DEVELOPMENT AND LIFE HISTORY OF FOURTEEN TELEOSTEAN FISHES AT BEAUFORT, N. C.[1]

By SAMUEL F. HILDEBRAND, *Director, United States Fisheries Biological Station, Beaufort, N. C.*, and LOUELLA E. CABLE, *Junior Aquatic Biologist, United States Bureau of Fisheries*

CONTENTS

	Page
Introduction	384
Methods	384
Remarks	387
Anchoviella epsetus (Bonnaterre) and Anchoviella mitchilli (Cuvier and Valenciennes). Anchovies	388
Economic importance	388
Spawning	388
Development of eggs and young	389
Distinguishing characters	393
Distribution of young	384
Growth	394
Food	395
Orthopristis chrysopterus (Linnæus). Pigfish; hogfish	395
Spawning	398
Development of eggs and young	399
Experiments in growing young pigfish in captivity	407
Age at sexual maturity	410
Food	411
Bairdiella chrysura (Lacépède). White perch; sand perch	411
Spawning	411
Development of eggs and larvæ	412
Distribution of young	412
Growth	413
Food and feeding habits	415
Leiostomus xanthurus, Lacépède. Spot	416
Spawning	417
Descriptions of young	419
Comparison of young spots and croakers	424
Distribution of young	424
Growth	424
Age at sexual maturity and the span of life	429
Food and feeding habits	430
Micropogon undulatus (Linnæus). Croaker; hardhead	430
Spawning	433
Descriptions of young	435
Distinguishing characters among young Sciænids	439
Distribution of young	441
Growth	441
Age at sexual maturity	444
Food and feeding habits	445
Parexocœtus mesogaster (Bloch). Short-winged flyingfish	445
Spawning and development of young	446
Distribution of young	448
Cypselurus furcatus (Mitchill). Four-winged flyingfish	449
Spawning	449
Descriptions of young	449
Distribution of young	452
Decapterus punctatus (Agassiz). Scad; cigarfish; round robin	453
Spawning	453
Descriptions of young	454
Distribution of young	457
Seriola dumerili (Risso). Amberfish; rudderfish	458
Spawning	459
Descriptions of young	459
Distribution of young	463
Growth and food	464
Paralichthys dentatus (Linnæus) and Paralichthys albiguttus, Jordan and Gilbert. Summer flounder; southern flounder	464
Spawning	469
Descriptions of young	470
Distribution of young	474
Growth	475
Food and feeding habits	476

[1] Submitted for publication, April 8, 1930.

	Page
Symphurus plagiusa (Linnæus). Tonguefish; sole	476
Spawning	477
Development of young	477
Distribution of young	481
Growth	482
Monacanthus hispidus (Linnæus). Foolfish	482
Spawning	482
Development of young	483
Distribution of young	486
Growth	486
Bibliography	487

INTRODUCTION

A special study of the development and the growth of teleosts in the vicinity of Beaufort, N. C., was begun in the spring of 1926. This investigation has been continued, as other duties permitted, to the present time (March, 1930). The work was conducted under the direction of the senior author who at first was assisted by Irving L. Towers, formerly junior aquatic biologist, Bureau of Fisheries, and since the summer of 1927 by Louella E. Cable, the junior author. Dr. James S. Gutsell, associate aquatic biologist with the bureau, too, rendered important service, for he did nearly all the offshore collecting, mentioned subsequently, and at times sorted collections and assisted in making measurements and preliminary identifications.

Irving L. Towers served as collector and general assistant during the first year of the investigation. Mr. Towers prepared most of the drawings, illustrating the development of the pigfish and the anchovy, accompanying this paper, and he also made many of the measurements used in the tables. Mr. Towers was succeeded by the junior author who prepared all the drawings, exclusive of those already mentioned. She also assisted in collecting and identifying specimens. She made most of the measurements used in the tables, drew the graphs, and carefully reviewed the manuscript. The senior author is responsible for the final identification of specimens, for any errors that may be included, and the conclusions drawn from the data presented.

In general, only those species for which fairly complete series of specimens showing the development, at least of the young, have been obtained and studied are included in this paper. Many others for which the information is less complete are being held for further study and future report. Although the investigation is to be continued, it nevertheless seems advisable to make available to others the information gained relative to the species included in this paper. The stages in the development of the forms discussed, at any rate, are fairly completely shown. Little or no hope is entertained of soon getting the eggs of the species reported upon in this paper for which they have not already been obtained. It seems quite evident that the eggs either must be sought by a new method of collecting or in areas not yet explored with the apparatus used. On the other hand, eggs have been obtained of a few species not reported in this paper for which all the stages in development either of the egg or the young or both have not yet been found or studied.

METHODS

The collection of specimens and life history data was begun in the spring of 1926, as stated elsewhere, and continued more or less regularly to the present time (March, 1930). Specimens were collected at various places in Beaufort Harbor and its many arms, including two large estuaries and numerous bays, creeks, and ditches. Occasional collecting trips also were made in Bogue and Core Sounds, both connected with Beaufort Harbor. The principal collecting stations are shown on the chart. (Fig. 1.) All of these waters, except for Ocracoke, Beaufort, and Bogue Inlets, are

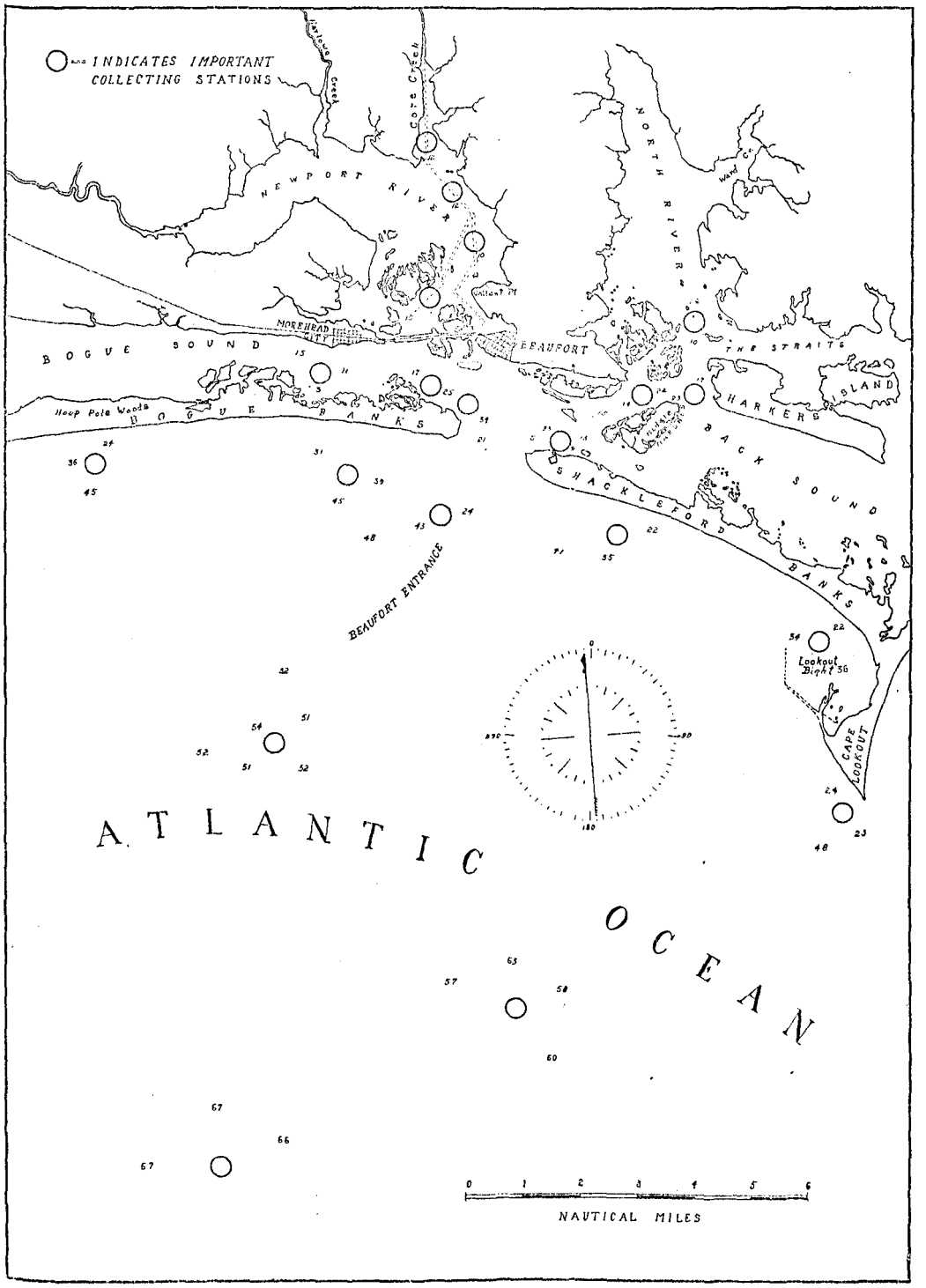

FIGURE 1.—Map of Beaufort Harbor and neighboring waters. Numbers on the map show the depth of the water in feet at the principal collecting stations

inclosed by Bogue and Shackleford Banks, consisting of long, narrow strips of land, usually referred to merely as the "banks." Wherever the designation "banks" is used in the present paper, without further qualification, it refers to Bogue and Shackleford Banks.

During the winter of 1926 and 1927 the collection of specimens off Beaufort Inlet also was undertaken. From that time, until near the end of 1929, offshore collecting trips at weekly intervals, the weather permitting, were made. Although the course was varied from time to time, the most usual one followed extended from Beaufort Inlet to Cape Lookout. From Cape Lookout a west-southwest course was held for 12 to 15 miles, and from thence a due north course was taken until comparatively shallow water was reached off Bogue Banks, about 6 miles west of Beaufort Inlet. Thereafter, the shore of the bank was followed back to Beaufort Inlet. Generally five to seven stations were made during the course of each trip.

During the early months of the investigation eggs and fry were collected with small plankton nets. Other collecting was pursued with an otter trawl and with small collecting seines. A small dragnet about 12 feet long and 3 feet deep, made of bobbinet, was found especially useful for collecting young fish in shallow water from their favorite hiding places in eel grass and other vegetation. This net was very useful also in collecting young fish in small brackish creeks and ditches and was used to good advantage from time to time throughout the investigation.

In January, 1927, 1-meter townets, made of bolting silk with a suitable ring for hauling at the surface and a frame for dragging the bottom, were acquired. This apparatus was used exclusively in the offshore collecting until the autumn of 1929. It was used regularly for a couple of years in the inshore waters also to supplement the collecting done there with other gear.

Meter townets were by far the most useful gear used. They are excellent for collecting the eggs and the fry. However, after the young fish reach a length of about 10 millimeters and more, they are not readily caught in 1-meter townets. Certain species may then be collected in shallow water with a fine-mesh seine, such as is described in a preceding paragraph. Others do not enter shallow water and can be taken only with nets that may be hauled in somewhat deeper water. Because no apparatus suitable for taking the young after considerable growth had been attained, some of our series remained incomplete for a long time. In some cases numerous fry, as well as fish large enough to be caught in ordinary collecting seines and trawls, were at hand, but intermediate sizes were missing.

During the last year of the investigation considerable success in catching intermediate or missing sizes was attained by covering the cod end of an otter trawl with a sack of bobbinet constructed like a 1-meter townet, except that it was found advantageous to make it longer in order to cover more of the trawl. To attach the bobbinet to the trawl, a heavy cord is run through the meshes of the large net, and the smaller net is fastened to the cord with harness snaps or with strings. It was feared that the bobbinet would be torn. This difficulty has seldom been experienced. By placing the bobbinet on the outside instead of the inside of the trawl—another method considered—the small fish are "screened" from the big ones. The catch in the bobbinet may be washed into a container, without hand picking, like a townet collection, preserved, and sorted at leisure in the laboratory.

It will be seen from the frequency tables presented in this paper that fewer measurements generally were made of certain intermediate-sized specimens than of smaller and larger ones of the same year class. The reason is that the method devised

for collecting fish of such sizes was used only during the last year of the investigation, whereas methods for taking the small fry and larger young were used much longer. The result is, of course, that fewer specimens of the intermediate sizes generally were obtained.

In addition to the collections made during the present investigation the authors have had for study and comparison certain collections of young fish from the South Atlantic coast of the United States and in the West Indies made by the United States Bureau of Fisheries vessels, the *Fish Hawk*, the *Albatross*, and the *Grampus*.

The discussions, measurements, and drawings of eggs and of the recently hatched young, resulting from these eggs, are based upon living material. In all other instances the data were obtained from preserved specimens. Length measurements of specimens as given in this paper are total lengths; that is, they include the caudal fin or fin fold.

REMARKS

Many species of fishes that are common in the shallow waters during the summer leave these areas in the autumn upon the approach of cold weather. This not only happens at Beaufort, but it takes place in Chesapeake Bay and, no doubt, quite generally along the Atlantic coast of the United States. The following spring the fish return to reoccupy their summer feeding grounds. In most cases it is not known, however, where these fish have their winter homes.

The spot and the croaker—two species subsequently discussed in this paper—are among the species that leave their summer homes in the autumn and, at Beaufort, at least, are seldom seen during the winter. In view of this fact it is especially interesting that their young are exceedingly numerous in the local waters during the winter, and that this season, in fact, is their spawning time. Fry of these species, so small and so young that they certainly are not more than a few days old, occur regularly in abundance along the outer shores of the banks and at sea as far offshore as winter collecting has been extended; that is, about 15 miles. How much farther they occur at sea, of course, remains unknown.

It is pointed out in subsequent sections of this paper that the smallest fry collected—only 2, 3, and 4 millimeters in length—are helpless creatures and certainly unable to swim in any definite direction. This leads to the conclusion that, under the usual weather conditions prevailing at Beaufort, they must have been hatched in the general vicinity where they are taken. If that be true, then it follows that the spawning fish can not be far away. The theory, therefore, is advanced, in subsequent sections of this report that the adult fish, after leaving their summer homes, occupy water not very far from the shores and there perform their reproductive processes.

Some evidence also is produced in that section of this paper dealing with the pigfish indicating that this fish, too, has its winter home only a comparatively short distance from the shores. The writers, accordingly venture to predict that, in time, it will be found that most of the numerous species taken in the shallow shore waters during the summer, constituting in fact the bulk of our food fishes, merely migrate to deeper and warmer water, possibly in the vicinity of the Gulf Stream which flows past Beaufort at a distance of only about 30 miles offshore.

It is very interesting, also, that the young of the scad, *Decapterus punctatus* and of the flyingfishes, *Parexocœtus mesogaster* and *Cypselurus furcatus*—all summer spawners—have been taken in large numbers off Beaufort Inlet, while the adults are known from that vicinity from only a few to several specimens. It is judged from the abundance of the young that the adults too must be common. These species

probably escape capture, because they evidently seldom enter shallow water near the shores where they would be caught in fish nets, and being principally pelagic in their habits, efficient apparatus for their capture at sea, at or near the surface, is not available.

ANCHOVIELLA EPSETUS (Bonnaterre) and ANCHOVIELLA MITCHILLI (Cuvier and Valenciennes). Anchovies

Only two species of anchovies, namely, *Anchoviella epsetus* [2] and *A. mitchilli*, are common in the vicinity of Beaufort. Two others, *A. perfasciatus* and *A. argyrophanus*, both generally of more southern distribution, have been recorded from there once. These species were not seen during the present investigation and may be regarded as mere stragglers. The life histories of the two common anchovies of Beaufort are closely related, and it seems advisable to consider them together. They are both of wide distribution; *A. epsetus* ranging from Cape Cod, Mass., to Uruguay and *A. mitchilli* from Cape Cod to Brazil. Locally *A. mitchilli* is much more numerous than its relative.

ECONOMIC IMPORTANCE

So far as known to the writers, anchovies are not used commercially in America, although in Europe they are packed in oil somewhat similar to sardines. *A. epsetus* reaches a maximum length of about 6 inches and a weight of 1 ounce, and an average length of about 4½ inches with a weight of one-half ounce. This size, therefore, apparently is sufficiently large, and if this fish could be obtained regularly and in sufficient quantity over a considerable period of time, it probably could be utilized commercially. This, apparently, is not possible locally, as it is erratic and uncertain in its appearance. *A. mitchilli*, on the other hand, is much more constantly present and much more numerous. Since it seldom reaches a length of 4 inches and its average length is only about 3 inches, its size probably is too small for commercial use.

The economic importance of the local anchovies, therefore, is indirect and probably only as they enter into the food of commercial fishes. In this respect they appear to be very important, for anchovies occur in the stomach contents of local predatory fishes more often than any other fish, with the possible exception of the silversides. The smaller anchovy, *A. mitchilli*, probably because of its greater abundance and more universal local distribution, is by far the more important of the two in this respect. These small fishes quite certainly are of much economic value and their great importance as food for commercial fishes generally is not realized.

SPAWNING

Comparatively little information is obtainable in the literature concerning spawning in the two species of anchovies now under consideration. Kuntz (1914, p. 13) found the eggs of *A. mitchilli* in the tow when he began working at Beaufort on June 9, 1913, and every day until he quit on August 23, and he concludes that the height of the spawning season probably is reached during July. Hildebrand and Schroeder (1928, pp. 110 and 111) state that the spawning seasons of these two species appear to be identical in Chesapeake Bay, and that both extend through May, June, July, and August.

The collection of the eggs and the young at Beaufort during the present investigation appears to show, however, that *A. epsetus* begins spawning earlier than

[2] This species long was known as *brownii* but this name had to give way to *epsetus*, owing to the law of priority. (Jordan and Seale, 1926, p. 396.)

A. mitchilli, and that it also completes the process considerably earlier. The eggs of *A. epsetus* were taken as early as April 16; they were abundant throughout May, but early in June they diminished in number, although a few were taken throughout July. The eggs of *A. mitchilli* were first taken on April 26, and they occurred in the tow throughout the summer and well into September. Small young only about 12 millimeters long were taken in December, which further indicates that spawning extends well into the autumn.

Both anchovies spawn within the harbor, the estuaries, and sounds, as well as along the outer shores of the banks.

DEVELOPMENT OF EGGS AND YOUNG

The eggs of *A. epsetus* were especially numerous at offshore collecting stations, and it seems probable that this species spawns principally along the outer shores of the banks, although exclusive of 1929, they were common, also within the harbor. The eggs and young of *A. mitchilli* were common wherever towings were made and spawning appears to take place generally in all the local waters.

The eggs, as already indicated, were taken for study with townets. No fish ripe enough for stripping were seen, and they will not stand transportation to the aquarium. The eggs of *A. mitchilli* were known already when this study was undertaken (Kuntz, 1914, p. 14) and the identification of the eggs of *A. epsetus*, therefore, was easy and certain, for anchovy eggs are quite distinctive, and the identification could readily be made through a simple process of elimination. The identification was verified, however, by the examination of eggs secured directly from nearly ripe fish.

Spawning in these species, as in several other local marine forms, appears to take place very definitely early at night; that is, from about 6 to 9 o'clock. At least, no eggs in the early cell-division stages were taken at any other time, although numerous collections were made. Furthermore, eggs taken during the day appeared to be in two fairly uniform stages of development; that is, eggs taken in the tow during the morning, for example, and examined about noon, generally were either in a state of development that showed the embryonic streak or they contained advanced embryos. The eggs with an embryonic streak very probably had been spawned on the previous evening, whereas those containing advanced embryos were spawned 24 hours earlier.

Segmentation and the development of the embryo.—Cell division in *A. epsetus* is regular, and it proceeds rapidly. Unsegmented eggs taken in the plankton between 8 and 9 o'clock in the evening, apparently just laid, passed through the 2 and 4 cell stages and reached the 8-cell stage within an hour at a water temperature near 67° F. Segmentation proceeded rapidly and within 12 hours a definite embryonic streak was formed. Hatching occurred within about 48 hours at a water temperature varying from 66° to 70° F. (Figs. 2, 3, 4, 5, and 6.)

Soon after fertilization a very evident streaming of protoplasm to the upper pole of the egg takes place, forming a pronounced blastodisc. When cleavage takes place, very deep fissures are made and the first cells stand out, mountainlike, on the upper pole of the egg. As cell division proceeds, the fissures naturally become less pronounced and the bell shape of the blastoderm becomes very distinct. Because of the transparency of the egg, the development can be seen clearly.

When the embryonic streak once is formed, the embryo very soon becomes differentiated and development progresses rapidly. (Fig. 7.) Shortly before hatch-

ing, the embryo extends nearly around the circumference of the yolk. Heart action may be observed and the embryo is capable of considerable movement. (Fig. 8.)

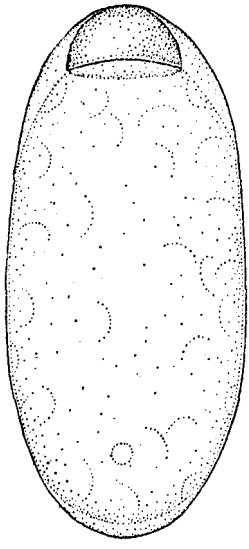

FIGURE 2.—*Anchoviella epsetus.* Egg with fully developed blastodisc

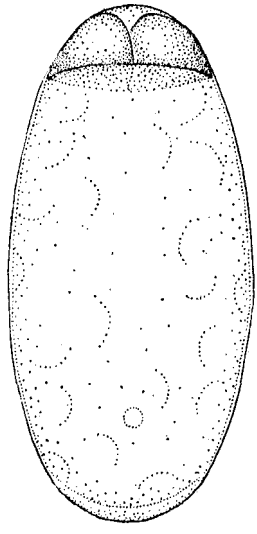

FIGURE 3.—*Anchoviella epsetus.* Egg in 2-cell stage

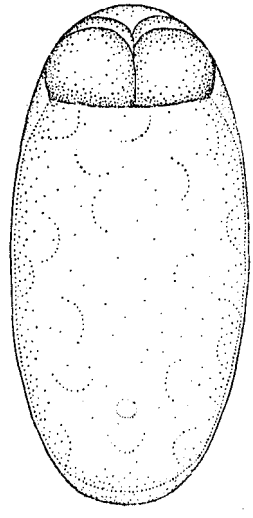

FIGURE 4.—*Anchoviella epsetus.* Egg in 4-cell stage

Newly hatched fish 3.6 millimeters long.—The newly hatched fish is very long and slender, averaging close to 3.6 millimeters in length. It is highly transparent,

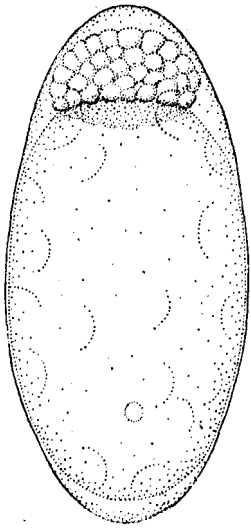

FIGURE 5.—*Anchoviella epsetus.* Egg in advanced cleavage stage

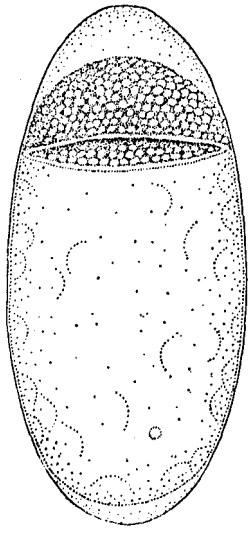

FIGURE 6.—Egg in cleavage stage, farther advanced than in Figure 5. Note bell-shaped blastoderm

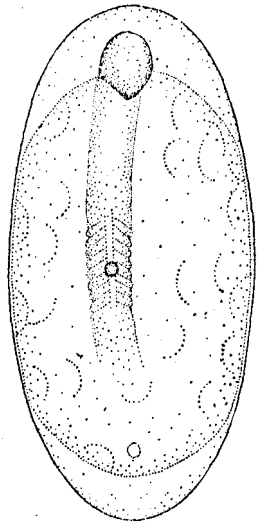

FIGURE 7.—*Anchoviella epsetus.* Egg with small embryo

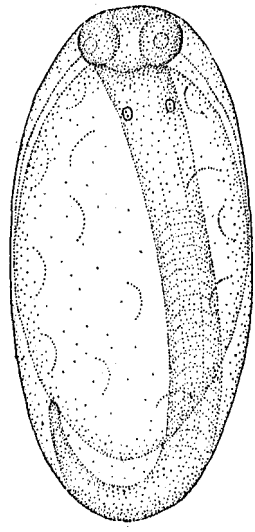

FIGURE 8.—*Anchoviella epsetus.* Egg shortly before hatching. Heart action is evident at this stage

having a slight greenish shade on the head, but no definite chromatophores. The head is somewhat decurved, and the body segments (myomeres) are very distinct. The fin folds are continuous, except where broken by the vent, which is placed slightly

behind the beginning of the posterior fourth of the body. Heart action is evident slightly in advance of the auditory canal, but a blood stream is not visible.

The newly hatched *A. epsetus* apparently is more active than most other forms that have been hatched in the laboratory at Beaufort. It most frequently descends to the bottom of the vessels used in hatching the eggs, but it may swim to the surface or occupy any part of the available space. In a period of 24 hours after hatching the yolk is mostly absorbed, the fish has reached a length of about 4.0 millimeters; and in the laboratory, since feeding experiments have failed, the fish usually dies about this time. There has been some advancement in the development of the mouth; the fin fold remains continuous; the head is still slightly deflected; and no chromatophores have appeared, the larvæ still being highly transparent. (Fig. 9.)

Specimens 5.0 millimeters long.—Specimens of this length and until the anal fin is sufficiently developed to admit the enumeration of the rays, at a length of about 9 to 10 millimeters, apparently can not be separated definitely from *A. mitchilli*. The body remains very slender at a length of 5.0 millimeters, and without chromatophores, except for a row of about five very small elongate ones situated near the ventral outline posterior to the head. Muscular rings remain quite evident and in addition to the rings, cross striations are present. The mouth is large; and the gape is quite oblique, extending to the eye. The alimentary canal is plainly visible and largely separate from the body; that is, it does not appear to be covered by the body wall, being attached loosely to the trunk by connective tissue only.

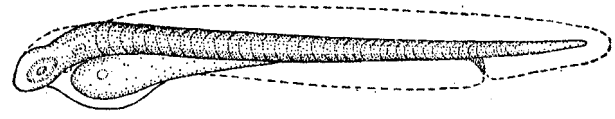

FIGURE 9.—*Anchoviella epsetus.* Newly hatched fish, 3.6 millimeters long

Superficially, the intestine gives the appearance of being coiled. Upon closer examination and dissection it is found, however, that the alimentary tract is almost a straight tube and the "coils" are muscular rings in the thin body wall. In some specimens the dorsal and anal fins already have become rather indefinitely differentiated at a length of 5.0 millimeters. The fins do not become evident, however, until a length of at least 6 millimeters is reached, and generally the rays can not be definitely enumerated until a length of about 10 millimeters is attained. The pectoral fins are just becoming evident at a length of 5 millimeters although rays are not developed. Ventral fins are not visible but the caudal fin is partly developed. The notochord is bent slightly upward posteriorly, extending into the partly developed caudal fin. (Fig. 10.)

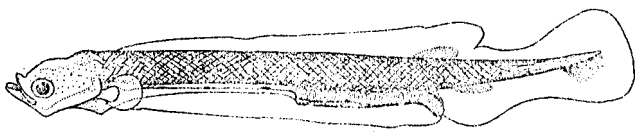

FIGURE 10.—*Anchoviella epsetus.* From a specimen 5.6 millimeters long

Specimens 10.0 millimeters long.—The body has become slightly less slender, the mouth is still terminal and oblique, and the gape extends somewhat past the anterior margin of the eye. Ventral fins are still missing; the dorsal and anal are now sufficiently well developed to admit of a fairly accurate enumeration of the rays. Since *A. epsetus* rarely has more than 20 rays in the anal fin, whereas *A. mitchilli* generally has about 26, the two species may now be definitely separated by this character. The caudal fin is well developed and definitely forked. The notochord is bent abruptly upward posteriorly, ending at the base of the upper rays of the caudal fin. Muscular rings are still faintly visible, at least in the caudal region, and pigmentation consists of a few dark points on the median line of the chest and along the ventral

edge extending from the anal base to the caudal fin. A definite invagination of the alimentary canal has not yet taken place as it remains loosely attached to the trunk. (Fig. 11.)

