish	Number of deliveries [1]	Average delivery	Number of fish	Number of deliveries	Average delivery	Weighted number of deliveries	Weighted average delivery
1911	5,760	65	88.62	----------	----------	----------	----------	----------
1912	214	8	26.75	11,169	93	120.10	110	101.54
1913	4,231	60	70.52	8,261	105	78.68	124	66.62
1914	18,784	146	128.66	29,015	255	113.78	303	84.16
1915	12,732	243	52.40	45,495	606	75.07	788	57.73
1916	8,940	266	33.61	26,218	410	63.95	533	49.19
1917	5,689	387	14.70	18,050	754	23.94	1,010	17.87
1918	27,552	266	103.58	58,685	459	127.85	620	94.65
1919	13,846	247	56.06	28,481	430	66.23	581	49.02
1920	2,188	66	33.15	13,808	146	94.58	196	70.45
1921	12,637	154	82.06	45,580	477	95.56	634	71.89
1922	7,999	132	60.60	35,216	326	108.02	434	81.14
1923	6,049	128	47.26	31,433	435	72.26	583	53.92
1924	4,643	80	58.04	23,038	305	75.53	400	57.60
1925	11,921	222	53.70	38,578	553	69.76	724	53.28
1926	3,406	122	27.92	34,477	498	69.23	647	53.29
1927	6,962	178	39.11	35,280	655	53.86	858	41.12
1928	8,174	242	33.78	70,146	1,046	67.06	1,360	51.58
1929	14,327	440	32.56	74,835	1,489	50.26	1,995	37.51
1930	6,275	135	46.48	25,781	542	47.57	726	35.51
1931	7,360	253	29.09	54,640	1,277	42.79	1,711	31.93
1932	8,255	157	52.58	58,166	1,072	54.26	1,447	40.20
1933	5,545	334	16.60	35,987	1,600	22.49	2,144	16.78
1934	4,486	240	18.69	36,357	1,069	34.01	1,421	25.59
Total	207,975	4,571	----------	838,696	14,602	----------	19,349	----------

Year	Indices from individual size classes					Index from grouped size classes		
	25-39 net tons							
	Number of fish	Number of deliveries	Average delivery	Weighted number of deliveries	Weighted average delivery	Number of fish	Number of weighted deliveries	Weighted average
1911	1,024	10	102.40	18	56.89	6,784	83	81.73
1912	----------	----------	----------	----------	----------	11,383	118	96.47
1913	1,067	9	118.56	16	66.69	13,559	200	67.80
1914	530	8	66.25	15	35.33	48,329	464	104.16
1915	645	16	40.31	29	22.24	58,872	1,060	55.54
1916	1,345	12	112.08	22	61.14	36,503	821	44.46
1917	11,890	211	56.35	390	30.49	35,629	1,787	19.94
1918	14,677	110	133.43	204	71.95	100,914	1,090	92.58
1919	11,833	125	94.66	234	50.57	54,160	1,062	51.00
1920	11,312	78	145.03	144	78.56	27,308	406	67.26
1921	58,882	424	138.87	780	75.49	117,099	1,568	74.68
1922	40,542	176	230.35	326	124.36	83,757	892	93.90
1923	34 578	295	117.21	546	63.33	72,060	1,257	57.33
1924	16,208	103	157.36	192	84.42	43,889	672	65.31
1925	31,709	303	104.65	561	56.52	82,208	1,507	54.55
1926	60,582	532	113.88	984	61.57	98,465	1,753	56.17
1927	55,697	624	89.26	1,167	47.73	97,939	2,203	44.46
1928	97,386	1,239	78.60	2,305	42.25	175,706	3,907	44.97
1929	91,493	1,486	61.57	2,779	32.92	180,655	5,214	34.65
1930	53,597	781	68.63	1,460	36.71	85,653	2,321	36.90
1931	95,752	1,760	54.40	3,326	28.79	157,752	5,290	29.82
1932	153,377	1,619	94.74	3,060	50.12	219,798	4,664	47.13
1933	66,264	1 974	33.57	3,731	17.77	107,796	6,209	17.36
1934	65,169	1,047	62.24	1,968	33.11	106,012	3,629	29.21
Total	975,559	12,942	----------	24,257	----------	2,022,230	48,177	----------

[1] Number of deliveries and weighted number of deliveries identical for this group, as efficiency weighting is unity.

TRENDS OF ABUNDANCE

The indices from traps and seines represent the relative availability of coho salmon to the particular type of gear and for the particular area in which that gear operated. The trap indices are for three individual areas, whereas the purse-seine index is necessarily based on catches made throughout the entire Puget Sound region.

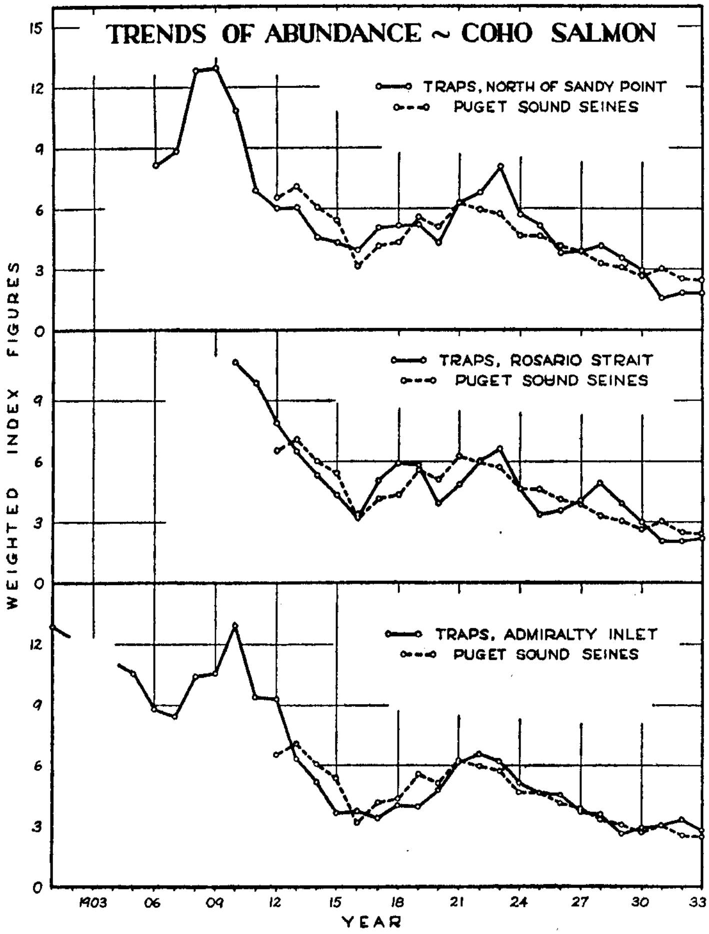

FIGURE 27.—Trends of abundance of coho salmon. Indices calculated from trap catches in three different areas are compared to the index calculated from purse-seine catches taken from the entire Puget Sound region. A considerable decrease in abundance has taken place since the early years of the fishery.

In order to show more clearly the trend of abundance of the species, the indices were smoothed once by threes. Since some 98 percent of these fish mature at 3 years of age, such smoothing also minimizes the effect of any predominate age-cycle. To facilitate comparison of the curves, it was necessary to reduce the indices to the same general range of variation, therefore each curve was proportionally reduced or increased so that the sum of the index figures for the years 1912–33 equalled 100.00. These smoothed indices are shown graphically in figure 27.

In the three sections of the figure the indices from traps north of Sandy Point, from Rosario Strait, and from Admiralty Inlet are compared with the seine index. The same general trend is apparent in all the indices.

A general high level of abundance is indicated prior to 1910, but the continued increase thereafter in numbers of all types of gear was accompanied by a decrease in abundance of the species. During the post-war depression, the considerable decrease in fishing effort throughout the region resulted in a general rise in abundance; this increase was quickly terminated, however, when fishing once more became profitable and the trend of abundance has declined from that point.

The indices correspond fairly well throughout, and since the post-war years the seine index is very similar to that for Admiralty Inlet traps. This is a direct corollary of the more intense purse-seine fishery in the southern district during these years, throughout which this area has been the heaviest producer of coho salmon. It is further evident from these curves that the general level of abundance throughout the region has been lower in recent years than at any previous time in the history of the fishery.

That changes in the intensity of the fishery have exerted a considerable influence on the abundance of cohos has been indicated. However, abundance has been further affected by changing conditions in the streams where the adult fish spawn and the young are reared. Lumbering has been, or is now being carried on in the drainage basins of almost every river in the southern part of the region, and most of the cut-over lands have been cleared for agricultural purposes. Rapidity of run-offs and resultant flood conditions have become increasingly prevalent on these streams, many former spawning grounds have been rendered useless, and the carrying capacity of the streams for young fish during their stream residence has been reduced. Utilization of streams for water power or for industrial purposes has had a similar effect. There is a further possibility of the withdrawal of spawning grounds due to the impounding of waters in the upper reaches of these rivers for the purpose of controlling floods and erosion.

It is difficult to determine how far the level of abundance can decline before the populations of some areas pass the point at which they are able to rehabilitate themselves, even under the most stringent protection that legislation might offer. In view of these conditions it appears highly probable that the decline in numbers of this species will be continued unless there is a drastic change in the factors influencing their abundance.

KING SALMON

By George B. Kelez

INTRODUCTION

Populations of king salmon are found in most of the important salmon streams in the region, the heaviest runs usually appearing in the larger rivers. Averaging more than 20 pounds in weight, the kings are the largest of the 5 species of Pacific salmon. Their large size and high quality have always commanded the highest individual price of any of the species, and the greater portion of the catch has been absorbed by the fresh-fish markets or used for mild curing.

Kings from the troll fishery of Cape Flattery appear in the city markets in early spring and they are taken in gill nets throughout the fall months, but the bulk of the commercial landings are made in late spring and summer. Except in the gill-net catches in the rivers, both immature and mature fish appear together in the landings during the greater part of the fishing season. Sport fishing for kings, which has been popular with residents of the region for nearly 50 years, is carried on from April to September.

LIFE HISTORY

Possibly because of their greater size and strength, kings usually spawn in deeper, faster water than do the other species of salmon. Although the spring runs may ascend to small head-water streams, the later runs often spawn in the larger tributaries or even in the main channels of the rivers. There is a recognizable difference in the time at which these runs enter the rivers; the races which spawn far upstream usually appear during the spring months, whereas the lower-spawning races do not appear until later in the summer or in early fall.

Gilbert (1913) and Fraser (1917 et seq.) both found that the greater part of the fry descend to salt water shortly after hatching, and a lesser proportion remain in the stream throughout the first winter and migrate seaward during the following spring. These findings were based on scale readings. Scales from fish which migrated to the sea as fry showed a typical rapid growth in the nucleus, those which migrated as yearlings showed a distinctly different nucleus, due to the less rapid growth in the stream. Fraser reported the proportions of these types in lower Gulf of Georgia fish to be 65.4 percent sea-type and 34.6 percent stream-type. His collections from the upper part of the Gulf of Georgia contained 78.2 percent of the former type and 21.8 percent of the latter.

Rich (1925) stated that in the Columbia River runs the stream-type nuclei indicated spring-running fish which spawned in the headwater streams, whereas sea-type nuclei predominated later in the season when the lower-spawning races of fish were entering the river.

After migrating to salt water, the young kings are frequently caught in the inner waters of the region before reaching the ocean. At this time they are called "blackmouth" by the fishermen.

Tagging experiments reported by Canadian investigators, Williamson (1925, 1926), Mottley (1929), Williamson and Clemens (1932), Clemens (1932), and Pritchard (1934), indicate that a considerable proportion of the young kings migrate northward and return along the coast of Southeastern Alaska and British Columbia on their migration to the streams where they will spawn. These experiments have also indicated the presence of large numbers of kings from the populations of other coastal rivers, both north and south of the region, in the same localities along the British Columbia coast. It is evident that a considerable mixture of populations occurs in the waters of the Pacific, and that catches of gear operating in the offshore waters may well contain large numbers of fish from streams other than those of the region.

Gilbert (1913) stated that kings taken in the commercial fishery of the region ranged in age from 3–7 years, and that the fish in their third year were grilse. Fraser (1921) reported that the commercial catch from the upper part of the Gulf of Georgia contained fish from 2–6 years of age, only part of which were mature. Of those individuals which had entered the sea shortly after hatching, nearly 50 percent were in their third, and approximately 35 percent were in their fourth year. The remainder were 2 and 5 years of age. Of those which had entered the sea after a considerable time in fresh water, some 30 percent were in their third year, 44 percent in their fourth year, 23 percent in their fifth year, and the remainder in their sixth year. The bulk of the mature fish were in their fourth and fifth years.

An important characteristic of the king salmon, unique to that species, is the considerable variation in the color of the flesh. Rathbun (1899) stated:

> While in some of the fish the flesh has its ordinary deep pink color, in others the flesh is white or only slightly tinged with pink. All intermediate gradations of colorations, as well as intermixtures of the two, occur, and no degree of this variation is distinguishable from the outside.

Cobb (1911) stated:

> In most places the flesh is of a deep salmon red, but in certain places, notably Southeast Alaska, Bristol Bay, Puget Sound, and British Columbia, many of the fish, the proportion being sometimes as much as one-third of the catch, have white flesh. No reasonable explanation of this phenomenon has yet been given.

Aside from color, the flesh of white and red kings taken at the same time in the fishery is of the same quality. This, together with the definite difference in proportion of white kings in various districts of the region throughout the season, which will be discussed later, indicates a strong possibility of a hereditary color-characteristic. The Fraser River king pack is canned as red, pink, and white kings. It is possible that a part of the late-season pack may consist of red kings whose color has faded with approaching sexual maturity. However, heavy catches of white kings are made by trollers off the west coast of Vancouver Island in late July and August, at which time the color cannot be ascribed to changes accompanying sexual development. Since these fish are not caught below Destruction Island, southwest of Cape Flattery, it is highly probable that they are part of the run which appears in the northern part of Puget Sound in September.

LOCALITY OF CAPTURE BY DIFFERENT TYPES OF GEAR

CATCHES IN VARIOUS DISTRICTS

The demands of the fresh-fish markets, and methods of processing other than canning, have absorbed the greater part of the catches of king salmon, hence the canned packs are of little use in determining the annual catch of the species. The catch on Puget Sound alone has averaged 264,000 fish a year during the 20-year period from 1915–34. The catch by 5-year intervals during this time was 1,597,246 fish from 1915–19; 1,219,492 fish from 1920–24; 1,380,225 fish from 1925–29; and 1,087,693 fish from 1930–34.

It is exceedingly difficult to obtain catch records for all districts of the region, but data are available for the period from 1927–34 for all districts except the Fraser River. For this district the canned pack has been converted to number of fish and it represents only a part of the early run on the river, but includes the greater part of the fall run. A small number of kings landed by trollers in the northern portion of the Gulf of Georgia have not been included. These data are presented in table 41.

TABLE 41.—*Catch of king salmon, 1927–34*

Year	Puget Sound traps	Purse-seines		Trollers		Puget Sound gill nets	Minor Puget Sound gear	Fraser River catch [1]	Total, all gear
		Puget Sound	High seas	Puget Sound	High seas				
1927	227, 909	18, 370	6, 818	1, 870	235, 866	37, 580	2, 033	53, 770	584, 216
1928	198, 443	11, 025	4, 067	1, 651	213, 784	31, 195	900	11, 629	472, 694
1929	249, 353	14, 181	13, 817	1, 366	206, 073	44, 485	2, 257	23, 533	555, 065
1930	208, 872	17, 136	8, 791	2, 645	235, 425	49, 934	1, 558	51, 084	575, 445
1931	156, 207	21, 497	13, 957	1, 156	245, 611	28, 522	516	28, 712	496, 178
1932	137, 770	20, 670	6, 897	192	169, 530	20, 910	24	84, 722	440, 715
1933	162, 991	23, 916	4, 596	68	113, 512	22, 960	667	16, 483	345, 193
1934	165, 013	15, 606	10, 490	9, 337	125, 377	19, 250	276	46, 227	391, 576
Total	1, 506, 558	142, 401	69, 433	18, 285	1, 545, 178	254, 836	8, 231	316, 160	3, 861, 082

[1] Converted from cases packed from fish caught on the Fraser River; does not include kings used for purposes other than canning.

The total catch by all gear in the region during these 8 years was 3,861,082 fish. Trollers on the high seas landed 40.02 percent of the total catch, and inside trollers 0.47 percent, a total of 40.40 percent. Puget Sound traps took 39.02 percent of the king catch during these years, Fraser River gill nets 8.19 percent, and Puget Sound gill nets 6.60 percent. Purse seiners on the high seas took 1.80 percent and those on Puget Sound 3.69 percent, a total of 5.49 percent. Landings from miscellaneous gear amounted to 0.21 percent of the total. The catch of trollers in the region of Swiftsure Bank differs from the "inside" gear in that it must, in view of the migrations indicated by tagging experiments, contain a considerable proportion of fish from populations other than those of the Puget Sound-Fraser River region.

LOCALITY OF TRAP CATCHES

A consideration of catch data from traps shows the general proportions of the king-salmon catches in the different parts of the Puget Sound district. These data, from 1895–1934, are presented in table 42. The districts used are similar to those discussed under trap catches of coho salmon in the preceding section.

The total catch of king salmon includes 5,659,793 fish. Of this total, 2,644,524 were taken in traps north of Deception Pass, the greater part of these being from the populations of rivers in the northern part of the region. There were 1,741,479 fish from districts wherein a considerable mixture of populations migrating to both northern and southern streams must be present; 1,128,835 fish were taken in the southern portions of the region, and 144,955 fish were taken in miscellaneous and unidentified areas. These data indicate that the greater portion of the catch of king salmon on Puget Sound is supplied by the populations of the northern rivers, and the size of the catch in the northernmost districts would further indicate that a considerable portion of these populations are migrating to the Fraser River and to the smaller streams entering the Gulf of Georgia.

TABLE 42.—*Annual catch of king salmon in different areas, 1895–1934* [1]

Year	Area												Total
	Point Roberts and Boundary Bay	Sandy Point to Boundary Bay	Lummi Island and Rosario Strait	Haro Strait and Waldron Island	Salmon Banks and South Lopez	Hope Island and Skagit Bay	West Beach	West of Middle Point	Admiralty Inlet	Lower Sound	Miscellaneous	Unidentified	
1895	912												912
1896	10,192		97									788	11,077
1897	1,449	720	3,164		71		3,384						8,788
1898	30,255	3,000	41				94					4	33,394
1899	19,980	4,635	12,286	96	2,814		79	129					40,019
1900	30,979	9,215	364	2,412	20,365	14,755	5,758		8,922		850	4,777	98,397
1901	7,881	4,442	3,568	2,933	5,963	5,180	5,047		461		218	5,410	41,103
1902	5,312	7,681	5,497	5,378	14,891	4,829	9,077		885				53,550
1903	6,005	15,427	5,563	2,489	17,360							121	46,965
1904	15,695	17,478	5,807	2,343	6,960		12,911						61,194
1905	14,105	5,065	4,883	2,080	7,472	9,787	10,469		2,684				56,545
1906	8,731	7,981	8,048	9,081	3,627	5,609	19,103		10,084				72,264
1907	14,952	8,829	6,543		5,011	8,903	34,977		740				79,955
1908	8,843	8,922	8,475	5,761	5,892	9,640	47,986		3,461				98,980
1909	7,374	5,666	9,877		6,911	8,945	19,648		254				58,675
1910	14,542	21,478	18,144		8,307	8,583	24,414		11,505			256	107,229
1911	28,054	26,590	25,996		9,647	4,752	34,090		6,770		380	83	136,362
1912	22,442	19,461	22,785	3,250	4,374	4,374	28,886		3,343		629		109,544

[1] Incomplete before 1915.