Specimens 15.0 millimeters long.—A somewhat further deepening of the body has taken place, although it is still much more slender than in the adult. The mouth remains terminal, but the gape now reaches well beyond the posterior margin of the eye, and the jaws are somewhat curved. The ventral fins first appear when the fish is about 13 millimeters long, and they are quite well developed at a length of 15 millimeters. The tail is now definitely homocercal and the notochord no longer remains visible. Muscular rings are still evident, but they are bent forward on the sides. Pigmentation remains essentially as it was at a length of 10 millimeters. However, in addition to the dark chromatophores on the chest and the ventral side of the body, extending backward from the base of the anal, there is now a considerable amount of dark pigment on the upper margin of the eye. The alimentary canal, anteriorly, is fairly definitely inclosed by the body wall. Posteriorly, however, the invagination is not complete. (Fig. 12.)

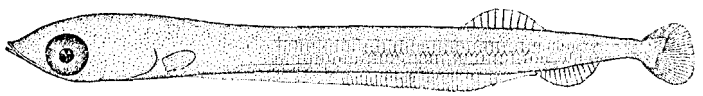

FIGURE 11.—*Anchoviella epsetus.* From a specimen 9 millimeters long

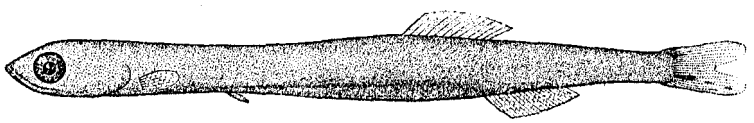

FIGURE 12.—*Anchoviella epsetus.* From a specimen 17 millimeters long

Specimens 25.0 millimeters long.—The differences between fish 15.0 and 25.0 millimeters in length are not great. The gradual deepening of the body has progressed slowly. A fish 25.0 millimeters long remains much more slender, however, than the adult, for the depth is contained about 8.0 times in the length to the base of the caudal fin, whereas in the adult the depth goes into the length about 4.5 times. The mouth is no longer strictly terminal, as it has become slightly inferior. The jaws, however, remain slightly curved; that is, the mouth is bent upward anteriorly. Pigmentation has progressed somewhat. A continuous dark line is present on the median ventral line, reaching from the gill covers to opposite the base of the pectorals. Two or three vertically elongate dark spots have appeared just behind the opercle, and in some specimens several other smaller and less definite dark spots are present. A row of about seven dark spots has developed near the ventral edge of the abdomen, between the pectoral and ventral fins. The dark chromatophores along the base of the anal and on the ventral line of the caudal peduncle remain, forming an almost continuous dark line posterior to the base of the anal. A few dark spots also have appeared at the base of the caudal and on the fin itself. The alimentary tract is now quite definitely inclosed in the body wall. (Fig. 13.)

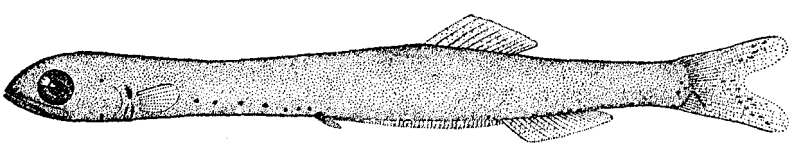

FIGURE 13.—*Anchoviella epsetus.* From a specimen 23.5 millimeters long

Specimens 35.0 millimeters long.—The most pronounced change that has taken place since a length of 25.0 millimeters was reached is in the shape of the mouth which has become definitely inferior, very nearly horizontal, and the maxillary reaches

almost to the margin of the opercle, as in the adult. The conical, projecting snout, characteristic of anchovies generally, is fully developed. Pigmentation has now appeared on the back of the fish and particularly in the concentration of chromatophores forming a brownish area on the head. The silvery lateral band has appeared, but it remains quite narrow and rather indistinct. A further deepening of the body has taken place, and the depth is contained about 6.0 times in the length. Scales are not evident on the specimens in hand. (Fig. 14.)

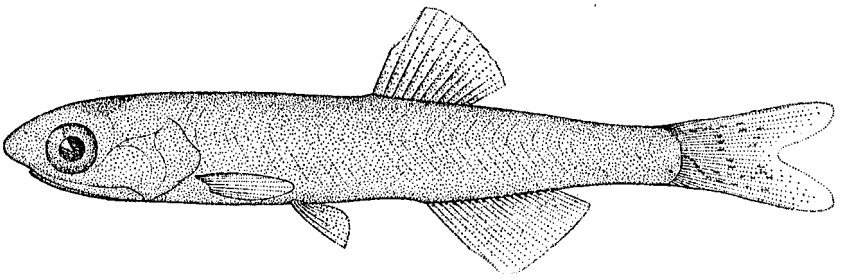

FIGURE 14.—*Anchoviella epsetus*. From a specimen 30 millimeters long

Specimens 45.0 millimeters long.—At this length the young fish has virtually all the characters of the adult and it may be recognized readily as this species. The body is very nearly as deep as in adult fish; the silvery lateral band is clear and distinct; and scales, or at least scale markings, are present. Owing to the deciduous nature of the scales they often are lost, leaving only scale markings on the body. (Fig. 15.)

DISTINGUISHING CHARACTERS

The number of rays in the anal fin constitutes the most reliable character for the separation of *A. epsetus* from *A. mitchilli*. However, after the dorsal and anal

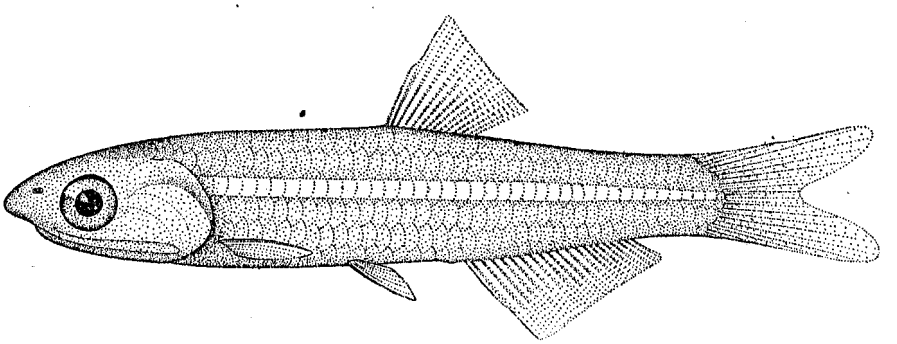

FIGURE 15.—*Anchoviella epsetus*. From a specimen 46 millimeters long

fins become well developed the two species may be separated more conveniently by the relative position of the dorsal and anal fin, and, also, by the position of the vent with respect to the origin of the dorsal. That is, in *A. epsetus* the origin of the anal is under the middle of the dorsal base, and the vent is definitely posterior to a vertical line from the origin of the dorsal. In *A. mitchilli*, on the other hand, the origin of the anal is only slightly behind the origin of the dorsal; and the vent is under, or more usually slightly anterior to, the origin of the dorsal fin. After *A. epsetus* reaches a length of about 45 millimeters it has a broader and a much more distinct silvery lateral band than its relative.

DISTRIBUTION OF YOUNG

Both species are hatched at the surface from floating eggs, as stated elsewhere, but some of the young appear to descend to the bottom at a very early age. In towings made with 1-meter nets when two nets were operated simultaneously, one at the surface and the other on the bottom, young anchovies 12 millimeters and less in length (larger fish seldom were caught in the townets) were taken 57 times at the surface and 86 times on the bottom. Some of the collections, both from the surface and the bottom, contain numerous fish, indicating that young (larval) anchovies, at times and in some places, may be numerous at the surface as well as on the bottom. The fact that they were taken more frequently in the bottom than in the surface tow appears to show, however, that these young may be more commonly present on the bottom, but it seems quite certain that they may occupy any depth within the area where the collections were made.

Very young anchovies were taken in abundance over the entire area in which towings were made, extending from stations 15 miles off Beaufort Inlet, through Beaufort Harbor, and throughout the salt and brackish estuary of Newport River.

After the young reach a length of about 12 millimeters and above, they may be taken with fine-meshed seines in shallow grassy areas which are favorite haunts of the adults also. The fish are not confined to the shallow, grassy water, however, as old and young are obtainable in the deeper waters with suitable collecting nets.

GROWTH

Young anchovies grow rapidly. According to collections made with a bobinet seine which permitted the escape of many of the smaller young, the average length of the fish of the O class of *A. epsetus* taken by this method of collecting was 28.3 millimeters (99 fish measured) in June, and the maximum length was 43 millimeters; in July, the average length had increased to 41.3 millimeters (157 fish measured), and the largest fish was 65 millimeters long; in August, the average length was 55.5 millimeters (218 fish measured), and the maximum length was 83 millimeters; and in September, the average length had increased to 61.1 millimeters (200 fish measured), and the largest fish of the O class taken was a little smaller than the largest of the previous month, as it had a length of only 78 millimeters. The measurements do not show the actual average length of the fish of the O class, for the earlier months at least; for the smallest young are not included, as already explained. For the later months (August and September) the fish taken probably are fairly representative. The measurements at least show the approximate rate of growth of the larger young during the first summer. Since *A. epsetus* frequently is sexually mature at a length of 75 millimeters (3 inches), it is quite certain that at least the early young of each spawning season reproduce the following season; that is, at the age of 1 year.

The rate of growth in *A. mitchilli* is much more difficult to follow, largely because of the longer spawning season and also partly because of the smaller size attained. It is reported elsewhere that small young (12 millimeters long) were taken in December, and these fish, because of slow growth during the winter, are still rather small when the new brood begins to appear the following May. The result is that some of the O class and some of the smaller fish hatched late in the previous season soon intergrade in length, and the measurements made are of no value in separating them. The younger fish (O class) appear to be more scantily pigmented, however, and they accordingly are more nearly transparent and more delicate in general

appearance. Fish having this appearance of early youth have been found in a gravid condition in the latter part of July and in August when only 45 to 50 millimeters in length. If the foregoing interpretation of age be correct, then it would follow that the early and largest young of the season of *A. mitchilli* may spawn at an age of 2½ to 3 months. If these small delicate-looking fish are not young ones, then they probably are not *A. mitchilli*, but this we have not been able to demonstrate to date.

FOOD

The food of *A. epsetus* when it reaches a length of about 20 millimeters consists largely of copepods. Prior to that time it appears to feed on such minute organisms that they are not visible, except under high magnification, and no study of the stomach contents of the very small fish has been made. As the fish increases in length it takes copepods in greater numbers; and this diet often is supplemented by minute gastropods, an occasional ostracod, and rarely by an annelid worm. Adult fish continue to feed on copepods but include more ostracods, annelids, small gastropods, some minute bivalve mollusks, and occasionally Mysis. The food of *A. mitchilli* has not been studied.

ORTHOPRISTIS CHRYSOPTERUS (Linnæus). Pigfish; hogfish

The pigfish or hogfish is known from New York to Mexico. It is taken in commercial abundance in southern Maryland, Virginia, North Carolina, and on both coasts of Florida; but, oddly enough, it does not appear in the statistical records of the Bureau of Fisheries from South Carolina and Georgia, where it does not seem to occur in commercial numbers. It is most abundant in North Carolina, where 385,270 pounds were marketed in 1923. The value of the pigfish, to North Carolina at least, should not be judged by the pounds marketed alone, as it offers sport to many anglers. Although the pigfish does not rank high as a game fish, it nevertheless holds a place of some importance; for it is the first fish in the harbors in the spring to take the hook, and it remains in the salt-water sounds and estuaries in North Carolina throughout the summer and may be caught there by the amateur sportsman, as well as by the more experienced angler, at such times when more desirable species are not biting. The pigfish reaches a maximum weight of about 2 pounds, and examples weighing from 1 to 1½ pounds are not unusual. It offers fair resistance when hooked, and its "grunt" may be heard before the fish is landed.

The pigfish as known in North Carolina waters, is distinctly a shore and shallow-water species, seeking its food principally on the bottom. It feeds largely on crustaceans, worms, and mollusks. Shrimp and fiddler crabs are good pigfish bait.

Its habit of feeding on the bottom, and especially on worms, causes the pigfish in midsummer sometimes to include in its diet Balanoglossus—a wormlike chordate which is strongly scented with the odor of iodoform. The scent of this "worm" penetrates the flesh of the fish, and occasionally examples are caught which have a distinctly bad odor and taste. This detracts somewhat from its value as a food fish. Fish that have fed on Balanoglossus, colloquially, are said to have a "ticky taste." It must be understood, however, that the great majority of the fish taken during the summer are not ticky and they do not have this taste at all in the spring and autumn, when Balanoglossus probably does not emerge from its burrows and is not available. The flesh of the pigfish is rather dark in color, is firm, and ordinarily of good flavor and rather highly esteemed.

The pigfish, as already stated, inhabits the local shore waters, the salt-water sounds, and estuaries throughout the summer, arriving in March and April and disappearing again the end of October and during the first half of November. Its winter home is not definitely known. No pigfish have been taken during the winter in catches made with a 30-foot otter trawl operated by the laboratory crew off Beaufort Inlet in depths as great as 10 fathoms. The local sea bass (blackfish) fishermen, however, take a few throughout the winter on the sea-bass grounds about 20 miles offshore in depths of about 18 fathoms. The hooks used for the sea bass are rather too large for the smaller mouthed pigfish, and the number taken may be no indication of the numbers actually present. Southward and northward migrations do not appear plausible for the reason that the pigfish does not appear in commercial abundance in the fisheries of South Carolina and Georgia, although it is a species of some commercial value in Florida. If the large body of pigfish which undoubtedly leaves the shallow waters of North Carolina and Virginia at the approach of cold weather migrated southward to return the following spring, one would expect the species to appear, at least in the early spring and late autumn, in commercial quantities in the shore fisheries of South Carolina and Georgia. Since this is not the case and since a few, at least, are known to occur on the sea-bass grounds after they leave the shore waters, it seems more probable that the fish migrate offshore rather than southward.

Wherever the winter habitat of the pigfish may be, it does not appear to offer the abundance of food that the fish find in their summer home, for they leave well fed and fat and return in the spring in a considerably emaciated condition, a fact well known to fishermen and dealers. Hildebrand and Schroeder (1928, pp. 259–260) have shown, from a limited number of length measurements and weights, that fish taken in May in Chesapeake Bay weighed considerably less than fish of equal lengths caught in October. The following table, based on fish taken at Beaufort in April and May and in October and November, shows a similar relationship.

TABLE 1.—*Comparison of lengths and weights of pigfish taken in the spring and autumn*

Date	Length	Weight	Date	Length	Weight	Date	Length	Weight
	Inches	*Ounces*		*Inches*	*Ounces*		*Inches*	*Ounces*
May 20	8.0	3.4	May 27	9.5	5.75	Nov. 1	8.9	6.8
May 27	8.0	3.5	May 12	10.75	10.0	Do	9.25	8.9
Apr. 22	8.9	6.1	Oct. 15	8.0	4.2	Do	9.5	9.4
Do	8.9	5.7	Nov. 1	8.0	4.7	Nov. 7	10.5	11.0
Apr. 15	9.25	5.0	Oct. 23	8.8	6.3			

Why does the pigfish leave the shallow shore waters of North Carolina (and northward) when cool weather comes? This question quite logically comes to mind in connection with the foregoing discussion. It can not be definitely answered at this time. It is thought that the main reason for its withdrawal is a disagreeable temperature, although a decrease in its food supply may be a secondary cause. Small crustaceans and at least some small fish—two of its principal foods—are present all winter. For that reason it would seem probable that the fish leaves because the temperature of the water is not agreeable rather than for the purpose of seeking better feeding grounds in which it does not seem to be very successful, as already shown. Since the pigfish is a member of a family of tropical fishes—namely, the grunts—and the only one of the family occurring north of Florida in commercial numbers, a dislike for low temperatures might be expected.

It appears to be of interest to mention, also, that the larger fish are the first ones to migrate away from the local waters in the autumn. No large fish appeared in our collections after the early days of November and some evidence, as shown subsequently, has been obtained indicating that even the largest young of the current season—namely, the largest representatives of the O class—leave the shallow waters somewhat earlier than the smaller fish of the same year class. On the other hand the older and larger fish are the first ones to return the following spring, some in March and many more in April.

The smaller young of the previous year, now the I class, do not appear to get back until about June, for the smallest individual taken of the older year classes in April was 175 millimeters long; the smallest one caught in May was 125 millimeters in length; and in June the smallest fish, evidently belonging to the 1-year class, were 105 millimeters long. (One specimen, probably belonging to this class, had a length of only 92 millimeters.) Fish of the last-mentioned size compare well with the smallest fish of the O class taken in November, which were 87 millimeters in length. Owing to the emaciated condition of the fish when they return from their winter habitat, one would not expect rapid growth. Their growth after returning to their summer home, however, appears to proceed rather rapidly, for the smallest fish in our collections assigned to the 1-year class taken in July was 145 millimeters long; the smallest ones in August were 150 millimeters long; in September and October the smallest fish for each month were 160 and for November 165 millimeters. It is rather certain that some of the smaller individuals of the I class are missing in the catches for July, as it is improbable that fish only 105 millimeters long in June had attained a length of 145 millimeters in July. Furthermore, the gap in length measurements for June between the O and I classes had almost closed, whereas in the July measurements an interval reappears, extending from 112 millimeters, the largest representatives of the O class, to 145 millimeters, the smallest representatives of the older year classes. In August the gap in the measurements again is almost closed, and it remained so during the rest of the summer.

A record of water temperatures taken daily at 4.30 p. m. at the laboratory pier shows a rather close similarity when comparisons are made for the months during which the principal pigfish migrations take place. That is, the temperature in March, when the fish usually begin to return to the shallow waters, are near those that prevail in November when the last ones leave. Similarly, the temperatures for April and October, the months when the main body of pigfish migrates, are not very different. The range in temperature and the averages, expressed in degrees centigrade, for the 4-year period, namely, 1926 to 1929, for the months during which the principal pigfish migrations take place locally, are shown in the accompanying table.

TABLE 2.—*Comparison of the average water temperature (centigrade) at Beaufort, N. C., in March and April with that of October and November from 1926 to 1929*

Month	Minimum	Maximum	Average	Month	Minimum	Maximum	Average
March	6	22	14.3	October	16	30	22.2
April	13	23	18.3	November	8	25	16.3

Since the temperatures given in Table 2 were taken just beside one of the principal channels between Beaufort Harbor and the estuary of Newport River, many fish in their migrations no doubt pass the place where the records were obtained;

and, therefore, the temperatures must be quite representative of those which prevail when the pigfish migrates. It is shown by the table that the spring temperatures (March and April) are a little lower than the autumn temperatures (October and November) when the fish perform their principal migration. It has been pointed out elsewhere that the larger and older fish are the first ones to leave the shallow waters in the autumn, and that they are also the first ones to return in the spring. Why the older fish lead the migrations is not well understood. Possibly they "know" the route better, and again they may "understand" better the significance of cooling and warming waters. Then, too, in the spring they may be driven on by the "urge" to spawn.

It seems in order to state here in defense of the foregoing statements and the use of the terms "know" and "understand" that one is driven to the conclusion by numerous observations in support thereof that the older fish of nearly all species are much better able to protect and to take care of themselves than the younger ones. In other words, intelligence in fishes, as in higher vertebrates, increases considerably with age. An instance of a seemingly high fish intelligence of adults may be seen in overflowed lands. Few large or adult fish become stranded when the water recedes, although countless young perish in pools. Yet there is no doubt that the large fish follow the flood waters. They seem to know, however, when it is time to return to the main body of water. This sense of self-protection appears to be possessed alike by both fresh and salt water species. It seems reasonable, therefore, to expect the older pigfish, because of their superior intelligence, to lead the migrations which no doubt are made in the interest of self-preservation.

SPAWNING

Almost nothing appears to have been known prior to the present investigation in regard to reproduction in the pigfish, for we find in the literature only the general statement that spawning occurs in the spring (May and June).[3] We find nothing relative to the place of spawning, the type of eggs produced, and the characters of the young—all discussed subsequently in this paper. Concerning the rate of growth of the young, also discussed herein, we find only Taylor's paper (1916, pp. 319–324) based partly on length measurements and partly on scale studies. Taylor's account appears quite inadequate to us, especially as he seems to have confused the O class with the I class. It is not particularly surprising, however, that such fundamental information is missing in regard to the pigfish, as equally as little is known about dozens of other common species of even wider distribution and greater economic value.

During the present investigation, extending over four seasons, recently hatched young were taken sparingly as early as March 16 (1927 only), although the eggs did not appear in the tow until April 13 (1928). The latest date upon which the eggs were observed was June 22 (1927), and they were most numerous each year during May. It may be concluded, therefore, that spawning may begin at Beaufort as early as the middle of March, that it ends near the latter part of June, and that the principal spawning period occurs in May. This conclusion is supported also by tables of measurements of young fish and by a growth curve included in this paper. (See Tables 3 and 4 and fig. 39.)

Gravid fish are particularly numerous along the inside shores of Bogue and Shackleford Banks during the spawning season, and it is here that the greatest concen-

[3] A preliminary account of a part of the present investigation, dealing principally with the embryology of the pigfish is given by Towers (1928, pp. 622–624).

tration of eggs occurs. It is rather certain that the comparatively quiet waters on the inside shores of these banks constitute the chief spawning grounds of the pigfish in the vicinity of Beaufort. However, some spawning certainly takes place elsewhere within the harbor, in the estuaries, and along the outer shores of the banks, for the eggs are distributed too generally throughout these waters to be carried there by tides and currents. Then, too, eggs in the early cell-divisions stages were taken just off the laboratory pier. Since the development proceeds very rapidly, as shown elsewhere, the eggs must have been cast almost where taken. Furthermore, ripe or nearly ripe fish may be taken in all of the waters where the eggs occur. All the young (larvæ) secured in March were taken outside of Beaufort Inlet, and some of them as far offshore as 7 miles. Towings were made in inside waters at the same time but yielded no pigfish larvæ. This apparently would indicate that spawning may begin somewhat earlier along the outer shores of the banks than it does on the inside shores.

In general the larger fish spawn first and the late spawners consist of small individuals which may be reproducing for the first time. This information is deduced from the observation that the roe in large fish early in the season is in a more advanced state of development than it is in smaller fish, whereas late in the season the large fish usually are spawned out and the smaller ones still contain roe. The spawn apparently is not all cast at one time, as the examination of the ovaries shows that the eggs contained therein are not all equally developed. Furthermore, partly spent fish are seen frequently.

DEVELOPMENT OF EGGS AND YOUNG

Spawning appears to take place, exclusively, early in the evening, mostly between 6 and 8 o'clock. It was positively necessary to collect eggs at this time to get the early cell stages, for they could not be obtained at any other hours. Fish confined in tanks laid eggs at that time only. Eggs taken in the tow generally are in two remarkably uniform stages of development, which appears to be further proof that spawning takes place only at definite intervals and over short periods of time, the eggs in the more advanced stage of development having been laid a day earlier than the others, as explained more fully subsequently. It may be remarked here that early evening spawning apparently is quite usual among local marine species.

Eggs.—The eggs were taken, often in great abundance, in meter townets, and they were secured also from the overflow of tanks in which ripe or nearly ripe fish had been confined. The eggs generally were cast on the first or second evening of confinement. Thereafter very few were obtained, for the pigfish, like some other species, appear to hold the spawn and refuse to cast it in confinement, unless quite ripe when caught. Stripping and artificially fertilizing the eggs failed. This is not surprising now that it is known that spawn is cast only during a few hours in the evening, and it is not recalled that artificial fertilization was attempted at that time.

The eggs are buoyant in sea water. They are spherical and vary in diameter from 0.7 to 0.8 millimeter with an average of 0.75 millimeter, as shown by measurements of 100 newly spawned eggs caught in the overflow of a tank in which ripe fish were confined. They are unattached but have a tendency to collect and to become arranged in regular series in the glass sediment dishes used for hatching them. The eggs are highly transparent and usually contain one comparatively large oil globule which has an average diameter of 0.16 millimeter and occupies the upper pole; that is, the pole opposite the blastodisc. Occasionally an egg has two and

rarely three oil globules. When more than one globule is present they are proportionately smaller than the single oil globule. The eggs float with the oil globule or globules uppermost and are never seen otherwise.

The similarity of the eggs of the pigfish and those of the white perch (*Bairdiella chrysura*)—the latter for the most part correctly described and figured by Kuntz (1914, p. 4, figs. 1 to 15)—is so great that they are confused easily. Confusion is especially liable to occur, because the eggs of both species are taken in the same areas and in the same towings during the greater part of the spawning season of the pigfish, as the spawning seasons of the two overlap. The separation of the eggs is especially difficult during the early stages, or until the embryo becomes well outlined, and for that reason it seems advisable to state the differences noticed. In size the eggs are nearly identical. The range, as shown by the measurements of 100 perch eggs spawned in a tank in which ripe fish were confined, is 0.66 to 0.72 millimeter with an average of 0.686 millimeter. Although the eggs of the perch according to these measurements average a little smaller than those of the pigfish, so many are identical in size that they can not be separated on this basis. The eggs of both species commonly have a single oil globule. That of the perch egg averages slightly larger (0.18 millimeter) than that of the pigfish egg (0.16 millimeter), but the difference is so slight and so many are of equal size that the character is of little use in making identifications. However, the oil globule in the perch egg seldom is as clear as that in the pigfish egg. Furthermore, the oil globule in the perch acquires dark greenish specks in the advanced cleavage stage, which increase in number and become quite prominent when the embryo becomes well outlined. At this time the granular specks appear on the embryo also. These markings persist both on the oil globule and on the embryo until hatching and for a short time (24 hours or so) after hatching. In the pigfish, on the other hand, dark specks, if they appear at all, are present only during the early embryonic stages and they disappear when an advanced embryonic stage is reached. When present they are fewer and smaller and, therefore, less prominent than in the perch.

The position of the oil globules in relation to the embryos forms a ready and reliable recognition mark when an advanced embryonic stage is reached, and this character may be employed also in separating the newly hatched young of the two species. In the pigfish the oil globule occupies an anterior position with respect to the embryo. That is, it lies under or near the ventral surface of the head, whereas in the perch it occupies a posterior position, lying well behind the head. Similarly, in the newly hatched pigfish the oil globule lies near the anterior periphery of the yolk sac, under the head of the fish, whereas in the perch it occuppies a position near the posterior periphery of the yolk sac, on the ventral surface of the abdomen.

Attention is called to the fact that Kuntz (1914, p. 4) gives the range in size of the perch egg as 0.7 to 0.8 millimeter, whereas the range obtained by us, as already stated, extends from 0.66 to 0.72 millimeter. It is evident from the range in size given that Doctor Kuntz included eggs of a larger size. It seems probable that he considered a certain larger egg, apparently always found in the tow with the perch egg herein described, as identical with the smaller egg which now is known definitely to be a perch egg. This larger egg appears to be identical, except for size, with the smaller one during the early developmental stages. In the advanced embryonic stage it, however, acquires a more profuse dotting with dark-green granules. The fish hatched from this egg is slightly larger, as would be expected, and it contains more pigment than the larva hatched from the smaller egg. This larger egg, as to

size, is distinct from the smaller perch egg, as its range in size is about 0.8 to 0.88 millimeter and its average is close to 0.84 millimeter. It seems probable, therefore, that this larger egg is from a different species. However, we have not yet succeeded in determining by which species it is produced.

Segmentation and the development of the embryo.—Segmentation occurs very quickly after fertilization takes place. (Fig. 16.) Eggs held in glass sediment dishes at a temperature varying from 67° to 69° F. reached the 2-cell stage (figs. 17 and 18) within one-half hour after fertilization, the 4-cell stage (fig. 19) within three-fourths of an hour, and an advanced cleavage stage (fig. 21) within 6 hours. Twelve hours after fertilization the germ ring had become visible in many of the eggs, within 24 hours the embryo was well formed (fig. 22), and at 36 hours the more advanced eggs

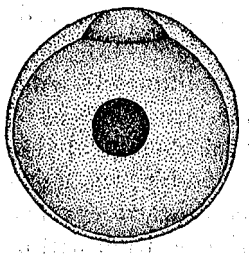

FIGURE 16.—*Orthopristis chrysopterus.* Egg with fully developed blastodisc, a few minutes after fertilization. Normal egg about 0.75 millimeters in diameter

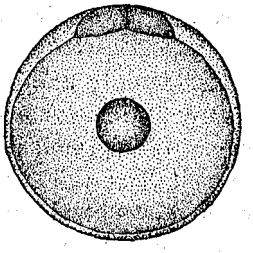

FIGURE 17.—*Orthopristis chrysopterus.* Egg in 2-cell stage, about a half hour after fertilization

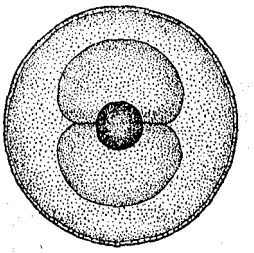

FIGURE 18.—*Orthopristis chrysopterus.* Egg in 2-cell stage, same as Figure 17, surface view

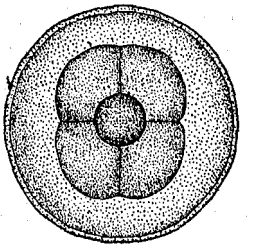

FIGURE 19.—*Orthopristis chrysopterus.* Egg in 4-cell stage, surface view, about three-fourths of an hour after fertilization

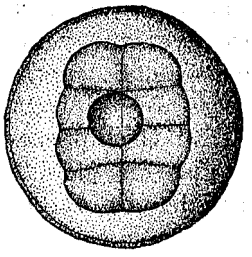

FIGURE 20.—*Orthopristis chrysopterus.* Egg in 8-cell stage, surface view, about one hour after fertilization

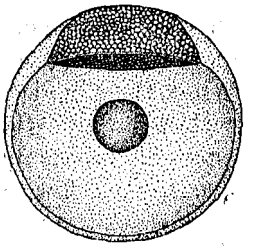

FIGURE 21.—*Orthopristis chrysopterus.* Egg in late cleavage stage, side view

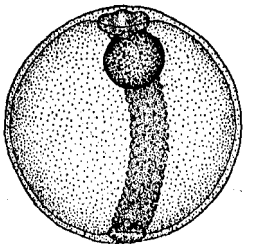

FIGURE 22.—*Orthopristis chrysopterus.* Egg embryo, showing distribution of chromatophores, about 24 hours after fertilization

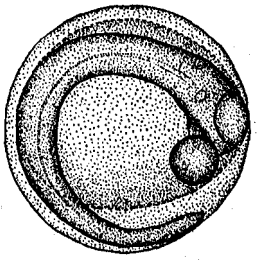

FIGURE 23.—*Orthopristis chrysopterus.* Embryo shortly before hatching, about 36 hours after fertilization. Heart action is evident at this stage

began to hatch (fig. 23). Early in the season the eggs developed less rapidly, but late in the season, when the temperatures were running high in the laboratory, development proceeded even more rapidly than described in the foregoing lines. It became very difficult, though, to hatch the eggs at the higher temperatures, as many of them died in various stages of development, apparently due to the excessive heat. The incubation period at the temperatures (ranging from about 60° to 85° F.) that prevail in the local waters during the spawning season, judging from results obtained in the laboratory, probably ranges from about 36 to 72 hours—the shorter period of time being required late in the season when temperatures are high and the longer period earlier when temperatures are low.

The mode of segmentation is quite usual for a teleost, and it does not differ noticeably from that described for the white perch (*Bairdiella chrysura*) by Kuntz (1914, pp. 4 and 5). The blastodisc becomes somewhat elongate just before the first cleavage occurs, and then it is cut at right angles to the longer axis. (Fig. 17.) The second cleavage plane cuts the first at right angles. (Fig. 18.) This manner of cleavage continues as long as the process can be observed.

The embryo shortly before it is released almost completely encircles the periphery of the egg. (Fig. 23.) The embryo is capable of considerable movement at this time, and the pulsation of the heart is clearly visible. Circulation of the blood, however, is not evident. Definite pigment spots are absent at this stage as already indicated, the auditory canals are plainly visible, the eyes appear to be extraordinarily large, and the single big oil globule which remains unchanged throughout the incubation period and for some time afterwards, lies opposite the ventral surface of the head of the embryo.

Newly hatched fish.—The newly hatched fish is only about 1.5 millimeters long. Its head is deflected rather prominently, and it contains a relatively large amount of yolk. The larva is quite helpless at this stage. It floats on its back, being capable of movement in this position only by the use of its free tail. Presumably, the larva is held in the position described—namely, with the ventral surface upward—by the yolk sac in which the large oil globule constantly occupies an anterior position within the sac. At hatching the larvæ have a few greenish spots on the dorsal surface of the head and body, generally placed as follows: A few indistinct ones over the snout, a few larger and more evident ones just behind the head, a pair a short distance behind the auditory canals, another pair above the posterior part of the yolk sac, two over the vent, and two more at mid-caudal length. When the pigment spots are seen from certain angles they give the appearance of crossbars. The oil globule is slightly greenish in color. Occasionally it contains a few rather definite darker spots, but usually spots are missing. (Fig. 24.)

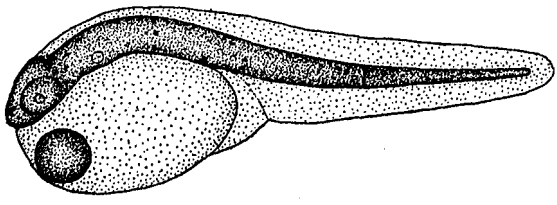

FIGURE 24.—*Orthopristis chrysopterus.* Newly hatched larva with yolk sac. Actual length of fish, 1.5 millimeters

Although the eggs of the pigfish and white perch are very similar, as already pointed out, the separation of the young is easy. In the pigfish the oil globule within the yolk sac lies near the head of the fish. In the white perch the oil globule lies near the posterior periphery of the yolk sac, far behind the head. Furthermore, at hatching nearly the entire fish, as well as the oil globule, in the white perch are dotted with greenish, granular markings, whereas these markings are missing in the pigfish and the color is as described in the foregoing paragraph.

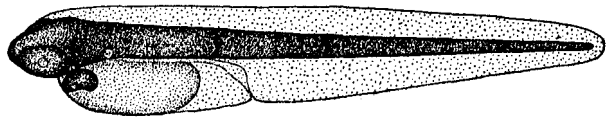

FIGURE 25.—*Orthopristis chrysopterus.* Larva 1 day old, actual length 2.5 millimeters

At a length of about 3.0 millimeters the white perch has become much deeper and stockier than the pigfish. Furthermore, the perch has a large amount of dark pigment on the body, especially over the abdominal mass, when preserved (color markings mostly greenish in life), whereas the pigfish at this size has no definite pig-

mentation. In fact pigfish have no outstanding color markings until a length of about 15 millimeters is attained, when a dark lateral band has developed.

The young fish attains a length of about 2.5 millimeters within a day or so after hatching. (Figs. 25 and 26.) At this size the body has become quite straight, the pigment spots on the anterior part of the body at first present have become diffuse, but the ones over the vent and at mid-caudal length are very distinct and form more or less definite crossbars. In some individuals the spots behind the auditory canals still persist at this age. The yolk sac has decreased to somewhat less than a fourth of its original size, but the oil globule persists. At this size, or a little later, the fish begins to orient itself in part; that is, it no longer swims on its back but more or less on the side. (Fig. 27.)

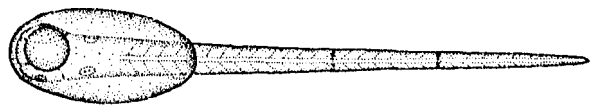

FIGURE 26.—*Orthopristis chrysopterus*. Larva 1 day old, ventral view. Actual length, 2.5 millimeters

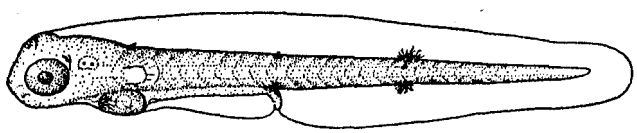

FIGURE 27.—*Orthopristis chrysopterus*. Larva 2½ days old; actual length, 3 millimeters

Usually by the third day at laboratory temperatures prevailing during May and June the yolk is nearly all absorbed, and generally the oil globule, too, disappears about this time. The fish now has attained a length of about 2.8 millimeters, pectoral fins have become evident, and it is able to swim in the usual upright position. It may continue to live for several days longer (a few individuals have lived nine days) in the sediment jars used, but there is no further gain in size and little change in structure. (Fig. 28.)

Specimens 3.1 millimeters long.—Specimens of this size are characterized chiefly by the long, slender tail, the vent being situated well in advance of mid-body length, and by the almost vertical mouth, which is only moderately oblique in the adult. A pronounced hump is present dorsally just behind the eyes; the intestine is attached loosely to the body and distally more or less free. The fin fold is continuous, and the vertical fins remain undifferentiated. Pigment spots are wanting in preserved specimens. (Fig. 29.)

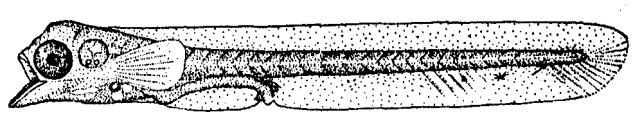

FIGURE 28.—*Orthopristis chrysopterus*. Larva somewhat older than the one represented in Figure 27, but actually a little shorter, 2.8 millimeters long. Note indication of fin rays within fin fold

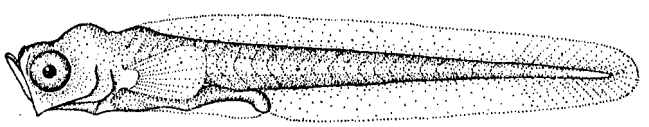

FIGURE 29.—*Orthopristis chrysopterus*. Larva slightly further advanced than one shown in Figure 28. Actual length, 3.1 millimeters

Specimens 4.9 millimeters long.—The body, especially posteriorly, has become deeper; and the only other pronounced change since a length of 3.1 millimeters was reached is in the development of the caudal fin which now has become partly differentiated, rather definite rays having appeared ventrally of the notochord. The notochord has curved upward somewhat, giving a heterocercal appearance to the tail, which is not as pronounced, however, in the pigfish as in several other species studied, especially in the croaker and the spot. (Fig. 30.)

Specimens 6.7 millimeters long.—The deepening of the body posteriorly continues. The caudal fin is now rather well developed and has a round margin. The notochord

is curved upward more strongly than previously. The dorsal and anal fins are becoming differentiated but, as yet, do not contain definitely developed rays. An expansion of the fin fold on the distal part of the tail gives the appearance of a third dorsal fin, which, however, fails to develop and gradually disappears. (Fig. 31.)

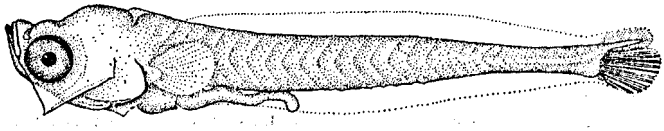

FIGURE 30.—*Orthopristis chrysopterus.* Young fish, 4.9 millimeters long

Specimens 10.0 millimeters long.—The body has continued to increase in depth, and it has become definitely compressed, the depth being contained in the length to the base of the caudal fin about 6.0 times. The mouth is now somewhat less vertical than in the smaller stages, but it remains much more oblique than in the adult. The soft dorsal and anal fins are far enough developed to admit of a fairly accurate count of the rays. The spinous dorsal and the ventral fins remain undeveloped. The caudal fin is well formed, and its margin is somewhat emarginate, approaching in that respect the forked shape of the adult. The notochord, now sharply bent upward, remains only faintly visible. Pigmentation is becoming evident in preserved specimens in the darkened margins of the opercle and preopercle, in the darkened distal ends of the fin rays, and the broken, black crosslines on the caudal fin. (Fig. 32).

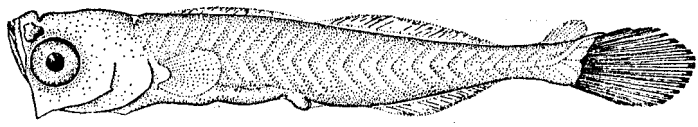

FIGURE 31.—*Orthopristis chrysopterus.* Young fish, 6.7 millimeters long

Specimens 11.0 millimeters long.—The principal changes from the previously described size are in the appearance of the spinous dorsal—a few spines having become slightly developed—and in the first appearance of the ventral fins. The notochord, in its sharply upward-curved position posteriorly, remains only faintly visible. The depth is now contained in the length to the base of the caudal fin about 5.3 times. (Fig. 33.)

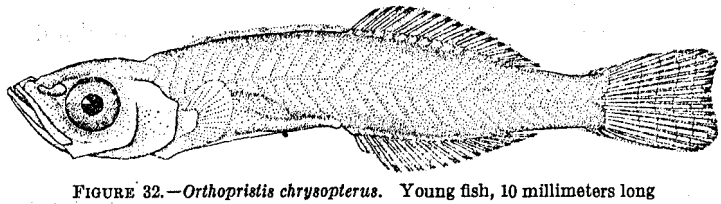

FIGURE 32.—*Orthopristis chrysopterus.* Young fish, 10 millimeters long

Specimens 15.0 millimeters long.—The head and body have increased in depth and are notably compressed, the depth being contained in the length about 4.2 times. The mouth is only slightly more oblique than in the adult. The upward-curved notochord—that is, the heterocercal character of the tail—has completely disappeared. The spinous dorsal is now partly developed, about 7 spines usually having appeared well in advance of, and entirely separate from, the soft dorsal. Variation in this respect has been noticed, as in some specimens of this size the spinous dorsal is further developed than in others. Pigmentation has progressed rather rapidly. A dark lateral band which aids greatly in identification has developed, the lips and snout are more or less dusky, small areas of dark chromatophores are present on the head and on the back, and scattered dusky dots occur along the base of the anal fin. (Fig. 34.)

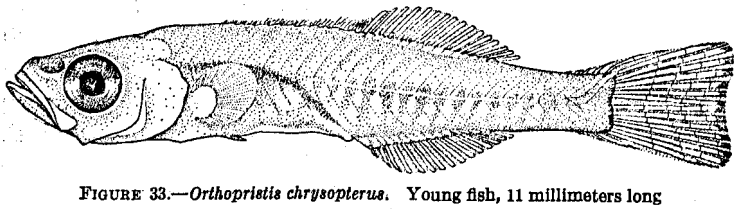

FIGURE 33.—*Orthopristis chrysopterus.* Young fish, 11 millimeters long

Specimens 17.0 millimeters long.—The develoment of the spinous dorsal has progressed rather rapidly. About 10 spines are fairly well developed, and the rudiments of a few more are visible anteriorly. This fin is now definitely joined to the soft dorsal. Pigmentation has become rather general. The dark lateral band, just

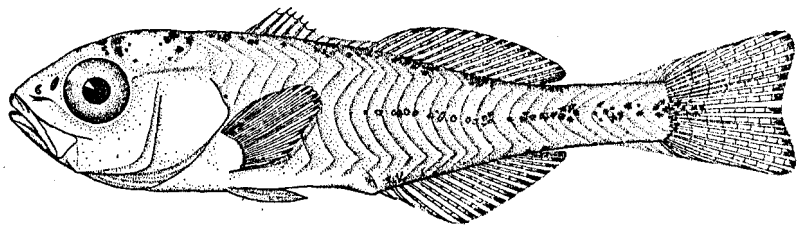

FIGURE 34.—*Orthopristis chrysopterus.* Young fish, 13.5 millimeters long

forming at a length of 15.0 millimeters, has become prominent, and it constitutes a ready recognition mark. The body is almost completely scaled, although not so shown in the accompanying drawing. (Fig. 35.)

Specimens 25.0 millimeters long.—The body has become deeper and more compressed although still relatively more slender than in the adult, its depth being

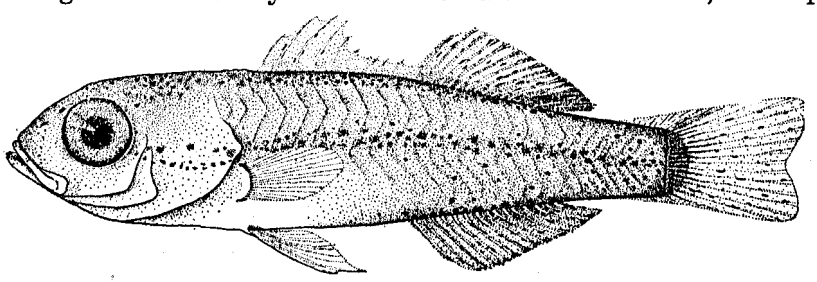

FIGURE 35.—*Orthopristis chrysopterus.* Young fish, 17 millimeters long

contained in the length about 3.0 times, whereas in the adult the depth usually goes into the length to the base of the caudal fin only about 2.4 times. The shape and position of the mouth are essentially as in the adult. All the dorsal spines are developed, and the general outline of the fin is approaching that of the adult. Pigmenta-

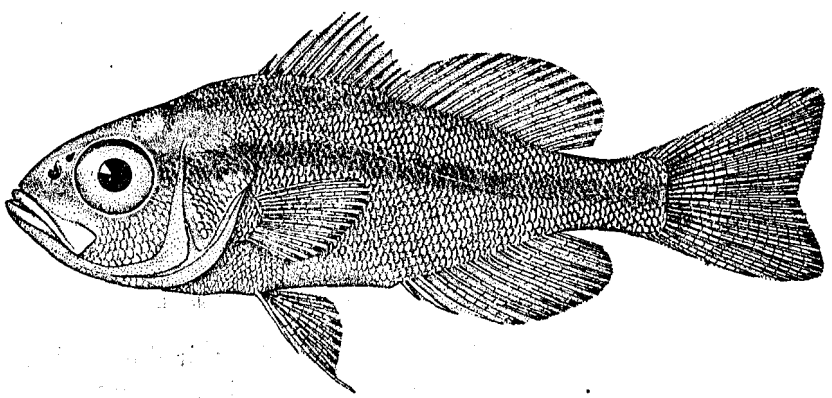

FIGURE 36.—*Orthopristis chrysopterus.* Young fish, 26 millimeters long

tion is general. The dark lateral band mentioned in the description of the 17.0 millimeter specimens is prominent and a second one, extending from the nape to the base of the second dorsal, is present. The body is fully scaled, as in the adult, and the ctenoid character of the scales is evident. (Fig. 36.)

Specimens 40.0 millimeters long.—The body has become more strongly compressed, the back is narrow and high, and the general form approaches that of the adult rather closely, the depth now being contained in the length about 2.8 times. The color is rather variable. The dark longitudinal bands, described for specimens 25 milli-

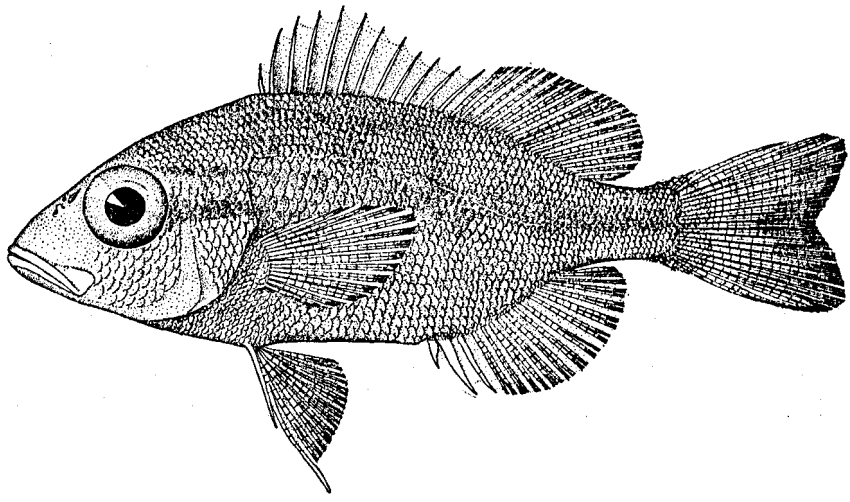

FIGURE 37.—*Orthopristis chrysopterus.* From a fish 38 millimeters long

meters long, often have disappeared, or the lower one may remain visible anteriorly. Occasionally specimens of this size and even larger ones are seen in which the bands remain evident. Some specimens, at least, have indications of dark crossbars. In life, yellow and green horizontal lines are present on the sides and are most prominent on the cheeks and opercles. (Fig. 37.)

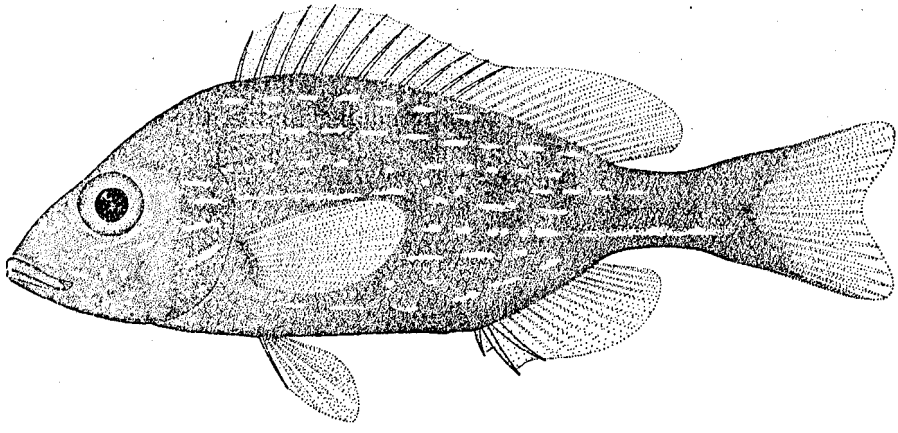

FIGURE 38.—*Orthopristis chrysopterus.* From a fish 70 millimeters long

Specimens 70.0 millimeters long.—The fish now has acquired essentially the form and shape of the adult. The back is prominently elevated, the ventral outline anteriorly is nearly straight, and the snout is pointed. In some specimens the two dark horizontal bands described in smaller fish remain faintly visible, dark cross shades sometimes are present, and in life greenish and yellowish lines are present on sides. A fish of this size is readily identified with the adult. (Fig. 38.)

EXPERIMENTS IN GROWING YOUNG PIGFISH IN CAPTIVITY

Several attempts at feeding and otherwise keeping the young fish alive and inducing them to grow, after the yolk had been absorbed, were made. No artificial food was found that gave any promise of success. Fry placed in glass dishes in the laboratory and supplied with running water, from which it was thought they might secure some natural food, fared no better than those kept in similar dishes without running water. Wooden frames (floats) covered with bolting silk were partly submerged in laboratory tanks, supplied with an abundance of running water. A similar but larger frame was anchored in the harbor. It was hoped that the fish might obtain natural food in this way. However, no fish were recovered from these "floats" if left over a period of several hours. It is believed the young fish are so delicate that they are injured by the roughness of the silk. It was not possible, at least, to transfer recently hatched fish alive on bolting silk from one dish to another, even though they were out of water for only a fraction of a second. Diatom mud was placed in dishes with sea water to which the fry were added after the mud had settled, or again the fish were placed in water decanted from diatom mud. These experiments all failed, and to date no method of growing the young fish in captivity has been found.

Since the fry could not be grown in captivity beyond a length of about 3 millimeters, it became necessary to catch fish of about that size, and larger ones, to obtain and to study all the stages in the development.

The identification of young fish only about 3 millimeters long, unless comparatively large series to connect them with larger or smaller specimens of known identity are available, obviously is difficult. Therefore, the completion of the series was attempted by "patching" out, one grading downward from individuals large enough to be readily recognized because of their resemblance to the adult. A series, ranging from adults downward to a length of 11 millimeters, was obtained within a few months after the work on the egg development was completed. These sizes were obtained with seines, the smaller ones occurring in abundance in shallow water in the immediate vicinity of the station where the bottom was overgrown with eelgrass. The missing sizes (3 to 11 millimeters long), however, were much more difficult to get. It was expected, of course, that they would occur in the tow, especially since the eggs were numerous and rather widely distributed. A few scattering ones were taken from time to time, but they were of such intermediate sizes that they were not recognized either as identical with the recently hatched young or as belonging to the series of larger pigfish already secured. It was not until the third season after this study was begun that the proper sizes were taken in sufficient numbers to complete the series, and then only once and by a mere chance. This particular time the bottom townet, which was being hauled on Newport River a short distance from the laboratory, became well filled with sand. A pailful of this sand was brought to the laboratory, and the missing, and much sought for, sizes of pigfish occurred in abundance in this sand. Although many hauls had been made over the same course with a bottom townet without gathering up sand, pigfish from 3 to 11 millimeters long had been missing almost constantly. It might be inferred from these results that the young pigfish after absorbing its yolk falls to the bottom, where it remains in the sand until a length of about 11 millimeters is attained, when it resorts to shallow water in grassy areas, which are its favorite haunts during its first summer.

Growth.—The study of the rate of growth of the pigfish after its first summer and its span of life, pursued by the junior author, has not progressed far enough to admit of an adequate discussion at the present time. Therefore, the account here

is limited almost wholly to the rate of growth of the O class; that is, from the time the fish are hatched in the spring until they leave the local waters in the autumn.

The only published account of the rate of growth and the span of life of the pigfish known to the writers, is by Taylor (1916, pp. 319–324). Taylor's discussion has for its basis a very limited number of length measurements and scale studies. It seems quite certain that Taylor, as stated elsewhere (p. 398) confused and combined the O class with older fish. His graph (fig. 7, p. 321, loc. cit.) shows a peak composed of fish 80 millimeters long. These fish, as shown by the graph (fig. 39), belong to the O class. Taylor's graph does not show a clear division between the O class and older fish, because the measurements very probably were taken over a period of from two to three months (for Taylor's investigation was carried on from the latter part of June until early in September) and the data were not treated separately by months. Since the measurements were taken during a season of rapid growth, overlapping of the young, namely, the O class, with fish of the previous year would be expected over the period of time covered by the investigation.

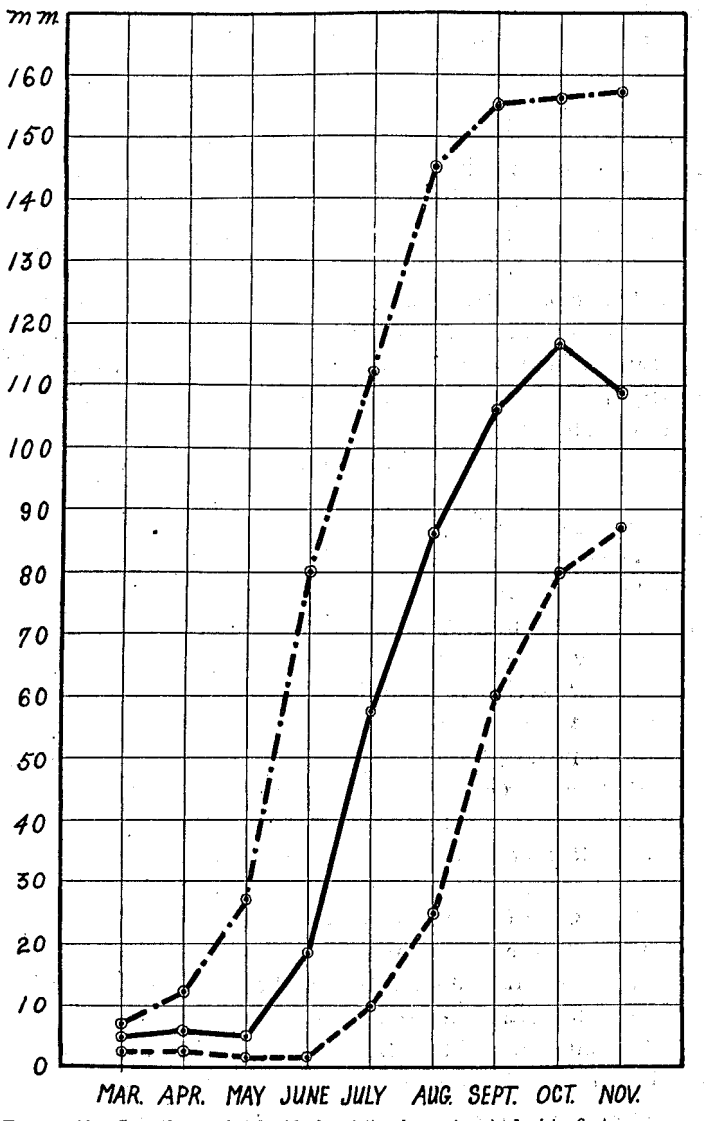

FIGURE 39.—Growth of pigfish (*Orthopristis chrysopterus*) during first summer. Solid line shows average size, dot-and-dash line illustrates maximum size, and dash line shows minimum size. (Based on Table 4)

In the present investigation, when much larger numbers of fish were measured and the data analyzed separately for each month, the division between the O class and the older fish always was so obvious that it seems scarcely necessary to offer a frequency table as evidence.