TABLE 42.—*Annual catch of king salmon in different areas, 1895–1934*—Continued

Year	Area												Total
	Point Roberts and Boundary Bay	Sandy Point to Boundary Bay	Lummi Island and Rosario Strait	Haro Strait and Waldron Island	Salmon Banks and South Lopez	Hope Island and Skagit Bay	West Beach	West of Middle Point	Admiralty Inlet	Lower Sound	Miscellaneous	Unidentified	
1913	22, 349	17, 984	20, 967	2, 126	9, 114	4, 038	18, 306	--------	4, 558	--------	--------	14	99, 456
1914	36, 134	25, 585	25, 619	3, 323	11, 838	4, 040	15, 330	--------	6, 479	--------	449	--------	128, 797
1915	43, 359	15, 867	31, 878	15, 386	20, 632	13, 903	42, 502	13, 310	19, 712	3, 780	4, 302	12, 553	237, 184
1916	40, 819	26, 219	29, 319	14, 567	21, 222	8, 607	46, 473	23, 917	24, 901	1, 332	6, 327	7, 930	251, 633
1917	45, 172	21, 257	26, 209	24, 795	41, 582	16, 971	42, 975	17, 332	26, 559	3, 321	9, 572	9, 486	285, 231
1918	42, 160	34, 916	35, 773	16, 772	35, 574	21, 057	59, 606	25, 921	40, 478	1, 992	10, 013	724	324, 986
1919	47, 869	17, 493	19, 937	12, 382	23, 707	22, 475	44, 627	14, 831	32, 913	2, 639	10, 085	448	249, 406
1920	58, 172	19, 053	33, 490	4, 577	19, 781	10, 583	35, 012	6, 104	22, 304	3, 548	5, 109	1, 069	218, 802
1921	41, 573	19, 627	17, 335	16, 268	27, 994	13, 313	31, 681	7, 140	23, 812	1, 678	3, 049	1, 832	205, 302
1922	41, 419	16, 430	21, 333	4, 525	17, 311	20, 234	29, 452	9, 749	20, 630	2, 121	3, 697	--------	186, 901
1923	37, 375	17, 406	16, 860	8, 119	22, 278	21, 409	32, 739	6, 801	28, 246	1, 434	16, 157	--------	208, 824
1924	51, 065	16, 511	21, 775	9, 861	16, 773	--------	39, 123	12, 903	35, 127	8, 117	3, 827	--------	215, 082
1925	48, 491	18, 223	24, 231	8, 746	25, 022	21, 745	33, 844	13, 087	33, 142	3, 526	4, 310	--------	234, 367
1926	43, 639	15, 497	18, 066	10, 899	12, 757	17, 465	29, 641	13, 855	31, 689	5, 330	2, 560	367	201, 765
1927	53, 690	25, 463	18, 568	8, 471	21, 230	21, 429	38, 585	13, 897	26, 614	3, 453	--------	--------	221, 400
1928	39, 856	16, 638	14, 583	4, 925	16, 318	10, 779	27, 607	11, 710	31, 689	6, 699	385	--------	181, 189
1929	48, 708	18, 557	30, 105	9, 117	10, 389	24, 873	35, 611	8, 937	32, 298	10, 121	1, 504	7, 506	243, 726
1930	45, 431	13, 940	22, 370	7, 507	16, 853	25, 741	28, 201	9, 086	31, 314	5, 153	2, 186	--------	207, 782
1931	36, 912	8, 569	17, 586	5, 573	9, 550	20, 951	21, 630	5, 279	23, 939	2, 015	916	--------	152, 920
1932	34, 493	4, 292	20, 943	2, 007	13, 243	17, 626	13, 875	7, 832	18, 818	3, 524	--------	--------	136, 653
1933	32, 407	16, 087	23, 855	5, 965	17, 606	12, 673	15, 072	2, 300	40, 088	1, 305	1, 307	2, 476	171, 141
1934	50, 187	10, 792	21, 143	7, 728	15, 990	12, 164	14, 764	12, 351	22, 606	3, 289	1, 279	--------	172, 293
Total	1, 188, 983	562, 996	653, 083	239, 462	552, 429	427, 433	952, 579	236, 471	627, 025	74, 377	89, 111	55, 844	5, 659, 793

In only one tagging experiment of those reviewed by Pritchard (1934) were the recoveries in southern Puget Sound greater than those in the northern part of the region. The major part of the recoveries of fish tagged in this experiment, on the northeast coast of Vancouver Island, were taken in the vicinity of the mouth of the Skagit River or in the river itself. This stream, which has supplied the greater portion of the kings gill netted in the Puget Sound region, supports the largest run in the southern area. The other tagging experiments confirm the inferences drawn from the trap-catch data as to the importance of the northern streams, since the greater proportion of recoveries made in the inner waters of the region have been taken in the northern districts of Puget Sound or in the Fraser River itself.

SEASONAL OCCURRENCE IN VARIOUS AREAS

The general seasonal occurrence of king salmon in different types of gear has already been presented, but a further consideration of occurrence in traps indicates certain specific differences in the runs in various parts of the region. The occurrence of kings from traps in several restricted areas was calculated in a manner similar to that used for the entire region, see section on trap fishery. The average proportions of the annual catch taken in each week of the season in these different areas are presented in table 43. For location of areas, see figures 2 and 3.

TABLE 43.—*Seasonal occurrence of king salmon from traps; proportion of total catch taken in each 7-day period*

Week ending—	Area						
	North of Sandy Point	Rosario Strait	West Beach	Middle Point	Admiralty Inlet	Hope Island	All districts
Apr. 21						0.556	0.425
Apr. 28			2.724			1.365	1.353
May 5	3.298	2.334	3.595	2.392	3.513	1.587	2.259
May 12	3.089	4.232	3.779	3.799	4.742	1.785	3.212
May 19	3.195	3.808	3.735	4.384	5.875	2.551	3.649
May 26	3.137	3.539	4.469	5.142	4.859	3.265	3.780
June 2	4.056	3.539	4.573	4.713	5.782	3.578	4.166
June 9	4.774	4.354	4.994	4.943	5.481	4.625	4.770
June 16	4.910	4.845	5.456	5.865	5.349	5.151	5.145
June 23	5.421	5.582	7.049	5.835	5.397	7.400	5.921
June 30	5.547	6.140	7.398	5.507	5.742	8.829	6.330
July 7	6.317	7.433	7.736	6.571	5.854	10.796	7.292
July 14	5.679	6.925	6.950	7.028	5.867	8.701	6.696
July 21	5.516	6.267	7.184	6.705	5.618	7.258	6.252
July 28	5.296	6.666	6.552	7.179	6.013	5.925	6.188
Aug. 4	5.069	6,153	6.224	7.191	6.590	6.385	6.072
Aug. 11	5.379	5.961	4.897	8.040	7.418	6.407	6.149
Aug. 18	5.796	5.654	4.430	6.151	5.132	5.776	5.565
Aug. 25	4.768	4.510	3.621	4.272	4.742	4.234	4.456
Sept. 1	5.037	3.693	2.022	2.050	2.554	2.133	3.406
Sept. 8	4.912	3.703	1.277	1.276	1.602	1.042	2.875
Sept. 15	5.011	2.544	.611	.584	.900	.371	2.074
Sept. 22	2.452	1.248	.300	.197	.385	.229	1.105
Sept. 29	.956	.554	.303	.076	.168	.024	.451
Oct. 6	.222	.198	.106	.044	.119	.020	.167
Oct. 13	.145	.063	.014	.039	.074	.007	.069
Oct. 20	.015	.029		.019	.062		.041
Oct. 27	.004	.015			.059		.038
Nov. 3		.011			.073		.064
Nov. 10					.030		.030
Total	100.001	100.000	99.999	100.002	100.000	100.000	100.000

In all areas the run is much more prolonged than that of the other species, and there are no extreme peaks of occurrence. The highest percentages for any single week in the district north of Sandy Point or in Rosario Strait occur in the first week of July. There is an additional run in these areas in late August and September, especially in the more northern one. West Beach, where the catches probably contain a considerable mixture of populations, shows a similar peak in that week, but there is no indication of the late-season run. The southern areas show proportionately higher percentages in the early part of the season, a peak early in August, and an abrupt decrease thereafter. There is also no indication of a late run in these areas.

SEASONAL OCCURRENCE OF RED AND WHITE KING SALMON

Thus far the runs of king salmon have been treated as entities, but some of the distinct differences between their occurrence in northern and southern areas may be explained by a consideration of the proportionate runs of red and white kings in these districts.

The catches of king salmon from certain traps in the region have been segregated as to red and white kings by the operators, especially where the fish were sold for market purposes. Such a segregation into only two classes undoubtedly introduces some errors in the determination of the proper classification of the individuals which intergrade between the color extremes of red and white. Grading has been purely on the basis of market demand, and the general practice has been to classify the vari-colored fish with the whites, since the reds bring a higher price. The following determinations are necessarily confined to the two main classes, but the presence of intergrading colors must not be overlooked. Data were available for some early years, and for most of the years between 1923 and 1934, for 3 traps in Haro Strait, 3 in Birch Bay, 1 on Lopez Island, and 2 in Admiralty Inlet. The average proportionate occurrence of red and white king salmon throughout the season was calculated for these four areas. These data are presented in table 44.

TABLE 44.—*Seasonal occurrence of red and white king salmon in different areas; proportion of total catch taken in each 7-day period*

Week ending—	Red king					White king				
	Haro Strait	Birch Bay	Haro Strait and Birch Bay	South Lopez	Admiralty Inlet	Haro Strait	Birch Bay	Haro Strait and Birch Bay	South Lopez	Admiralty Inlet
May 5				3.696	3.569				0.380	3.054
May 12	3.400		4.658	6.181	4.986	0.163		0.266	2.296	2.883
May 19	3.758	9.053	5.199	7.398	6.001	.713	3.209	1.391	8.466	4.760
May 26	5.645	4.799	5.533	6.887	4.947	.909	1.399	1.140	2.546	3.625
June 2	4.101	3.410	4.000	6.193	5.442	.769	1.567	1.051	2.133	5.398
June 9	5.614	8.932	6.437	5.555	5.347	.979	2.775	1.505	2.438	6.247
June 16	5.297	6.881	5.624	6.118	5.209	.952	1.791	1.231	3.003	5.415
June 23	6.709	6.543	6.493	6.267	5.209	1.343	2.059	1.619	3.613	5.637
June 30	5.052	6.422	5.323	6.095	5.665	1.161	1.522	1.333	3.352	6.034
July 7	4.856	5.718	4.985	7.325	6.023	.865	1.985	1.210	5.663	6.496
July 14	5.727	5.689	5.573	6.374	5.746	1.094	3.448	1.769	6.323	6.350
July 21	5.953	3.352	5.050	6.180	5.483	.849	2.089	1.223	7.643	5.604
July 28	5.989	5.718	5.761	6.374	5.981	1.583	3.396	2.154	5.713	5.993
Aug. 4	5.357	6.281	5.491	5.812	6.681	1.926	5.120	2.872	9.090	6.560
Aug. 11	10.988	6.957	9.544	4.774	7.514	3.608	4.179	4.003	9.953	7.565
Aug. 18	4.904	6.534	5.254	4.018	5.361	3.232	4.806	3.856	7.669	4.714
Aug. 25	5.787	3.746	5.050	3.060	4.740	3.526	3.134	3.670	6.475	6.170
Sept. 1	4.183	4.021	4.115	1.066	2.587	6.398	13.671	8.777	5.472	2.457
Sept. 8	3.365	2.298	2.562	.360	1.611	35.849	12.662	25.931	3.383	2.403
Sept. 15	2.267	.739	1.724	.158	.926	27.491	10.186	24.348	1.676	1.203
Sept. 22	.603	.845	.701	.041	.360	5.443	10.521	7.551	1.490	.834
Sept. 29	.150	2.060	.542	.051	.161	.948	10.480	2.835	.702	.332
Oct. 6	.057		.058	.015	.125	.137		.164	.057	.084
Oct. 13	.134		.184		.078	.061		.100	.129	.043
Oct. 20	.102		.140		.070				.335	.016
Oct. 27					.067					.016
Nov. 3					.075					.109
Nov. 10					.035					
Total	99.998	99.998	100.001	99.998	99.999	99.999	99.999	99.999	100.000	100.002

Occurrence of red kings does not differ materially in the various areas, although there is a greater early run in the northern districts and a heavier run in the Admiralty Inlet area. White kings differ considerably, however, with heavy fall concentrations in the northern areas. More than 75 percent of the season's catch in Haro Strait is made during the month of September, as is approximately 60 percent of the catch in Birch Bay. Occurrence of white kings in the southern portion of Rosario Strait (South Lopez) is more even throughout the season, the peak of the run appearing during the month of August, while in Admiralty Inlet no definite peak of occurrence is shown.

The average proportion of white kings in the total catch of red and white kings combined was then calculated for each week in the season and for the total season from the trap catches of the various areas. These data are presented in table 45.

In order to determine the proportionate occurrence of red and white kings in both northern and southern runs, the weekly percentages of kings from table 43 were divided as to proportion of red and white kings on the basis of the data presented in table 45. Since percentages were not available for the entire area north of Sandy Point, a combination of the Haro Strait and Birch Bay proportions were used for this northern district. Proportionate seasonal occurrence in the area north of Sandy Point is shown graphically in the upper section of figure 28, that of Admiralty Inlet in the lower section of the same figure.

TABLE 45.—*Proportion in each 7-day period of white king salmon in total king salmon catches in different areas*

Week ending—	Area				
	Haro Strait	Birch Bay	Haro Strait and Birch Bay	South Lopez	Admiralty Inlet
May 5	—	—	—	2.646	7.358
May 12	3.390	—	3.390	8.921	5.101
May 19	12.167	16.045	14.124	23.182	6.857
May 26	10.535	13.587	11.236	8.884	6.367
June 2	12.061	19.858	13.903	8.326	8.431
June 9	11.309	14.352	12.559	10.370	9.785
June 16	11.604	12.308	11.855	11.462	8.800
June 23	12.766	14.511	13.283	13.196	9.128
June 30	14.385	11.333	13.341	12.664	8.995
July 7	11.522	15.768	12.981	16.932	9.099
July 14	12.249	24.627	16.319	20.733	9.302
July 21	9.437	25.157	12.958	24.592	8.665
July 28	16.194	24.254	18.685	19.116	8.510
Aug. 4	20.811	30.530	24.324	29.201	8.352
Aug. 11	19.352	24.465	20.490	35.475	8.545
Aug. 18	32.512	28.395	31.083	33.481	7.545
Aug. 25	30.813	31.088	30.872	35.815	10.779
Sept. 1	52.778	64.706	56.720	57.513	8.102
Sept. 8	88.620	74.815	86.150	71.242	12.165
Sept. 15	89.861	88.136	89.668	73.684	10.759
Sept. 22	86.830	87.037	86.885	90.566	17.699
Sept. 29	82.193	73.288	76.256	78.261	16.107
Oct. 6	63.636	—	63.636	60.000	5.825
Oct. 13	25.000	—	25.000	—	4.839
Oct. 20	—	—	—	—	1.961
Oct. 27	—	—	—	—	2.128
Nov. 3	—	—	—	—	11.765
Proportion throughout season	34.161	31.503	33.390	20.295	8.665

The two peaks of occurrence of red kings, in early July and in late August, in the northern area may be compared to the sustained run in the southern area, where the highest percentages occur in early August. The run in both areas diminishes uniformly during late August and early September.

The run of white kings in the northern area is in striking contrast to that of Admiralty Inlet. In the latter area the white kings form a very small proportion of the run and are distributed throughout the season. In the northern area, however, they form a considerable portion of the run in the early part of the season, become increasingly important in midsummer, and form the major part of the run from early September to the end of the season. It thus appears that the more prolonged occurrence of king salmon in the northern areas is due to the presence of a considerable run of white kings, and that the major portion of white kings caught in the region must have been contributed by the populations of the Gulf of Georgia streams.

CHANGES IN ABUNDANCE

Traps are the only major gear taking king salmon for which sufficient data are available for any determination of changes in abundance of this species. The records of this gear are inadequate prior to 1910, but the following calculations are presented as the best measure which can be determined from present data.

The data were necessarily restricted, because of fishing seasons of varying lengths, to include only those traps for which the opening fishing dates for each season were known. The catches of all traps were then weighted according to the length of the season fished in a manner similar to that discussed under the trap index for coho salmon.

Suitable data from the area north of Sandy Point were available for the period from 1910–34. During these years, from 6 to 11 traps fished in each year except 1932. Four of these traps were in Birch Bay, 4 in Bounday Bay, and 3 at Point Roberts. During the same period of time, data were available from 2 traps in Rosario Strait for every year except 1910. In Admiralty Inlet, data were available between 1916 and 1934 from 4 traps, at least 2 of which fished in every year except 1916 and 1932. The number of traps fishing in each area, and their combined catches, are presented in table 46.

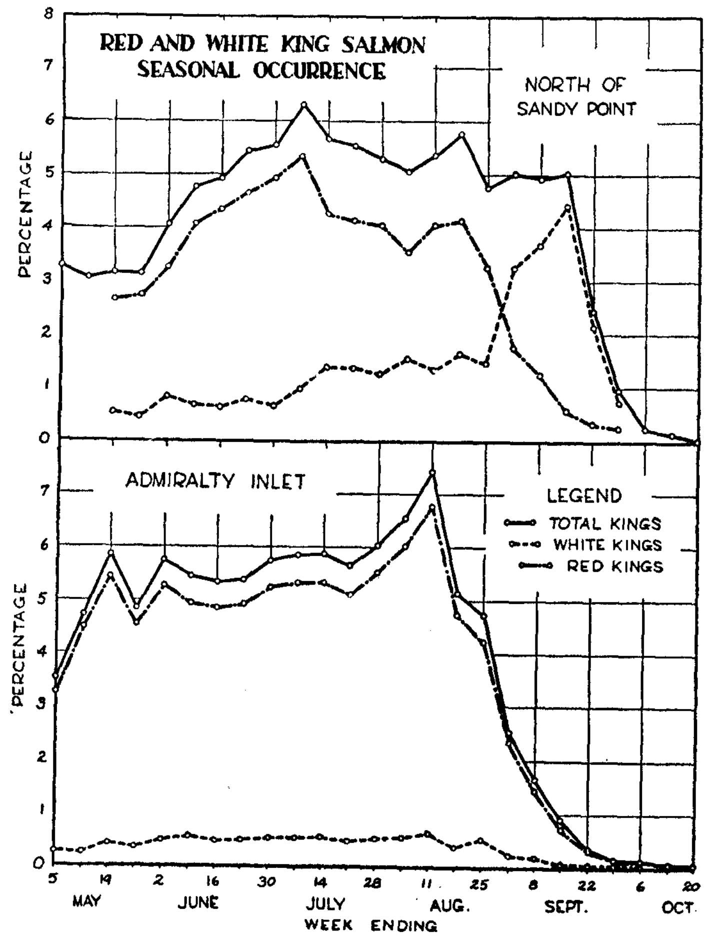

FIGURE 28.—Seasonal occurrence of red and white king salmon in trap catches of the northern and southern districts of Puget Sound. The greater abundance of white kings and the heavy late-season run in the northern district are apparent.

TABLE 46.—*Indices of abundance of king salmon from traps*

Year	Data by areas						Index figures		
	North of Sandy Point		Rosario Strait		Admiralty Inlet		North of Sandy Point	Rosario Strait	Admiralty Inlet
	Number of fish	Number of traps	Number of fish	Number of traps	Number of fish	Number of traps			
1910	20,824	6	12,053	1			1.611	1.741	
1911	28,475	6	19,265	2			2.110	1.780	
1912	31,841	9	13,904	2			1.631	1.382	
1913	22,806	6	9,844	2			1.747	1.007	
1914	31,317	7	13,385	2			1.966	1.344	
1915	23,110	8	11,106	2			1.145	1.168	
1916	29,577	8	7,808	2	4,869	1	1.661	.920	2.394
1917	27,640	8	9,367	2	11,420	2	1.627	.974	3.362
1918	35,562	8	13,432	2	17,244	2	2.290	1.416	5.105
1919	32,308	9	10,166	2	9,728	2	1.744	1.017	2.975
1920	44,266	7	19,595	2	16,279	4	2.859	1.848	1.548
1921	38,922	9	10,227	2	14,359	2	2.088	1.053	2.216
1922	39,717	7	18,333	2	7,217	2	2.676	1.675	1.937
1923	28,078	7	11,464	2	21,996	4	1.962	1.096	2.160
1924	46,926	8	11,650	2	28,693	4	2.887	1.061	2.645
1925	48,234	10	10,500	2	18,407	4	1.915	1.020	1.974
1926	36,890	10	10,749	2	16,220	4	1.534	1.071	1.640
1927	51,161	11	10,060	2	11,638	3	2.057	1.056	1.494
1928	26,972	9	7,129	2	7,915	3	1.590	.775	1.034
1929	44,423	10	11,287	2	12,862	4	1.868	1.113	1.368
1930	27,112	11	12,656	2	9,428	4	1.274	1.292	1.054
1931	24,914	10	7,060	2	3,927	2	1.204	.940	.697
1932	2,764	2	19,703	2	5,223	1	1.428	1.964	1.927
1933	16,559	7	13,431	2	11,046	3	1.529	1.325	1.426
1934	38,405	9	11,952	2	4,407	2	2.094	1.116	.947
Total	798,803		306,126		232,878				

Indices of abundance for these three areas, calculated in the same manner as were those from traps for coho salmon, are presented in the last three columns of table 46. The indices are high for the northern areas during the post-war period prior to 1925. Increased catches during this period may be due in part to the lesser competition of trolling gear, which fishes the runs before they reach the traps. The number of trolling licenses issued by the State of Washington for the Puget Sound district decreased from 1,032 in 1919 to 165 in 1922, and then increased considerably in number to 820 in 1927 (see table 23). There is little difference in levels of abundance in early and late years in the two northern areas.

In Admiralty Inlet, however, abundance is highest before 1920 and reaches a lower level by 1924; a decrease in the size of the runs in recent years is strongly indicated.