Prior to June the interval in the measurements of the recently hatched young and the older fish is large. Thereafter, it almost closes. Little, if any, overlapping occurs in the O and I classes, as previously indicated (p. 397); and, at most, only a few individuals could not be placed with certainty.

The apparatus used for collecting young fish—namely, townets, small collecting seines, and small otter trawls—is not adapted to catching many large fish. How-

ever, a limited number was taken and measured. An analysis of these data shows nothing distinctive concerning the older year classes and their rate of growth. (See Table 3.) It is evident, therefore, that large series of measurements would be required, if indeed it is at all possible, to separate the older fish into year classes on the basis of length measurements.

Very recently hatched pigfish—2.0 to 2.5 millimeters long—appeared in the tow as early as the middle of March (in 1927 and not until April in 1926, 1928, and 1929); and fry of this size were taken throughout April, May, and June. (See Table 4 and fig. 39.) Pigfish, as shown elsewhere (p. 402), are only about 1.5 millimeters long at the time of hatching, but they attain a length of 2.0 to 2.5 millimeters within a few days. Therefore, it is evident from the catches of these small fry, entirely aside from the fact that the eggs, too, were taken over most of this period, that spawning may occur from about the middle of March to the end of June. However, the young were taken in March only one year (1927) out of four (1926–1929), and they did not appear to be particularly numerous until May during any one year, and the very small fry again were fewer, according to townet catches, toward the end of June. It may be concluded, therefore, as already shown in another section of this paper (p. 398) in regard to the collection of eggs, that while spawning may occur as early as the middle of March, and ends near the last of June, it takes place principally during May.

The young at first, as is usual among fishes, do not grow as rapidly as they do a month or two later. This fact is brought out clearly by the growth curve. (Fig. 39.) The largest young taken in May, for example, when they may have been slightly over 2 months old, were 28 millimeters long. A month later the largest young of the season were 84 millimeters in length, or nearly three times as long as a month earlier. This rapid rate of increase in length of the largest young of the season continues through July and August, and thereafter it appears to be much slower. The reduced rate of increase in length in the largest fish of the season is reflected in the curve based on the average lengths of all fish measured, although at this time (September) the smaller fish of the season apparently were growing rapidly. (See Fig. 39.)

TABLE 3.—*Length frequencies of 9,512 pigfish*

[Measurements to nearest millimeter, grouped in 5-millimeter intervals]

Total length	March	April	May	June	July	August	September	October	November
0–4	9	93	1,033	91	-----	-----	-----	-----	-----
5–9	6	411	252	40	-----	-----	-----	-----	-----
10–14	-----	70	365	524	13	-----	-----	-----	-----
15–19	-----	-----	15	704	63	-----	-----	-----	-----
20–24	-----	-----	-----	541	109	-----	-----	-----	-----
25–29	-----	-----	2	121	100	2	-----	-----	-----
30–34	-----	-----	-----	49	95	2	-----	-----	-----
35–39	-----	-----	-----	10	109	7	-----	-----	-----
40–44	-----	-----	-----	15	88	9	-----	-----	-----
45–49	-----	-----	-----	7	74	17	-----	-----	-----
50–54	-----	-----	-----	20	80	27	-----	-----	-----
55–59	-----	-----	-----	16	76	59	-----	-----	-----
60–64	-----	-----	-----	25	113	77	2	-----	-----
65–69	-----	-----	-----	5	88	91	6	-----	-----
70–74	-----	-----	-----	3	123	113	10	-----	-----
75–79	-----	-----	-----	8	91	120	14	-----	-----
80–84	-----	-----	-----	2	86	164	27	3	-----
85–89	-----	-----	-----	-----	89	154	26	5	3
90–94	-----	-----	-----	2	78	200	31	12	23
95–99	-----	-----	-----	-----	72	182	30	23	56
100–104	-----	-----	-----	-----	41	168	45	37	98
105–109	-----	-----	-----	1	15	91	33	27	117
110–114	-----	-----	-----	1	6	48	47	46	108
115–119	-----	-----	-----	2	-----	19	33	37	87
120–124	-----	-----	-----	5	-----	28	22	45	42
125–129	-----	-----	1	2	-----	14	29	22	14
130–134	-----	-----	1	4	-----	16	24	22	10
135–139	-----	-----	1	8	-----	11	13	18	9
140–144	-----	-----	1	8	-----	3	14	15	9
145–149	-----	-----	1	8	1	2	10	4	3
150–154	-----	-----	8	8	1	2	7	6	1
155–159	-----	-----	4	11	2	5	1	1	2
160–164	-----	-----	2	10	1	1	-----	3	-----
165–169	-----	-----	-----	11	3	7	-----	3	2
170–174	-----	1	2	12	3	5	1	6	1
175–179	-----	-----	1	9	1	2	1	8	-----
180–184	-----	1	1	10	4	6	2	11	2
185–189	-----	-----	-----	2	3	4	5	7	1
190–194	-----	4	-----	4	5	2	4	13	1
195–199	-----	2	1	3	3	2	2	11	1
200–204	-----	11	-----	5	2	3	5	12	1
205–209	-----	8	-----	3	4	-----	3	6	3
210–214	-----	9	-----	6	3	2	1	11	2
215–219	-----	1	-----	5	1	5	1	5	4
220–224	-----	7	-----	3	-----	1	2	7	3
225–229	-----	5	-----	5	1	1	5	2	-----
230–234	-----	3	-----	4	1	1	1	3	4
235–239	-----	1	-----	1	1	-----	1	4	5
240–244	-----	-----	-----	2	-----	-----	1	3	5
245–249	-----	-----	-----	-----	1	-----	1	5	1
250–254	-----	-----	-----	-----	-----	-----	2	-----	-----
255–259	-----	-----	-----	-----	-----	-----	1	-----	3
260–264	-----	-----	-----	1	-----	-----	2	-----	-----

TABLE 4.—*Rate of growth of 9,011 pigfish during their first summer*

Month	Fish measured	Smallest	Largest	Average	Month	Fish measured	Smallest	Largest	Average
		Millimeters	*Millimeters*	*Millimeters*			*Millimeters*	*Millimeters*	*Millimeters*
March	15	2.5	7.0	4.3	August	1,656	25.0	145.0	85.9
April	571	2.5	12.0	6.2	September	482	60.0	155.0	106.1
May	1,580	2.0	27.0	5.6	October	326	80.0	156.0	116.6
June	2,188	2.0	80.0	18.6	November	585	87.0	157.0	[1] 108.7
July	1,608	10.0	112.0	57.4					

[1] Decrease in average length explained in text.

The almost total cessation of growth indicated in the graph (fig. 39) of the largest fish for October and November and a decrease in the average length of all fish measured in November, while the smallest fish apparently were still growing rather rapidly, seems to require an explanation. The number of fish taken and measured during September, October, and November is not large (see Table 4), yet the catches are believed to represent fairly accurately samples of the fish present. In other words, the methods of collecting, mostly with the otter trawl, did not differ from those used the previous months and are believed to have been successful in taking representative samples. It has been shown that the larger fish appear to leave the local waters earlier than the smaller and younger fish. Since fewer and fewer large fish appeared in the catches, it would seem as if the earlier exodus of the larger fishes extended down to the O class and that the larger fish of the season were migrating in October and particularly in November, whereas the smaller ones remained in the shallow waters somewhat later. These migrations appear to explain why the growth curve (fig. 39) shows virtually no increase in the length of the largest fish taken during October and November. They also explain the decrease in the average length of all fish taken, from 116.6 millimeters in October to 108.7 millimeters in November, even though the graph shows an increase in the length of the smallest fish of the O class from 80.0 millimeters in October to 87.0 millimeters in November.

According to the data presented herewith (Table 4 and fig. 39) the earlier and fastest growing young may reach a length as great as 157 millimeters (about 6¼ inches) during their first summer, whereas the later and smaller young of the same season apparently are only 87 millimeters (3½ inches) long. Growth does not appear to proceed rapidly after the fish withdraw from the local waters, as already pointed out, for the smallest individuals definitely assigned to the I class in June were only 105 millimeters long. The length of the largest representatives of the same year class at this time was not definitely determined, because of insufficient data. However, a frequency curve indicates it to be near 180 millimeters.

AGE AT SEXUAL MATURITY

The smallest sexually mature pigfish observed were from 8 to 8½ inches (200–215 mm.) in length. It may be concluded from this fact and the data presented in the preceding paragraph that the fish of the I class are too small to spawn, the largest being only about 7¼ inches in length in June, at the end of the spawning season; and it seems certain that sexual maturity is not reached until the fish are about 2 years old. This conclusion was arrived at by Taylor (1916, p. 321) also, who based his conclusion mainly on the study of scales. Taylor found a great diminution in number after the age of 2 years, and he believes that many of the fish may perish after the first spawning. According to this author, comparatively few pigfish reach an age of 3 years and very few 4 years.

FOOD

Young pigfish, 12 to 25 millimeters in length (smaller ones not examined), according to the contents of 14 stomachs, feed almost wholly on copepods supplemented occasionally by a few ostracods. Somewhat larger fish, ranging from 25 to 35 millimeters in length, as indicated by the contents of 29 stomachs, still feed chiefly on copepods and sparingly on ostracods. This diet is now strongly supplemented, however, by minute gastropods. When the fish attain a length of 40 to 100 millimeters, according to the contents of 55 stomachs, they feed on larger crustaceans, such as amphipods, small shrimp, and crabs; and they take larger gastropods, also bivalve mollusks; they add worms in considerable quantity and also a few small fish.

The diet does not change greatly after the fish reaches a length of 100 millimeters, although larger representatives of the classes of foods mentioned are taken. In the examination of 108 stomachs of adult fish, crustaceans, including principally amphipods, shrimps, and crabs, were found 78 times; mollusks, principally bivalves with razor clams in the majority, were found 63 times; worms, 36 times; and starfish, 9 times. The wormlike cordate, Balanoglossus, which scents the flesh and gives it an unpleasant flavor, as pointed out elsewhere, was found only once.

The foods eaten by the pigfish, after it attains a length of about 40 millimeters, occur largely on the bottom only. The fish may be classed, therefore, as a bottom feeder, which includes in its diet such burrowing forms as Balanoglossus (found once) and Upogebia (found six times). The forms eaten, exclusive of a few shrimp and fish, are not utilized commercially. Furthermore, the pigfish utilizes mostly foods not entering into the diet of many of the other common local food fishes; and, therefore, it does not appear to be an important competitor.

BAIRDIELLA CHRYSURA, Lacépède. White perch; sand perch

The white perch occurs in the shore waters from Massachusetts to Texas, and it is very abundant from New Jersey to North Carolina. Although a fish of good flavor, it is not of much commercial value because of its small size. The maximum length attained is about 9¼ inches, and the greatest weight is close to 6 ounces. Only the largest individuals, 7½ inches and over in length, are seen in the markets; and these constitute only a very small percentage of the catch, the rest frequently being wasted. The species is not marketed in sufficient abundance to be shipped separately, the small quantities that reach the markets being thrown in with "mixed fish." For this reason this white perch, which must not be confused with the other white perch, *Morone americana*, is not listed in the statistical records of the Bureau of Fisheries.

The white perch is present in the local waters throughout the year. It is most abundant during the summer and becomes scarce during the winter, particularly during cold snaps. The young, or smaller, individuals of this species, as in the spot and croaker (as pointed out in the sections of this paper dealing with those species) are the ones that remain in the shallow waters, whereas the large individuals are seldom seen during the winter.

SPAWNING

At Beaufort spawning takes place from near the end of April to the middle of July. In 1927, for example, the eggs were taken for the first time during the last week in April, and by the end of June they had become scarce. Kuntz (1914, p. 3)

working at Beaufort in 1913 says, "The height of the spawning season of *Bairdiella chrysura* occurs during the last week of June and the first week of July." This has not been the case during the four seasons (1926–1929) over which our observations extend, for each year spawning was just about over by the end of June, as shown by the scarcity of gravid fish in the catches examined, by the scarcity of eggs in the tow, and by the absence of fry under 5 millimeters in length in our collections for the month of July. According to our data the most prolific spawning in the white perch takes place during the last half of May and early in June.

Welsh and Breder (1923, p. 171) state that in New Jersey this fish spawns in June, July, and August and the height of the spawning season is reached in June. Hildebrand and Schroeder (1928, p. 282), working with the fishes of Chesapeake Bay, found ripe fish, trawled in 12 fathoms of water off Crisfield, Md., as early as May 16, and many of the fish were spawned out by June 11. These authors make the general statement that in Chesapeake Bay spawning takes place "in the late spring and early summer."

During the height of the spawning season the eggs are very numerous in the vicinity of Beaufort and frequently may be taken in large numbers in surface nets. The eggs, as well as the fry, occur in collections made at this time within the harbor and adjacent estuaries and sounds, also along the outside shores and at collecting stations as far as 12 to 15 miles (beyond which collecting was not extended) off Beaufort Inlet, indicating that spawning takes place within the harbor, the estuaries and sounds, and also for some distance out at sea. The eggs are small, averaging only about 0.68 millimeter in diameter, and are produced in large numbers, as the nearly ripe ovaries are so large that they cause a very pronounced expansion of the abdominal walls. A female from Chesapeake Bay, only 140 millimeters (5.6 inches) long, contained approximately 52,800 eggs (Hildebrand and Schroeder, 1928, p. 28). Larger examples no doubt produce a correspondingly greater number.

DEVELOPMENT OF EGGS AND LARVÆ

The development of the eggs and larvæ is quite fully discussed by Kuntz (1914 pp. 4–13), to which the reader is referred for information on this subject. It is sufficient to state here that Doctor Kuntz's work has been checked by the present authors and found substantially correct. Because of the similarity of the eggs of the white perch and the pigfish and, furthermore, because their eggs often are taken together in towings (for the spawning periods overlap) the difference between the eggs of the two species are pointed out and discussed in that section of this paper dealing with the pigfish.

DISTRIBUTION OF YOUNG

The fry, like the eggs, occur within the harbor and adjacent waters and at sea off Beaufort Inlet as far out (12 to 15 miles) as the collecting was extended. According to the frequency of the fry in the towings, they are more numerous at sea than in the inside waters. Although the fry were taken at the surface, they appear to be on the bottom more commonly, for in an approximately equal number of hauls made with two 1-meter townets, hauled simultaneously at the surface and on the bottom, the fry occurred in 12 surface hauls and in 23 bottom ones. Furthermore, the bottom towings generally contained more specimens than the surface hauls.

Young white perch, like young pigfish, as stated elsewhere in this paper, are present in grassy areas within the harbor at an early age, or when a length of about

10 millimeters is attained. In these areas they remain throughout their first summer. Although the majority leave their first summer's habitat when cold weather comes, a few remain there throughout the winter.

GROWTH

In the present studies an effort was made to secure information, mainly, relative to the rate of growth of the white perch during its first year of life. However, older fish often were taken and such examples have been measured and are included in frequencies in Table 5. Table 6 and Figure 40 include only the data pertaining to the O class. Since this fish has a comparatively short spawning season, little if any overlapping occurs between the O class and the older fish during the first 9 or 10 months of life. It is comparatively easy, therefore, to follow the rate of growth of the young fish during that time.

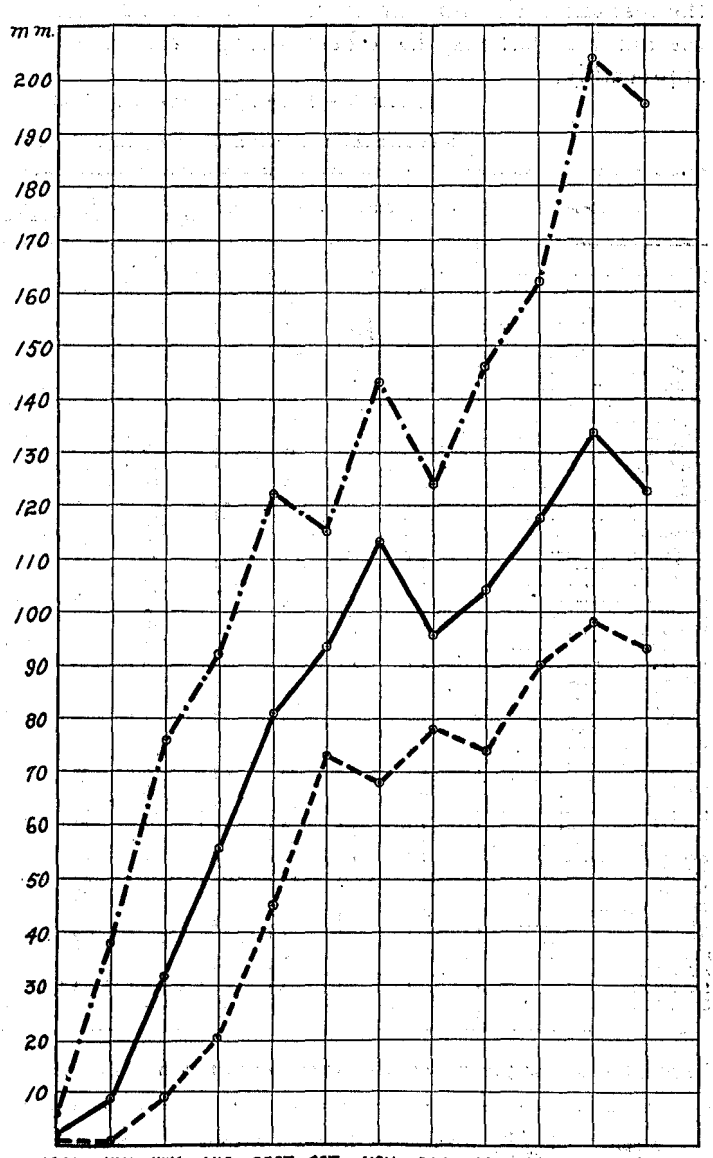

FIGURE 40.—Growth curve of young white perch, based on Table 6. Solid line, average of all fish; broken line, smallest fish; dot-and-dash line, largest fish

Tables 5 and 6 show that the young of the white perch grow rapidly during the first several months of life. For example some of the individuals attained a length of 30 to 39 millimeters in June when only 2½ months old at the most. The average length for June for 1,642 specimens measured, however, is only 8.7 millimeters. This low average is due to the very large number of recently hatched fry, less than 5 millimeters long, which occur in the collections. In July, when the smallest fry taken were 9 millimeters and the largest fish 76 millimeters long, the average for 987 fish is 31.9 millimeters. In September the young secured range in size from 45 to 122 millimeters, and the average size for 559 specimens is 81 millimeters.

In February when the fish are only about 9 or 10 months old the range in size for 98 specimens is 90 to 162 millimeters (4 to 6.5 inches), and the average length is 117.5 millimeters (4.7 inches). The year classes are less distinct thereafter, as some overlapping probably takes place and, furthermore, our data are too meager to show the exact situation. In April, when the fish of this year class are still mostly under a year of age, the minimum size is 93 millimeters. There is some doubt relative to the maximum size but the average size is not far from 123 millimeters (5 inches), as the number that may have been wrongly assigned is too small to affect the average appreciably.

TABLE 5.—*Length frequencies of 6,347 white perch*

[Measurements to nearest millimeter, grouped in 5-millimeter groups]

Total length	May	June	July	August	September	October	November	December	January	February	March	April
0–4	966	918										
5–9	3	47	5									
10–14		223	48									
15–19		176	102									
20–24		223	146	2								
25–29		49	139	1								
30–34		5	148									
35–39		1	149	17								
40–44			91	32								
45–49			71	84	2							
50–54			56	101								
55–59			19	98	9							
60–64			9	71	26							
65–69			2	25	37		1					
70–74			1	20	78	2			1			
75–79			1	11	95	5		1				
80–84				5	110	5		3				
85–89	1			2	80	12		3				
90–94	1			1	42	15	1	5	3	3		2
95–99	1				34	11	2	11	11	8	1	6
100–104	3		1		14	6	13	6	14	12	14	14
105–109	3				8	9	5	1	12	9	21	9
110–114	4	1			13	2	4	1	10	17	35	14
115–119	1	1	2		8	1	9		8	5	40	11
120–124	1	1	7		3		4	1	4	15	38	1
125–129	4	2	3				2		5	6	40	2
130–134	1	1	29	2			3			9	15	1
135–139			31	2	3		3		1	6	5	2
140–144			60	4	4		2		2	4	3	
145–149				1	5	4			1	1		2
150–154	1		42		14	15	2			2		2
155–159	5		110	1	20	22	1			1	1	
160–164	3	2	72		10	53	3			1	3	1
165–169		2	69	3	6	35	3				3	2
170–174	1		3	2	7	34	4				5	1
175–179	1	1	99		1	27	2		1			2
180–184	1	1	62	3	2	24	2				3	1
185–189			20			14	1			1	1	4
190–194			18			10	4				1	1
195–199	1					6	2				1	1
200–204	1		4	2		3	1		1		2	
205–209			1			2	1				1	
210–214		1	2			5	1					
215–219							1					
220–224			1			1						
225–229							1					

TABLE 6.—*Monthly summaries of length measurements of 5,285 white perch during the first year of life*

Month	Fish measured	Smallest	Largest	Average	Month	Fish measured	Smallest	Largest	Average
		Millimeter	*Millimeter*	*Millimeter*			*Millimeter*	*Millimeter*	*Millimeter*
May	969	1	6	2.4	November	49	68	143	113.0
June	1,642	1	38	8.7	December	32	78	124	95.6
July	987	9	76	31.9	January	72	74	146	109.1
August	500	20	92	55.8	February	98	90	162	117.5
September	559	45	122	81.0	March	233	98	204	123.8
October	68	73	115	93.2	April	76	93	195	122.6

The data presented in the foregoing paragraph and in Tables 5 and 6 indicate that many white perch grow amply large to be sexually mature when 1 year of age, as gravid fish only 130 to 140 millimeters (about 5½ inches) in length are common, particularly during the latter part of the spawning season. It is not known, however, that these fish, although of ample size, actually spawn when only about 1 year old. The majority of the fish no doubt are too small to spawn at a year of age and quite certainly do not reproduce before they are 2 years old.

Welsh and Breder (1923, p. 174), working with fish from Beaufort and Chesapeake Bay, arrived at about the same conclusion relative to the rate of growth during the first summer, stating that a length of "6 to 14 centimeters (2½ to 5½ inches)" is attained by the first winter. These authors state, furthermore, "The first spawning occurs in the third season when the fish are 2 years old and between 15 and 21 centimeters in length (6 to 8¼ inches)." From scale studies these authors conclude, "After the first spawning growth is slow, the largest fish of which scales were examined having reached a length of 23 centimeters (9 inches) at the age of 6 years."

Hildebrand and Schroeder (1928, p. 281), working with fish from Chesapeake Bay, indicate a somewhat slower rate of growth than the data of the present investigation show for Beaufort fish. In September, for example, the range for Chesapeake Bay fish is from 40 to 109 millimeters, whereas the range for Beaufort fish is 45 to 122 millimeters. In November the range in size for Chesapeake Bay fish is given as extending from 76 to 117, while the range for Beaufort examples is 90 to 143 millimeters (one specimen taken 68 millimeters long). It is quite probable, therefore, that the rate of growth, as expected, is a little faster at Beaufort, the more southern locality, than in Chesapeake Bay.

FOOD AND FEEDING HABITS

The white perch with its terminal and slightly oblique mouth is not marked as a bottom feeder to the same extent as the croaker. However, it is shown on a preceding page that the fry were taken nearly twice as frequently and more abundantly on the bottom than at the surface. It is to be expected, therefore, that many although not all the forms constituting the food are bottom forms.

Small white perch, 7 to 20 millimeters long (smaller ones were not examined), as shown by the stomach contents of 30 specimens, feed chiefly on copepods, supplemented by ostracods, a few amphipods, cladocera, and an occasional Mysis and chætopod. Somewhat larger fish, 25 to 50 millimeters long, according to the contents of 64 stomachs, feed sparingly on copepods, ostracods, isopods, and more abundantly on somewhat larger crustaceans, including Mysis, small shrimp, and crabs. Also a few chætopods and mollusks were found. Examples 50 to 80 millimeters long (15 stomachs examined) had fed very largely on Mysis, shrimp, Gammarus, and chætopods. The diet of the last-mentioned group of young does not differ greatly from that of adult fish of which 20 specimens were examined, the only difference being that the adults had included a few fish (anchovies) in their diet.

Welsh and Breder (1923, p. 174) list the following forms found in 21 specimens taken at Cape Charles, Va., ranging in standard length from 60 to 82 millimeters: Schizopods, isopods, amphipods, polychæte worms, fish, and unidentified crustaceans. Hildebrand and Schroeder (1928, p. 280) say, "The food of this fish in Chesapeake Bay, as shown by the stomach contents of 100 specimens examined, consists very

largely of small and minute crustaceans. Foods of much less importance are annelids and fish. Only two individuals of the entire lot examined had fed on fish."

It may be concluded from these studies of the food that the white perch feeds largely on the bottom, that it is strictly carnivorous, and that small to medium-sized crustaceans, frequently substituted by worms, constitute the chief foods eaten. It is evident also that this species is not a serious enemy of other fishes nor of commercially utilized crustaceans. On the other hand, the white perch not infrequently occurs in the food of such important commercial species as the weakfishes and flounders.

LEIOSTOMUS XANTHURUS (Lacépède). Spot

The spot is known from Massachusetts to Texas, and it is of sufficient commercial importance to be listed separately in the statistical reports of the United States Bureau of Fisheries from all the border States from New York to Louisiana. At Woods Hole, Mass., the northernmost limit of its range, Smith (1898, p. 101) found it only in the fall, when it was common, and all specimens taken were about 6 inches long. Fish of this size probably are young ones that visit these northern waters for a short period of time only. Pearson (1929, p. 210) reports the spot as common on the coast of Texas where it has little commercial value because it does not attain a sufficiently large size. This author states that fish as large as 9.8 inches are taken only occasionally and when spot are marketed they are thrown in with the mixed fish. The States producing spots in large quantities, according to the latest statistics available, are New Jersey (1,217,704 pounds in 1926), Virginia (1,768,206 pounds in 1925), and North Carolina (1,959,252 pounds in 1927).

The maximum size recorded for the spot appears to be a Chesapeake Bay record of 13⅝ inches and a weight of 22 ounces. In the vicinity of Beaufort the usual size of adults seen in the markets is around 10 inches. Such fish weigh close to one-half pound each. This fish, like the croaker and the squeteagues, apparently grows larger in the more northern parts of its range than it does farther south. Reference already has been made to Pearson's statement (loc. cit.) that the spot, although a regular resident and common on the coast of Texas, does not attain a sufficiently large size there to be of much commercial value. According to observations by the senior author the average size of the fish in commercial catches at Beaufort, N. C., is somewhat smaller than at Norfolk, Va. A similar discrepancy in size appears to prevail in the croakers and also in the weakfishes. The reason or reasons for an average decrease in size in the more southern waters of these sciænids is not known.

The spot is taken in small commercial quantities in the local waters throughout the summer, but the principal catches are made in the fall (October and November), when the large fish school. From November 4 to 7, 1914, for example, large schools appeared on Beaufort Bar and the fish were taken in schooner loads with purse seines. This method of catching food fishes is now forbidden by law, and locally the fish are caught mostly with drag seines and to a limited extent with sink nets; that is, with gill nets weighted and sunk to the bottom in the deeper waters.