PINK SALMON

By George A. Rounsefell

GENERAL LIFE HISTORY

Because pink salmon invariably mature in their second year, as has been well established, there is no overlapping of generations as in the sockeye, king, and chum salmon, and, in some regions, in the coho. In this region there is an abundant run of pink salmon every second year, in the odd-numbered years. They spawn in scores of small streams, as well as the lower tributaries of the main rivers. In the Fraser River they even spawned above Hell's Gate in Seton and Anderson lakes and the Nicola and Thompson rivers until the blockade at Hell's Gate in 1913, which, coming in an odd-numbered year, destroyed this up-river run. In the even-numbered years no pink salmon spawn in Puget Sound streams or in the Fraser River, although a few thousand are usually caught north of Deception Pass. Most of these pinks are probably bound to the streams in the northern end of the Gulf of Georgia, which have pink runs in both odd- and even-numbered years.

The pink-salmon fry, upon emerging from the gravel, migrate at once to the sea, which permits great numbers to propagate in streams that might be unsuitable for the support of large numbers of young fish.

Recently evidence has been gathered on the homing instinct in pink salmon. Pritchard (1934) in an experiment at McClinton Creek, Masset Inlet, in which 108,000 fry were marked by clipping of fins before being liberated, recovered 3,285 when they returned from the sea as adults. Of this total, over 3 percent of the number marked, only 7 fish were taken outside of the Queen Charlotte Islands, and 2,950 were recaptured in the same creek. Davidson (1934) in an earlier experiment marked 50,000 pink fry at Olive Cove, Alaska. Twenty-three marks were recovered there from 7,944 adult salmon dipped over the counting weir. Since 10,640 of the run were not examined for scars the total number of marked fish in the run was calculated as 54.

MIGRATION

Information is scarce on the migrations of pink salmon in the region. Pritchard (1930) tagged 205 pinks in Johnstone Strait in 1928. All of the recoveries were made in local streams. In 1929 the experiment was repeated (Pritchard, 1932) and out of 468 tagged in the same area 37 were recovered, 20 in the Fraser River, and 1 at West Beach, Whidbey Island. None were recaptured farther to the north than the point of tagging. The difference between the 1928 and 1929 results was quite as expected, since Puget Sound and the Fraser River support a tremendous run of pinks in the odd-numbered years, but almost none in the even-numbered years. The recoveries show that a fair share of the run to this region may ordinarily come around the north end of Vancouver Island.

Pink salmon were also tagged in 1929 from the traps at Sooke. Out of 185 released there were 14 recoveries, 1 at the point of tagging, 6 in Puget Sound waters (3 from north of Deception Pass), and 7 in the Fraser River.

METHOD AND LOCALITY OF CAPTURE

The Swiftsure Bank-Puget Sound-Fraser River pink salmon catch from 1925–34 amounts to 52,240,000 fish, excluding Vancouver Island and the Gulf of Georgia for which sufficient data are not at hand (see table 47). Previous to 1925 data are lacking on the Swiftsure Bank catch or of the amounts canned on the Fraser River that were not shipped in from other districts.

TABLE 47.—*Catch of pink salmon, 1925–34*

Year	Fraser River catch [1]	Puget Sound traps	Purse seines		Miscellaneous Puget Sound gear	Total
			Puget Sound	High seas		
1925	1,355,592	1,950,468	4,602,188	729,702	108,386	8,746,336
1926	19,236	21,669	1,764	1,529	1,052	45,250
1927	1,378,762	3,062,604	3,341,419	2,136,570	125,142	10,044,497
1928	938	5,882	3,445	68,877	114	79,256
1929	1,957,760	2,945,720	4,365,513	3,373,529	152,962	12,795,484
1930	13,118	7,057	9,520	42,058	738	72,491
1931	186,298	3,688,006	4,346,600	3,903,188	52,110	12,176,202
1932	----------	3,678	5,130	5,981	21	14,810
1933	1,298,766	1,729,775	4,298,591	844,895	58,384	8,230,411
1934	4,788	2,964	10,044	20,096	117	38,009
Total	6,215,258	13,417,823	20,984,214	11,126,625	499,026	52,242,746

[1] Converted from cases at 14 per case, does not include pinks caught elsewhere in the Gulf of Georgia and canned on the Fraser River.

The purse seines are the most important factor, accounting for 32 million fish, or about 60 percent of the total catch, during the past 10 years. Purse seines do better, compared to the traps, in taking pinks than they do in the capture of sockeyes. The pink salmon swim in dense schools, frequently jumping or "finning," so that the schools are much easier to locate. Also, a much larger proportion of the pinks may use Haro Strait than is the case with the sockeyes, as the pinks that are bound northward spawn not only in the Fraser River, but in a number of smaller rivers and streams entering the Gulf of Georgia from both the mainland and Vancouver Island shores, and, since only a few traps are favorably located to capture fish using Haro Strait they would catch relatively less.

Accurate data on the locality of capture is available for the trap-caught pinks. Traps north of Deception Pass have taken over 45 million, whereas the southern traps have caught but 9 million, or a proportion of 5 to 1. During the past 10 years the proportion has been 2 to 1; 9 million northward and 4½ million to the south.

The records of one large company over a 7-year period show that the bulk of the seine-caught pinks are from the Salmon Bank area, with large numbers from around Stuart Island and Mitchell Bay in Haro Strait, and also from Lummi Island, Birch Bay, Boundary Bay and Point Roberts areas, only minor quantities being captured south of Deception Pass. It would thus appear that a large proportion of the pink salmon captured in Puget Sound waters, probably well over half, are bound toward Canadian spawning grounds.

TABLE 48.—*Pink salmon caught by traps north of Deception Pass* [1]

Year	Point Roberts and Boundary Bay	Birch Bay [2]	Rosario Strait and Lummi Island	Haro Strait and Waldron Island	Salmon Bank	South Lopez	Undetermined	Total
1895	28, 660							28, 660
1896								
1897	38, 637	9, 026						47, 663
1898								
1899	1, 198, 461	56, 861	4, 555	24, 493	353, 640		6, 634	1, 644, 644
1900								
1901	59, 564	94, 246	19, 068	28, 139	38, 956			239, 973
1902								
1903	959, 905	6, 062	66, 988	175, 270	198, 195		88, 287	1, 494, 707
1904								
1905	236, 504	79, 526	55, 825	75, 138	81, 522			528, 515
1906								
1907	1, 885, 463	708, 077	472, 717		397, 916			3, 464, 173
1908	278	449	280	761	838			2, 606
1909	1, 992, 165	809, 846	1, 472, 042	50, 260	387, 316			4, 711, 629
1910	457	22	139		335			953
1911	3, 049, 686	1, 227, 578	1, 180, 549	83, 396	650, 980	168, 520	35	6, 360, 744
1912	3, 309	2, 076	381	371	774			6, 911
1913	2, 211, 470	1, 471, 812	1, 443, 287	715, 922	685, 701			6, 528, 192
1914	1, 308	3, 279	2, 448	1, 200	5, 654	19		13, 908
1915	744, 701	166, 854	519, 415	160, 924	117, 114	83, 287		1, 792, 295
1916	129	161	96	206	232	36		860
1917	1, 777, 330	584, 472	536, 769	386, 945	306, 233	161, 085		3, 752, 834
1918	8, 822	12, 838	13, 146	3, 203	6, 905	3, 084		47, 998
1919	932, 419	272, 762	248, 654	201, 849	203, 004	79, 801		1, 938, 489
1920	3, 753	2, 470	3, 180	434	832	538		11, 207
1921	723, 232	200. 577	167, 678	170, 399	157, 478	87, 867		1, 507, 231
1922	7, 706	3, 547	4, 440	2, 108	3, 234	2, 888		23, 923
1923	974, 883	173, 289	252, 037	235, 262	153, 731	67, 812		1, 857, 014
1924	25, 714	8, 096	7, 764	17, 054	12, 683	8, 831		80, 142
1925	834, 226	65, 300	158, 589	276, 117	201, 707	93, 034		1, 628, 973
1926	7, 515	4, 427	2, 626	2, 674	1, 011	474		18, 727
1927	1, 124, 516	223, 548	333, 276	248, 316	162, 896	221, 063		2, 313, 615
1928	1, 692	1, 011	867	549	615	329		5, 063
1929	805, 697	113, 454	409, 851	247, 587	169, 910	89, 595		1, 836, 094
1930	1, 485	1, 436	1, 040	477	243	309		4, 990
1931	648, 250	183, 059	598, 836	267, 078	132, 664	95, 035		1, 924, 922
1932	355	558	148	77	251	730		2, 119
1933	490, 513	132, 857	134, 507	131, 061	161, 709	93, 877		1, 144, 524
1934	1, 264	566	380	336	126	98		2, 770
Total	20, 780, 069	6, 620, 142	8, 111, 578	3, 507, 606	4, 594, 405	1, 258, 312	94, 956	44, 967, 068

[1] Incomplete before 1915. [2] Including Alden Bank.

TABLE 49.—*Pink salmon caught by traps south of Deception Pass* [1]

Year	West Beach	Hope Island	Middle Point and Ebeys Landing	Admiralty Bay and Bush Point	Oak Bay and Hood Canal	Useless Bay and Point No Point	Meadow Point and south	South side Strait of Juan de Fuca	Total [2]
1897	125								125
1898									
1899	5, 050								5, 050
1900									
1901	400	14, 383		9, 455					24, 238
1902		429							429
1903	15, 816								15, 816
1904									
1905	18, 498	19, 613		10, 859					48, 970
1906									
1907	123, 140	61, 044		417, 812		53, 356			655, 687
1908	333	2							335
1909	90, 506	553							91, 059
1910	59								59
1911	64, 288	10, 745	160, 303	146, 062					381, 398
1912	302	9							311
1913	285, 221	44, 721	128, 757	110, 772					570, 195
1914	782		113	10					905
1915	145, 771	109, 971	160, 507	558, 897	15, 052	32, 470	32, 000	24, 714	1, 079, 382
1916	522	6	92	22		7		92	741

[1] Incomplete before 1915. [2] Total for 1913 includes 724 with locality undetermined.

TABLE 49.—*Pink salmon caught by traps south of Deception Pass*—Continued

Year	West Beach	Hope Island	Middle Point and Ebeys Landing	Admiralty Bay and Bush Point	Oak Bay and Hood Canal	Useless Bay and Point No Point	Meadow Point and south	South side Strait of Juan de Fuca	Total
1917	107,709	56,783	121,128	273,722	10,815	29,909	14,936	37,998	653,000
1918	5,989	751	1,886	898	55	106	---	838	10,523
1919	12,791	11,601	11,990	56,553	6,869	6,033	1,800	1,736	109,373
1920	1,412	10	197	1,164	1	13	---	170	2,967
1921	76,416	72,308	36,034	201,839	---	32,274	---	33,176	452,047
1922	1,158	147	313	434	75	---	46	258	2,431
1923	52,562	50,790	32,545	422,933	29,625	10,357	6,180	10,453	615,445
1924	3,188	---	724	1,062	137	10	37	921	6,079
1925	45,710	33,497	33,068	161,496	2,552	13,859	4,509	26,804	321,495
1926	1,181	80	486	304	21	1	73	796	2,942
1927	130,280	74,019	56,265	414,171	---	6,311	18,669	49,274	748,989
1928	228	---	109	323	---	---	---	159	819
1929	224,968	150,968	118,409	461,574	9,351	15,420	18,979	109,957	1,109,626
1930	590	105	549	326	16	8	---	473	2,067
1931	249,637	166,426	210,816	987,625	15,409	12,999	20,673	99,499	1,763,084
1932	59	135	164	591	---	---	14	596	1,559
1933	90,892	42,847	100,532	312,500	---	32,578	3,955	1,947	585,251
1934	36	5	25	56	---	---	---	72	194
Total	1,755,619	921,948	1,175,012	4,551,460	89,978	245,711	121,871	399,933	9,262,256

SEASONAL OCCURRENCE IN NORTHERN AND SOUTHERN DISTRICTS

The southern pink salmon runs are earlier than the northern. The southern run, south of Admiralty Head, Ebeys Landing, Admiralty Bay, and Bush Point areas, reaches its peak about August 22, the northern run, areas north of Deception Pass, about September 1, making a difference of about 10 days in the modes. By August 11 about 22 percent of the southern run has passed, but only about $2\frac{1}{2}$ percent of the northern. By September 8, over 95 percent of the southern run has appeared, as against 78 percent of the northern.

This difference in time of run of trap-caught pinks in the two districts is good evidence of the existence of different populations or groups of populations. It is therefore necessary to allow a sufficient number of spawners in each district, as either one can doubtless be depleted regardless of the size of the escapement to the other.

CHANGE IN ABUNDANCE BETWEEN EARLY AND LATE YEARS

In the earlier years pink salmon were evidently tremendously abundant. Rathbun (1899) says that in 1891 four drag seines operating for the Seattle cannery caught 275,000 pinks, but this number represented only a small part of the fishery in progress that year. At that time, and for a few years thereafter, pinks were canned only in Seattle, the output finding a ready sale at a low price in the southern part of the United States.

TABLE 50.—*Seasonal occurrence in traps of odd-year pink salmon in northern and southern districts, 1919–33*

Week ending	North of Deception Pass [1]		South of Admiralty Head [2]	
	Percentage	Cumulative percentage	Percentage	Cumulative percentage
May 26			0.003	0.003
June 2			.004	.007
June 9			.010	.017
June 16			.011	.028
June 23			.014	.042
June 30			.019	.061
July 7			.034	.095
July 14	0.002	0.002	.051	.146
July 21	.037	.039	.302	.448
July 28	.167	.206	2.759	3.207
Aug. 4	.616	.822	6.704	9.911
Aug. 11	1.756	2.578	11.994	21.905
Aug. 18	4.654	7.232	15.579	37.484
Aug. 25	14.270	21.502	27.969	65.453
Sept. 1	29.787	51.289	17.887	83.340
Sept. 8	27.045	78.334	12.136	95.476
Sept. 15	13.855	92.189	3.464	98.940
Sept. 22	6.508	98.697	.395	99.335
Sept. 29	1.001	99.698	.659	99.994
Oct. 6	.208	99.906	.006	100.000
Oct. 13	.080	99.986	.001	100.001
Oct. 20	.007	99.993		
Oct. 27	.005	99.998		
Number of fish	2,537,611		1,929,504	
Number of traps	9		7	

[1] Week ending Sept. 15, empirically determined.
[2] Week ending Sept. 1, empirically determined.

Speaking of the trap fishery Rathbun says:

> The trap nets would appear, however, to afford the best means for the capture of the humpback in the salt water, and they are sometimes so taken in immense quantities during the sockeye run. In fact, they often compose by far the larger part of the catch, and as it is generally impracticable to do the sorting in the water at the net, the entire catch may be emptied into scows and the overhauling take place at the wharves. Here the humpbacks are culled out and discarded, causing a wholesale destruction of the species.

In addition to discarding pink salmon, the traps were often closed in odd-numbered years while some sockeyes were still available, in order to avoid capturing the later-running pink salmon for which they had no use. Owing to these factors during the early years of the fishery, the total catch figures are entirely unreliable for measuring abundance. Since the total catches of the individual traps do not give us an adequate measure of abundance in these years the problem has first been attacked by plotting the frequency distributions of the pink-salmon catches of all regularly operated traps north of Deception Pass in the odd-numbered years from 1899–1933 (see table 51).

From 1899–1905 there was practically no demand for pink salmon, and only small quantities were used; the remainder was discarded. This is especially obvious in 1901 and 1905, both of which were big years for sockeye.

TABLE 51.—*Pink salmon catch per trap north of Deception Pass*

Catch in thousands	1899	1901	1903	1905	1907	1909	1911	1913	1915	1917	1919	1921	1923	1925	1927	1929	1931	1933
0	15	29	14		1	5		7										
0–10	7	24	17	35	1	7		2	26	14	5	9	7	18	10	28	9	19
10–20	4	4	6	7	2	5	1	9	20	12	12	18	11	9	6	10	11	12
20–30	2	2	1	9		2		2	9	11	7	12	9	7	7	11	10	2
30–40	1	1	7	1	5	3	2	2	1	8	10	5	3	5	9	5	6	6
40–50			5		5	5	1	5	6	4	5	4	2	5	4	4	7	3
50–60	5	1	2		6	6	3	4	1	5	5	4	6	2	7	2	2	3
60–70				1	5	4	1	3	2	5	3	1	3	3	5	3	1	2
70–80	1				6	3	2	4	1	5		1	1	1	2	2	1	1
80–90	1				3	3	8	2	1	5	2	1	2	1			1	
90–100	1		1		1	1	2	1		2	1				1		1	
100–110				1	3	1	3		3				1		3	1	2	
110–120			1			1	1	2		1	1			1				
120–130					1	2	3			1								
130–140							2	1					1			1		
140–150								4						1				
150–160			1		1	1		2					1					
160–170						1	1	1		2								
170–180					1		2	5										
180–190	1				1	1	2	1		1								
190–200						3	1	1										
200–210					2			1										
210–220					1		1	1										
220–230																		
230–240																		
240–250						1												
250–260						1	2	1										
260–270							2	1										
270–280																		
280–290							2	1										
290–300																		
300–310							1	1										
310–320																		
320–330																		
330–340																		
340–350																		
350–360								1										
360–370						1		1										
370–380																		
380–390																		
390–400							1											
400–410																		
410–420																		
420–430																		
430–440																		
440–450																		
450–460						1												

In 1907 there was some demand for pinks and the medium take per trap was over 60,000. In 1909, a big sockeye year, only 50,000 per trap were utilized. In 1911, with a small sockeye run and an increasing demand for pinks, the median catch per trap was over 100,000. The median catch per trap was only 60,000 in 1913, again a big sockeye year, but on comparing it with 1911 and 1909 it is obvious that in the big years, either no pinks, or very few, were used from many of the traps. Eliminating those traps taking less than 20,000 pinks from the 1913 distribution, and they are not part of the distribution, as shown by 1911, the median catch is over 110,000.

Since 1913 the demand for pink salmon has been good, and yet the highest median catch, in 1917, has only been over 30,000 per trap. If this evidence of a tremendous decline in abundance is not sufficiently convincing, one needs but note the size of the maximum trap catches.

In the past 10 cycles, 1915–33, only 8 trap catches have exceeded 120,000 pink salmon, yet in the 8 earlier years this was exceeded 64 times. Considering only the earlier years when there was some demand, 1907–13, it was exceeded 62 times. In the same 4 cycles 29 catches were made of over 190,000—larger than any single catch in the past 10 cycles. Therefore, we must conclude that a tremendous decline in the abundance of pink salmon took place between 1913 and 1915.

INDICES OF ABUNDANCE FROM TRAPS

Because of the great difference in the time of the run between the northern and southern pinks, separate indices were made for the two districts. For the district north of Deception Pass 31 traps were selected fishing in the 14 odd years between 1907 and 1933, and taking 21,051,873 pinks, up to and including September 8 of each year. To use a longer season was impractical as the traps did not fish late during the early years and were subjected to a 10-day closed period from September 6–15 in the later years.

The 31 traps selected were distributed as follows: Point Roberts 3, Boundary Bay 9, Birch Bay 6, Lummi Island 4, Salmon Bank 4, South Lopez 2, Rosario, Waldron Island, and Haro Strait areas 1 each. The index was calculated in the same manner as described for sockeye. For a standard curve 12 traps were used, 3 each from Boundary Bay and Birch Bay areas, 2 each from Lummi Island and Salmon Bank areas, and 1 each from Point Roberts and Rosario Strait areas. The standard covered the years from 1911–31.

For the southern district only 7 traps were available, 2 from Middle Point area, 2 from Admiralty Bay, and 3 from Bush Point. For a standard curve all 7 traps were used for the 4 odd years from 1923–29.

The northern index (table 52) shows a tremendous fall in abundance after 1913. In 1911 and 1913 the index was 284, in the following 20 years, 10 odd years, it has averaged 67.7 or about 24 percent of the former level.

The reason for this sudden drop in abundance can best be explained by the following quotation from the Report of the British Columbia Commissioner of Fisheries for 1915:

> . . . That there would be a great decrease in the run of pink salmon to the Fraser River District this year was clearly indicated in the Department's report from the spawning grounds in 1913. Owing to the blockade in the canyon of the Fraser at Hell's Gate in 1913, no pink salmon were able to reach the spawning-beds in the waters above that point. Up to that year countless millions spawned in the Thompson and Nicola Rivers and in the vicinity of Seton Lake. As is shown in our report for the spawning-beds this year, no pinks reached those waters.

Since, as pointed out above, the pinks invariably mature at two years of age, the very abundant odd-year run of pinks spawning in the Fraser River above Hell's Gate Canyon was completely wiped out.

TABLE 52.—*Pink salmon index of abundance from traps north of Deception Pass, 1907–33*

Year	Catches	Efficiency weights	Number of traps	Index of abundance	Year	Catches	Efficiency weights	Number of traps	Index of abundance
1907	1,403,010	689,171	10	203.579	1921	967,059	1,731,927	30	55.837
1909	1,220,370	343,969	5	354.791	1923	1,354,003	1,556,160	26	87.009
1911	4,136,212	1,453,493	24	284.570	1925	937,627	1,581,422	27	59.290
1913	3,487,858	1,225,884	20	284.517	1927	1,395,948	1,556,160	26	89.705
1915	909,462	1,833,634	31	49.599	1929	947,559	1,500,928	27	63.132
1917	1,517,903	1,713,587	29	88.580	1931	1,262,263	1,520,336	24	83.025
1919	988,092	1,557,144	25	63.455	1933	524,512	1,394,611	23	37.610

The southern pink-salmon index is very different from the northern (see table 53). There was no fall after 1913 because the Hells Gate slide, which so seriously affected the northern run, had, of course, no effect on the spawning grounds of the southern run.