The individuals in any one school generally are of rather uniform size. For example, the greatest range in size found in a catch consisting of several hundred fish, all taken in one haul with an otter trawl, was from 9¼ to 10½ inches.

The young spots—that is, those of the O and I classes—are present in the shallower waters throughout the winter, but the larger ones are seen rarely. During cold snaps that last long enough to cause a considerable drop in the water temperature the I class, too, become scarce in the harbor and estuaries. At other times

during the winter they often may be taken in considerable numbers in the deeper channels within these waters, and more sparingly on grassy flats. These young spots, and frequently larger ones, are common off Beaufort Inlet during the winter. In fact, the larger ones that remain there, although rather small, often are caught with sink nets and marketed during the winter, when more choice fish are scarce.

In January, 1927, the water temperature at the laboratory pier, taken daily at 5 p. m. dropped as low as 5° C. on the 9th day of the month, and it remained there until the 14th when it came up to 9° C. On the morning of the 14th, the last day of the cold spell, many spots of the I class became numb and drifted ashore on Pivers Island and elsewhere in the vicinity which appears to show that they are unable to endure a very low temperature, 5° C. probably being close to lethal. It was not noticed that the young of the new year class suffered a similar mortality. However, as these fish were still quite small when the cold snap occurred, even a considerable mortality might have escaped notice. It is the opinion of the writers, though, that the recently hatched young are less sensitive to the cold than the older fish, as the former have been taken in large numbers in the harbor in an apparently active condition during cold snaps when larger spots had become scarce in the shallow waters.

It is evident from the foregoing remarks that adult spots, at least, make definite migrations. It is still an unanswered question, however, where the schools of large spots that appear in the inshore waters during the fall come from. It is true that small quantities of large spots are taken within the shallow waters during the summer, but the number is so small that it seems entirely unreasonable that they could form the large schools which appear suddenly in the fall and which are caught in large quantities. One is almost obliged to conclude that these fish come from the sea. If that were true, what would be the purpose of the migration? This is difficult to answer, especially as it is a migration of short duration and, as stated elsewhere, it evidently is not definitely a spawning migration, for spawning does not appear to take place within the sounds and harbor. A limited outward movement of the smaller and younger fish (I class) is indicated also. That the latter, at least, do not go far is shown by their quick return, for they reoccupy the harbor and estuaries between cold snaps. The accompanying length frequencies in Table 7 appear to show that some of the larger individuals of the O class probably move away from the shallower water for the winter along with the older and larger fish. This subject will receive further consideration under the subhead Growth.

That the adult fish do not go far after leaving the shallow inshore waters seems to be shown by the presence throughout the winter of numerous very small fry near the outer shores and also within the harbor and estuaries, as shown subsequently. Under the discussion on "spawning" it is shown, furthermore, that the principal spawning quite certainly takes place after nearly all the adult fish have left the shallow waters. It is deduced from these facts that the adult fish spawn only a short distance offshore. If this were not true it would seem highly improbable that the very small and comparatively helpless fry, only a few millimeters in length, would be common in the inshore waters. Since spawning appears to take place during most of the winter (p. 418), the indications are that the winter home of the adult spot is only a short distance offshore.

SPAWNING

The eggs of the spot, if taken, were not recognized. Numerous males with running milt were seen, but no females ripe enough for stripping were found. If the eggs were taken in the tow, which seems to us unlikely, they were not recognized.

During four successive years an effort was made to secure the eggs by confining gravid fish in tanks. The overflow was screened for eggs and the tanks were examined carefully daily for demersal eggs, also, but none were secured. One winter (1928–29), for example, a fine lot consisting of 18 large spots was held for several months in a tank in the terrapin brooder house at a warm temperature. Although these fish took food (cut fish) regularly and appeared to be in good condition they, like others, kept in tanks out of doors (until killed by the cold), failed to cast their eggs. Those that died during the winter were found to contain roe which appeared to be in about the same state of development as in specimens examined at the time of capture in October. Others which either died or were killed in May (long after the spawning season was over) still contained roe, but the eggs showed signs of disintegration. This, and other experiments, indicate that the spot will not cast its eggs in captivity under the conditions described unless by chance very ripe individuals should be confined which might spawn during the first or second day of captivity. At least, that was our experience with the pigfish and hogchoker from which we succeeded in getting the eggs during the first night and a few during the second night of captivity, but none thereafter.

The retention of the spawn in captivity under the conditions described is an interesting phenomenon, apparently well worthy of further study. The natural environment evidently must be more closely simulated than in the present experiments to induce the spot to carry out the spawning process. It was not determined what would happen eventually, whether the developing sexual products would be reabsorbed, discarded in an unnatural way, or whether their retention would result in death. It was noted only that an apparent disintegration of the eggs was taking place, as already stated, in those individuals retained the longest.

We find no record in the literature of spot eggs having been taken and since the fish failed to spawn in captivity and the eggs, if taken in the tow, were not recognized, their identity and manner of development remain unknown.

The time and duration of spawning, nevertheless, have been fairly accurately determined from the collections of young (larvæ) made during four seasons (1927, 1928, 1929, and 1930). The earliest young, a single specimen 3 millimeters long, was taken on November 12, 1927, at a station 12 miles WSW. of Cape Lookout. The larvæ did not reappear in the collections until early in December, when they became numerous and remained so for several months. The smallest larvæ taken during December, January, and February were, respectively, 1.5, 4, and 3 millimeters long. During the next three months—namely, March, April, and May—the smallest fry appearing in the collections were, respectively, 10, 7.7, and 11 millimeters in length. (Table 8.)

Larvæ only about 1.5 millimeters in length, without doubt, are hatched from a very small egg with a short period of incubation, probably not exceeding one week even during cold weather. This tentative conclusion is arrived at from our knowledge of the length of the incubation period of several other species having small eggs, especially the pigfish (*Orthopristis chrysopterus*) which begins spawning in April when the waters are still quite cold. This species has an egg from 0.65 to 0.8 millimeter in diameter and hatches a larva 1.5 millimeters in length. The newly hatched pigfish, therefore, is equal in length to the smallest spot larvæ secured and it seems plausible that the eggs of the two species are nearly of the same size. This supposition is supported further by the size of nearly mature eggs in the ovaries of both species. The incubation period of the pigfish, at the lowest temperatures that have

prevailed during the spawning season, has never been observed to exceed three days. Therefore, one week would appear to be a liberal estimate of the duration of the incubation period of spot eggs.

If these deductions be approximately correct, it would follow, from the size and number of young in the collections, that at Beaufort some spawning may take place in November but that the principal spawning months are December and January, with diminished spawning activity in February.

Ova of several sizes are present in well-developed ovaries which suggests that the eggs probably are cast, a few at a time, over a period of several weeks. It was noticed, furthermore, that the sexual organs generally were further advanced in large individuals than in smaller ones in examinations made in October, which would indicate that the large fish spawn earlier than the smaller ones. This would lengthen the spawning season still further, causing it to extend, as already shown, probably during a part of November, throughout December and January, and possibly through at least a part of February.

The foregoing deductions in regard to the spawning period at Beaufort and the place of spawning are not out of accord with recently published statements for other localities. Hildebrand and Schroeder (1928, p. 274) state that spawning takes place (in the Chesapeake Bay vicinity) during late fall and probably during the winter and, apparently, at sea. That spawning occurs at sea was thought to be the case, because a large exodus from the bay of big fish with maturing roe takes place each year during late September and in October. It may be noted here also that, although winter collecting with townets and other fine-meshed gear was rather vigorously pursued during the investigation on Chesapeake Bay, the smallest spots taken were 15 millimeters long. It would seem, therefore, that the very small fry probably do not occur in the bay, in any considerable numbers, which is contrary to the situation in the vicinity of Beaufort where the larvæ are abundant in the inside waters, as already stated.

Pearson (1929, p. 204) states that the spot spawns in the Gulf of Mexico in close proximity to the mouths of the passes that lead into the partly inclosed coastal bays, and that spawning occurs from late in December until the last of March. The spawning season in Texas, therefore, would appear to be nearly identical with that at Beaufort. Mr. Pearson, apparently, did not take the eggs and presumably arrived at the conclusions given in regard to the place, time, and durations of spawning from the collection of young.

DESCRIPTIONS OF YOUNG

Specimens 1.5 millimeters long.—In fish of this small size the yolk sac appears to be completely absorbed. The mouth is quite well developed and very oblique; the body decreases in depth posteriorly, coming to a sharp point. The fin fold is present but plainly visible only on the posterior part of the tail. A dark membrane (peritoneum) lying above the air bladder (very distinct in slightly larger specimens) already is evident. Occasionally at this size there also is present a row of dark chromatophores along the ventral side, posterior to the vent, one on the middle of the side above the vent, and a few others on the head. The color markings become more definite in slightly larger fish. (Fig. 41.)

Specimens 2.8 millimeters long.—Many specimens of this size and larger ones are before the writers. The mouth is very oblique to nearly vertical; the body anteriorly, with the apparently loosely joined visceral mass, is rather deep, and posteriorly it is very slender, ending in a sharp point. In the dorsal profile there is a

prominent swelling (hump) over the eyes and another at the nape. The hind gut is prominent and appears to be entirely free from the body distally. (In larger specimens it is plainly connected by membrane, and the membrane may have been broken in these larvæ.) A fin fold is present but rays are not yet evident in any of the fins. The dark membrane (peritoneum) lying dorsally of the abdominal cavity is plainly visible through the thin wall and is crescent shaped (conforming to the contour of the dorsal wall) when the fish is viewed from the side. An elongated dark chromatophore lies dorsally of the hind-gut. In addition, a row of dark chromatophores is present along the ventral edge of the entire caudal portion of the body.

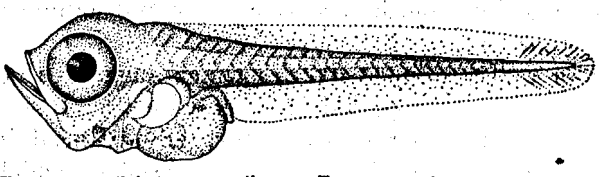

FIGURE 41.—*Leiostomus xanthurus*. From a specimen 1.7 millimeters long

Specimens 3.6 millimeters long.—The principal development that has taken place between this size and the smaller ones (2.8 millimeters) already described, is the appearance of rudiments of rays on the ventral side of the distal part of the tail. The fin developing here is destined to become the caudal fin. The mouth at this age (size) is less strongly oblique than in the younger individuals, already described. A dark chromatophore is present at the hinge (joint) of the mandible, situated slightly behind the vertical from middle of eye, and a few small indefinite dark specks are sprinkled over the head. (Fig. 42.)

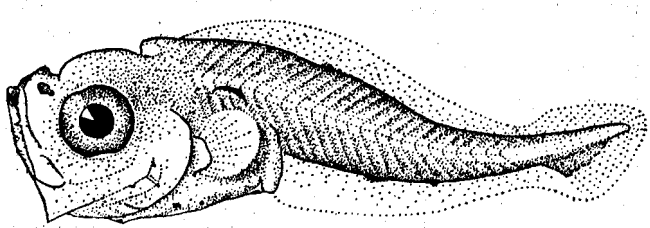

FIGURE 42.—*Leiostomus xanthurus*. From a specimen 3.2 millimeters long

Specimens 4.0 millimeters long.—The principal development that has taken place, since a length of 3.6 millimeters was attained, consists of the greater development of the caudal fin. The notochord, usually, although not always, is curved upward at this size giving the tail the appearance of being heterocercal. In some specimens, as in the one drawn, the notochord remains straight, however, the caudal rays being below it and directed obliquely downward. The dorsal profile of the head has become much more even in outline, the depressions and the humps having largely disappeared. The fin fold is prominent, and usually no thickening of the membranes in the regions somewhat later to be occupied by the dorsal and anal fins has taken place. (Fig. 43.)

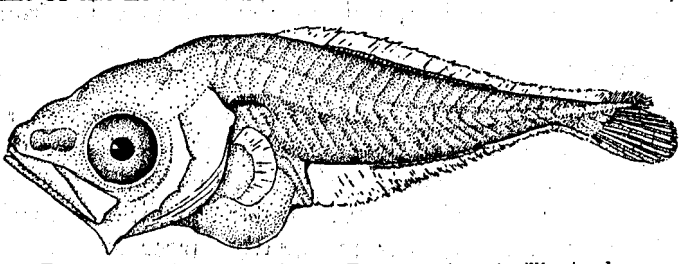

FIGURE 43.—*Leiostomus xanthurus*. From a specimen 4 millimeters long

Specimens 6.0 millimeters long.—At this size the caudal portion of the body has become proportionately much deeper and the break in the ventral outline between the body and tail is much less pronounced than in younger individuals. The caudal fin is fairly well formed and its base (oblique in smaller fish) now is in a vertical plane, the notochord being strongly curved and ending at the base of the upper rays. A thickening and a slight projection of tissues has taken place in the region that will be occupied by the base of the anal and for a part of

the base of the dorsal also. The bases of a part of the rays are becoming evident as pale and slightly protruding areas. No changes in color worthy of note have taken place since a length of 3.6 millimeters was attained.

Specimens 7.0 millimeters long.—At this size the anal fin occasionally is well enough developed to show the anal rays, or at least the articulations between the rays and the interhæmal spines generally are evident, appearing as somewhat elongate, rectangular pale areas, surrounded by a dark line. (The prominence of these markings appears to depend partly on preservation, as in some lots they are uniformly more distinct than in others.) It often is possible to get a fairly accurate count of the rays from these sutures even though the rays themselves are not evident. The dorsal fin generally is somewhat less definitely developed than the anal, and the spinous portion is still missing. The pectoral and ventral fins are just becoming visible, being short and without definite rays. The hind gut no longer projects prominently. However, a large space, with only a semitransparent membrane, remains between the vent and the origin of the anal. This area exceeds in length the diameter of the eye. The notochord is still evident and its extremity is visible in the fin membrane above the base of the uppermost ray of the caudal. The spinal column, too, is visible on the median line of the side at the base of the caudal. Pigmentation now consists of a dark spot at the articulation of the mandible; the dark peritoneum above the viscera (very evident in smaller specimens) is still rather faintly visible through the abdominal wall; a dark chromatophore remains at a point slightly in advance of the origin of the anal; other pigment spots are situated along the ventral edge, as in smaller specimens. (Fig. 44.)

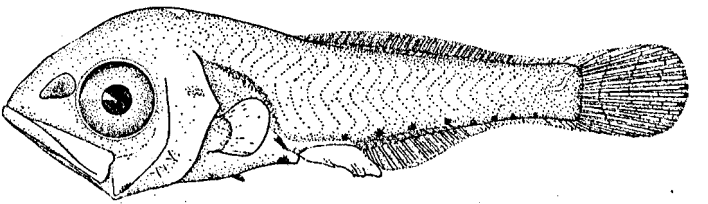

FIGURE 44.—*Leiostomus xanthurus.* From a specimen 7 millimeters long

Specimens 10.0 millimeters long.—The anal spines and rays are quite fully developed, and an accurate count can be made under proper magnification and illumination. The soft dorsal is well developed, except posteriorly where the rays are very short and indefinite. Although a variation in the progress of development exists, the base of the spinous dorsal usually is evident only as a thickened membrane and generally no spines, as yet, are evident. The middle rays (about 10) of the caudal fin are all of nearly the same length, making the posterior margin of the fin straight. (In smaller specimens the margin is round.) The pectorals and ventrals are short but have definitely differentiated rays. The mouth is much less oblique than it is in smaller specimens and it is slightly inferior, approaching in both respects the position it has in the adult. The heterocercal character of the tail—that is, the upward bend in the notochord, prominent in somewhat smaller specimens—scarcely is discernible. Pigmentation has undergone no changes worthy of note. (Fig. 45.)

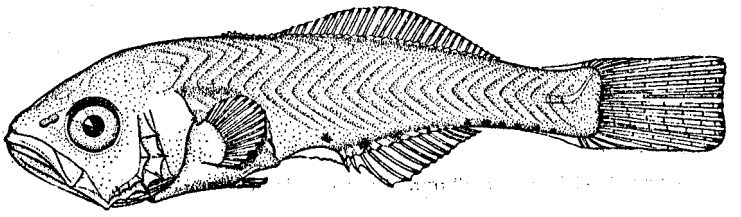

FIGURE 45.—*Leiostomus xanthurus.* From a specimen 11 millimeters long

Specimens 15.0 millimeters long.—The changes in development in fish of this length and those 10 millimeters long are not pronounced. The first dorsal now has

most of the spines (anterior ones) developed. They are very slender and become short and usually indistinct, or are missing, posteriorly, and generally no definite count can, as yet, be made. The heterocercal character of the tail has disappeared completely. The membrane between the vent and the origin of the anal, previously described, has become narrower, and the almost vacant space is gradually becoming smaller. The pigmentation remains essentially the same as described for 7.0 millimeter specimens, except that the black peritoneum no longer is visible through the body wall and a few dark markings are present on the base of the caudal. (Fig. 46.)

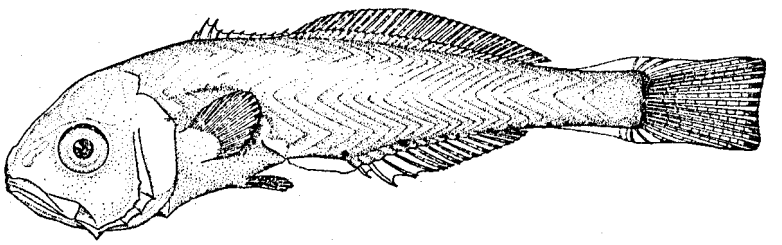

FIGURE 46.—*Leiostomus xanthurus*. From a specimen 15 millimeters long

Specimens 20.0 millimeters long.—The body at this age (size) continues to be more slender than in the adult, the greatest depth being contained in the length to base of caudal about 3.8 times (adults about 2.6). The dorsal outline is quite convex but not nearly as much so as in the adult. All the fins, including the spinous dorsal are well developed, and it is possible to enumerate for the first time all the dorsal spines. The posterior margin of the caudal fin at this size is distinctly concave. The fish is still without color, except for the few pigment spots described for smaller individuals. At this age, as well as in much younger individuals, there are distinct spines on the preopercular bones, which disappear later. (Fig. 47.)

Specimens 25.0 millimeters long.—No pronounced changes in the development occur between a length of 20 and 25 millimeters. The body has become proportionately deeper, and the back is higher. The mouth is less oblique and somewhat more inferior. A vacant area between the vent and the origin of the anal, previously occupied only by a semitransparent membrane, is now filled in with heavier tissues, leaving only a slight concavity. The principal development between a length of 20 and 25 millimeters is that of pigmentation. A dark chromatophore previously situated on the side, a little in advance of the origin of the anal, has disappeared. The rest of the dark spots, extending along the ventral edge from the origin of the anal to the caudal are still present, as in much smaller individuals. A row of vertically elongate dark spots on the base of the caudal fin has become more pronounced, and new chromatophores have appeared about the mouth, on the head, and a row of widely spaced ones along the upper edge of the back. A very small chromatophore is present on the median line of the side of the caudal peduncle, slightly in advance of base of caudal, and a few dark points of even smaller size lie in the same plane forward of it. A dark spot situated about at the "hinge"

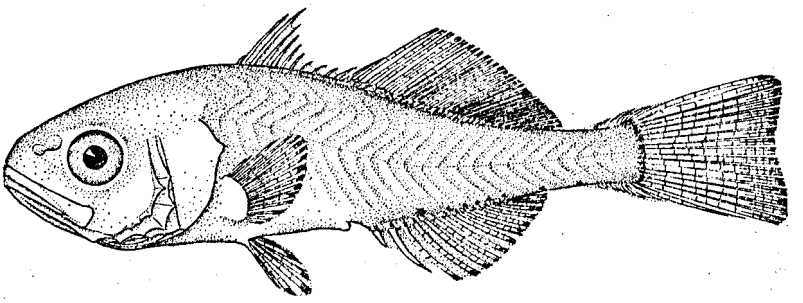

FIGURE 47.—*Leiostomus xanthurus*. From a specimen 20 millimeters long

of the mandible, described for very young (3.6 millimeters), still persists. There is also a prominent chromatophore on the median line slightly behind the isthmus and another at the base of each ventral. Some variation from the pattern described has been noticed, as well as a considerable difference in the intensity of the markings. (Fig. 47.)

Specimens 30.0 millimeters long.—No scales are visible in fish 25 millimeters long. However, when a length of 30 millimeters is attained scales are evident nearly everywhere, the rows forming first and being furthest developed on the sides of the abdomen. None of the scales as yet appear to overlap or have free margins. The spines attached to the preopercular bones, described for smaller specimens, have completely disappeared or more usually are visible within the membrane bone of the preopercle, and frequently their tips extend slightly beyond the preopercular margin. The lateral line is largely developed. Pigmentation proceeds rapidly while the fish grows from 25 to 30 millimeters in length. At the larger size the fish is silvery on the lower part of the sides of head and body, and (in alcohol) it is brownish on the back and upper parts of the sides. The body nearly everywhere is marked with dark chromatophores which extend on all the fins, exclusive of the ventrals. In

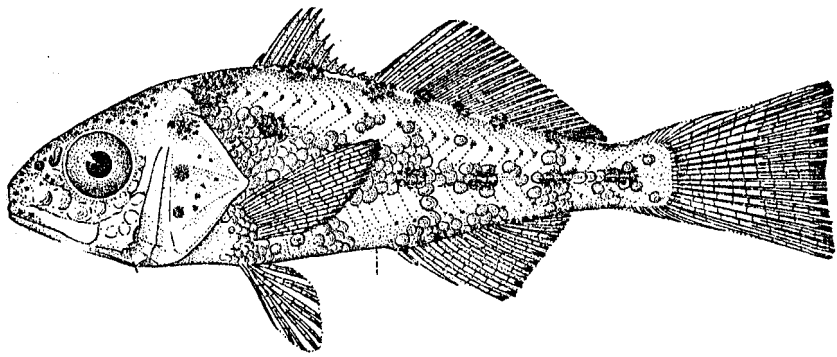

FIGURE 48.—*Leiostomus xanthurus.* From a specimen 30 millimeters long

most specimens 30 millimeters long a row of dark blotches is evident along the median line of the side, and faint saddlelike blotches sometimes may be seen on the back. (Fig. 48.)

Specimens 50.0 millimeters long.—At this size the fish has acquired essentially the form and the color of the adult. The snout is definitely blunt, and the mouth is horizontal and inferior. The back is decidedly elevated, and the lower outline is nearly straight. The body has become rather deep, the depth now being contained in the length to the base of the caudal about three times, whereas in the adults the depth is contained in the length about 2.6 times. Dark oblique bars (generally of a yellow or brassy shade in life) are present on the back, as in the adult, although less distinct. The dark spot at the shoulder, from which the species derives its common name, is faintly visible. In fact, the principal characters which distinguish this species from all other forms—namely, the comparatively short, compressed body, high back, short obtuse head, the small horizontal mouth, the rather long anal fin, the concave margin of the caudal fin, the oblique bars, and the dark shoulder spot—are all fairly well developed at this size, and the fish is readily identified with the adult. (Fig. 49.)

COMPARISON OF YOUNG SPOTS AND CROAKERS

Young spots and croakers are very similar and until a length of about 10.0 millimeters is reached are difficult to distinguish. A comparison of the larvæ of the two species, therefore, has been prepared and is presented under the discussion of the croaker (p. 439). The differences between the very young of the spot and croaker unfortunately are largely of degree only; that is, one has a slightly larger eye and a deeper tail than the other, etc., and are difficult to apply unless specimens of like sizes of both species are available for comparison.

DISTRIBUTION OF YOUNG

The fry occur in about equal abundance in towings made in Beaufort Harbor and in those made off Beaufort Inlet, some of the stations being as much as 12 to 15 miles offshore. The fry were taken in the bottom tow 103 times and in the surface tow 50 times, indicating that the larvæ may be present at any depth but that they occur more frequently at the bottom than at the surface.

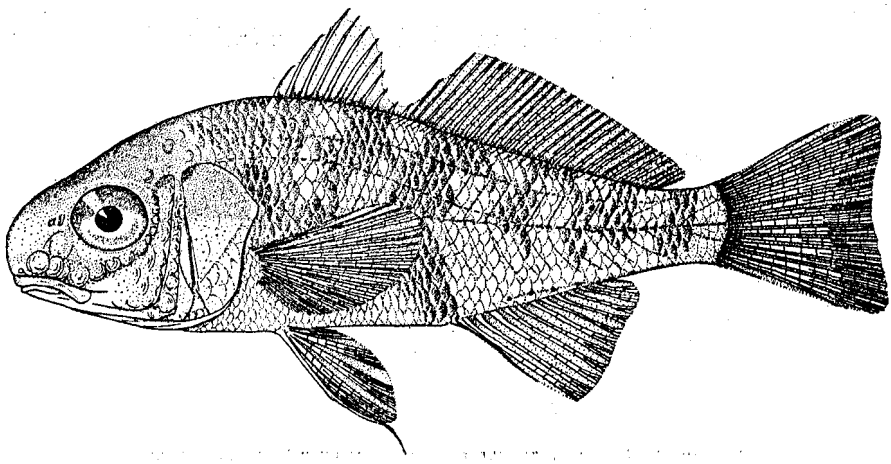

FIGURE 49.—*Leiostomus xanthurus*. From a specimen 46 millimeters long

From February to April schools of young fish often are seen along the shores of Pivers Island, the favorite places being protected coves around stone breakwaters and jetties. Somewhat later, fish an inch and above in length become numerous in shallow water in places where an abundance of vegetation is present. In such places young fish may be taken with dragnets throughout the summer and far into the winter. In other words, young spots remain in this environment until at least a year old. Young spots also ascend brackish water ditches to fresh water during the spring and early summer. Fish found in such an environment generally are larger than those found among vegetation in saltier water. Fish taken in the deeper channels in Beaufort Harbor during the winter months, too, are larger than those commonly found in the shallow, "grassy" waters. Spots ranging from about 3 to 6 inches in length, presumably mostly still in their first year, are abundant off Beaufort Inlet during the fall and early winter, and many are taken in shrimp trawls.

GROWTH

In the present studies a special effort was made to acquire information relative to the growth of the spot during its first year. In the course of the work considerable information was gained, however, in regard to its growth during the first six months

or so of its second year. No special effort was made to secure the older fish, but when taken along with the younger fish they were measured and the data are included in Table 7. Table 8 and Figure 50 include the measurements of young fish only; that is, until an age of about 18 or 19 months is attained, as determined from Table 7.