From 1915–33 the two indices differ at many points, the northern index not showing the extreme fluctuations of the southern. In 1919 the southern abundance was extremely low, possibly due to the intense fishery of 1917. The highest point reached was in 1931. In this southern district our data show no depletion within a recent year.

TABLE 53.—*Pink salmon index of abundance from traps south of Deception Pass, 1907–33*

Year	Catches	Efficiency weights	Number of traps	Index of abundance	Year	Catches	Efficiency weights	Number of traps	Index of abundance
1907	400,054	185,762	2	215.358	1921	223,143	134,863	3	165.459
1909					1923	495,933	432,280	7	114.725
1911	314,603	290,426	3	108.325	1925	254,732	432,280	7	58.928
1913	154,210	134,375	1	114.761	1927	492,875	432,280	7	114.018
1915	531,439	338,059	5	157.203	1929	485,619	432,280	7	112.339
1917	432,541	397,919	6	108.701	1931	813,810	239,527	4	339.757
1919	49,891	397,919	6	12.538	1933	334,525	290,914	5	114.991

ABUNDANCE FROM PURSE-SEINE CATCHES

The purse-seine catches have been a fairly reliable guide to the abundance of pink salmon in Puget Sound since 1911, except in 1913 and to some extent in 1917, as they were usually the chief object of the summer seine fishery. To measure the abundance the average catch per seine boat delivery has been employed, using all of the catches made from August 5–September 8, inclusive, these 5 weeks taking in all of the important part of the season.

Because of the difference in efficiency between purse-seine vessels of different size, the number of deliveries made by vessels of each 5-net-ton class was tabulated separately, and then weighted according to the efficiency scale for all species (see p. 738). The weighted numbers of deliveries for all sizes of purse-seine vessels were pooled, as were the catches, and the average catch per weighted delivery calculated (see table 54).

TABLE 54.—*Pink salmon abundance from Puget Sound purse seines*

Year	Number of fish	Number of catches	Weighted number of catches	Average catch	Year	Number of fish	Number of catches	Weighted number of catches	Average catch
1911	441,920	194	175.6	2,516.63	1923	1,493,749	1,136	1,621.7	921.10
1913	471,627	272	301.3	1,565.31	1925	1,514,755	745	1,067.4	1,419.11
1915	1,059,304	1,558	1,866.2	567.63	1927	1,800,778	1,497	2,181.5	825.48
1917	763,626	705	898.3	850.08	1929	3,686,797	3,019	4,546.0	811.00
1919	251,337	272	391.0	642.81	1931	3,399,825	3,678	5,765.5	589.68
1921	699,099	982	1,408.0	496.52	1933	3,677,705	5,003	7,719.3	476.43

COMPARISON OF PURSE SEINE AND TRAP INDICES

The indices of abundance from Puget Sound purse seines and northern traps are compared in figure 29. The similarity between the indices is striking, as in only 2 out of 12 years do they show any degree of divergence, namely 1913 and 1925.

In 1913 the purse seiners were fishing primarily for sockeyes. Consequently, when the sockeye run was over the seiners quit; only 4 out of 272 catches being made in the last week of the 5-week period covered, and 89 catches being made in the first week; before the pinks were really abundant. For this reason the difference in level of the curves in 1913 cannot be considered significant. In 1925 the purse-seine curve is considerably higher than the northern trap curve, but the data do not suggest any reason for this difference.

The purse seines take large quantities of pink salmon from the areas north of Deception Pass, and the close correspondence with the northern trap index would seem to indicate that the southern run does not contribute much to their catch. Correlating the northern trap index with the average purse-seine delivery gives a coefficient of correlation of .8468 with a probability of less than .01. Such a high correlation certainly indicates that they are drawing largely upon the same general population.

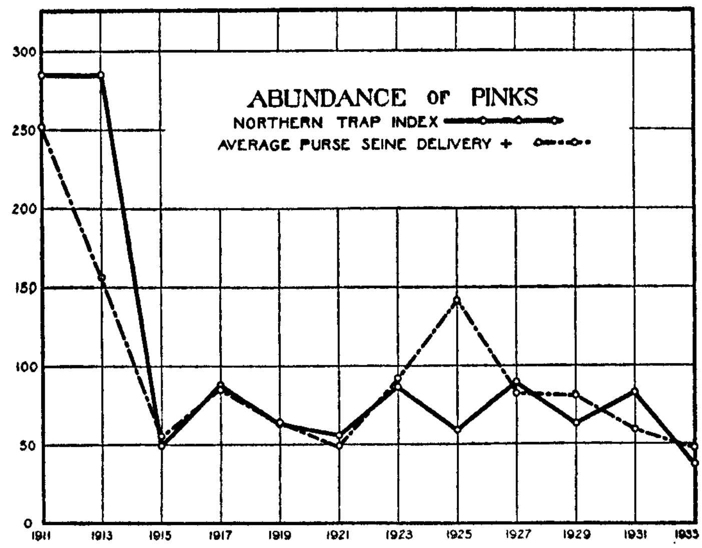

FIGURE 29.—Showing two measures of the abundance of pink salmon. One measure is an index calculated from the catches of Puget Sound traps located north of Deception Pass. The other measure of abundance is the average weighted purse-seine delivery for the period from August 5 to September 8, inclusive. The average purse-seine delivery has been plotted to one-tenth scale to facilitate comparison between the two measures. Note their close correspondence.

CHUM SALMON

BY GEORGE A. ROUNSEFELL

GENERAL LIFE HISTORY

Chum salmon spawn in the lower tributaries of the main rivers of the region as well as in a great many of the smaller streams. They are the latest running of the Pacific salmons; although there are runs that reach some streams as early as September, the bulk of the run is much later. In earlier years chums were often seined in salt water as late as January. As with the pink salmon, the chum-salmon fry, upon emerging from the gravel of the spawning beds, migrate to salt water.

Because less is known of the life history of the chums than of the other species of Pacific salmon, data were collected during the 1935 fishing season on several hundred adults. Out of 890 individuals taken in Admiralty Inlet between October 10 and November 11, the scales could be read for age on 875. Of these there were 334 three-year-olds, 463 four-year-olds, and 78 five-year-olds, or percentages of 38, 53, and 9. However, none of these percentages are more than an indication of the true proportion, since the percentage of 3-year-olds increases, and that of 5-year-olds decreases, as the season progresses.[7] These ages compare favorably with those reported by Pritchard (1932) in Johnstone Strait, except that we had fewer in their fourth year.

[7] These chum salmon ages were read by Milton Lobell.

METHOD AND LOCALITY OF CAPTURE

Chum salmon are taken chiefly by purse seines in Puget Sound and the Gulf of Georgia and by gill nets in the Fraser River. Chums run so late in the fall that most of the traps close before they are abundant, and very few are taken on Swiftsure Bank, as the weather is not conducive to ocean fishing at that season The chum-salmon catches have depended as much upon economic conditions as upon abundance, usually being larger on the even-numbered years, due to the absence of pink salmon, which furnish the cheaper grades on the odd-numbered years.

The actual number of chum salmon caught in Puget Sound is shown in table 55. These figures cannot be correlated with the canned pack as large quantities of chums were sometimes bought in British Columbia. The numbers taken in adjacent Canadian waters cannot be estimated from material on hand as chums were used for canning, freezing, smoking, dry-salting, and for export in a raw state.

SEASONAL OCCURRENCE IN NORTHERN AND SOUTHERN DISTRICTS

With the chums, as with the pinks, there is a considerable difference in time of run between the northern and southern districts of Puget Sound. However, the southern pink salmon run earlier than the northern, whereas for chums the situation is reversed.

TABLE 55.—*Puget Sound chum salmon catch, 1913–34*

Year	Purse seines [1]	Traps	Other gear	Year	Purse seines [1]	Traps	Other gear
1913	445,384	159,473		1924	713,258	84,200	62,525
1914	1,431,983	254,154		1925	436,408	67,204	31,200
1915	1,280,931	177,764	127,383	1926	838,371	125,164	100,160
1916	1,852,859	191,492	146,757	1927	398,549	99,472	28,847
1917	832,922	131,804	130,289	1928	852,411	142,708	48,982
1918	799,833	173,782	182,956	1929	1,291,448	128,214	66,772
1919	1,112,404	185,292	177,395	1930	903,081	78,688	29,591
1920	541,213	111,433	30,424	1931	581,781	85,576	15,136
1921	211,198	32,414	26,581	1932	1,009,605	50,017	32,687
1922	405,905	89,427	6,898	1933	418,620	67,445	18,074
1923	528,542	74,465	34,875	1934	777,833	51,893	37,103

[1] Includes other gear in 1913 and 1914.

TABLE 56.—*Seasonal occurrence in traps of chum salmon in northern and southern districts, 1900–34*

Week ending	North of Deception Pass		South of Admiralty Head		Week ending	North of Deception Pass		South of Admiralty Head	
	Percentage	Cumulative percentage	Percentage	Cumulative percentage		Percentage	Cumulative percentage	Percentage	Cumulative percentage
May 12			0.001	0.001	Sept. 22	5.880	14.878	1.929	13.650
May 19			.001	.002	Sept. 29	10.520	25.398	5.804	19.454
May 26			.003	.005	Oct. 6	15.704	41.102	6.014	25.468
June 2	0.007	0.007	.005	.010	Oct. 13	17.387	58.489	9.011	34.479
June 9	.010	.017	.012	.022	Oct. 20	15.033	73.522	11.467	45.946
June 16	.002	.019	.011	.033	Oct. 27	14.115	87.637	13.407	59.353
June 23	.000	.019	.010	.043	Nov. 3	9.120	96.757	10.943	70.296
June 30	.015	.034	.012	.055	Nov. 10	3.244	100.001	9.075	79.371
July 7	.003	.037	.037	.092	Nov. 17			8.621	87.992
July 14	.003	.040	.046	.138	Nov. 24			4.923	92.915
July 21	.010	.050	.089	.227	Dec. 1			2.798	95.713
July 28	.035	.085	.241	.468	Dec. 8			1.645	97.358
Aug. 4	.079	.164	.635	1.103	Dec. 15			.646	98.004
Aug. 11	.332	.496	1.058	2.161	Dec. 22			1.004	99.008
Aug. 18	.691	1.187	1.506	3.667	Dec. 29			.829	99.837
Aug. 25	1.146	2.333	2.221	5.888	Jan. 5			.099	99.936
Sept. 1	1.442	3.775	2.031	7.919	Jan. 12			.022	99.958
Sept. 8	1.880	5.655	2.026	9.945	Jan. 19			.009	99.967
Sept. 15	3.343	8.998	1.776	11.721	Feb. 23			.031	99.998

For the district north of Deception Pass, data were analyzed for seven traps catching 124,831 fish from 1902–34. For the district south of Admiralty Head, the six traps used caught 821,263 chums from 1900–1934.

In the northern district the run really commences about the middle of September and reaches its peak by October 10. In the southern district there is a small early run in late August and early September, but the main run does not really start until nearly the end of September, and the peak is not reached until October 24, just 2 weeks later than the northern run.

Because of the difference in time of run in the 2 districts, only a small fraction of the northern chums are protected by the closed season commencing November 11. This same closing date, however, protects about 20 percent of the southern run.

ABUNDANCE FROM ADMIRALTY INLET TRAPS

For the chum-trap index, 8 Admiralty Inlet traps were employed, 3 each from the Admiralty Bay and Bush Point areas, and 1 each from the Oak Bay and Point No Point areas. The total catch of each trap up to and including November 3 was used, as this period normally includes 70 percent of the southern run and it was not feasible to use a longer period as many of the traps ceased fishing by that date. In 1934, 1921, and 1920 they all closed too early to be usable. The index was calculated in the same manner as that described for sockeyes. Three traps, over a 19-year period, were used for the standard curve.

Because a small number of traps were used, and only a portion of the run occurred during the period they fished, the index is not especially reliable for any particular year. However, it does show that the chums of the southern district were very abundant at one time. In the last 12 years they were less than half as abundant as during the period just previous to the war (see table 57).

ABUNDANCE FROM PURSE SEINES

An estimate of the abundance of chums was made from the Puget Sound seine catches. The average catch per weighted delivery, each delivery was weighted by the efficiency weight given in the purse-seine section of this report, was first obtained for a 6-week period from September 23–November 3. From 1910–34 data were available for 25,838 deliveries containing 5,322,546 chums.

The first 2 weeks of the 6-week period chosen represented a large number of catches but only a few chums, the run having not yet attained any proportions. The efforts of the fleet up to this time had been almost wholly directed toward the capture of cohos. For this reason the average delivery was also obtained for a 4-week period from October 7–November 3, which, over the 25 years, represented 19,584 catches and 4,973,971 fish (see table 58).

The average catch per delivery obtained from the purse seine data appears to reflect economic factors as well as abundance. Thus 11 out of 12 of the even-numbered years are higher than the year preceding them, whereas 8 out of 12 of the odd-numbered years are lower than the preceding year. Since the chums vary from 3–5 years in age at maturity, there is no apparent biological reason for a higher level of abundance in the even years.

TABLE 57.—*Chum index of abundance for Admiralty Inlet traps, 1902–33*

Year	Catches	Efficiency weights	Number of traps	Index of abundance	Index from standard curve
1902	21,952	15,324	2	143.252	
1903					
1904					
1905	36,589	34,921	4	104.776	118.043
1906	34,911	15,324	2	227.819	
1907	19,068	33,988	2	56.102	
1908	26,221	24,586	3	106.650	106.650
1909	86,368	24,586	3	351.289	351.289
1910	94,885	41,906	4	226.423	207.435
1911	67,474	41,906	4	161.013	155.483
1912	48,357	41,906	4	115.394	155.829
1913	24,777	18,503	2	133.908	
1914	31,730	24,586	3	129.057	129.057
1915	32,629	41,906	4	77.862	83.238
1916	26,690	24,586	3	108.558	108.558
1917	35,209	48,336	5	72.842	68.592
1918	31,578	48,336	5	65.330	65.907
1919	28,815	29,833	3	96.588	
1920					
1921					
1922	8,871	24,992	2	35.495	
1923	22,897	56,660	6	40.411	36.094
1924	29,604	50,577	5	58.533	
1925	13,809	56,660	6	24.372	17.929
1926	34,565	56,660	6	61.004	70.630
1927	26,439	50,327	6	52.534	55.349
1928	24,539	50,327	6	48.759	62.637
1929	45,843	67,647	7	67.768	61.962
1930	20,883	67,647	7	30.871	19.556
1931	21,346	34,737	3	61.450	
1932	9,626	18,659	2	51.589	
1933	24,275	59,323	6	40.920	38.062
Total	929,950				

TABLE 58.—*Chum-salmon index of abundance from Puget Sound purse seines*

Year	From September 23–November 3				From October 7–November 3			
	Number of fish	Number of catches	Weighted number of catches	Average catch	Number of fish	Number of catches	Weighted number of catches	Average catch
1910	7,211	20	18.40	391.90	7,211	20	183.40	391.90
1911	42,190	111	103.24	408.66	42,190	111	103.24	408.66
1912	88,268	163	155.44	567.86	86,156	124	117.56	732.87
1913	37,612	174	199.78	188.27	36,851	163	187.34	196.71
1914	169,628	360	405.10	418.73	154,475	261	295.26	523.18
1915	129,855	620	779.38	166.61	121,178	461	576.84	210.07
1916	157,217	665	786.90	199.79	151,755	520	614.76	246.85
1917	190,120	1,471	1,838.92	103.39	186,042	1,330	1,659.78	112.09
1918	149,824	749	973.54	153.90	140,178	598	764.04	183.47
1919	174,512	753	963.04	181.21	154,926	551	709.50	218.36
1920	76,038	298	394.04	192.97	70,043	217	283.18	247.34
1921	48,546	688	1,004.46	48.33	40,606	383	551.74	73.60
1922	79,111	552	761.30	103.92	71,675	412	541.50	132.36
1923	146,388	671	971.16	150.74	136,875	526	759.82	180.14
1924	176,332	490	640.26	275.41	157,939	376	486.74	324.48
1925	117,305	817	1,102.88	106.36	111,886	672	901.16	124.16
1926	285,644	1,116	1,698.14	168.21	258,216	758	1,149.84	224.57
1927	95,651	1,061	1,581.94	60.46	88,328	766	1,122.44	78.69
1928	462,882	2,004	3,134.97	147.65	441,033	1,511	2,378.50	185.42
1929	725,733	2,527	3,766.80	192.67	674,788	1,858	2,721.71	247.93
1930	342,117	1,167	1,904.25	179.66	327,533	695	1,146.29	285.73
1931	335,268	2,061	3,314.75	101.14	319,927	1,596	2,538.51	126.03
1932	693,046	2,528	4,140.78	167.37	648,097	1,931	3,113.67	208.15
1933	230,945	2,519	4,013.42	57.54	215,860	1,988	3,168.02	68.14
1934	361,103	2,253	3,425.82	105.41	330,203	1,756	2,651.12	124.55

There is usually a greater demand for chums in the even-numbered years, owing to the lack of pinks, and the deliveries are raised by increased effort on the part of the fishermen. Another factor may be lessened competition between gear on the even years, as usually there is a smaller fall fleet than on the odd years.

All that can safely be said is that the purse-seine data seem to indicate that the general trend has remained about the same since 1915. Before that the data are scant but seem to indicate a higher level of abundance.

SUMMARY

By George A. Rounsefell and George B. Kelez

THE GILL-NET FISHERY

On the Fraser River sockeye salmon was at first used to the practical exclusion of other species, but in later years the fishery was extended to include the others. Drift gill nets, introduced in 1864, have been the only gear used there. The fishery developed rapidly and the number of canneries increased steadily, reaching maxima of 49 plants in 1898 and in 1901; mergers and decreasing runs caused many of the plants to be closed thereafter. Less than a dozen have operated in any year since 1921.

The Fraser River gill nets were at first fished mainly by Indians, later more white fishermen were engaged, and Japanese fishermen were introduced on the river in 1888. The early flat-bottomed skiffs were replaced in the 1890's by round-bottomed Columbia River boats, which were generally equipped with engines by about 1914. Each of these changes increased the efficiency of the individual units of gear. The number of gill nets licensed on the river reached a peak of more than 3,600 in 1900, but decreased considerably within a few years, until at the present time about half that number are employed.

Regulations, some in effect since 1878, have limited the size and the mesh of gill nets, and have provided for a week-end closed season intended to permit escapement of salmon up the Fraser River.

The sockeye, pink, and chum salmon overlap but slightly, in their seasonal occurrence on the Fraser River, but the runs of coho and king salmon are more extended. The bulk of the sockeye catches have been made between July 22 and August 25, those of the pinks, which are abundant only in odd-numbered years, between September 2 and September 29, and of the chums between October 7 and November 10. The major catch of cohoes is made between September 9 and October 13, that of the kings between July 1 and September 15.

Gill nets are of minor importance on Puget Sound, where they are used chiefly in or adjacent to the estuaries of the larger Puget Sound rivers, catching mainly coho and king salmon.

THE TRAP FISHERY

Salmon traps were driven in Puget Sound as early as 1880, but were not developed to a point of success until about 1891, at which time the first sockeye cannery was built on Puget Sound. This success caused a great expansion of the American fishery, and 163 traps were driven by 1900. The peak year for traps was 1913, when 168 were driven on Puget Sound, 2 in the Canadian waters of Boundary Bay, and 6 near Sooke on Vancouver Island. Available data show that between 1895 and 1934, over 156,-

000,000 salmon were taken by traps, 53 percent of which were caught in the waters north of Sandy Point, 27 percent in the region of the San Juan Islands, 4 percent on the west shore of Whidbey Island, north of Point Wilson, 5 percent west of Point Wilson, and 11 percent in areas south and east of Point Wilson.

In the period from about 1900–1934 the average number of days of operation of each trap has increased from 46–95 days in Boundary Bay, and in Admiralty Inlet the time at which they commence operations has advanced 85 days.

The average seasonal occurrence of each species of salmon is quite distinct in the trap catches. Kings run very early, 40 percent of the catch being made by June 30. They are followed by the sockeyes, whose run is practically over by August 25, at which date only 40 percent of the pinks have been taken. The latter species reaches a peak about August 29, the cohos about October 1 and the chums about October 23.

THE PURSE-SEINE FISHERY

Purse seines were used in this region before 1882, and within a decade had become the most important type of gear on Puget Sound. Later they were surpassed by the traps, but the introduction of the gasoline engine, completed by 1907, returned them to a place of considerable consequence in the fishery.

The purse-seine vessels have improved steadily in design and equipment, and have increased in size throughout the history of this fishery. The average efficiency of the fleets has correspondingly increased so that, although the modern fleet is smaller in numbers than were those of many earlier years, the total fishing efficiency of today is greater than in all but 1 previous year.