It is evident from Table 7 that it is a little difficult to separate the largest representatives of the O class after they attain an age of 6 or 7 months from the I class, partly

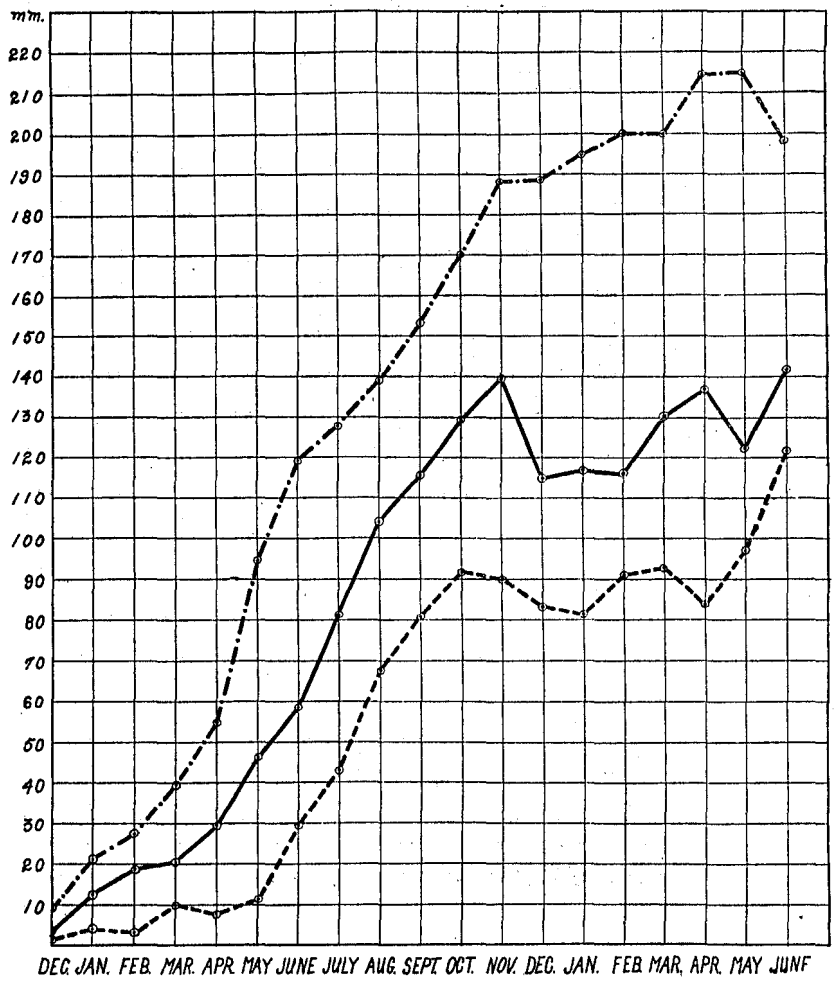

FIGURE 50.—Growth of spot (*Leiostomus xanthurus*) during first year or so of life; also illustrating size of fish of same year class which spend their second winter in shallow water. Reason for decrease in average length explained in text. Solid line, average size; dot-and-dash line, maximum size; broken line, minimum size. (Graph based on Table 18)

because the two classes intergrade in size and partly because insufficient measurements of the larger fish are available. However, the average size given for the various months in Table 8 and Figure 50 must be nearly correct, as the larger fish, which may have been wrongly assigned as to the year class, are so few in number that the average could not have been affected greatly because of the error involved. While the maximum sizes given for the O class may be somewhat in error, it is believed, nevertheless, that the average lengths shown for this year class are very nearly correct.

TABLE 7.—*Length frequencies of 20,082 spots*

[Measurements to nearest millimeter, grouped in 5-millimeter intervals]

Total length	December	January	February	March	April	May	June	July	August	September	October	November
0–4	102	3	12									
5–9	20	64	31		5							
10–14		64	44	73	7	7						
15–19		94	180	1,179	16	24						
20–24		3	163	1,081	70	36						
25–29			5	313	130	104	1					
30–34				53	190	172	38					
35–39				4	74	89	68					
40–44					30	76	116	1				
45–49					3	84	183	4				
50–54					1	97	194	5				
55–59						100	59	29				
60–64						84	48	63				
65–69						63	28	32	1			
70–74						37	44	65	14			
75–79						25	51	77	21			
80–84	1	2			1	16	39	86	34	2		
85–89	8	10			4	2	36	85	41	4		
90–94	30	93	4		14	4	26	53	54	28	3	5
95–99	88	261	17	1	31	6	16	49	63	36	8	4
100–104	259	583	124	16	54	12	10	39	88	48	19	8
105–109	360	625	312	36	67	29	15	26	86	72	50	11
110–114	534	676	457	71	56	52	6	21	67	59	45	41
115–119	358	509	303	99	69	53	5	15	74	83	41	62
120–124	219	446	186	87	66	51	11	11	48	74	41	115
125–129	121	302	84	77	54	41	26	3	30	57	47	119
130–134	101	241	65	82	60	32	29	2	12	35	58	157
135–139	81	190	29	46	44	29	28	4	8	19	56	110
140–144	52	150	25	38	31	16	37	7	7	14	25	110
145–149	42	93	13	28	25	10	22	9	5	5	8	67
150–154	27	50	16	22	35	7	22	4	4	7	23	79
155–159	24	25	5	14	28	3	8	1		3	14	59
160–164	10	18	5	25	32	7	12	3	7	9	22	58
165–169	6	14	4	17	48	3	5	2		13	13	29
170–174	1	10	4	7	35	6	4		3	8	5	31
175–179	2	4	1	10	29	7	1	2	3	3	5	24
180–184	3	3	5	7	28	2	3	2	2	4	4	34
185–189	2	3	1	3	20	4		2		1	4	6
190–194		1		1	26	4		1		1	3	8
195–199		1	1	2	19		2		1		1	3
200–204	1		2	1	17			1	2		2	1
205–209					4			1	1	3	1	1
210–214			1		4	1						2
215–219					5	1		2	1			
220–224								2				
225–229						1				1		
230–234					1					1	2	1
235–239											1	
240–244												
245–249												
250–254											3	
255–259											1	
260–264											2	1
265–269											1	

TABLE 8.—*Monthly summaries of length measurements of spots during their first 18 or 19 months*

Month	O class				I class			
	Number of fish	Smallest	Largest	Average	Number of fish	Smallest	Largest	Average
		Millimeter	*Millimeter*	*Millimeter*		*Millimeter*	*Millimeter*	*Millimeter*
December	122	1.5	9.2	3.7	2,329	84	188	[1] 115.6
January	228	4	21	12.6	4,310	82	195	[1] 116.9
February	435	3	27	18.5	1,660	91	200	[1] 115.8
March	2,703	10	39	20.3	690	93	200	130.4
April	526	7.5	54	29.8	875	84	214	137.0
May	1,020	11	94	45.8	376	97	215	123.0
June	983	29	119	57.7	210	122	198	142.6
July	664	43	127	81.4				
August	641	67	139	104.6				
September	543	81	153	115.5				
October	478	92	170	129.5				
November	1,140	90	188	139.3				

[1] Reason for decrease in average length in December explained in text.

It seems rather certain, as pointed out elsewhere (p. 397), that many of the larger representatives of the O class (becoming the I class during the winter) leave the shallow waters along with the adult fish upon the approach of cold weather. This is thought to be the case because the average size of the young fish, now the I class, taken during the winter months is smaller than it was in October and November. For example, the average size of 1,140 fish of the O class taken in November is 139.3 millimeters, while the average for 2,329 fish of the same year class taken during December is only 115.7. The average size of 4,310 fish of the same year class taken in January is 116.9 and for 1,660 fish taken in February it is 115.8. Such a decrease in size, since the methods and places of collection did not change and occurred each winter from 1927–28 to 1929–30, inclusive, apparently can be explained only on the basis that the larger fish were not properly represented (although some large ones were present) on the collecting grounds.

An increase in the average size occurs in March, as shown by Table 8, but it is not until June when the November average is exceeded. While the data are not sufficient for a definite conclusion, they do indicate that many of the larger representatives of the I class probably fail to reoccupy the shallower waters, where the collections were made, after their early winter departure.

Small fish, presumably of the O class, are reported from Chesapeake Bay for December and January by Hildebrand and Schroeder (1928, p. 273). The average size of these fish was notably smaller than that of specimens of the same year class taken in October and November. The authors came to the tentative conclusion that the fish taken in Chesapeake Bay during the winter probably were the "runts" of the last spawning season which had remained in the bay, while the larger representatives of the same year class had departed. This contention certainly is strongly supported by the behavior of the fish at Beaufort, as shown by the present investigation.

Growth appears to progress fairly rapidly in young spots. The largest fish taken in January, when probably only a little more than a month old, was 21 millimeters long and many examples exceeded a length of 15 millimeters. The largest specimen of the recently hatched fish caught in February was 27 millimeters and many had reached a length of over 20 millimeters. In March the largest fish was 39 millimeters long and numerous specimens had attained a length of over 25 millimeters. The average length of the fish of this year class taken during January, February, and March, as shown by comparatively large series of measurements was, respectively, 12.6, 18.5, and 20.3 millimeters. These averages were held down by the continued presence of very small fish, presumably resulting from recent hatchings, for in January and during the early part of February many larvæ under 10 millimeters in length appeared in the collections. However, none under that length was taken in March, and thereafter the average size of the specimens increased rapidly.

Although the growth of young spots during their first several months, regardless of the winter weather, is fairly fast, development proceeds even more rapidly in the spring when the water becomes warmer, for in April the average length of 526 fish was 29.8 millimeters and in May for 1,020 fish the average length had increased to 45.8 millimeters. This rapid rate of increase in length continues until September, when the fish, according to measurements of 543 fish, had attained an average length of 115.5 millimeters. It is a well-known fact, of course, that when fish attain a fairly large size the rate of increase in length decreases, and this is what takes place in the spot when an age of about 8 to 10 months and a length of about 115 millimeters

is reached. The spot thereafter increases in depth and plumpness; and the gain in weight very probably is proportionately greater, even though the increase in length is smaller, than it was earlier in life.

The average size of the spot at the age of about 1 year, as shown by Table 8 and Figure 50, is 139.3 millimeters (5.6 inches) and the maximum size probably is about 188 millimeters (7.5 inches). Owing to the apparent departure of many of the larger spot of this year class from the local shallow waters, as shown by the decrease in the average length of specimens taken (Table 8) and pointed out elsewhere (pp. 416, 417), the rate of growth of the spot after an age of about 1 year is attained can not be followed now at Beaufort and must remain unknown until the winter home of these larger fish is found, together with means and methods of taking them there. The data accumulated for the I class are included in the graph (fig. 50), not because they show rate of growth but merely to illustrate the decrease in average length which presumably is due to the absence of many of the larger fish of this year class in the harbors, estuaries, and inshore waters of the vicinity where the collections were made.

Welsh and Breder (1923, p. 179) state that growth during the winter months, even in southern waters, appears to be retarded or altogether lacking. The authors state, furthermore, that "postlarval" examples taken in Florida between January and April showed no increase in length during this period. The authors do not state how numerous their collections were, and it is conceivable that their material might not have been entirely representative. The young fish assemble in schools (at Beaufort, at least) when a length of about 12 to 15 millimeters is attained. These schools appear to break up later when the fish are 25 millimeters or so in length. When schooled the fish may be taken in large numbers, but they might not be representative of the year class, because each school appears to consist of fish of nearly uniform size. It is necessary, therefore, to obtain samples from many different schools in order to secure the true range in size, as well as a true average length. Since we found a fairly rapid rate of growth of the fry during the winter months at Beaufort, we are inclined to believe that the samples secured in Florida by Welsh and Breder were faulty; that is, the collections did not include the true range in size and for that reason failed to show the rate of growth. Furthermore, Pearson (1929, p. 207) working in Texas found a range in length from April 17 to May 22 (1927) of 40 to 120 millimeters and an average length of 70 to 80 millimeters which indicates rapid winter growth and which considerably exceeds the rate of growth at Beaufort, for the range in size in our collections for May is 11 to 94 millimeters and the modal length is about 45 millimeters.

Welsh and Breder (loc. cit.), furthermore, state that a large series of 1-year-old fish taken at Fernandina, Fla., in December and March showed no increase in length during the period between observations. It is quite conceivable that at Fernandina, as at Beaufort, some of the larger fish withdraw from the shallower waters and that no growth was shown, because the collections were not representative of the year class. It may be pointed out also that very little winter growth is indicated by the rather meager data secured by Pearson (loc. cit.) in Texas. Possibly this, too, was due to the departure of the larger fish of the I class from the collecting grounds.

The rate of growth of the spot appears to be slightly more rapid in southern waters than in more northern ones. Welsh and Breder (1923, p. 178) estimate that the spot reaches a length of only 80 to 100 millimeters (3 to 4 inches) during its first year in New Jersey. Hildebrand and Schroeder (1928, p. 274) assign a modal length

of about 125 millimeters (5 inches) to 1-year-old spots in Chesapeake Bay. The present investigation indicates that the average length attained at Beaufort at an age of 12 months is about 140 millimeters (5.6 inches). Welsh and Breder (loc. cit.) assign the same modal length, namely 140 millimeters (5.6 inches) to 1-year-old fish at Fernandina, Fla., and Pearson (1929, p. 209) indicates an average length of about 130 to 140 millimeters (5.1 to 5.6 inches) at 1 year of age for fish taken in Texas. The difference in the rate of growth of the spot during the first year, as shown by the information available, is not great for the different localities given, except for New Jersey.

No special effort was made during the present investigation to follow the rate of growth of the spot after the first 12 months of life, as already stated. Furthermore, it would be extremely difficult, if not impossible, to obtain reliable information on the growth of the older fish from length frequencies. Such work certainly would have to be supported by scale studies, and even then it would be difficult because of the migrations performed by the fish, as pointed out elsewhere.

Welsh and Breder (1923, p. 179) found it difficult to determine the age of spots by scale examinations, owing to the faintness of the winter rings. However, they estimated from such studies that 1-year-old spots in New Jersey are 3 to 4 inches; 2-year-old ones, 6¾ to 8¾ inches; and 3-year-old ones, 9½ to 11½ inches long. The largest example examined was 11¾ inches long, and the age indicated by the scales was 4½ years. Pearson (1929, p. 209) assigns a length of 7.4 to 8.2 inches to the fish at the end of their second year, and few older fish were observed.

The data in frequencies in Table 7 show that a considerable percentage of the fish of the I class reach a length of 190 to 200 millimeters (7½ to 8 inches) at Beaufort by April when about 16 or 17 months old. The data for this year class after that month are too meager to be significant but the indications, at least, are that many of the fish at the end of their second year exceed a length of 8 inches. It seems improbable, however, that the 2-year-old fish constitute the bulk of the schools of large fish taken locally in the fall of the year which generally range upward of 9½ inches in length. Such fish quite certainly are near the end of their third year or older.

AGE AT SEXUAL MATURITY AND THE SPAN OF LIFE

No spots less than 8 inches in length with developing or nearly mature roe were seen during the present investigation. The small, ripening fish contrary to the larger ones are not found in schools but are taken one or a few at a time. Hildebrand and Schroeder (1928, p. 274) examined 104 fish, ranging from 4½ to 10½ inches in length, taken at Ocean View, Va., in October, shortly prior to the spawning season, and found no fish less than 8½ inches in length with gonads in such a state of development that they would have spawned that year. Pearson (1929, p. 209) found some fish in Texas (where the spot does not grow large) only a little over 6½ inches in length in spawning condition. However, he concludes that these small fish were approaching an age of 2 years. It is evident also that Beaufort and Chesapeake Bay fishes do not reach sexual maturity at 1 year of age, for it has been shown in the preceding pages that few, if any, fish from these localities reach a length as great as 8 inches during their first year and that the average length attained is only about 5 to 5½ inches, whereas the minimum spawning size, as already shown, is 8 to 8½ inches.

The present writers, as stated elsewhere, did not make a special study of the age and growth of the spot after they are a year old, and they have no specific data

to present which would show when sexual maturity is reached. However, the data in Table 7 show that a considerable percentage of the fish of the I class have reached a length as great as 190 to 200 millimeters (7.6 to 8 inches) in April. It seems certain that fish of this size will have grown amply large by the following December, January, or February to be spawning fish. It may be concluded, therefore, that at least some of the spots spawn at Beaufort when 2 years old.

Comparatively little is known of the duration of life of the spot, and the present authors have little to add. Welsh and Breder (1923, p. 179) took a spot in New Jersey 11¾ inches long which had attained an age, as shown by winter rings on the scales, of 4½ years, and they found many that were 3 years old. Pearson (1929, p. 209), on the other hand, found few fish in Texas over 2 years old; and he concludes, "* * * few fish reach an age of over 2 years in Texas coastal waters." The writers have reason to believe, as shown elsewhere (p. 429) that the bulk of the commercial catches made at Beaufort consists of fish not less than 3 years old, but they have no information relative to the greatest age that may be attained.

FOOD AND FEEDING HABITS

The small inferior mouth at once indicates that the spot is a bottom feeder and that it subsists on rather small objects. An examination of the stomach contents shows this to be the case. Published accounts (Breder and Welsh, 1923, p. 179, and Hildebrand and Schroeder, 1928, p. 272) show that this fish feeds very largely on small crustaceans, principally amphipods and ostracods, and also on minute mollusks, annelid worms, fish, and vegetable débris.

The published records, apparently, are based on fish that had attained a length of upward of 2 inches, and many of the specimens examined were adult. In the present investigation 135 stomachs of small specimens ranging from 15 to 100 millimeters (⅝ of an inch to 4 inches) in length were examined. The smallest specimens, or until a length of about 25 millimeters was attained, had fed wholly on small crustaceans, principally copepods with comparatively few ostracods. Thereafter, detrital material occurred in the stomachs in increasing abundance, apparently supplementing the previous diet which consisted of small crustaceans. After the detrital material appeared in the stomachs minute mollusks and annelid worms also were taken. In the detrital material, fragments or shreds of plants frequently were noticed and the relatively large amount of sand present—sometimes constituting fully 50 per cent of the contents—appears to be worthy of note.

The appearance of detritus in the stomachs when the fish has reached a length of about 25 millimeters, coincides quite accurately with the time when the schools of young spot, frequently seen during the winter and early spring in quiet coves, appear to break up and disappear. It is at this size, when the previously oblique terminal mouth has become inferior, as in the adult, that the fish is ready to begin feeding on the bottom and to subsist essentially on those foods that will furnish nourishment during the remainder of its life.

MICROPOGON UNDULATUS (Linnæus). Croaker; Hardhead

The croaker is known from Massachusetts to Texas and is of sufficient commercial importance to be listed separately in the statistical reports of the United States Bureau of Fisheries from all the border States from New York to Texas. In Massachusetts it is occasionally taken at Cape Cod (Welsh and Breder, 1923, p. 180), and in Texas it is common, but the size attained, according to Pearson (1929, p. 203),

is so small (average about 8.6 inches) that the species has comparatively little commercial value. The States producing croakers in large quantities, as shown by the most recently published statistics of the United States Bureau of Fisheries, are New Jersey (2,455,867 pounds in 1926), Maryland (2,602,861 pounds in 1925), Virginia (22,649,295 pounds in 1925), and North Carolina (3,932,058 pounds in 1927). Other States producing considerable quantities, according to the United States Bureau of Fisheries statistics of 1927, are Florida (85,392 pounds), Louisiana (185,642 pounds), and Texas (104,098 pounds).

The maximum size attained by the croaker is about 20 inches, and a weight slightly in excess of 4 pounds (Hildebrand and Schroeder, 1928, p. 287). Most of the croakers marketed at Beaufort are small, belonging to a size known as "pinhead croakers" on Chesapeake Bay, ranging from about 7 to 10 inches in length. This is the usual size of the croakers taken in the vicinity of Beaufort in strictly salt water. Larger fish, with red fins, known locally as red-fin croakers, are taken in brackish to fresh water. In general, it may be stated that the croakers, as seen in the markets, run smaller in the vicinity of Beaufort than they do at Norfolk and other points on Chesapeake Bay. The decrease in the average size attained would appear to become more pronounced farther southward, as Pearson (loc. cit.) points out that the croaker has comparatively little value in Texas because of the small size attained. A somewhat similar decrease in size in the more southern parts of the range of the spot is pointed out in the section of this paper dealing with that species.

The croaker is taken at Beaufort virtually throughout the year. It disappears from the shallower waters where fishing operations are carried on during cold snaps, but it returns as soon as the temperature increases. Although this species is not plentiful during the winter and the average size of the individuals is small, they bring a fair price because of the scarcity of other fish at that season. The winter catches of croakers are of importance not only because they keep the local, as well as certain distant markets, supplied with fresh fish at a season when they are scarce, but they are of considerable aid to the fishermen and fish dealers who find the winter a rather lean season. The largest catches of croakers are made during the spring (March, April, and May), when the prices drop. About 15 to 20 years ago the croaker was taken in such large quantities in the spring of the year that the dealers were unable to find a market for all of them, and at times the fish were wasted. The senior author has seen the shores in the bight at Cape Lookout literally covered with dead and decaying croakers, usually of rather small size, which the fishermen had sorted from their catches and thrown away because they could not sell them. This has not happened during recent years, probably largely because of better marketing facilities.

The croaker generally is considered inferior in flavor to many other species, and it seldom commands a fancy price. It is wholesome, however, and it meets a demand for a cheap and a nutritious fish. Locally its importance increases, as already pointed out, because it may be taken during the winter when other fish are scarce.

Young croakers, ranging from recently hatched larvæ only a few millimeters long to fish an inch or so in length, are present in the harbor and its arms throughout the winter, whereas the larger fish generally are scarce or missing in these shallow waters. The croakers that are marketed during the winter, to which reference is made in a foregoing paragraph, are caught chiefly with sink nets (that is, gill nets that are weighted and sunk to the bottom) set usually in about 6 to 7 fathoms of water.

The winter fishery for croakers (and other species) although pursued intermittently for years may be said to be of rather recent origin, as it was not carried on regularly prior to the World War. It is subject to considerable fluctuation. The past winter (1929–30), for example, the fishery was not very remunerative off Beaufort Inlet, and the fishermen transferred their activities chiefly to Ocracoke and Hatteras Inlets, where the fish were more plentiful this season.

It is shown in the foregoing paragraphs that the croaker makes fall and spring migrations, similar to those of the spot, as explained in that section of this paper which contains a discussion of the last-mentioned species. However, the croaker, unlike the spot, is not known to school locally. Its abundance in the spring seems merely to result from extensive migrations from the winter home to the shallow-water feeding grounds for the summer. Another season of abundance occurs in the autumn, which apparently marks the exodus from the summer feeding grounds. It has been stated that large croakers, like large spots, either are entirely absent or very scarce during the winter in the shallower shore waters where fishing operations are carried on. The same situation as in the spot prevails; that is, the very young (the fry) are present in the harbor and its arms throughout the winter. Between cold snaps larger fish, ranging from a few to 6 or 7 inches in length, may be present also. The last-mentioned sizes and somewhat larger ones, apparently, are present nearly always off Beaufort Inlet in water ranging from a few to several fathoms in depth, but are especially numerous during the winter. The very small fry, ranging from about 2 to 10 or 15 millimeters in length, are common along the banks during the winter (the spawning season) and may be taken at least as far offshore as 12 to 15 miles. (How much farther offshore they occur is not known, as collecting was not extended beyond the distance stated.) The somewhat larger young, ranging from 10 to 25 millimeters in length, seem to be much more numerous within the harbor than off Beaufort Inlet and have been taken at various times in almost countless numbers with an otter trawl, the cod end of which was covered with bobbinet.

The winter home of the large or adult croakers remains unknown. However, there is reason to believe that they do not go far away and that they probably are only a comparatively short distance farther offshore than the smaller ones, which inhabit the shore waters to a depth of 6 to 9 fathoms, beyond which fishing operations are not easily extended with the equipment in use. The chief reason for believing that the larger croakers are not far away is the presence of very small fry—only a few to several millimeters in length—throughout the winter. Such small fry, many of them less than 5 millimeters long, are comparatively helpless and could not have swum far. The larger fish taken along the shores during the winter, with few exceptions, obviously are too small to be mature. It seems reasonable to believe, therefore, that the larger, mature fish, producing the eggs from which the young result, are occupying water not a great distance offshore.

The indications are that young croakers, like the young spot, are less sensitive to low temperature than the larger ones, although other factors not understood may be involved. However, in January, 1927, when the water temperature at the laboratory pier dropped as low as 5° C., as described on page 417, many croakers, ranging from 7 to 10 inches in length (also spot, pigfish, and white perch), became numb and drifted ashore within the harbor. No mortality was noticed among the smaller fish at that time. Furthermore, the fry have been taken repeatedly within the harbor in large numbers and in a very active condition during cold snaps when

the larger croakers were absent. It seems rather certain, therefore, that the young are less sensitive to low temperature than larger fish.

SPAWNING

The eggs of the croaker, if taken, have not been recognized. It is highly probable, though, that they have not been secured, as winter towings (that is, during the spawning season of this species) have yielded very few eggs not already known. Furthermore, the writers have seen only one croaker—a female 170 millimeters (6.8 inches) long—taken at Beaufort on October 16, 1926, which contained fairly well developed roe, notwithstanding that numerous fish were examined over a period of several years. J. H. Potter, a local fish dealer of long experience, states that he has seen croakers with roe only in August. Walter Dudley, a local fisherman of many years' experience, claims to have seen croakers with roe from time to time during the fall of the year. Since the young were taken first in September and throughout the winter, croakers with roe, of course, would be expected during the late summer, fall, and winter. Due to the very long spawning season, as shown by the presence of very young croakers in the local waters over a long period of time, it seems probable that no large number of fish become heavily roed at any one time. Furthermore, during the greater part of the spawning season large, mature croakers are very scarce or absent in the shallower waters where the commercial catches and our collections were made. It is not surprising, therefore, that croakers with roe are not seen often locally. Fish in spawning condition apparently are seen more frequently in other localities, as shown subsequently.

Very small fry, less than 10 millimeters in length, appear in our collections for every month from September to May. In other words, recently hatched young were taken every month in the year, exclusive of June, July, and August. The presence of very small fry in the local waters seems to show conclusively that spawning occurs during nine months of the year. The larvæ were not plentiful in September, but they were taken in considerable abundance from October to March, again becoming fewer in April and May. From the comparative abundance of the young in our collections, made over a period of four years, it may be concluded that, although some spawning takes place from September to May, the principal spawning period at Beaufort extends from October to March.

Pearson (1929, pp. 196–198) caught larval and postlarval croakers on the coast of Texas, in Aransas and Corpus Christi Passes, from October to February but they occurred in greatest abundance in November. He concludes, therefore, that in Texas the height of the spawning season occurs in the last named month. Pearson, unlike the present investigators, seems to have had no difficulty in finding ripe adult croakers which, he states, were migrating from the bays to the Gulf during September and October.

Welsh and Breder (1923, p. 180) state, "The spawning season is a long one, extending from August to December and possibly later in southern waters." These investigators had taken males with running milt at Atlantic City, N. J., early in July and, although they had not seen ripe females, they judged by the size of the young caught in Chesapeake Bay and in New York Bay in September, which ranged from 22 to 41 millimeters in length, that spawning must occur as early as August. If the size of the young caught in these more northern waters may be accepted as a criterion, then spawning must begin earlier in Chesapeake Bay and northward than it does in the vicinity of Beaufort, for we have no fry over 9 millimeters in length for Sep-

tember. Pearson (loc. cit.) did not get the fry in Texas until October, when this new year class had "a mode around 1 centimeter."

Hildebrand and Schroeder (1928, p. 284), working with fishes from Chesapeake Bay, agree essentially with Welsh and Breder (loc. cit.) relative to the duration of spawning. The first named authors found croakers with well-developed roe "common" during October and early in November which they believed to be the principal spawning period in Chesapeake Bay. These investigators took specimens of the O class in October which were 10 to 105 millimeters long; in November the range in the length of specimens assigned to this year class was 15 to 116; in December, 11 to 120; in January, 10 to 110 (none reported for February); and in March the range was 32 to 64 millimeters, the largest fish of this year class not being represented. The absence of very small fish in the catches after January suggests that spawning may end in December or January in Chesapeake Bay, whereas at Beaufort fry 3 to 15 millimeters long were common as late as April. (Table 9.) It is of interest to note that Pearson (1929, p. 200, Table 28) took a single specimen around 10 millimeters in length in February, none much less than 30 millimeters in March, and only 2 around 20 millimeters in length in April. It would appear, therefore, from published accounts and the present investigation, that spawning probably begins in August in Chesapeake Bay and northward, in September at Beaufort, and in October in Texas; also, that it probably ends in December or January in Chesapeake Bay and northward, in April at Beaufort, and in February in Texas.

A spawning season of about nine months' duration, as found at Beaufort, must be considered an exceptionally long one. It is by far the longest reproductive period known to the writers among oviparous fishes. Such a long spawning season suggests the possibility that we are dealing with more than one species. It is pointed out in a preceding paragraph that the croakers inhabiting the brackish to fresh waters during the summer run larger in size than those from strictly salt water and, furthermore, they have pinkish to reddish pectoral, ventral, and anal fins, whereas these fins are pale to slightly yellowish in the salt water inhabiting croakers. These differences may be due entirely to environment, but the fish are worthy of a much more detailed study than they have received to date. It would not be surprising if a thorough study would reveal structural differences; possibly somewhat different, yet overlapping, spawning periods; and finally that they are separate and distinct species. The fact that few croakers seem to contain spawn at any one time at Beaufort, as shown in a preceding paragraph, however, militates somewhat against the 2-species theory.

The almost total absence of adult croakers from the shallow shore waters during the greater part of the chief spawning period, as already pointed out, shows almost conclusively that the eggs at that time are not deposited in these shallow waters. The distribution of the very small fry, on the other hand, indicates that the eggs can not be cast at a great distance from the harbor. Young fish, only 3.5 millimeters long, have been taken in the harbor during the winter and smaller ones, some of them slightly under 3 millimeters, have been collected on the outer shores of the banks. These small fry, and especially somewhat larger ones, usually are common to abundant throughout the winter and are quite generally distributed in the waters wherein towings were made, extending from the estuaries through the harbor and a distance of about 15 miles out to sea. Fry only 3 or 4 millimeters in length are helpless creatures; they are without developed fins, and no doubt are wafted from place to place by winds and tides. Therefore, under ordinary weather conditions, with only

about 3 feet of tide, with fairly deep water near shore, and without definite shoreward currents except during flood tides, it seems reasonable to believe that such small fry must have been hatched at a comparatively short distance from the place of capture.

The smallest fry taken (2.8 millimeters long), although probably only a few days old, already had absorbed all the yolk. We judge, from our knowledge of the size of young hatched from ova of various diameters, that the egg of the croaker is somewhat less than a millimeter in diameter. Such small eggs, according to our observations, invariably have a very short incubation period which quite certainly would not exceed a week, even during the coldest weather which prevails locally. It seems unlikely, therefore, that the eggs, if they be buoyant, would drift far during the short incubation period, and it seems reasonable to expect them to be cast at no great distance from the place where they are hatched.

For the reasons advanced in the two preceding paragraphs, it seems rather certain that while the eggs are not deposited within the harbor nor immediately offshore at sea, they are cast at no great distance (probably 30 miles or less) from the outer shores of the banks, which accordingly would constitute the chief spawning ground of the croaker in the vicinity of Beaufort.

Welsh and Breder (1923, p. 180) say, "Spawning takes place in the larger estuaries, such as Delaware and Chesapeake Bays," and Pearson (1929, p. 196) states that on the coast of Texas croakers spawn "in the open Gulf of Mexico near the mouths of the various passes that lead into the shallow bays and lagoons." It seems probable, therefore, that the croaker generally, at least, deposits its eggs in large open waters.

The number of eggs produced appears to be large, for Hildebrand and Schroeder (1928, p. 284) found approximately 180,000 eggs of uniform size in a specimen 15.5 inches long, taken in Chesapeake Bay.

DESCRIPTIONS OF YOUNG

Specimens 2.8 millimeters long.—The mouth is large and nearly vertical; the body is rather deep, the caudal portion being comparatively quite deep, becoming slender only near the tip where it terminates in a sharp point. The dorsal outline is quite regular and rather evenly convex. The visceral mass is rather small. The hind-gut is very evident and it projects rather prominently, but it does not appear to be wholly free distally. Fin folds are visible only along the ventral edge of the caudal portion of the body and around the extremely slender distal part of the tail, and are wholly without indication of rays. Pigmentation consists of a dark crescent-shaped area above the visceral mass where the dark peritoneum is visible through the body wall; also a row of dark points along the ventral edge of the caudal part of the body, and an indistinct dark spot at the point of articulation of the mandible. (Fig. 51.)

Specimens 3.6 millimeters long.—The most conspicuous change, while the fish grows from a length of 2.8 millimeters to 3.6 millimeters, takes place in the development of the tail. The notochord has become bent upward slightly, and rudiments of fin rays are evident in the fin fold below the curved notochord. These rays, although directed obliquely downward, are destined to become horizontal in position and to form the caudal fin. Fin rays are not yet evident elsewhere. The viscera at this age (size) appears more firmly connected with the body and smaller in size than in younger individuals. The hind-gut, however, remains conspicuous and

appears to be connected with the body, both anteriorly and posteriorly, by semi-transparent membranes only.

Specimens 4.0 millimeters long.—At this age (size) the notochord is bent upward prominently and the caudal fin is well formed, the rays now being in a horizontal plane. The upward curve in the notochord gives the tail the appearance of being heterocercal. A thickening of tissues has occurred in the area to be occupied by the base of the anal. A similar development is evident for the base of the soft dorsal. The hind-gut remains prominent and the vent is becoming situated near the anal, the distance between it and the origin of the anal being shorter than the diameter of the eye. The pigmentation remains the same as in the very young, except for a few black chromatophores that now have appeared around the hind-gut. (Fig. 52.)

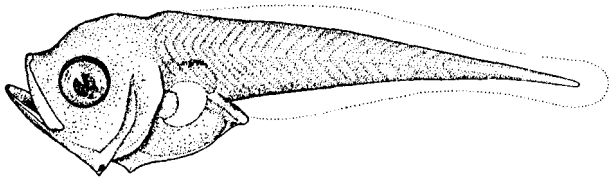

FIGURE 51.—*Micropogon undulatus.* From a specimen 2.5 millimeters long

Specimens 6.0 millimeters long.—At this size the soft dorsal and the anal fins are fairly well developed and it is possible to make a reasonably accurate count of the anal spines and rays. Some of the rays in the dorsal fin (especially the posterior ones), however, are not fully enough formed to permit of enumeration. The caudal fin is well developed. The heterocercal character of the tail is still evident, but in addition to the upward-curved notochord (now ending at the base of the upper rays of the fin), the backbone also has become visible at the base of the caudal. Pectoral fins for the first time are evident, but the ventrals appear to be undeveloped. The mouth is still quite oblique but much less so than in the very young. (Fig. 53 is based on a specimen 7 millimeters long and, therefore, in general a little further developed than the specimen just described.)

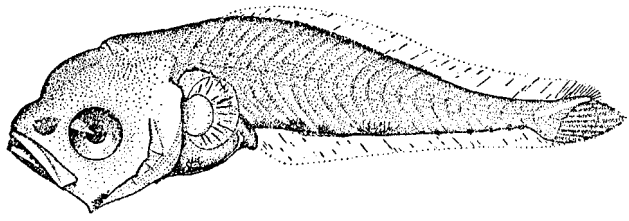

FIGURE 52.—*Micropogon undulatus.* From a specimen 4 millimeters long

Specimens 10.0 millimeters long.—The soft dorsal is now fully formed; the spinous dorsal is only partly developed, as all the spines are not yet visible. The caudal fin is quite long and its posterior margin is strongly convex. The heterocercal character of the tail remains only faintly visible. The pectoral fins are fairly well developed and the ventrals are just becoming visible appearing as slight tufts of membrane. (Fig. 54 is based on a specimen 12.5 millimeters long and, therefore, represents a stage in the development about midway between the 10-millimeter specimen just described and the 15-millimeter one described in the next paragraph.)

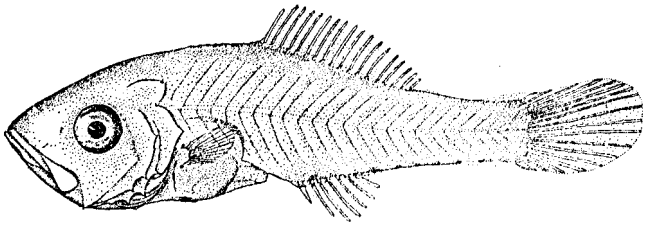

FIGURE 53.—*Micropogon undulatus.* From a specimen 7 millimeters long

Specimens 15.0 millimeters long.—No outstanding changes in development have taken place since a length of 10.0 millimeters was reached. The spinous dorsal is now well enough formed to permit of a reasonably accurate enumeration of the

spines, although the posterior ones (which appear last) are still very short and feeble. The heterocercal character of the tail, described for smaller specimens has disappeared completely. The caudal fin has become longer and more pointed; the anal fin is well developed and the second spine has become much enlarged; and the pectorals and ventral have become much larger and now have definite rays. Prominent serrations are present on the opercle and preopercle. General pigmentation has not yet taken place. The blackish spot at the articulation of the mandible, described for specimens 2.8 millimeters long is still present; a row of 4 black chromatophores is present on the median line between the isthmus and the vent; a prominent black chromatophore lies at the base of the first soft ray of the anal; a row of 5 is situated on the median line between the end of the anal and the base of the caudal; and about 3 black chromatophores are situated on the base of the caudal fin. The rest of the body remains unpigmented.

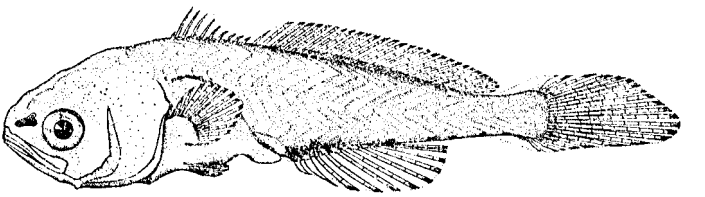

FIGURE 54.—*Micropogon undulatus.* From a specimen 12 5 millimeters long

Specimens 21.0 millimeters long.—The body at this age (size) as in younger ones, is somewhat more slender than in adults, the depth being contained in the length about 3.4 times, whereas in adults it is contained about 2.9 times in the length. The mouth is still oblique (although much less so than in very small specimens) and terminal. Pigmentation has progressed somewhat but it has not become general. In addition to the markings described for specimens 15.0 millimeters long, specimens 21.0 millimeters long have a row of about 6 dark chromatophores, extending from the nape to the end of the dorsal base and another row of about 4 dark spots along the middle of the side, between the point of the pectoral and the base of the caudal. (Fig. 55.)

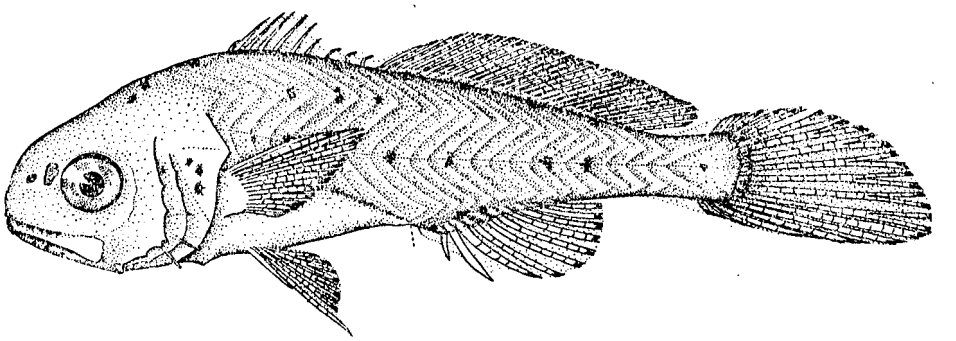

FIGURE 55.—*Micropogon undulatus.* From a specimen 20 millimeters long

Specimens 30.0 millimeters long.—Scales at this size (age) are becoming visible for the first time, and they are present and partly formed nearly everywhere on the head and body. The mouth is nearly but not quite horizontal and slightly inferior and the spines (serrations) on the preopercle and subopercle are large and sharp. The middle rays of the caudal fin are much produced, being nearly equal to the length of the head. General pigmentation has not yet taken place but dark chromatophores have multiplied greatly in number and are scattered over most of the body, the largest ones being visible with the unaided eye. Barbels on the mandible appear

to develop very unevenly, being evident in some specimens of this size, whereas they often can not be found in specimens considerably larger. (Fig. 56.)

Specimens 50.0 millimeters long.—Many of the characters of the adult have been acquired at this size, yet the young fish in general appearance is rather strikingly different from the adult. The caudal fin is still long and pointed, the snout does not yet project beyond the premaxillaries; and the mouth remains a little oblique. A row of barbels on the chin generally is evident and the scales are quite fully formed.

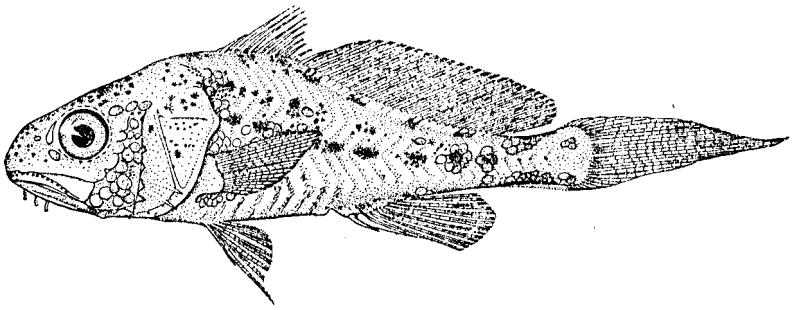

FIGURE 56.—*Micropogon undulatus.* From a specimen 32 millimeters long

They have free edges and are beginning to show their ctenoid character. Pigmentation has progressed fairly rapidly since the last-described age (length 30.0 millimeters), but it has scarcely become general. When viewed with the unaided eye, there are now present principally three rows of dark spots; one along the edge of the back, forming with their fellows of the opposite side more or less saddlelike blotches; another row occupies the middle of the side; and a third row lies between the two rows already described.

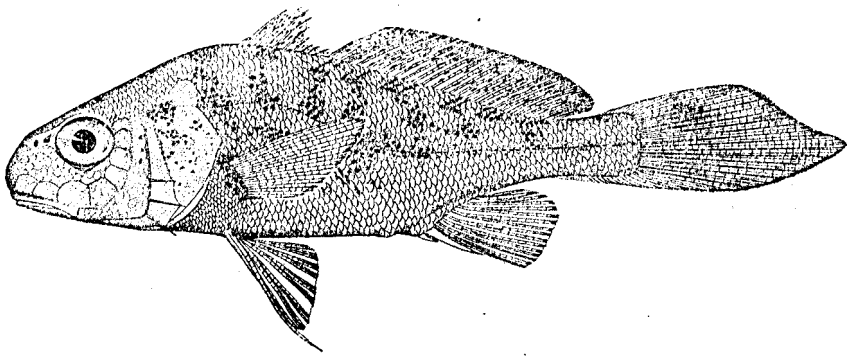

FIGURE 57.—*Micropogon undulatus.* From a specimen 65 millimeters long

Specimens 65 millimeters long.—The mouth is horizontal, the snout projects slightly beyond the premaxillaries; and the lower jaw is definitely included. The back is less prominently elevated than in the adult and the ventral outline is scarcely as straight. The caudal fin remains pointed, but is becoming proportionately shorter. Pigmentation has become general, the sides are largely silvery, shading into a silvery-gray and green toward the back and pale silvery underneath. A more or less definite dark blotch is evident on the opercle; the other dark markings described for 50-millimeter specimens have increased in size and are about to become connected and to form wavy bars, characteristic of the adult. (Fig. 57.)

Specimens 110 millimeters long.—It is not until the fish attains a length of 100 millimeters or more that it acquires the characteristic shape and color of the adult. At a length of 110 millimeters the back is prominently elevated; the ventral outline, from the chin to the vent, is straight; the snout projects prominently beyond the inferior horizontal mouth; and the margin of the caudal fin is approaching the slightly double-concave shape of the adult with the upper and middle rays longest. Although serrations on the opercle and preopercle are less prominent than for a somewhat smaller size they are larger than in the adult. The characteristic color of the adult, including oblique wavy bars (dark in preserved specimens, brassy to brownish in life) on the sides, a dark blotch on the opercle and another at the base of the dorsal, is well developed. The fish would be recognized readily at this size by anyone who knows the adult. (Fig. 58.)

DISTINGUISHING CHARACTERS AMONG YOUNG SCIÆNIDS

The extremely close resemblance between young croakers and spots makes the following comparison appear of value in identifying small specimens. Unfortunately

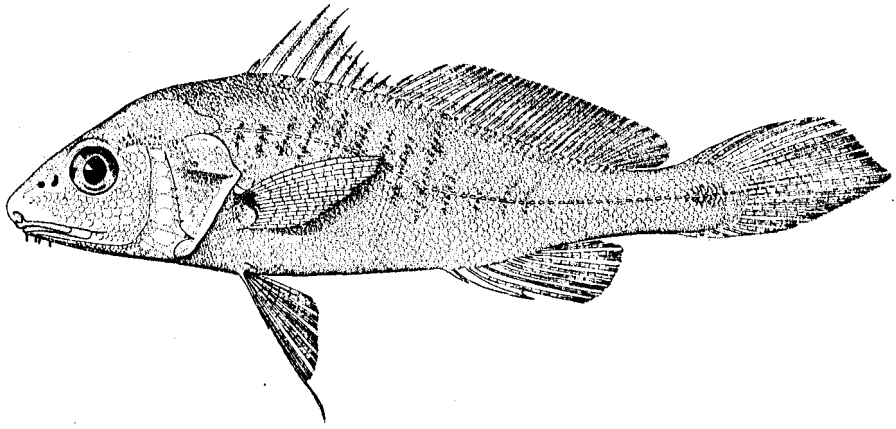

FIGURE 58.—*Micropogon undulatus*. From a specimen 110 millimeters long

many of the differences are only of degree and are difficult to apply unless specimens of like size of both species are available for comparison.

SPOT	CROAKER
LENGTH, 2.5 MILLIMETERS	
Caudal portion very slender, an abrupt break occurring in the ventral contour between the abdominal and caudal parts of body.	Caudal portion of body notably deeper, the break in the ventral contour much less pronounced.
LENGTH, 3.5 MILLIMETERS	
General development progressing slowly; no indications of rays in the caudal and dorsal fins.	General development a little further advanced; indications of rays in the caudal and dorsal fins present.
Notochord not bent upward posteriorly.	Notochord bent upward posteriorly.
Caudal portion of body very slender.	Caudal portion of body deeper, tapering more strongly posteriorly.
Eye comparatively large.	Eye smaller. This difference evident only when specimens of even size are compared.

SPOT—continued	CROAKER—continued
LENGTH, 6 MILLIMETERS	
Anal rays not definitely developed, the articulations between the rays and the interhæmal spines, however, are evident and, although a definite count generally can not be made, it is clearly evident that the anal base is a long one.	Anal fin developed about as in the spot. Although a definite count usually can not be made, it is evident that the fin base is shorter than in the spot.
Caudal fin imperfectly developed and short.	Caudal fin somewhat better developed, longer, and more pointed.
Body at origin of anal quite slender in proportion to the anterior part of body.	Body at origin of anal proportionately much deeper.
Vent usually more than an eye's diameter in advance of anal.	Vent always less than an eye's diameter in advance of anal.
Eye large.	Eye somewhat smaller.
LENGTH, 10 MILLIMETERS	
Body at origin of anal comparatively slender, tapering gradually to caudal peduncle.	Body at origin of anal deeper, tapering more abruptly to caudal peduncle.
Anal fin with II, 12 or 13 rays, the spines rather weak.	Anal fin with II, 7 or 8 rays, the spines, especially the second one, much larger and stronger.
Caudal fin moderately long and round.	Caudal fin longer and strongly pointed.
Dorsal spines largely undeveloped; that is, they are just beginning to appear and have no free points.	Dorsal spines better developed, with free points.
Eye comparatively large, nearly as long as snout.	Eye smaller, shorter than snout.
Vertebræ 10 or 11+14 or 15.	Vertebræ 8 to 10+15 or 16.

The similarity of the young spot and croaker (*Leiostomus xanthurus* and *Micropogon undulatus*) on the one hand and the red and black drums (*Sciænops ocellatus* and *Pogonias cromis*) on the other is pronounced and separation is difficult until a sufficient size (about 6 to 10 millimeters) is attained to admit the enumeration of the fin rays. Specimens less than 5 millimeters long of the red and black drums are not available for comparison. However, at a length of 5 millimeters the drums generally may be separated from both the spot and croaker by the presence of dark markings along the back which are entirely wanting in the spot and croaker of this size and for some time afterwards. According to Pearson (1929, pp. 139 and 158) the dark chromatophores appear on the upper parts of the body of both drums at an early age and, therefore, may be used, also, in identifying young less than 5 millimeters long of the species under consideration. Furthermore, at a length of about 3 millimeters a rather definite row of dark chromatophores, about 3 to 7 in number, usually appears along the ventral edge of the tail (caudal peduncle after the anal fin is developed) in the spot and croaker. These color markings seem to be missing in the drums. In specimens about 7 millimeters long and until pigmentation becomes general the drums are much more profusely spotted than the other two species.

In addition to the differences in color markings already noted, the spot and croaker have a somewhat deeper body at a length of 5 millimeters and a slightly larger eye than either species of drum. The differences are evident only when specmens of like size are compared and are not readily used in making identifications.

It is understood, of course, that the most reliable characters for the identification of all of these species are the ray counts of the dorsal and anal fins as soon as these members are sufficiently developed to make an enumeration possible. On this basis the spot is readily separated from the other three species by the long anal fin which consists of 2 spines and 12 or 13 soft rays, whereas the croaker and red drum each have only 8 and the black drum only 6 or 7 soft rays in addition to 2 spines. The croaker, red drum, and black drum all differ in the number of dorsal rays, having respectively in the order named I, 28 or 29; I, 23 to 25; and I, 20 to 22 rays.

The only other member of the family Sciænidæ from the vicinity of Beaufort of which the larval development has been studied is the white perch (*Bairdiella chrysura*). The larvæ of this species are readily recognized at a very small size (2.5 to 3 millimeters) by the prominent black coloration over the abdominal mass which quickly develops into a broad, indefinite crossbar.

DISTRIBUTION OF YOUNG

Recently hatched croakers are quite generally distributed throughout the local waters during the winter, or spawning season. They have appeared in towings made as far as about 15 miles offshore (beyond which collecting was not extended) as well as within Beaufort Harbor and adjacent estuaries. The very small fry, only a few to several millimeters long, appear to be more numerous at offshore collecting stations than within the harbor, but for somewhat larger fish (10 millimeters and over) the reverse seems to be true.

The fry, like the adults, as shown by townet collections, dwell principally on the bottom. In towings made with two 1-meter nets hauled simultaneously at the surface and on the bottom, the fry occurred in 23 surface and in 119 bottom collections.

GROWTH

In the present studies an effort was made to obtain information relative to the development and rate of growth of the croaker during the first year. However, older fish often were obtained in the collections, and such fish were measured and the data are included in frequencies in Table 9. Table 10 and Figure 59 include only the measurements of the fish assigned to the O class. Due to the very long spawning period, it is not surprising that the year classes intergrade. Our collections for some of the months are not nearly as complete as desirable, and therefore the measurements are sufficient to show only in a general way the rate of growth of the young until some of them, at least, have attained an age of 12 to 14 months.

It is quite evident that the larger representatives of the O class are missing for several months. For other months intermediate sizes are not included. This seems to be due largely to the methods of collecting, for it was only during the later

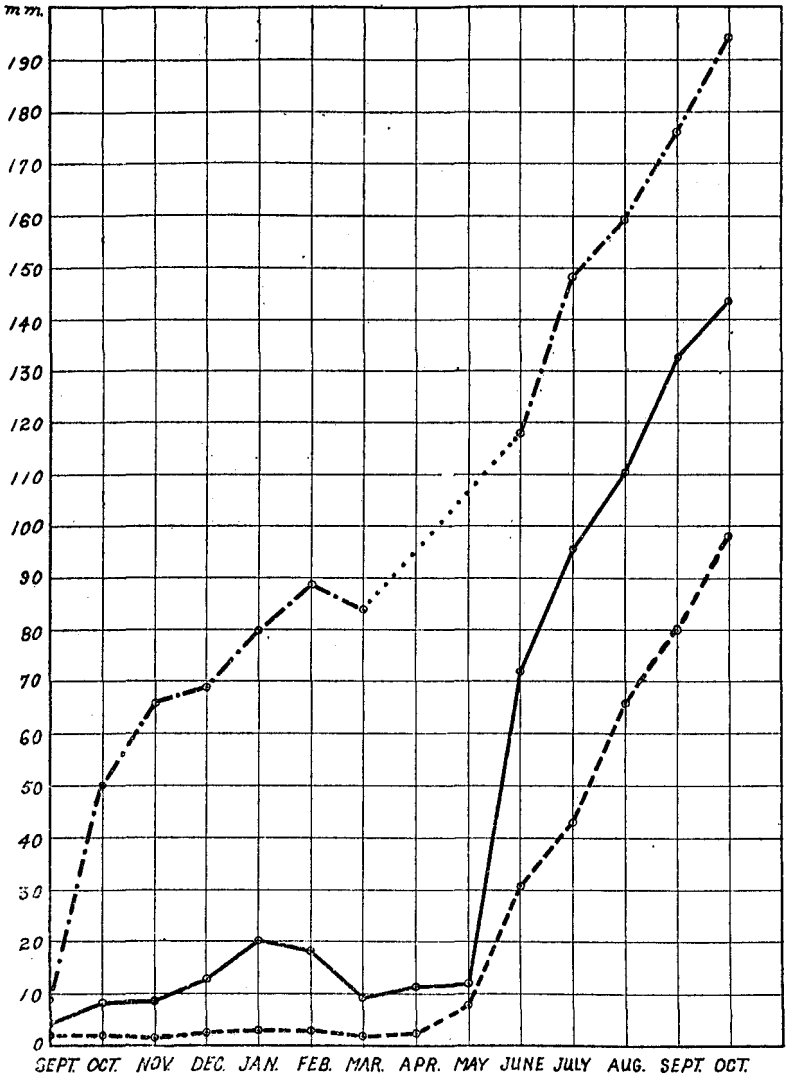

FIGURE 59.—Growth curve of young croakers based on Table 10. Solid line, average of all fish; broken line, smallest fish; dot-and-dash line, largest fish

months of the work that proper methods were developed for collecting fishes too large to be captured with 1-meter townets, yet too small to be caught with the ordinary collecting seines and trawls.

TABLE 9.—*Length frequencies of 14,184 croakers*

[Measurements to nearest millimeter, grouped in 5-millimeter groups]

Total length	September	October	November	December [1]	January [1]	February [1]	March [1]	April	May	June	July	August
0–4	23	95	36	32	3	2	10	8				
5–9	11	397	404	122	39	38	24	28	2			
10–14		23	278	208	343	427	244	57	22			
15–19		10		10	46	432	59	1	3			
20–24		42			4		4		1			
25–29		13			17	2						
30–34		4		1	10					1		
35–39		4		1	9					4		
40–44			1	9	23	3	1			10	1	
45–49				7	32	9	5			16		
50–54		1		5	20	14	22			13	1	
55–59				4	2	13	36			10	2	
60–64				2	6	9	21			24	4	
65–69			1	6	8	6	7			25	3	1
70–74					2	6	3			30	20	8
75–79					5	9	6			30	50	10
80–84	1				1	9	9			20	89	23
85–89			1	2	2	3				13	139	33
90–94	3			2	2	1	1			12	156	77
95–99		1		5	4	3	4			6	134	95
100–104	7	2		3	22	4	7	1		9	120	190
105–109	7	4		7	15	12	9			3	108	161
110–114	11	12	6	3	16	21	13	1		3	60	176
115–119	23	26	10	8	14	20	8	3		6	28	140
120–124	40	38	13	8	21	27	28	5		1	17	89
125–129	35	52	25	11	22	31	23	1			12	52
130–134	64	74	39	12	39	51	46	9		2	6	60
135–139	75	77	48	9	67	68	74	10		2	5	41
140–144	56	80	46	12	71	104	112	23		3	4	19
145–149	26	62	72	23	57	96	149	34		5	2	19
150–154	9	52	56	20	76	126	221	66		5	6	12
155–159	7	31	63	32	52	144	253	42		9	3	4
160–164	7	28	50	46	52	146	296	49		16	2	5
165–169		25	35	31	44	148	297	45		21	1	7
170–174	2	17	38	22	53	124	246	56		19	3	8
175–179	1	20	30	16	42	81	209	31		15	4	7
180–184		17	32	13	54	76	155	33		24	3	14
185–189		10	29	7	43	44	115	13		11	4	19
190–194	1	2	18	2	36	35	94	11		13	4	10
195–199	4	7	19	4	19	29	68	5		16	3	18
200–204	3	7	25	2	15	23	45	6	2	7	4	14
205–209		5	20	1	9	17	43			5	1	6
210–214	3	7	15	1	2	15	27	4	2		1	13
215–219		4	14		1	16	10	2		2		7
220–224	2	9	10			9	9	1		4	1	2
225–229	1	2	4			4	6		1	2		7
230–234	2	8	6		1	2	3	3		3		1
235–239	2	6	4				1	1	1	3	1	2
240–244	2	7	2					1		3		
245–249	1	2	1			1		1				
250–254	2		5			2	1	1				1
255–259			3	1								1
260–264	3	1	3			1				1		
265–269		1	2		1		1					
270–274						4				1		
275–279	1		1									
280–284			1							1		
285–289												1
290–294		1				1	1					

[1] The apparent break in the frequency of the O class for the months of December, January, February, and March probably is due to the mode of collecting, for it was only during the last season of the 4-year investigation that a successful method was found for collecting fish too large to be caught in meter townets, yet too small to be taken with ordinary collecting seines and trawls.