Both fishing season and the size of the fleets vary considerably in odd- and even-numbered years. The summer fishery is most important in the odd-numbered years, when pink salmon are abundant, while the fall fishery for cohoes and chums is considerably greater in even years. The number of vessels fishing is usually greater in odd than in even years. The larger vessels fish on the high seas in spring and early summer, moving into Puget Sound later in the season.

Seasonal occurrence of the various species in purse-seine catches is similar to that in trap catches, but the periods of abundance are more prolonged. From 1917–34, pink salmon have averaged 75 percent of the catch in odd years, but less than 1 percent in even years. Over this 18-year period their average was 37.44 percent of the catch, chums were 32.07 percent, sockeyes 15.63 percent, cohoes 14.16 percent, and kings 0.70 percent.

The proportion of pink salmon in odd and even years at the cape is similar to that on Puget Sound. During the period from 1927–34, pinks averaged 46.54 percent of the cape catches, cohoes were 36.83 percent, and sockeyes 14.84 percent. Chums and kings both averaged less than 1.0 percent.

THE TROLL FISHERY

Coho and king salmon provide almost the entire catch of the troll fishery, which was of slight consequence until the introduction of engines increased the efficiency of the boats. During recent years almost the entire troll fleet has fished at the cape, the season extending from April to October. Over the 8-year period from 1927–34, Puget Sound trollers took 104,692 cohos and 18,285 kings, while the cape fleet took 2,411,312 cohos and 1,545,178 kings.

SOCKEYE SALMON

The Fraser River produces the only sockeye run of consequence in the region. From 1873–1934, over 250 million sockeyes have been canned, of which 46 percent were taken by Fraser River gill nets, 37 percent by traps, 14 percent by purse seines, and 3 percent by miscellaneous gear. An analysis of seasonal occurrence from gill-net catches indicates that the heavy, early-season run of superior quality sockeyes has suffered the greatest decrease in abundance. Indices of abundance from gill-net and trap catches both show a tremendous decline in all cycles.

The cycle of years ending in 1934 fell about 39 percent in abundance between 1898 and 1914, reached a very low point in 1918, and has been increasing considerably in each cycle after that date.

The big year cycle, 1933, etc., tremendously abundant in early years, was severely reduced by over fishing and the Hell's Gate slide, but has recuperated slightly in recent years.

The cycle of years containing 1932 was the least abundant in the early years of the fishery, and declined still further in 1904. The run of 1932 was the best since that of 1912.

The cycle of years containing 1931 has been the least abundant since 1899, although it was second in abundance for several years preceding that date.

COHO SALMON

Cohoes are the most widely distributed species of salmon found in the region. Approximately 98 percent mature at 3 years of age, and the migration to the spawning beds occurs during the fall months, at which period the greater part of the catch is made. During the 9 years from 1926–34, approximately 5½ million cohoes were taken on the high seas, a slightly greater number in Puget Sound waters, and about one-half million in the Fraser River. The greater part of the Puget Sound catches are taken in the southern part of that district. Seasonal occurrence is generally earlier in the northern than in the southern districts. Indices of abundance from both trap and purse seine catches show a high level of abundance in early years and a present level that is lower than at any previous time in the history of the fishery.

KING SALMON

King salmon are caught from early spring to fall, the bulk of the catches being made during early summer. During the 8 years from 1927–34, nearly 4 million were landed in the region, of which trollers landed approximately 40 percent, traps 39 percent, gill nets 15 percent, and purse seines and miscellaneous gear 6 percent. Indices of abundance from trap catches do not show any definite trends in the northern areas, but do indicate a decrease in the runs of recent years in the southern part of Puget Sound.

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PINK SALMON

In the 10-year period from 1925–34, the pink salmon catch in the region was more than 50,000,000 fish, of which 60 percent were taken by purse seines, 27 percent by traps, 12 percent by Fraser River gill nets, and 2 percent by minor gear. Of the trap-caught fish, taken between 1895 and 1934, about 5 times as great a catch was made north of Deception Pass as south of that point. The peak of the seasonal runs in the southern part of Puget Sound is about 10 days earlier than in the northern part. Indices of abundance from purse seines and traps indicate that, following the obstruction at Hell's Gate in 1913, which prevented them from reaching their spawning grounds in the upper Fraser River, the pinks declined to about one-quarter of their former abundance.

CHUM SALMON

The runs of chum salmon occur during the last part of the fishing season, and have been taken chiefly by purse seines in the Puget Sound district, as most of the traps have ceased fishing by the time that the runs appear in any quantity. The chums of Admiralty Inlet were found to be approximately 38 percent 3-year-olds, 53 percent 4-year-olds, and 9 percent 5-year-olds at maturity. The peak of the runs in the northern part of Puget Sound occurs about 2 weeks earlier than in the southern part. An index of abundance from Admiralty Inlet traps shows abundance in recent years to be less than half that of the period previous to the war. The average size of delivery by purse seines also indicates a higher level of abundance previous to 1915.

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THE LIFE HISTORY OF THE STRIPED BASS, OR ROCKFISH, *Roccus saxatilis* (WALBAUM)

By John C. Pearson

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THE LIFE HISTORY OF THE STRIPED BASS, OR ROCKFISH, *Roccus saxatilis* (WALBAUM)[1]

By JOHN C. PEARSON, *Assistant Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

INTRODUCTION

The purpose of this Bulletin is to review a considerable amount of scattered information on the life history of the striped bass, or rockfish, and to present data collected by the author during the course of a study of the spawning habits and migrations of the fish in Chesapeake Bay during 1930–31, and in the Roanoke River, N. C., during May 1937.

The striped bass ranks close to the immortal codfish in the vital part which our fishery resources played in early American history.

> In the year 1623 the Plymouth colonists had but one boat left, and that none of the best, which then was the principal support of their lives, for that year it helped them for to improve a net wherewith they took a multitude of bass, which was their livelihood all that summer—Hubbard (1815).

The striped bass astonished the early settlers in New England by its abundance and choice food qualities.

> The Basse is an excellent Fish, both fresh and Salte. They are so large, the head of one will give a good eater a dinner, and for daintiness of diet, they excell the Marybones of Beefe. There are such multitudes, that I have seene stopped into the river close adjoining to my house with a sande (seine) at one tide, so many as will loade a ship of 100 tonnes—Morton (1637).

The striped bass and the codfish were probably the first natural resources in colonial America that were subject to conservation measures enacted by statute.

[1] Bulletin No. 28. Approved for publication July 28, 1937.

The following act, passed by the General Court of Massachusetts Bay Colony in 1639, ordered that neither cod nor bass should be used as fertilizer for farm crops:

> At the Generall Courte, holden at Boston, the 22nd of the 3rd M., called May, 1639—"And it is forbidden to all men, after the 20th of the next month, to imploy any codd or basse fish for manuring the ground, upon paine that every pson, being a fisherman, that shall sell or imploy any such fish for that end, shall loose the said priviledge of exemption from public charges, & that both fishermen, or others who shall use any of the said fish for that purpose, shall forfeit for every hundred of such fish so imployed for manuring ground twenty shillings & so pportionally for a lesser or greater number; pvided, that it shall bee lawful to use the heads & offal of such fish for corne, this order notwithstanding."

The value and probably the limited supply of striped bass seemed to be realized by the colonists within 19 years after the landing of the Pilgrims at Plymouth.

Another distinction shared by the striped bass was an act of the Plymouth Colony in 1670 that granted all income that should accrue annually to the Colony from the fisheries at Cape Cod for bass, mackerel, or herring, be employed for and toward a free school in some town of this jurisdiction. As a result of this act the first public (free) school of the New World was made possible through moneys derived in part from the sale of striped bass. A portion of this fund was also expended in helping the widows and orphans of men formerly engaged in the service of the Colony.

Appreciation of the striped bass as a superb game fish and a source of unexcelled recreation came during the last century when Herbert (1849) noted that with the sole exception of salmon fishing, striped bass fishing was the finest of the "seaboard varieties of piscatorial sport" and that the striped bass was the "boldest, bravest, strongest, and most active fish that visits the waters of the midland States." Today the striped bass is esteemed far more by sportsmen than by epicures and its value to the Nation is far greater from a recreational than from a food standpoint.

DISTRIBUTION

The striped bass, or rockfish, *Roccus saxatilis* (Walbaum)[2] ranges along the Eastern coast of North America from the St. Lawrence River, Canada, to the Tchefuncta River, La. Introduced on the Pacific coast in San Francisco Bay, in 1879 and 1882, the species now occurs from the Columbia River, Wash., south to Los Angeles County, Calif. The striped bass has probably the most extended geographic range of any American food and game fish. Its ability to exist in fresh, brackish, or salt waters throughout the year and from the cold rivers of Eastern Canada to the subtropical bayous of Louisiana, provides a unique record of successful adaptation to environment. (See fig. 1.)

The most distant inland fresh-water range on the Atlantic coast from which striped bass have been recorded is Quebec, on the St. Lawrence River. Most coastal rivers from New Brunswick to Georgia contained striped bass in abundance in early colonial times according to various writers.[3] Inland coastal ranges for the species have included the Hudson River at Albany, the Delaware River at Lambertville, the Susquehanna River to Luzerne County, Pa., the Potomac River to Great Falls, the Roanoke River at Roanoke Rapids, the Alabama River at Montgomery, and 250 miles up the Sacramento River in California.

Few records exist to define the exact range of the striped bass in tributaries of the Gulf of Mexico. The Escambia River, at Pensacola, Fla., the Alabama River, at

[2] The scientific name of the striped bass has been corrected from *Roccus lineatus* (Bloch) to *Roccus saxatilis* (Walbaum).

[3] Early records of striped bass distribution and abundance are noted by Perley (1850), Atkins (1889), Wood (1634), Mease (1815), Schoepf (1788), and Burns (1886).

Montgomery, Ala., and the Tangipahoe River, at Osyka, Miss., have been recorded as localities where the species has been taken previous to 1884. In recent years additional distributions of the fish have been secured from the Tchefuncta River, La., from the Jordan and Wolf Rivers, Miss., and from various coastal streams along the west coast of Florida, from St. Marks to Pensacola.[4] On the Gulf coast the striped bass appears to be confined to fresh or brackish coastal rivers and is unknown in salt water.

The introduction of the striped bass into California has provided a classic example of successful fish transplantation. From an initial stocking of 435 small fish, brought from New Jersey and liberated in San Francisco Bay in 1879, the species has

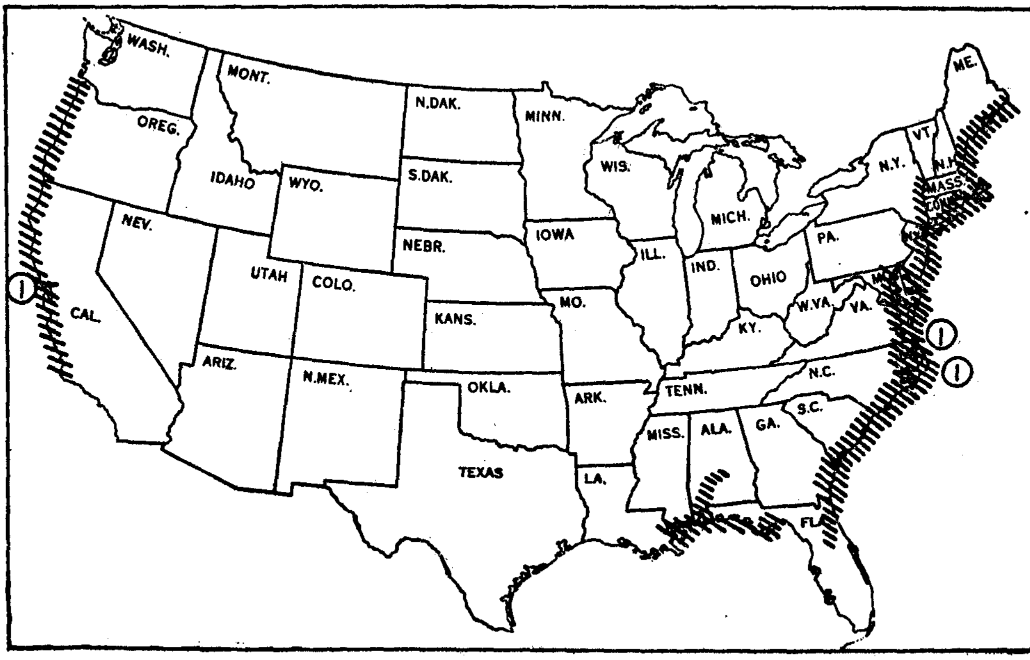


FIGURE 1.—Geographic distribution of striped bass, or rockfish, *Roccus saxatilis* (Walbaum), within the United States. Circle numbers represent centers of commercial abundance.

gradually extended its range to about 850 miles along the Pacific coast. It has become a favorite game fish among many sport fishermen and was reported as a commercial food fish in San Francisco within 10 years after its introduction. The favorite habitat of this species appears to be the fresh and brackish rivers and coastal estuaries. They range freely along the coast line but captures at sea are practically unknown. The record of a 6-pound striped bass, taken on Cod Ledge, 4 miles off Cape Elizabeth, Maine, on October 15, 1931, provides the most distant offshore record.

ABUNDANCE

The notes of early writers indicate that the striped bass formerly occurred in considerable abundance in areas now recognized as completely depleted of this fish. In addition to the striped bass conservation law, enacted in 1639 by the colonists of

[4] The occurrence of considerable numbers of striped bass in various coastal streams of Louisiana, Mississippi, and Florida, has been reliably reported to the author by Whitaker Riggs, of Covington, La., U. A. Cuevas, of Cuevas, Miss., and Robert G. Lincoln, of Minneapolis, Minn.

Massachusetts Bay, New York, in 1758, passed a law to prohibit the sale of bass during the winter months on account of the great decrease of that kind of fish. In 1762 the inhabitants of Marshfield, Mass., also sought to regulate the fishery for bass by passing favorably on a petition to the General Court to enact a bill for the preservation of the fish and to prevent its capture in the winter season.

Abundant as the supply of striped bass may have seemed to many early historians, its ease of capture, because of its large size and habit of dwelling close inshore about coastal streams throughout the year, made possible the depletion of the species over the greater part of its northerly range along the Atlantic coast. North of Cape Cod only one localized population of striped bass, at Parker River, Mass., appears to have maintained itself in appreciable quantities (Pearson, 1933 b). The gradual decline of striped bass in southern New England waters was indicated by Bean (1905) who reported a decrease in the annual catch at various angling clubs during the last century.

Although overfishing was probably the original cause of depletion in the northern rivers, the industrial uses to which nearly all rivers along the North Atlantic seaboard

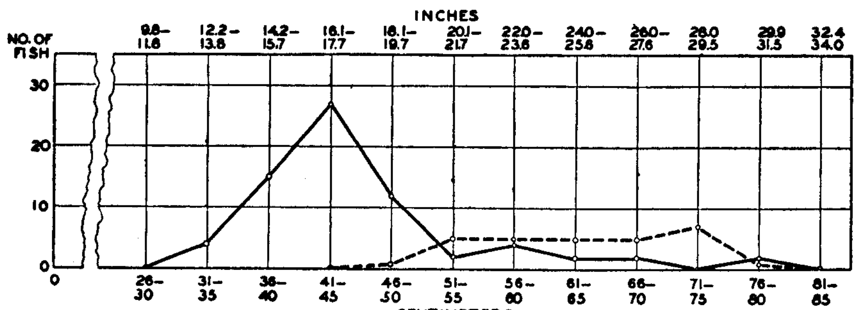


FIGURE 2.—Length-frequency distributions of mature striped bass taken by commercial fishing gear near Havre de Grace, Md., in April and May 1932. Solid line indicates male, and dotted line indicates female fish.

have been devoted for many years has had an effective part in the diminishment of the species and in the retardation of reestablishment of the fish in depleted areas. The construction of impassible dams in the lower reaches of the Merrimack, Connecticut, and Susquehanna Rivers, shutting off probable spawning grounds; the pollution of the Hudson and Delaware Rivers; and unregulated commercial fishing in all sections have been exceedingly detrimental to the striped bass as well as to other anadromous food fishes such as the shad, smelt, salmon, and sturgeon. Restoration of these fishes to their original abundance clearly involves a restoration of coastal streams, where possible, to their primeval conditions of purity and accessibility, together with adequate restrictions against overfishing.

A reduction in the natural supply of striped bass at centers of greatest abundance in Chesapeake Bay and North Carolina has not been so marked as in more northerly areas. This condition has been influenced by the relative absence of industrial development and the limited population in these localities. Nevertheless, a diminishing annual catch of striped bass is noted in many sections of the Southern States. (See fig. 26.)

In California, particularly in the San Francisco Bay region, the striped bass has increased many fold since its introduction. The commercial fishery, prior to 1930, yielded over 17 million pounds despite many years of restricted fishing. In 1931 it became unlawful to take the species by nets and no estimation of their present abundance is possible.

SPAWNING GROUNDS

The first mention of the spawning grounds of the striped bass was probably by Josselyn (1672), who stated: "The Basse is a salt-water fish too but most an end taken in Rivers where they spawn." [5] A more definite spawning habitat was suggested by Schoepf (1788), who, describing the vast number of fishes that came up to the falls on the upper Roanoke River, N. C., every spring, stated that the rockfish (striped bass) especially came up the river in millions to spawn and that being checked at the falls "sprang" and "tumbled" so that the water foamed with the fish.

This spawning area in the Roanoke River, 100 miles above tidewater, was so well defined that it was possible for Holton (1874) to artificially fertilize and hatch the eggs of the striped bass at Weldon, N. C. It appears probable that the most important spawning ground for the species, at least along the Atlantic coast, is in the upper Roanoke River where there occurs a fall of 50 feet in about 6 miles and that in the rapids, where the current is exceedingly strong and rendered erratic by islands, boulders, and rocks, the striped bass prefers to spawn. Collections of eggs from ripe fish for artificial propagation have occurred at irregular intervals during the past 64 years at Weldon.

It has also been noted by observers that ripe striped bass are found during May at the head of Chesapeake Bay. Past efforts made by fish culturists at Havre de Grace, Md., to obtain eggs suitable for artificial fertilization and hatching proved unsuccessful because of the difficulty experienced in obtaining ripe male and female fish simultaneously. The most important spawning grounds were believed to be located along a rocky swift-running stretch of the Susquehanna River extending from Port Deposit to Octoraro, Md.

Eggs of the striped bass were secured by the author in river plankton at night during various times in May and June 1932, in the Susquehanna River at Garrett Island. The occurrence of these eggs, brought down the river by the strong current, definitely establishes a spawning ground for the fish at a point between the locality of capture and the impassable Conowingo Dam, 12 miles upstream. The eggs taken in 1932 would normally have been carried into the head of Chesapeake Bay near the Susquehanna flats.

There occurs only one record of a spawning striped bass from the Gulf coast of the United States. A female with eggs was taken on April 7, 1883, in the Alabama River, near Montgomery.

The deltas of the Sacramento and San Joaquin Rivers are believed to be the principal spawning grounds of the striped bass in California. The fish appear to spawn, according to Scofield (1931), in fresh-water sloughs and creeks. Free eggs have not been taken in California.

The definite records of striped bass eggs in the lower Susquehanna River, and of spawning adults in the upper Roanoke River, indicate that spawning occurs in rock-strewn coastal rivers characterized by rapids and strong currents. Rivers, such as the James, Potomac, and Hudson, offer a similar environment for the spawning fish, and are known to contain either young or ripe adult striped bass.

While some writers have stated that the striped bass spawns in brackish water, there is no conclusive evidence to justify this belief. Ripe striped bass, presumably taken at the entrance to the Hudson River off Governors Island, were noted by Rice (1883). A ripe female fish was caught by Corson (1926) near Barnegat Inlet,

[5] Other early notes on the spawning grounds are in the works of Belknap (1792), Mease (1815), and Mitchell (1815).

N. J. It is well to remember, however, that many anadromous fishes often appear to be near spawning on entering tidal estuaries from the sea but that actual spawning probably does not occur until fresh water is reached.

Many larvae of the striped bass were taken by Leim (1924) during the summers of 1922 and 1923 in the Shubenacadie River, Nova Scotia. The young were taken in plankton near the head of the tidal zone.

SPAWNING SEASON

The spawning season of the striped bass has generally been recognized to occur in the spring and early summer months. Ripe fish have been noted in the rivers of New Brunswick about the middle of June; in Delaware and New York Bays about the middle of May; in the Roanoke River during May; in the Alabama River in April; and in upper San Francisco Bay principally during May.[6]

Ripe fish were taken by Worth (1884 b) at Weldon, N. C., from April 19 to May 17, 1883, at a water temperature rising from 58° to 71° F. This observer also recorded the spawning period at Weldon during 1904, as extending from May 2 to May 24. During hatchery operations at Weldon, in 1931, the first ripe female fish was secured on May 5 and the last on May 21. Water temperatures at the hatchery, supplied by filtered and underground piped city water from the Roanoke River, gradually increased from 61° to 71° F. During hatchery operations at the same point, in 1937, ripe females were taken from about May 7 to May 22.

The eggs of the striped bass were taken in river plankton in the lower Susquehanna River, Md., from May 16 to June 8, 1931. These eggs were secured during the early half of the night and were probably only a few hours spawned. Water temperatures in the river increased from 60° to 70° F. during the period of egg collection.

SIZE AND AGE AT MATURITY

The weights of 19 female striped bass, taken and stripped for eggs at Weldon, N. C., were recorded by Worth (1904). Three females ranged between 3 and 7 pounds, seven from 10 to 18 pounds, four from 23 to 35 pounds, and five from 40 to 70 pounds. The approximate lengths of these ripe fish would have ranged from 20 in. (50.8 cm) to over 4 ft., according to a length-weight correlation given by Scofield (1932).

It appears, on the basis of considerable data collected by Scofield (1931) for California striped bass, that 35 percent of the female fish mature and spawn by their fourth year at an average length of 50 cm (19.7 in.), 87 percent by their fifth year at an average length of 54 cm (21.2 in.), 98 percent by their sixth year at an average length of 61 cm (24 in.), and 100 percent by their seventh year. It was observed that many male striped bass mature and spawn in their third year while all are mature by their fifth year.

Ripe male striped bass, 12–18 in. (30.5–45.7 cm) in length, were taken in the Potomac River, Md., late in April 1875, by Milner (1876).

Length measurements were obtained of 70 mature male and 29 egg-bearing female striped bass taken by commercial fishing gear near the entrance to the Susquehanna River, Chesapeake Bay, during April and May 1932. The lengths of the male fish ranged from 33–78 cm (13–30.7 in.) with an average length of 40–45 cm (15.7–17.7 in.). Most males were approximately 3 years old. The lengths of the female fish

[6] Adams (1873); Mease (1815); Holton (1874); Bean (1884); Smith (1895); and Scofield (1931).

ranged from 50–78 cm (19.7–30.7 in.). No females under 4 years of age were obtained with eggs. The smallest fish taken in these collections probably represent the minimum size of spawning fish in both sexes. The largest fish taken do not represent the maximum size which the species attains because the samples were limited to 15 pounds, about 32 inches in length, by legal-size restrictions. The length-frequency distributions for these striped bass are given in figure 2.

There appears to be many more mature male than female fish on the spawning grounds and the average size of the males is much smaller than that of the females. Both numerical superiority and smaller size of the males may be due to their earlier age at maturity. It was observed by Worth (1903), at Weldon, that where the female fish are in spawning condition the males gather around them in great numbers and there will be 1 large female, weighing from 5–50 pounds, surrounded by 20–50 small males weighing not more than 2 pounds each. A somewhat similar predominance of small males was also noted at Weldon by the writer in May 1937.

EGGS AND YOUNG

The number of eggs spawned by the striped bass was calculated by Worth (1904), who found a total of 14,000 eggs in a 3-pound fish and 3,220,000 eggs in a 50-pound fish. The Manual of Fish Culture (1900) estimated 1,280,000 eggs from a 12-pound striped bass taken in the Susquehanna River in 1897. This estimate is closely approximated by volumetric measurement of the eggs taken from a 13-pound fish, measuring 70 cm (27.5 in.) in length, on May 14, 1932, at Havre de Grace, Md. The count totaled 1,337,000 eggs.

No complete description of the eggs and young of the striped bass has been available, despite frequent artificial propagation of the species. Various writers have offered partial descriptions of the eggs and fry, however, based on fish-cultural operations.[7]

A series of eggs and larvae of the striped bass was obtained during May 1931, at Weldon, N. C., through the artificial fertilization and hatching of the eggs at this point on the Roanoke River by the Bureau of Fisheries and the State of North Carolina. Samples of eggs and larvae were preserved in a weak formalin solution at 12 hour intervals after the fertilization of the eggs. The eggs were stripped from a ripe female at the fishing grounds, fertilized by the usual dry-pan method, and placed in McDonald hatching jars supplied with filtered river water within 30 minutes after fertilization. The eggs were taken and fertilized about 10 p. m. on May 5 and hatched in approximately 48 hours at a water temperature averaging 64.2° F. during the incubation period.

No effort was made to rear the larvae through the introduction of food and consequently all young fish had perished by 312 hours after fertilization of the eggs. Successful attempts were made during May and June 1937, at Weldon and Edenton, N. C., to rear the larval striped bass in aquaria and outdoor ponds through the introduction of natural foods such as *Daphnia*. These rearing experiments provided additional specimens of larval and post-larval fish.[8]

The eggs of the striped bass immediately after fertilization are spherical, nonadhesive, and measure 1.28–1.36 mm in diameter after preservation. The eggs are

[7] These writers include Ferguson and Hughlett (1880), Worth (1882) (1883), Ryder (1885), Scofield and Coleman (1907), Bigelow and Welsh (1924), and Scofield (1931).

[8] The author expresses appreciation to W. C. Bunch for the time and care spent in the preservation of the series of eggs and larvae and Louella E. Cable for the painstaking and accurate drawings contained in this report.

slightly heavier than fresh water and sink to the bottom of unagitated water. However, a slight movement of the water serves to float the eggs and keep them in suspension. The egg membrane, or chorion, appears heavily corrugated and nearly opaque after preservation. Living eggs show a transparent chorion at all times. The yolk sphere is heavily granulated, about 1.10 mm in diameter, of a rather intense green color in live eggs, and usually of a pale amber color in preserved eggs. It contains an amber-colored oil globule that measures 0.56 mm in diameter. Several much smaller oil globules may also be present. (See fig. 3.)

The egg at 15 minutes after fertilization increases by the rapid absorption of water to about 1.84 mm in diameter. The size of the yolk sphere and the oil globule remains the same during the early developmental stages. The blastodisc appears differentiated at one end of the yolk sphere. The chorion, becoming stretched, is less corrugated. It was noted by Scofield and Coleman (1907) that the first cleavage of the germinal disc takes place about 2 hours after fertilization. (See fig. 4.)

The egg at 12 hours after fertilization shows a considerable increase in size. The egg diameter may range from 3.2–3.8 mm and water absorption appears complete. The chorion is thin, transparent, and fragile. The blastoderm is in late cleavage and the periblast appears clearly differentiated about the yolk sphere and becomes a paler green with age. (See fig. 5.)

The egg at 24 hours after fertilization shows no further expansion of the chorion. The embryo becomes differentiated and extends about half way around the circumference of the yolk. A moderately intense pigmentation of the embryo occurs and consists of small black dots distributed over the dorsal aspect of the body and over a part of the adjacent blastoderm. (See fig. 6.)

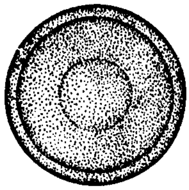
The egg at 36 hours after fertilization has an embryo about 1.6 mm in length. Eyes become differentiated but lack pigmentation. The posterior part of the embryo body is free from the yolksac. (See fig. 7.)

The egg at 48 hours after fertilization, kept at a temperature averaging 64.2° F., is about to hatch. The embryo is approximately 2.5 mm in length upon leaving the egg. (See fig. 8.)

The larva at 60 hours after fertilization of the egg measures about 3.2 mm in length. The oil globule, embedded in the anterior end of the yolksac, projects beyond the head of the larva. The newly hatched fish tends to settle to the bottom of a still aquarium despite swimming efforts to remain near the surface. A strong current of water, however, enables the fish to keep suspended and in more or less constant motion. Hatchery fish are usually liberated soon after this stage. (See fig. 9.)

The larval fish at 84 hours after fertilization of the egg increases to about 4.4 mm in length. The head projects beyond the oil globule. A series of small chromatophores appears along the ventral surface of the body posterior to the vent but the eyes continue to lack pigmentation. (See fig. 10.)

The larva at 120 hours after fertilization of the egg measures 5.2 mm in length. The eyes now possess pigmentation and the jaws are somewhat developed. The oil globule and yolksac are considerably reduced as the rudiments of the digestive tract appear. The pectoral fins become differentiated. The ventral chromatophores become somewhat stronger and several of them now lie along the edges of the gut. (See fig. 11.)



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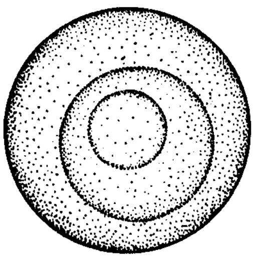

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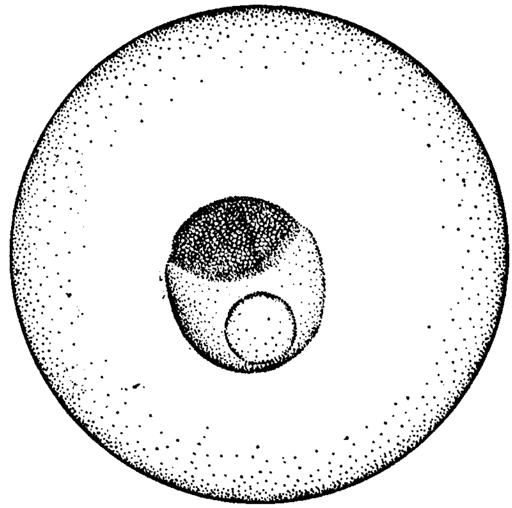

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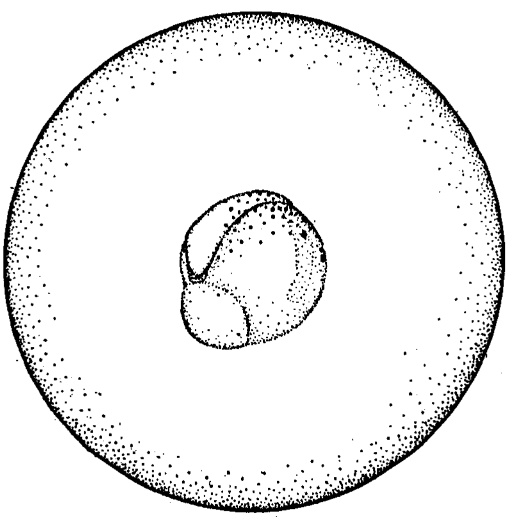

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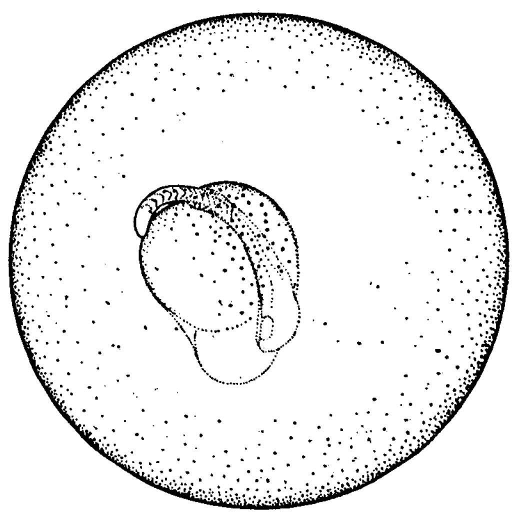

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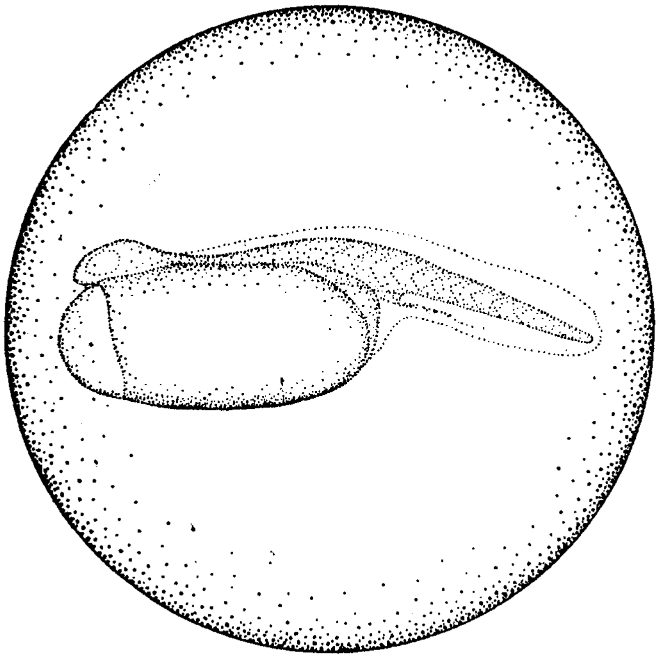
FIGURE 3.—Striped bass egg at fertilization; diameter 1.3 millimeters.

FIGURE 4.—Striped bass egg 15 minutes after fertilization; diameter 1.8 millimeters.

FIGURE 5.—Striped bass egg 12 hours after fertilization; diameter 3.7 millimeters.

FIGURE 6.—Striped bass egg 24 hours after fertilization.

FIGURE 7.—Striped bass egg 36 hours after fertilization.



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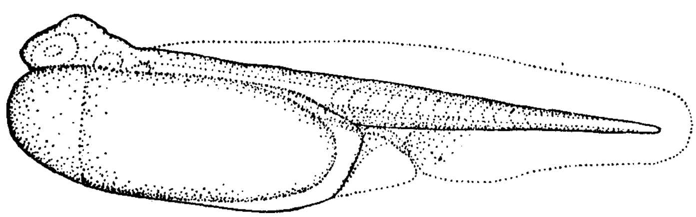

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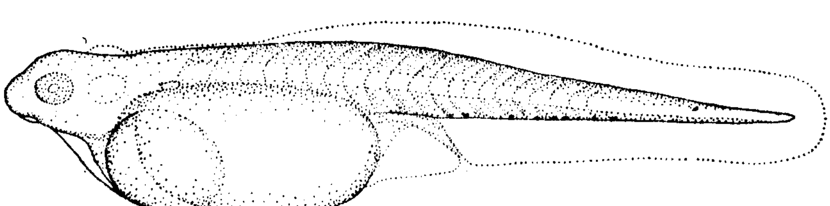

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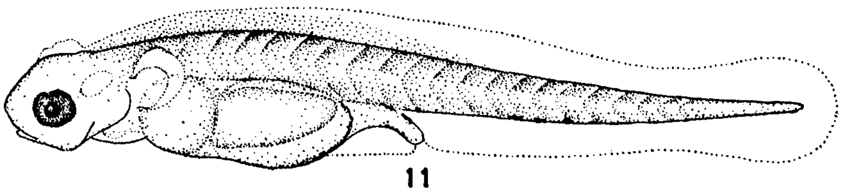
FIGURE 8.—Striped bass egg 48 hours after fertilization.

FIGURE 9.—Striped bass larva 60 hours after fertilization of egg; length 3.2 millimeters.

FIGURE 10.—Striped bass larva 84 hours after fertilization of egg; length 4.4 millimeters.



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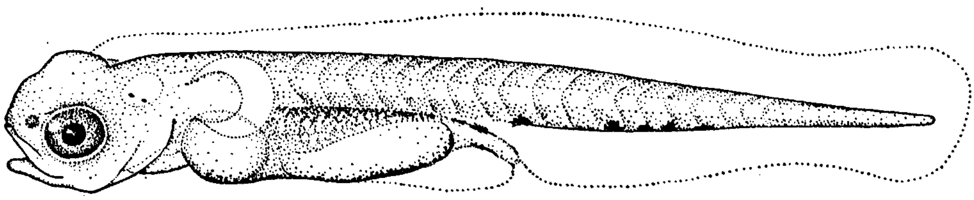

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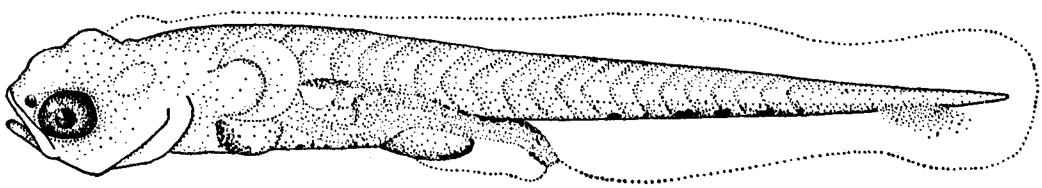

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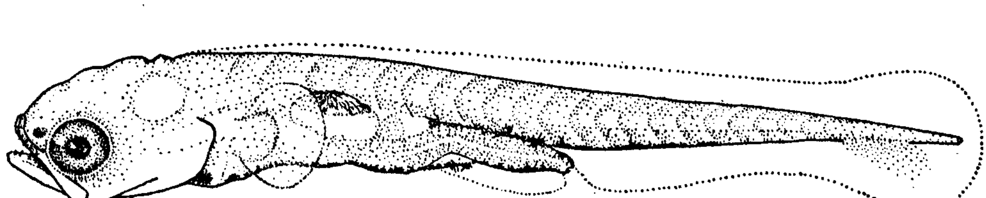

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FIGURE 11.—Striped bass larva 120 hours after fertilization of eggs; length 5.2 millimeters

FIGURE 12.—Striped bass larva 144 hours after fertilization of egg; length 5.8 millimeters.

FIGURE 13.—Striped bass larva 192 hours after fertilization of egg; length 6 millimeters.

FIGURE 14.—Striped bass larva 288 hours after fertilization of egg; length 6 millimeters; no food available to fish.

The larval striped bass at 144 hours after fertilization of the egg reaches about 5.8 mm in length. The mouth parts and digestive tract become better developed preparatory to feeding. A series of small chromatophores now extends along the ventral edge of the entire yolksac. (See fig. 12.)

The larva at 192 hours after fertilization of the egg has the oil globule and yolksac nearly absorbed. The length of the fish increases only slightly, to about 6 mm. Pigmentation on the ventral surface of the body becomes stronger. (See fig. 13.)

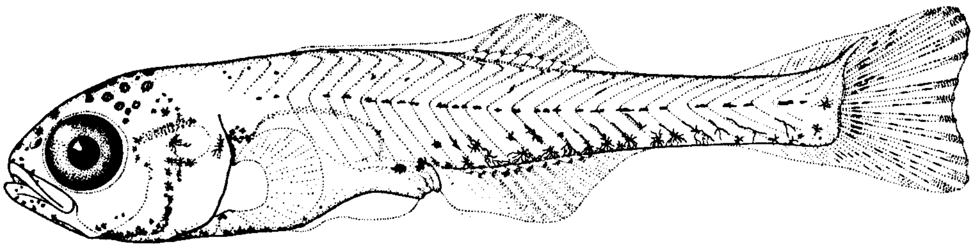

FIGURE 15.—Striped bass young 240 hours after fertilization of egg; length 9 millimeters; food available to fish.

The larva at about 288 hours after fertilization of the egg, about 6 mm in length, commences to die rapidly in an aquarium not supplied with food. No fins have developed on the fish except the pectorals. The finfold still extends from the region of the head around the body to the abdomen, becoming interrupted at the vent. A more or less continuous line of pigmentation extends along the ventral portion of the body from the opercle to a point about midway between the vent and the tail. A large chromatophore lies on the upper surface of the swim bladder. (See fig. 14.)

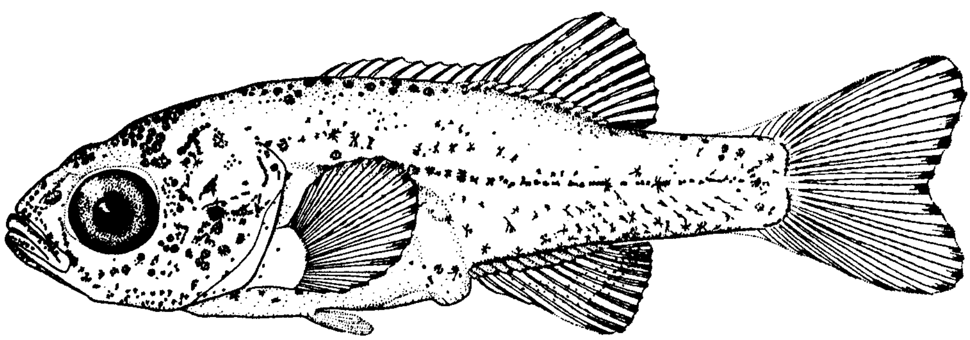

FIGURE 16.—Striped bass young 18 days old; length 13 millimeters; reared in aquarium at Edenton, N. C., May 1937.

The young striped bass reach a post-larval stage at 240 hours after fertilization of the egg provided food is made available. At 9 mm in length the postlarva has lost most of the larval finfold. The second dorsal and anal finrays become slightly differentiated although the first dorsal and ventral fins are wanting. Large chromatophores are scattered profusely on the top of the head and a series of branching chromatophores run along the ventral edge of the body from the head to the tail, becoming interrupted along the intestine and the vent. A regular but broken line of pigmentation extends medially along the side from the pectoral fin to the base of the tail. Mouth parts are well developed. (See fig. 15.)

The postlarva at 13 mm (one-half inch) in length, 18 days after fertilization of the egg, has the dorsal and anal finrays well differentiated. The spinous and soft dorsal fins are still connected by the finfold and the spines are still quite rudimentary. The body has become much more robust and all traces of the larval finfold are gone. The ventral fins are now present. Pigmentation is heavy and consists of a medial line of chromatophores that extend along the side from the pectoral fin to the tail, a large number of heavy chromatophores on the head, and various scattered markings on the body, expecially in the ventral region. (See fig. 16.)

The young striped bass at a length of 36 mm (1.4 in.) and from 3 to 4 weeks old has the general shape of the adult fish, is well scaled, and has fully developed fins and

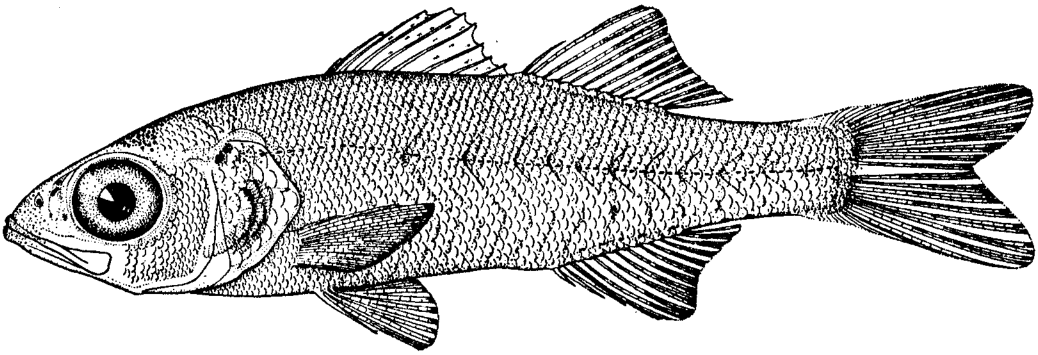

FIGURE 17.—Striped bass young, 36 millimeters (1.4 inches) in length. Taken August 28, 1929, at Back River, Va.

rays. Pigmentation consists of minute black dots scattered over the entire body. Larger chromatophores are present on the top of the head. A series of about nine oblique V-shaped lines appear along the lateral line of the fish and probably represent blood vessels. (See fig. 17.)

The young fish at a length of 130 mm (5.1 in.) and approximately 1 year old possesses the characteristic lateral black stripes ranging from six to eight in number and extending from the edge of the opercle to the base of the tail. There appears also about

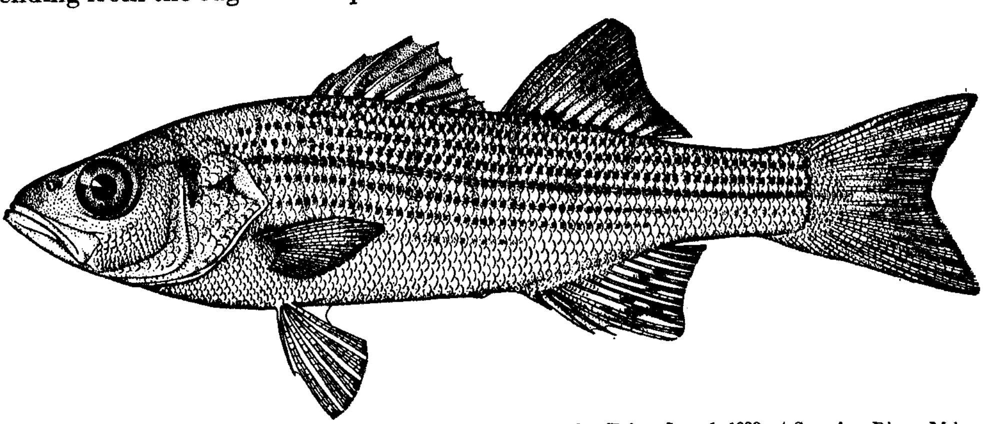

FIGURE 18.—Striped bass young, 130 millimeters (5 inches) in length. Taken June 1, 1932, at Sassafras River, Md.

seven fainter vertical bars extending from the base of the dorsal fins to somewhat below the lateral line. The dorsal and caudal fins are quite heavily marked with fine dots. (See fig. 18.)

GROWTH

A thorough study of the growth of the striped bass in California was made by Scofield (1931). This investigator found that on the basis of length-frequency distributions the average length of the fish at the end of the first year of life (April) was approximately 10 cm (4 in.), at the end of the second year 25 cm (9.8 in.), at the end of the third year 34 cm (13.4 in.), and at the end of the fourth year about 47 cm (18.5 in.). It was found impossible to determine the age or growth of the species beyond the fourth year by the length-frequency groupings. Calculations of growth for the first 4 years by scale examinations of winter annuli were approximately the same as indicated by the length-frequency distributions. The scales revealed further that at the end of the fifth year the average length of the female striped bass is 54.2 cm (21.3 in.) and of male fish 51.6 cm (20.4 in.), at the end of the sixth year 61.3 cm (24 in.) for female fish and 56.3 cm (22 in.) for males, and at the end of the seventh year 68 cm (26.8 in.) for female fish and 61.2 cm (24 in.) for males. It was noted that both sexes grow at about the same rate during the first year. From then until the fourth

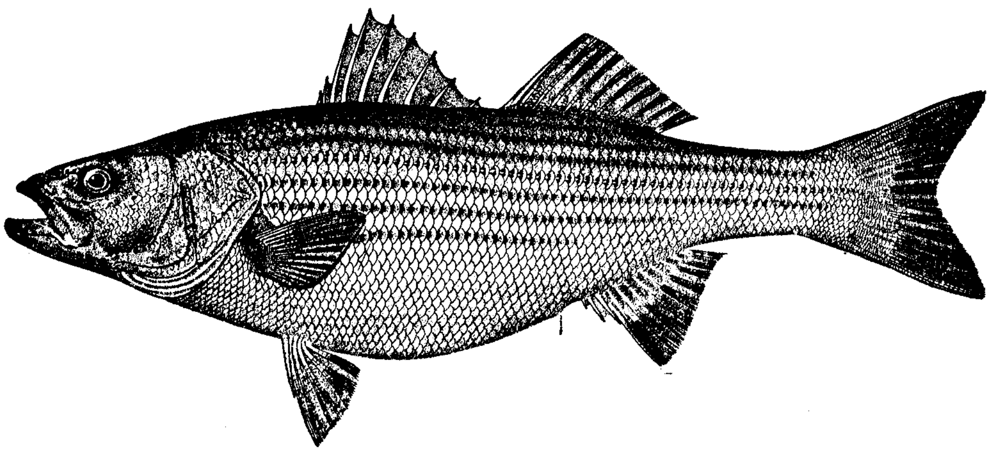

FIGURE 19.—Striped bass adult, 21.4 inches (54.7 centimeters) in length. Taken in April 1880, at Washington, D. C.

year the males are larger, but beyond this point the females continue their rapid growth while the males show a retarded growth. At the end of the tenth year the males are about 7 cm (2.7 in.) shorter than the females. Male striped bass older than 10 years were found to be rare, as were females beyond 16 years.

Various length-frequency distributions of striped bass were secured during the summer months, chiefly in 1931 and 1932, from Chesapeake Bay. Although the number of fish represented are few in most age groups, the annual growth for the first 3 years of life appears approximately the same as for the species resident in California waters. The O age group, or fish in their first year (spawned about May), attain a length of about 4 cm (1.6 in.) by July, and about 9 cm (3.5 in.) by September. The I age group, or 1-year-old fish, attain a length of 20–27 cm (7.9–10.8 in.) with a mode at 25 cm, by August. The II age group, or 2-year-old fish, reach a length of 26–38 cm (10.4–15 in.), with an average length of 31 cm, by July. The III age group, or 3-year-old fish, may reach a length of 34–50 cm (13.5–19.7 in.), with an average length of 40–43 cm by May, or at the approximate third birthday (see fig. 20).

Selectivity of the fishing gear, and the nature of the environment, affected the length-frequency distributions considerably. Likewise, the limited sampling occasioned an unknown error in the determination of the average growth rate. The study of the scales verified the age as indicated by the length-frequency distributions. No attempt was made to determine age or growth after the third year, as material was inadequate.

The early growth of striped bass appears quite rapid, for larvae hatched at Weldon, N. C., on May 14–16, 1937, and planted in a pond at Edenton, N. C., several days after hatching, attained a total length of 30–33 mm (1¼ in.) by June 10, less than a month after hatching.

The maximum growth of the striped bass is indicated by the capture of several fish at Edenton in April 1891, weighing about 125 pounds each. It is of interest to note that Worth (1882) recorded a seine catch of striped bass at Avoca, N. C., on May 6, 1876, composed of 840 fish, totaling over 35,000 pounds. Three hundred and fifty fish are said to have averaged 65 pounds each.

A female striped bass kept on exhibition at the New York Aquarium for over 19 years reached only 20 pounds. It is assumed that this fish did not reach its full

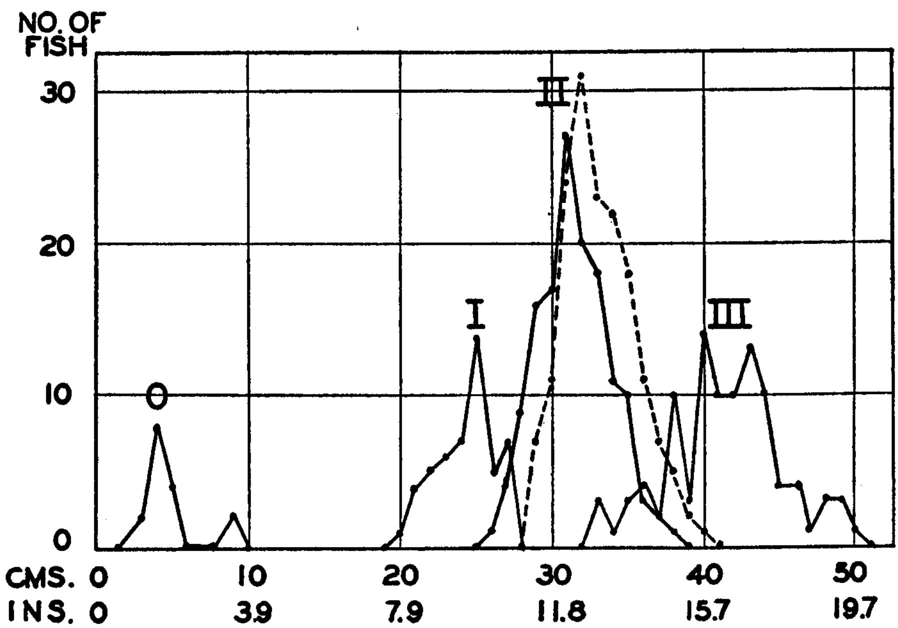

FIGURE 20.—Length-frequency distributions of striped bass taken principally during summers of 1931 and 1932 in Chesapeake Bay. The smaller distribution of O age-group taken in early July; larger distribution in late August. The distribution of I age-group taken during July and August. The smaller distribution of II age-group taken in July; larger distribution in August. The III age-group taken from April to June and composed of mature male fish.

development in captivity where variety of food and freedom of movement were restricted. Length-weight and length-age correlations for California fish (Scofield, 1932) are given in figure 21.

FOOD HABITS

The striped bass is carnivorous, predacious, and an active feeder. The species is known to consume all kinds of fishes and crustaceans. Shad, river herring, and menhaden are favorite prey in fresh and brackish waters, while crabs and lobsters are eaten along rocky coast lines. Shrimps, squids, clams, and other crustaceans have been noted in the stomachs of striped bass taken along the Atlantic seaboard. Young striped bass reared in aquaria were fed live *Daphnia*. Young fish taken in the Hudson River were found to feed largely on the shrimp, *Gammarus* (Curran, 1937).

Investigators on the Pacific coast have found that the species feed on every marine form common to the San Francisco Bay region.[9] The food included the Pacific herring, silver salmon, steelhead trout, shad, carp, and perch; such crustaceans as *Gammarus* and *Neomysis,* and even *Velella,* the Portuguese man-of-war. It has

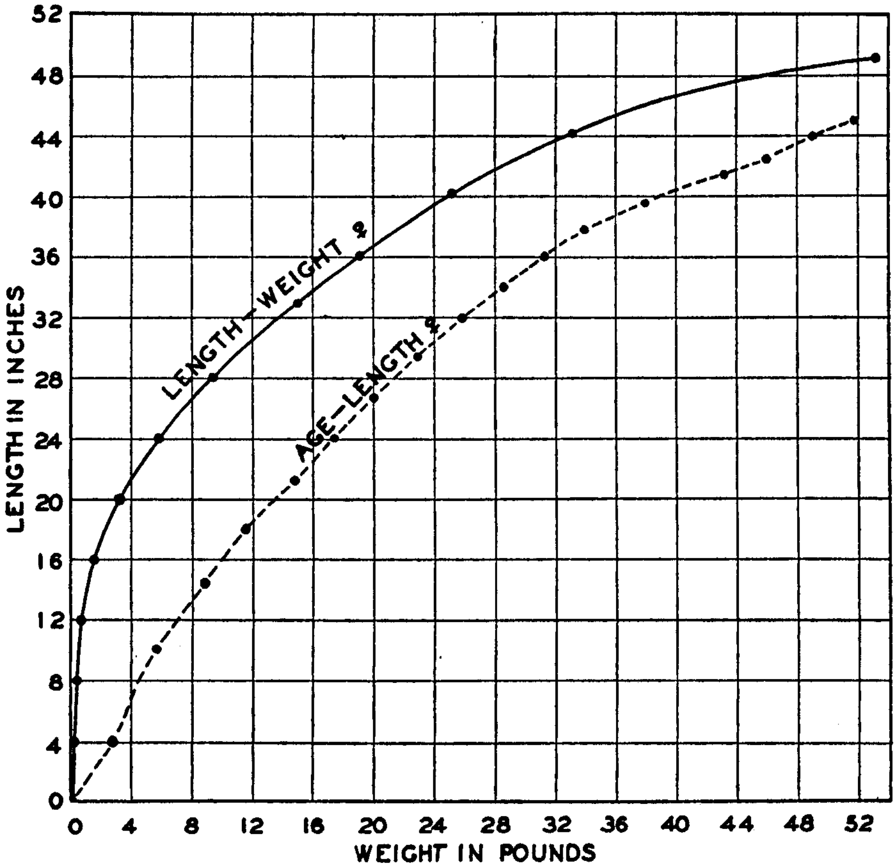

FIGURE 21.—Length-weight and length-age correlation of striped bass in California. After Scofield (1932).

been observed that striped bass feed heaviest in the warm months of the year and in salt water.

Nearly every type of angling bait can be successfully used to hook striped bass. Eel tails, and silvery trolling lures resembling fishes, are particularly effective.

MOVEMENTS

The movements of striped bass can be broadly classed as coastal, seasonal, and spawning. The exact nature and intensity of these movements are probably determined largely by the character of the environment. That coastal movements occur is clearly indicated by the geographic range of the species along the Pacific and Atlantic coasts of the United States. Along the Pacific coast the striped bass has spread from the initial stocking in San Francisco Bay over a coastal range of about 850 miles. Self-sustaining colonies of striped bass are known to exist in San Francisco Bay and

[9] Various writers on the food of striped bass are Ayres (1842), Verrill (1873), Rice (1883), Scofield (1931), Shapovalov (1936), and Merriman (1937).

its tributaries, and in Coos Bay, Oreg., about 400 miles north of San Francisco. Marking experiments in California waters have indicated, however, that no regular or definite coastal movement of striped bass occurs, and that the fish appear to diffuse at random to all points from the locality of release. In a marking experiment in San Francisco Bay, Clark (1936) found that the time elapsing between release and recapture ranged from 4 to 477 days with an average of 111 days of freedom. Yet the distances traveled by the marked fish varied from 0 to 46 miles. Such a restricted dispersion indicates limited coastal movement.

Along the Atlantic seaboard Merriman (1937) has recently shown that seasonal coastal movements of striped bass occur in southern New England with an apparent incursion of fish from southern waters in early summer and a return movement to the south in late fall.

Local seasonal movements of striped bass are quite pronounced. In November and December, as noted by Mease (1815), the fish leave the sea and run into the rivers along the New Jersey coast to pass the winter, where they remain, unless disturbed, until the following spring.

In colonial times a winter fishery for striped bass along the North Atlantic coast was possible because the fish moved into the deep river channels during cold weather and lay semidormant near the bottom, from whence they could be easily captured by large dip nets operated under the river ice. In the tidal Parker River, Mass., the fishery now depends entirely on the formation of firm river ice. It is believed by fishermen that the ebb-tide movement of the river water also tends to force the striped bass off the shallow tidal flats into the deeper channel holes where dip nets can be operated to best advantage. In Chesapeake Bay the striped bass are known to winter in the deeper channels of the bay and river mouths. A concentration of fish is known to occur in a deep channel near Kent Island where fishermen find it profitable to sink gill nets for the sluggish fish. A movement of bass takes place in the fall of the year in California. The fish come out of the bays, run into sloughs, and for some distances up the rivers. When cold weather sets in the fish leave the flats and seek the depths of the channels and sloughs.

In the summer, following spawning, the striped bass leave the rivers and creek and move out into more open areas in the sea or estuaries. This summer movemen of fish appears to be induced by food requirements. As observed by Wood (1634):

> These (striped bass) are at one time when the Alewives passe up the Rivers to be catched in Rivers, in Lobster time at the Rocks, in Macrill time in the Bayes, at Michelmas in the Seas.

In southern waters the species prefers to dwell in fresh or brackish water at all times and relatively few fish are found near ocean inlets or in the open sea. North of Chesapeake Bay a more pronounced movement of bass occurs along the open seacoast during the summer months The annual summer appearance of large striped bass along the sandy beaches of New Jersey and off the rocky headlands of southern New England has provided angling sport for many years.

In California during the summer striped bass from the region of San Francisco Bay move down along the coast of southern California and from upper Suisan Bay down into San Francisco Bay after spawning. These movements, according to Scofield (1931), appear induced by the more abundant food supply in the salt water than in the fresh water of the delta country.

Spawning movements of the species consist essentially of the migration of adult fish from salt, brackish, or fresh waters, up suitable rivers where spawning occurs.

A spawning movement of striped bass was definitely noted in May 1932, at the entrance to the Susquehanna River where captures of ripe fish indicated a nocturnal spawning migration up the river from Chesapeake Bay.

On the upper Roanoke River, at Weldon, N. C., a pronounced spawning movement occurs during the latter part of April and throughout May. This movement provides an opportunity for fishermen to enjoy the sport of capturing the spawning fish with large skim nets. This fishing operation is carried on during the early evening in and just below the rapids.

In the region of San Francisco Bay the spawning migration is made up of fish that come from the deeper holes in the lower rivers and bays, and from the ocean, to run up the Sacramento and San Joaquin Rivers and some of the smaller tributaries. It was thought by Scofield (1931) that a spawning movement of fish also occurred

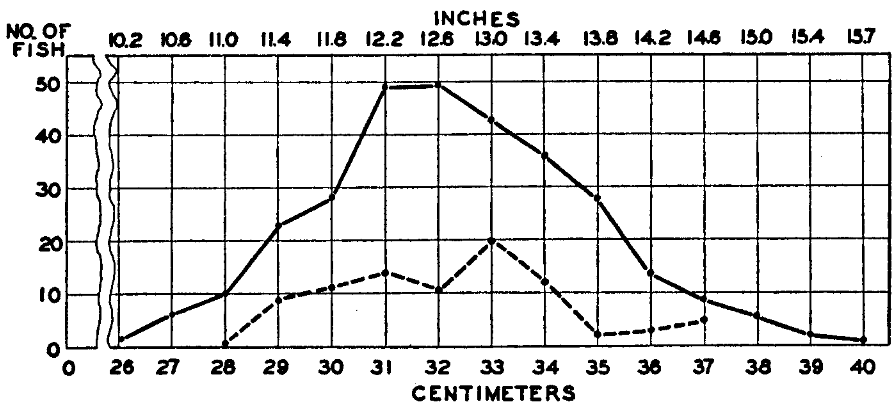

FIGURE 22.—Length-frequency distribution of striped bass marked for migration studies in Chesapeake Bay. Solid line indicates number of fish marked and released; dotted line indicates number of fish recaptured.

from the coast of southern California back to common spawning grounds in the San Francisco Bay area.

An early suggestion of a spawning migration of striped bass involving a parent-stream theory, and the feasibility of stocking depleted streams with fish, was advanced by Belknap in 1792. This historian wrote:

> It is said by some, that fish which are spawned in rivers, and descend to the sea, return to those rivers, only where they are spawned. If this principle be true, the breed might be renewed by bringing some of the bass, which are caught in the Merrimac River, alive, over the land, to the nearest part of the waters of the Piscataqua, a distance of not more than 12 miles. This must be done before the spawning season, and might easily be accomplished.

The first attempt to determine the migrations of the striped bass through marking experiments was made by the author in July and August 1931, in upper Chesapeake Bay (Pearson, 1933 a). A total of 305 fish, ranging in length from 26–40 cm (10.2–15.7 in.) were caught, marked, and released. Most fish were in their third summer (2 years of age) and were immature so far as could be determined. The fish were taken on hook and line and were released immediately at or near the place of capture, about 1 mile east of Hacketts Point, off Annapolis, Md. (See fig. 22.)

The tags were the modified Nesbit disk consisting of two 12-mm (one-half inch) circular celluloid disks connected by a length of nickel wire. The wire, sharpened at one end and headed at the other, was run through one disk and then through the back of the fish slightly below the second dorsal fin and another disk was placed against the other side of the fish and secured by twisting the end of the wire. One disk was red and bore a serial number to identify the individual fish; the other was white and bore the words: "Bureau of Fisheries, Washington, D. C. Return Both Disks. Reward." A nominal fee was paid for the return of the disks together with information as to date and place of capture.

Soon after marking operations were commenced, on July 7, 1931, disks were returned from various localities in upper Chesapeake Bay and they continued to be returned over a 2-year period. From July 1931, to September 1933, a total of 89 marked fish were recaptured either by sportsmen or commercial fishermen. The

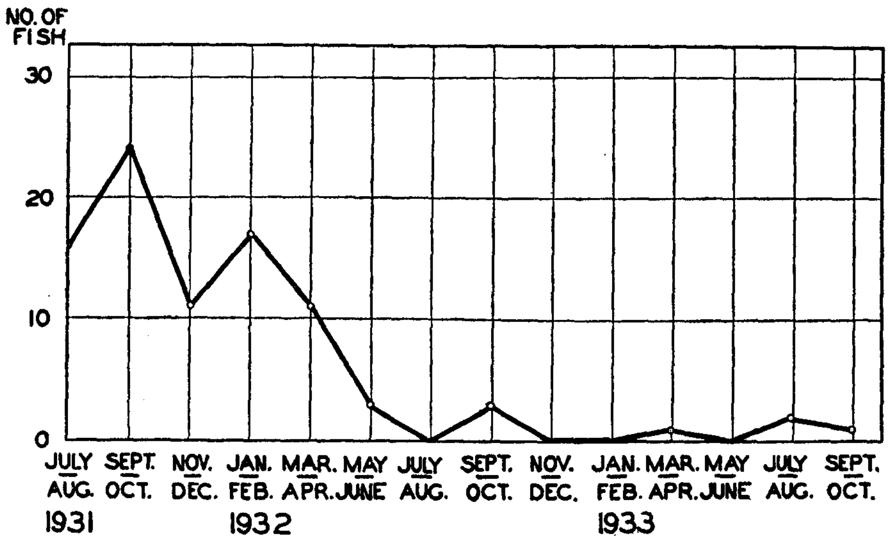

FIGURE 23.—Bimonthly recapture of marked striped bass in upper Chesapeake Bay from July 1931 to September 1933.

recaptured fish totaled 29.1 percent of the number released, or about 1 out of every 3 fish marked. Twenty percent of these fish were retaken within the first 6 months after release. (See fig. 23.)

None of the marked striped bass were recaptured at the immediate point of release. Only 9 fish out of 89 were recaptured south of the point of release off Annapolis, Md. The majority of fish were taken at various points along the shores of upper Chesapeake Bay from the Magothy River and Love Point north to the Susquehanna and Elk Rivers. The point of greatest concentration of marked fish was in the vicinity of Rock Hall near the entrance to the Chester River. (See fig. 24.)

Six out of nine marked fish taken in Chesapeake Bay, or tributaries below the point of release off Annapolis, were recaptured the following spring after marking. One striped bass was recaptured off Maryland Point in the Potomac River on March 17, 1932, while another was secured in the Wicomico River, near Salisbury, on March 23, 1932. These localities were the most distant points to which the marked fish dispersed over a 2-year period.

The steady decrease in the number of recaptured fish after the first 2 months (see fig. 23) was probably caused by the ultimate detachment of the disks from the back of the fish and by the continually reduced number of marked fish available for capture.

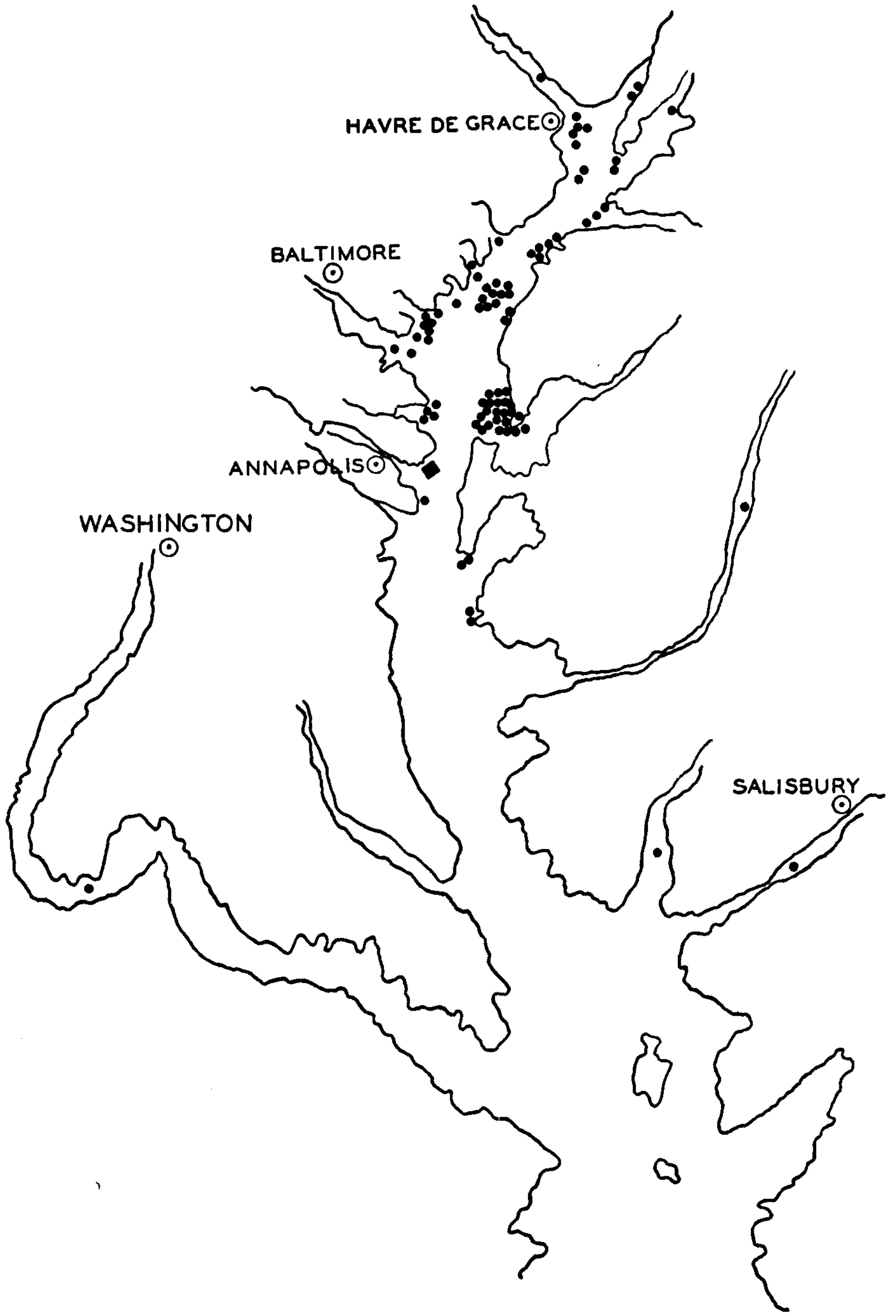

FIGURE 24.—Movements of striped bass in upper Chesapeake Bay, 1931-33. The solid square off Annapolis indicates point of release; dots represent individual recaptures of fish.

It is obvious that a clear-cut movement of fish occurred to the north of the point of release which indicates that the bass preferred the fresh or slightly brackish water at the head of the bay to the more saline water down the bay. South of the point of release the four most distant recaptures were at considerable distances up rivers in brackish water. Although the absence of marked fish south of the Potomac River might indicate a local stock of striped bass in upper Chesapeake Bay, a recent increase in the stock of fish within the entire bay, together with a simultaneous increase in the number of fish annually visiting southern New England waters, suggests that the limited distributions of the marked fish during 1931–33 were perhaps caused by a low population density of striped bass in the upper bay and by an abundance of food for the fish with little incentive for widespread movements in or out of the bay.

FISHERY

The fishery methods employed to capture the striped bass afford ample evidence of the severity of the struggle that this food and game fish has undergone in order to survive. These methods are applicable in most instances to other anadromous fishes, such as the shad and salmon, which have suffered alarming decreases in abundance along our Atlantic coast.

The early settlers in New England laid efficient traps for the striped bass during the summer months as they used to "tide it in and out to the Rivers and Creekes by stretching long seins and weirs across coastal streams at high tide." As the water ebbed from the creeks the stranded fish were often obtained in far greater quantities than the fishermen could haul to land. The fish were consumed either fresh, salted, pickled, or smoked. Pickled bass furnished a medium of trade in the West Indies along with salted codfish. The earliest colonial records of the smoking of striped bass as a means of preservation contain the following statement of Wood (1634):

> They drie them to keepe for Winter, erecting scaffolds in the hot sunshine, making fires likewise underneath them, by whose smoake the flies are expelled till the substance remaine hard and drie. In this manner they dry Basse and other fishes without salt, cutting them very thin to dry suddenly, before the flies spoyle them, or the raine moist them having speciall care to hang them in their smoaky houses, in the night or dankish weather.

In the St. Johns River, New Brunswick, according to Adams (1873), the Indians captured the bass at spawning time. A few canoes would drop down the river, each with an Indian in the bow, spear in hand, and another in the stern paddling gently. A sudden spash close by would indicate a bass and like an arrow the birchbark skiff was shot toward the spot while the man in front, resting on his knees, with much force and dexterity sent his three-pronged harpoon into the fish.

The winter months proved the most destructive to the striped bass in northern waters. The fish normally sought the shelter of river channels during cold weather, lying more or less dormant along the bottom until spring. Fishermen soon learned to capture them under the ice by means of large dip nets (Pearson, 1935 b). The havoc of this type of fishery on the resident stock of striped bass was noted by various early writers.[10]

Various methods have been developed to capture the striped bass in southern rivers. It has been the practice for many years on the Roanoke River near Weldon, N. C., to secure the spawning fish in and below the rapids each spring. The adult fish move up the river in late April and May and, if there is sufficient water in the

[10] Tenney (1795), Mease (1815), and Perley (1850).

river, they distribute themselves about the falls where the strong current renders them inaccessible to fishermen. The fish work upstream into numerous channels between various islands lying amid the rapids. During summer low water fishermen at one time prepared traps to capture the fish in these channels by constructing wooden slides at favorable points in the rapids. The fish, forced to descend the rapids through lowered river level, were guided onto the slides and were forced to remain against slats by the pressure of the current and could be easily removed by the fishermen. As many as 300 fish of 30 pounds each have been removed from a slide in a single day. This efficient fishing device has been recently outlawed by the State of North Carolina. (See fig. 25.)

The striped bass congregate at the foot of the rapids at Weldon and are taken in large quantities during the spawning season by skim nets. A skim net consists of a large bow frame of hickory, about 6 feet long and 4 feet wide, to which is hung a linen net about 6 feet deep and 1½-inch square mesh. The bow frame is fastened to a stout wooden pole at least 20 feet long. Two such nets may be fished from a small power boat simultaneously but a man must sit in the stern of the boat and keep it broadside to the river current as it drifts downstream. A fisherman usually stands amidship holding the net in a rigid vertical position against the gunwale with the bow frame lifted a few inches from the river bottom. The touch of a fish against the net signals the fisherman who quickly lifts the net vertically out of the water and deposits the fish in the boat. The catch consists chiefly of ripe fish from which eggs and milt are taken for artificial propagation.

Most commercial fishery methods for the capture of striped bass are confined, through legal restrictions, to more open areas than narrow river channels and rapids. Pound nets, haul seines, and gill nets effectively take the fish from Rhode Island to North Carolina. Salt-water areas provide the most abundant catches in northern waters while brackish and fresh-water estuaries and rivers afford the best fishing from Chesapeake Bay south. Sunken gill nets are used in winter and drift gill nets in summer. Pound nets or trap nets are most advantageous along the open coast line and off river mouths. Haul seines are favored in large estuaries and purse seines, now outlawed, were formerly employed to capture schooling striped bass in Chesapeake Bay. No commercial fishery for the striped bass now exists in California; the species is reserved for hook-and-line sportsmen.

Commercial catch statistics for striped bass from the waters of Maryland, Virginia, North Carolina, and the Middle Atlantic States are given in figure 26. The annual catch records show a decreasing supply of fish despite the more efficient gear employed. The catch in Maryland decreased from a peak of 1,413,000 pounds in 1925 to 314,000 pounds in 1933. The striped bass in various Middle Atlantic States has provided an annual catch of less than 207,000 pounds (40,000 pounds in 1933) since the early part of the present century although this area in 1889 produced over a million pounds of the fish. North Carolina, relatively free from coastal river obstructions and widespread industrial water pollution, shows a decrease in the catch from 1,175,000 pounds in 1902 to 362,000 pounds in 1934. Virginia, however, shows a steady catch at about one-half million pounds annually.

The intensity of the fishery for striped bass in upper Chesapeake Bay may be estimated by the high return of released fish in a marking experiment conducted in 1931. A total of 29 percent of the 305 released fish were recaptured by fishermen within 2 years, and about 20 percent of these fish were retaken within 6 months after

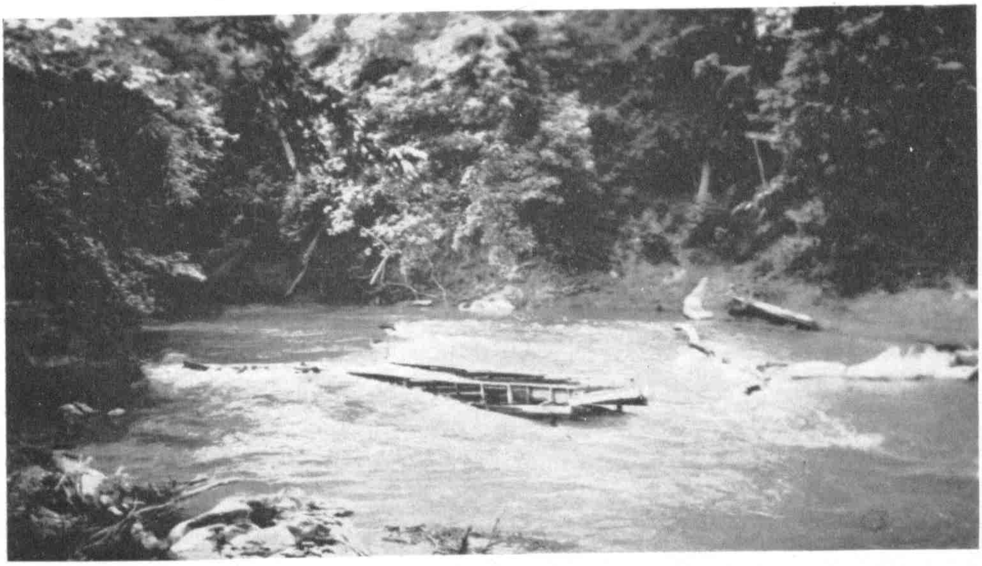

FIGURE 25.—Rockfish slide in a channel of the Roanoke River at Weldon, N. C. The striped bass spawn in these channels characterized by swift currents.

release. The high rate of recapture is indicative of a severe strain on the local stock of fish.

It is surprising to note that after an extended period of lean years the catch of striped bass in Maryland waters increased from 332,000 pounds in 1934 to 928,000 pounds in 1935. This increase of nearly threefold cannot be definitely explained in the absence of field observations but a likely cause for the greater abundance of fish is suggested. In 1932 the use of the purse seine was forbidden in Maryland. This type of net had accounted for about 25 percent of the annual catch for several years prior to 1931. Although the catch remained low from 1932 to 1934, it is significant that the striped bass do not generally attain commercial size until their third summer. Hence, fish which were spawned in 1933 did not appear in the catch until 1935. It might be assumed that enough adult striped bass 3 years old or older were spared by the abolition of the purse-seine fishery in 1932 to aid greatly in spawning production

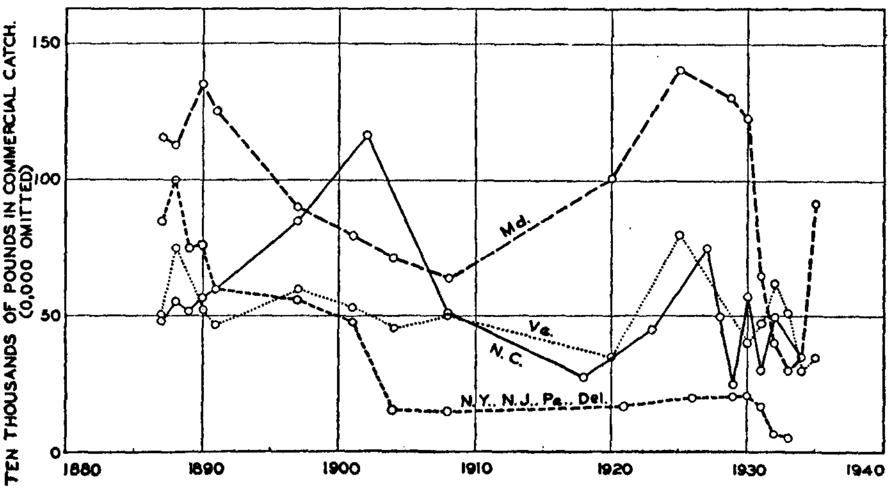

FIGURE 26.—Commercial catch of striped bass in the Middle Atlantic States, Maryland, Virginia, and North Carolina, compiled by Bureau of Fisheries for various years since 1887.

in the spring of 1933. Many fish spawned in 1933 undoubtedly reached the commercial catch during 1935. If such a condition actually occurred then a heavy production of young also occurred in 1934, making possible a large commercial catch in 1936. Field reports again indicate that the striped bass was as abundant in 1936 as in 1935, and that most catches were composed of small fish.

Another indication of the recent increase in the stock of striped bass along the Atlantic seaboard is shown by the incursion of many 2-year-old fish to the coast of southern New England in 1936 as noted by Merriman (1937). This movement of fish into southern New England is perhaps definitely correlated with the increase of striped bass shown by the commercial catch in 1935 in upper Chesapeake Bay. A movement of fish out of Chesapeake Bay and into northern areas may therefore occur at times when the local stock of fish becomes so abundant as to seriously reduce its food supply. Whether depleted northern waters will be permanently restocked as a result of this recent influx of striped bass from apparently overstocked southern areas is unknown.

The striped bass has shown, by its remarkable reproduction in California and its recent increase in Chesapeake Bay, that it has the ability to establish itself as an important aquatic resource in favorable environments within a short period of time. However, unless the fishery strain on the stock of fish in most eastern waters is eased appreciably by adequately restricted fishing, it is feared that only the past glories of this superb food and game fish will remain for future generations to contemplate. Nevertheless, with vigorous and well-considered conservation measures adopted, the striped bass can be expected to increase to some degree of its former abundance and assure the future of the "boldest, bravest, strongest, and most active fish that occurs the year round in our American coastal waters."

SUMMARY

The striped bass, or rockfish, occurs over an extended coastal range along the Atlantic and Pacific coasts of the United States. This fish is also found in small numbers in streams tributary to the Gulf of Mexico from St. Marks, Fla., to Lake Pontchartrain, La.

The species is taken most abundantly at the present time in the fresh and brackish waters of Chesapeake Bay, Albemarle Sound, and San Francisco Bay.

The spawning grounds are located in coastal rivers, apparently characterized by strong rapids and rock-strewn bottoms, and the spawning season extends from late April to early June in most areas.

Sexual maturity, accompanied by spawning, is attained by most male fish at the end of the third year and at a minimum length of about 10 inches. Female fish mature at the end of the fourth year and at a minimum length of about 19 inches.

The eggs of the striped bass are semibuoyant, spherical, and measure about 1.3 millimeters in diameter at fertilization, increasing to about 3.5 millimeters within 12 hours. The eggs hatch in 48 hours at about 65° and in about 36 hours at 71° F. The yolk is absorbed and the young begin feeding by 240 hours after fertilization of the egg.

The average length of the striped bass is 4 inches at the end of the first year; 10 inches at the end of the second year; 15 inches at the end of the third year; and 18.5 inches at the end of the fourth year.

The food of the species is largely fishes and crustaceans.

The striped bass show coastal, seasonal, and spawning movements. Coastal movements are widespread but are probably regulated by the population density of fish in natural centers of abundance. Seasonal movements consist of a summer movement of fish into more open water with better feeding grounds and a winter movement into deep river channels for a semihibernation period. Spawning migration occurs in the spring of the year when the striped bass move up favorable rivers from the sea or estuarine areas.

A marking experiment in upper Chesapeake Bay in 1931 showed purely local movements within the upper bay over a 2-year period with a 29.1 percent recapture of marked fish.

The fishery for striped bass has shown a general decline over the greater part of its range despite a more intensive fishing effort. Restrictive fishing regulations appear to offer suitable means for increasing the stock of fish appreciably.

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GENERAL INDEX

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