TABLE 10.—*Monthly summaries of length measurements of 7,286 croakers during the first year, or so, of life*

Month	Fish measured	Smallest	Largest	Average	Month	Fish measured	Smallest	Largest	Average
		Millimeter	*Millimeter*	*Millimeter*			*Millimeter*	*Millimeter*	*Millimeter*
September	34	2.0	9.0	4.2	April [1]	94	2.5	15.0	11.7
October	589	2.0	50.0	8.2	May [1]	28	8.0	25.0	12.1
November	720	1.5	66.0	8.8	June	236	31.0	118.0	72.1
December	406	2.5	69.0	13.0	July	961	43.0	148.0	95.8
January	570	3.0	80.0	20.2	August	1,210	66.0	159.0	110.6
February	983	3.0	89.0	18.2	September	374	80.0	176.0	132.7
March	451	2.0	84.0	9.4	October	630	98.0	194.0	143.4

[1] An insufficient number of specimens was secured to show the rate of growth, and the larger representatives of this year class obviously are missing.

The data show that the young fish gain considerable growth during the winter, for some of the larger representatives of the O class, according to our measurements, attain a length of 75 to 80 millimeters (3 to 3.2 inches) in January when, at most, only 4 months old, and the average length for 570 specimens measured is 20.2 millimeters (¾ inch). In June, when the oldest ones are about 9 months old, some of them have attained a length of 100 to 118 millimeters (4 to 4.6 inches) and the average length for 236 specimens measured is 72.1 millimeters (3 inches). In October, when the earliest young of this year's class are about a year old, the largest, according to our data, have attained a length of 175 to 194 millimeters (7 to 7.8 inches) and the average length for 630 specimens is 143.4 millimeters (5.7 inches).

The rate of growth, as shown by our data, does not differ greatly from that found in Texas by Pearson (1929, p. 198 to 200), who indicates, for the month of May, a mode for the O class at 80 and for the I class at 180 millimeters. Unfortunately, our data for May are too incomplete for comparison, but for June they show a mode at 70 for the O class and 175 millimeters for the I class. Therefore, the data indicate a somewhat slower rate of growth in North Carolina than in Texas.

The present writers did not make a special effort, as stated elsewhere, to determine the rate of growth of the croaker after an age of about 1 year is attained and have nothing to offer, other than the measurements of the older fish contained in Table 9. Pearson (loc. cit.) working with Texas fish found a modal length in May of 240 millimeters (9.4 inches) for fish in their third year and 280 millimeters (11 inches) for those in the fourth year. Welsh and Breder (1923, p. 183) working with Atlantic coast fish, taken from New Jersey to Florida, indicate a modal length of 220 millimeters (8¾ inches) for fish in their third winter and 265 millimeters (10½ inches) for those in the fourth winter.

It is noteworthy that the croaker and the spot, both winter spawners, whose young appear to be similar in habits and occupy very largely identical feeding grounds, grow about equally fast during the first several months of life. It has been shown, both for the spot and the croaker in Tables 8 and 10, that the maximum size attained by these species at 1 year of age, for example, is about 175 to 190 millimeters (7 to 7.6 inches). Our records of lengths and weights, furthermore, show that examples of equal size of the two species at this age are nearly equal in weight; that is, fish 7.5 inches long weigh close to 3 ounces each. These fish in part, at least, enter into the commercial catches made during the winter, with sink nets set off Beaufort Bar, as reported elsewhere in this paper.

AGE AT SEXUAL MATURITY

The present writers have little to offer on this subject, other than that the largest representatives of the croakers a year old generally have the appearance upon dissection of being sexually quite immature. Yet, the single specimen seen with roe (see p. 433) was only 170 millimeters (6.8 inches) long and, therefore, with respect to size falls into the 1-year class, as shown by Table 10 and Figure 59. Welsh and Breder (1923, p. 183) say, "Maturity is reached at the age of 3 or 4 years." Pearson (1929, p. 201), on the other hand, found "matured" croakers in Texas only 140 millimeters (5½ inches) long, which he judged to be in their second year. He concludes, "It appears, therefore, that sexual maturity must be reached and spawning take place for the first time at the end of the second year of life."

The age attained by the croaker, or its duration of life, remains undetermined

FOOD AND FEEDING HABITS

The croaker, with its inferior mouth and chin barbels, is at once marked as a bottom feeder. The habit of dwelling on the bottom, which no doubt is correlated with bottom feeding, appears to apply equally as well to the young (fry) as to the adults, as shown by the much more frequent catches made at the bottom than at the surface (see p. 441), even though the fry do not have an inferior mouth nor barbels.

Not many stomach examinations were made during the present investigation. However, the literature contains rather full accounts of the foods utilized by croakers of all sizes, except small ones, less than 17 millimeters in length. Welsh and Breder (1923, pp. 183–184) found mollusks, ostracods, copepods, polychæte worms, and fish—named in the order of their apparent importance—in the alimentary tract of 45 specimens, taken in Chesapeake Bay in December, ranging in length from 17 to 42 millimeters. Examples 42 to 62 millimeters long, collected in Winyah Bay, S. C., in July, had utilized a few mollusks and fish and had fed abundantly on polychæte worms. In addition they had utilized amphipods, small crabs, a few shrimp, and unidentified larval crustaceans. The octracods and copepods, abundantly utilized by the smaller fish, were missing in these larger examples. Twenty-four individuals, 90 to 170 millimeters long, taken in Cape Canaveral Bight, Fla., in December had fed on echinoderms, shrimp, and polychæte worms, and 8 examples, 120 to 160 millimeters long, taken in Cape Lookout Bight in December, had fed on polychæte worms and mollusks.

Hilldebrand and Schroeder (1928, p. 284) report for 392 examples (mostly adults), taken in Chesapeake Bay at various times over a period of about two years, the following foods named in the order of their apparent importance: Crustaceans, annelids, mollusks, ascidians, ophiurians, and fish. The first three foods named appeared to be important, whereas the others occurred as mere traces. Only 3 of the 392 croakers examined had fed on fish. It is pointed out, furthermore, that the croaker utilizes as food principally forms that have no direct commercial value.

Pearson (1929, p. 203) reports the following: "Of 60 Texas croakers 21 to 35 centimeters (8.2 to 13.7 inches) long, 55 per cent had eaten shrimp; 13 per cent, annelids; 12 per cent, fish; 5 per cent, crabs; 5 per cent, mollusks; and 10 per cent had a mixed diet. Of 19 fish 14 to 20 centimeters (5.5 to 7.8 inches) long, 21 per cent had eaten shrimp; 63 per cent, annelids; 5 per cent, fish; and 11 per cent had a mixed diet."

In addition to the foods reported in the literature cited the croaker during the summer not infrequently includes Balanoglossus, a wormlike chordate, strongly scented with the odor of iodoform, in its diet. The odor and taste of Balanoglossus penetrates the flesh of the fish, making it quite unpalatable. Such fish are described, locally as being "ticky."

PAREXOCŒTUS MESOGASTER (Bloch). Short-winged flyingfish

This flyingfish is known from all tropical seas. It was first recorded from Beaufort by Radcliffe (1914, p. 414), presumably from specimens taken off Beaufort Inlet by the *Fish Hawk*. In fact, all the many specimens from the vicinity of Beaufort at hand were collected by that vessel when operating from the Beaufort stations during the summer months from 1913 to 1915, and none have been taken during recent collecting expeditions.

This flyingfish, when adult, is characterized by the rather short pectorals which reach only to about the middle of the dorsal base and are colorless. The dorsal and anal bases are equal in length, and the snout is short and blunt. The adult characters are acquired by the young fish at a comparatively small size. The maximum size attained is only about 175 millimeters (7 inches). Its life history seems to be little known.

SPAWNING AND DEVELOPMENT OF YOUNG

The eggs of this species have not been taken or, at least, not recognized. Very small fry, ranging from 3 millimeters upward, were common 20 miles and more off Beaufort Inlet in August and September, 1914. Fry only 3 millimeters or so in length, obviously, are very young and it may be concluded from their presence on the coast of North Carolina that spawning takes place there during the summer.

Specimens 3 millimeters long.—The body is rather more compressed at this size than in the adult, although it is already elongate and shapely. The mouth is vertical and the eye is very large. The vent is situated far behind the middle of the body and all the fins already are evident, although only the caudal contains definite rays. Some specimens at this size already are profusely dotted with black. (This size was not drawn, because no perfect specimens are at hand, and, furthermore, the difference between a 3 and a 5 millimeter fish, which was drawn, is not pronounced.)

Specimens 5 millimeters long.—The body has become a little more robust since a length of 3 millimeters was attained and the caudal fin, which was nearly square previously, now has the lower rays somewhat produced. Rays have definitely developed in the pectoral fins, but none is clearly outlined in the ventrals—dorsal and anal. The development of rays in the pectoral fins prior to their appearance in the dorsal and anal is unusual, as the reverse apparently is true in most fishes. Early development of the pectorals probably takes place because they are destined to become very large fins. Pigmentation varies considerably among preserved specimens. The majority of them appear to be rather profusely dotted with black, although others are quite plain brownish. (Fig. 60.)

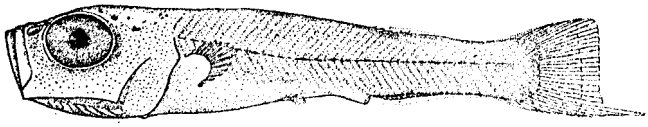

FIGURE 60.—*Parexocoetus mesogaster.* From a specimen 5 millimeters long

The vertical mouth, the very large elongate eye, the almost straight margin of the tail with a few of the lower rays produced, and the presence of dark dots at least on the head are the most outstanding characters of the larval *Parexocoetus mesogaster.*

Specimens 10 millimeters long.—The body is elongate, somewhat compressed, and proportioned much as in the adult. The head is comparatively small and slightly depressed above. The mouth is very strongly oblique but not quite vertical, as in the smaller fry. The fins are all well developed; the pectoral fins are about two-thirds the length of the head; the ventral fins are large, reaching nearly or quite to the origin of the anal; the caudal fin is short above, the rays increasing gradually in length to about the second or third from the lowermost one, the longest rays being nearly twice as long as the shortest. The margin of the fin, therefore, is almost straight and rather strongly oblique. Pigmentation consists of a general brownish cast, the head being paler than the rest of the fish, and the entire body is profusely dotted with black chromatophores, which are crowded along the median line of the side, forming an almost continuous dark line. A few chromatophores also are present on the base of the caudal and extend slightly on the base of the longest rays, the fins

being otherwise plain translucent. Some of the specimens at hand are much darker than others, which, however, may be due largely to the method of preservation. The darker-colored specimens appear to be less profusely spotted than the lighter ones. (Fig. 61.)

Specimens 20 millimeters long.—Scales first become evident at a length of about 18 millimeters, although not shown in the accompanying drawing (fig. 62), and at a length of 20 millimeters the body is fully scaled. The pectoral fins are equal to or a little longer than the head, the ventral fins reach the vent, the dorsal fin is high and the rays are slender, reaching slightly beyond the base of the caudal when deflexed. The middle rays of the caudal fin are now a little shorter than the upper ones, making the margin of the fin slightly concave. The upper lobe is short and rounded and the lower lobe is much longer but also rounded. The characteristic shape of the fin in the adult, therefore, is closely approached at this early age. Two short barbels, or dermal flaps, usually, although not always (unless they have been lost in some of the preserved specimens), are present at the symphysis of the lower jaw. Pigmentation remains about as in 10-millimeter specimens, except that dark spots are developed on the ventral and dorsal fins, the dorsal fin being mostly black in some specimens. In some individuals the posterior rays of the anal fin also are dark. (Fig. 62.)

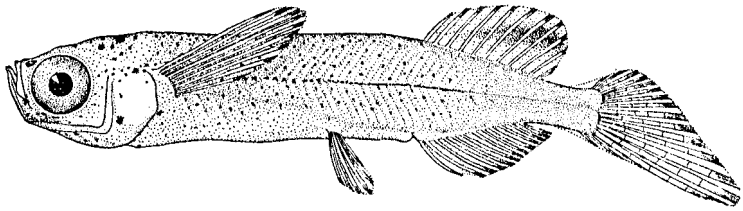

FIGURE 61.—*Parexocoetus mesogaster.* From a specimen 11 millimeters long

Specimens 35 millimeters long.—The body has the shape and form of the adult. A slight keel, in which the lateral line is situated, is present along the ventral edge of the body as in the adult. Two short dermal tentacles usually are evident at the tip of the lower jaw. It is quite probable that normally two tentacles are present.

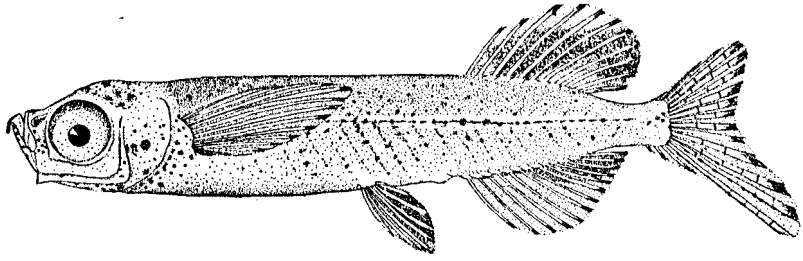

FIGURE 62.—*Parexocoetus mesogaster.* From a specimen 18 millimeters long

However, they are delicate and no doubt sometimes are lost in preserved specimens. The pectoral fins reach slightly past the base of the ventrals or about to the origin of the dorsal. The ventral and dorsal fins are proportionately as large as in the adult, for the ventrals reach to or a little past the origin of the anal and the longest rays of the dorsal reach a little beyond the base of the caudal. The caudal fin with its long lower lobe and upper short one is slightly forked and shaped virtually as in the adult. Pigmentation remains about the same as in 20-millimeter specimens, except that the dark chromatophores on the body have decreased slightly in size and probably in number and have become profuse on the large pectoral, which is plain translucent in fish 20 millimeters and under in length. (Fig. 63.)

Specimens 45 millimeters long.—At this size the fish virtually has all the characters of the adult. While the body acquires essentially the shape and form of the adult at a much smaller size, the adult colors are not acquired until the fish attains a length of about 40 to 50 millimeters. At about this range in size the back becomes dark bluish, the sides silvery, and the underneath parts pale. In the meantime, the dark chromatophores, present on the body in smaller fish, have disappeared. The pectoral fin has increased further in length and now reaches well past the origin of the dorsal, although not opposite the middle of the dorsal as in the adult. Two dermal flaps attached to the tip of the lower jaw, first noticed in specimens 20 millimeters in length, are now about half as long as the eye and, being dark in color in contrast with a light background, they are readily visible.

Specimen 85 millimeters long.—The differences between a fish of this size and those that are about 45 millimeters long is not pronounced. However, at a length of 85 millimeters the pectoral fin has attained the proportionate length of the adult and now reaches opposite the middle of the dorsal base. The dermal flaps at the tip of the lower jaw have increased in length, as shown by the single specimen of this size in the collection, and are nearly as long as the eye. In 20 adult specimens, ranging from 130 to 140 millimeters in length, these flaps are entirely missing. The size

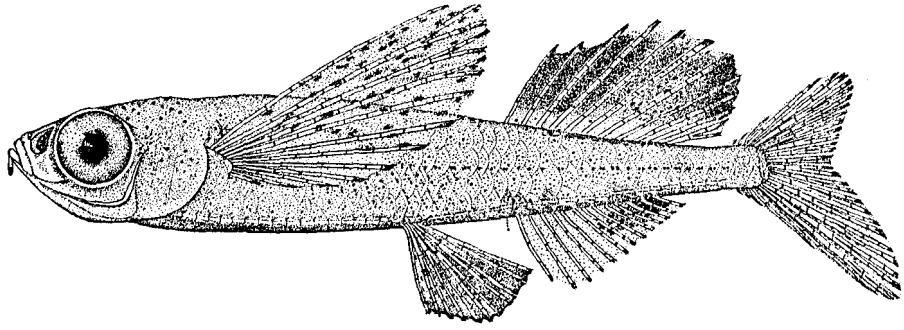

FIGURE 63.—*Parexocetus mesogaster.* From a specimen 36 millimeters long

attained by the fish at which the maximum stage of development of the dermal flaps is reached can not be stated at this time, because the collection contains only one specimen (85 millimeters long) between sizes ranging from the young 45 millimeters long to the adult 130 to 155 millimeters long. Nor is it known when they again disappear. The use, or significance, of these interesting structures, not present in the very young and again disappearing in the adult, is not understood.

DISTRIBUTION OF YOUNG

The numerous specimens of young *Parexocœtus mesogaster* in the present collection all were taken at the surface by the *Fish Hawk*. Since nets suitable for taking the fry were not hauled on the bottom in those areas where the young were taken at the surface, it can not be definitely stated that the young, like the adults, are chiefly pelagic. It is probable, however, that this fish spends its entire life at or near the surface of the ocean.

The young were all taken at stations a considerable distance offshore; that is, in the vicinity of Cape Lookout Lightship, the blackfish (sea bass) grounds, and in the Gulf Stream. Intensive collecting during the past three years (1927 to 1929) with 1-meter townets along the outer shores of the banks and out at sea a distance of about 12 to 15 miles, has yielded no specimens of this flyingfish. Neither were

any of the adult specimens at hand taken near the shore. It seems probable, therefore, that this species, on the coast of North Carolina at least, lives at some distance (20 miles and more) from the shore. It is judged from the numerous specimens secured by the *Fish Hawk* that this small flyingfish is common off the coast of North Carolina during the summer.

The rate of growth of this fish, its food and feeding habits, its age at maturity, its range of flight, and many other things about its life history remain unknown.

CYPSELURUS FURCATUS (Mitchill). Four-winged flyingfish

The four-winged flyingfish is known from all warm seas and it occurs on the Atlantic coast of the United States as far north as Cape Cod. However, there is no published record of its occurrence at Beaufort. The 50 specimens in the present collection, with a single exception, were taken off Beaufort by the *Fish Hawk* during July, August, and September, 1914 and 1915, when that vessel was used in carrying on investigations from the Beaufort laboratory. Some of the specimens were taken near Cape Lookout Lightship, others on the sea-bass (blackfish) ground, and a few in the Gulf Stream. A single specimen, about 10 millimeters long, was taken on July 20, 1927, about 6 miles from Cape Lookout. This is the only specimen secured during the systematic weekly collecting trips conducted from 1927 to 1929 and extending from Beaufort Inlet to Cape Lookout and offshore 12 to 15 miles. Neither have the adults been secured near the shores nor within the harbor.

This four-winged flyingfish, when adult, is characterized chiefly by its enlarged ventrals as well as pectorals, the short anal with only about nine rays, and by the pearly-white spot near the base of the ventrals. Many of the adult characters, exclusive of the coloration, as pointed out in the descriptions of the young, are developed at an early age. The maximum size attained is only about 150 millimeters (6 inches). The life history is little known.

SPAWNING

The eggs have not been taken, or at least not recognized. The smallest young in the present collection are about 5 millimeters long. Young of this size, as well as somewhat larger ones, were taken during July, August, and September. It may be concluded, therefore, that spawning off the coast of North Carolina takes place during the summer. Since none of the young were taken very near the shore and the majority of them were secured from 20 to 30 miles offshore, it seems probable that spawning takes place at some distance from the shores.

DESCRIPTIONS OF YOUNG

Specimens 5 millimeters long.—The head is large, robust, and depressed, and the body is notably compressed, the shape at this early age being rather strikingly similar to that of the adult. However, the head is proportionately somewhat broader and more robust, and the body is more strongly compressed. The mouth is very strongly oblique to nearly vertical; the eye is relatively very large and elongate, and the gill covers are exceptionally well developed for such a small fish. The fins are all present, the caudal and pectorals showing a more-advanced stage of development than the other fins. Unfortunately the fins are more or less frayed in our specimens of this size, and their exact shape can not be definitely determined and may not be accurately represented in the accompanying drawing. The ground color of preserved specimens is pale brown, and the entire fish is dotted with large, black chromatophores. Develop-

ment is far advanced for such a small fish, as some of the adult characters already are evident. In general, the state of development in this flyingfish at a length of 5 millimeters is far ahead of most species studied. (Fig. 64.)

The very oblique mouth, the excessively large eye, and the very prominent dark chromatophores that are quite generally distributed over the body are outstanding characters. The early development of the fins makes an enumeration of the fin rays possible at a remarkably small size.

Specimens 8 millimeters long.—The head is rather less robust than in specimens 5 millimeters long, and the body is a little less strongly compressed, the shape and form being more nearly as in the adult. The mouth is strongly oblique but less so than in smaller fish. The fins have developed rapidly; the pectoral fins are relatively large and broadly rounded, being about twice as long as the eye; the ventral fins reach to, or a little beyond, the origin of the anal; and the margin of the caudal fin is slightly rounded, or more usually nearly straight and oblique, for the lower rays are longer than the upper ones. The color remains essentially as in the 5-millimeter specimen. (Fig. 65.)

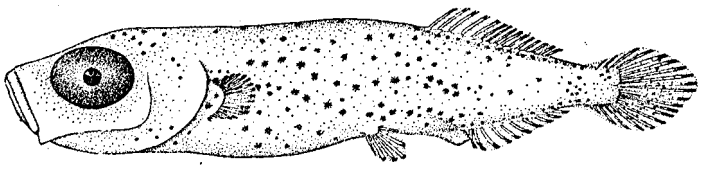

FIGURE 64.—*Cypselurus furcatus.* From a specimen 5 millimeters long

Specimens 12 millimeters long.—The principal advancement in development has taken place in the fins. The pectorals are notably longer than the head and reach nearly or quite to the origin of the dorsal. The ventrals are only slightly smaller than the pectorals and reach well beyond the origin of the anal. The margin of the caudal fin is straight and strongly oblique, the lower rays being much longer than the upper ones. Pigmentation remains about the same as in smaller fish, except that the pectorals and ventrals now are dotted with black chromatophores.

Specimens 18 millimeters long. — The body has become more robust posteriorly and is only slightly compressed. The mouth remains strongly oblique, and it has become proportionately smaller in size. Two dermal flaps about half as long as the eye, not present in the smaller fish, now are evident at the tip of the lower jaw. The margin of the caudal fin is concave, and the lower lobe is much longer and larger than the upper one. Pigmentation has undergone no changes worthy of note since a length of 12 millimeters was attained. (Fig. 66.)

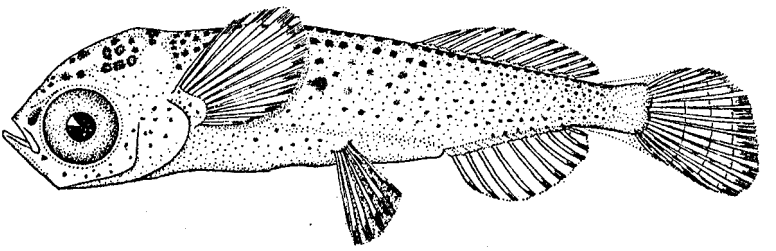

FIGURE 65.—*Cypselurus furcatus.* From a specimen 7.7 millimeters long

Specimens 25 millimeters long.—Scales are not evident on specimens 18 millimeters long. Indications of scale pockets are present, however, and at a length of 25 millimeters scales are well developed although usually lost, as they appear to be loosely attached. The pectoral and anal fins have increased in proportionate length, for the first-named pair now reaches nearly opposite the middle of the base of the dorsal and the other pair reaches to or a little beyond the base of the caudal. These proportions are those attained by these fins in the adult, except that the ventrals in the adult do

not quite reach the base of the caudal. Dermal flaps at the tip of the lower jaw are variously developed and occasionally absent. Since these appendages are quite delicate and since the two on the same fish often are of very unequal size, it seems probable that they often are injured and occasionally lost, at least in preserved specimens. The pigmentation on the pectoral and ventral fins has become concentrated in certain places in such a way as to form spots. No other important changes in color are evident. However, some specimens of this size, as well as somewhat smaller

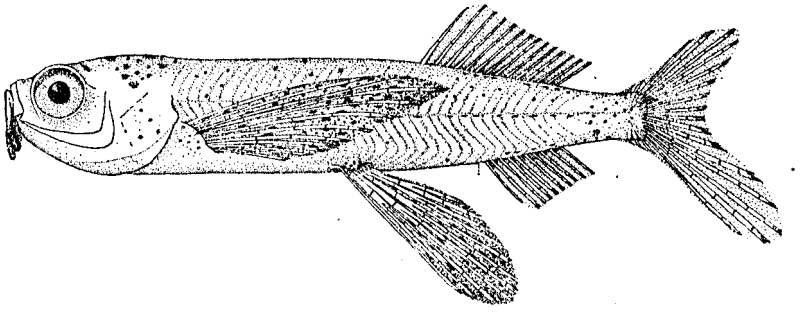

FIGURE 66.—*Cypselurus furcatus*. From a specimen 18 millimeters long

ones, have indications of dark crossbars, formed by a concentration of black chromatophores.

Specimens 35 millimeters long.—The shape and form of the adult has been very closely approximated. The slight keel along the ventral edge of the body in which the lateral line is situated is now visible and causes the body to appear slightly quadrangular in cross section as in the adult. The dermal appendages, inserted at the tip of the lower jaw, are large (about as long as the eye) at this age and have a

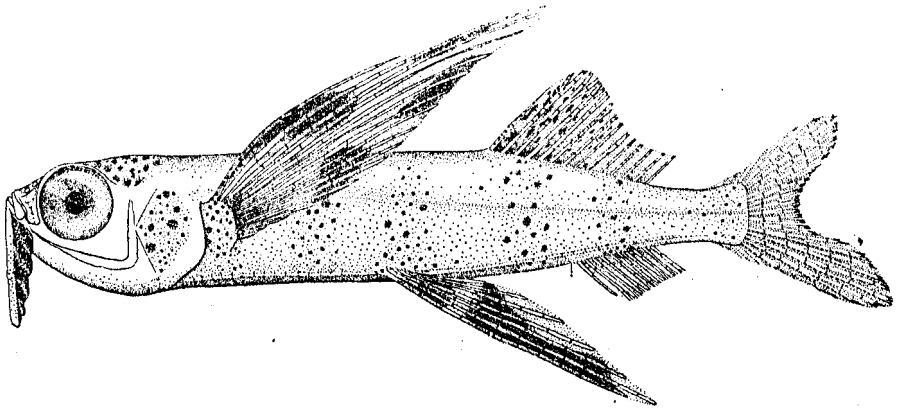

FIGURE 67.—*Cypselurus furcatus*. From a specimen 36 millimeters long

scalloped outer margin which is black, in contrast with the pale color of the rest of the tentacle. The caudal fin has definitely acquired the shape of that of the adult, being forked and having a small upper lobe and a much larger and longer lower one. All the specimens at hand of this size have dark rings around the body, formed by a concentration of chromatophores. The first dark ring runs across the chest and the base of the pectorals, the third one crosses the base of the ventrals, and the sixth and last very indefinite one lies on the base of the caudal. The pectorals and ventrals are blotched with black and the dorsal bears a few dark chromatophores. The other fins remain plain translucent. The body, of course, is fully scaled at this size. How-

ever, the scales generally are lost and they are not shown on the accompanying drawing. (Fig. 67.)

Specimens 55 millimeters long.—The shape and form of the adult is now fully developed. The dermal tentacles, inserted at the tip of the lower jaw, are comparatively large, reaching slightly beyond the eye in the single specimen of this size at hand. The limited number of specimens of this and larger sizes in the collection indicates that the maximum stage of development is reached at this length. Pigmentation on the body still consists principally of the dark rings described in specimens 35 millimeters long. The pectoral fin now has two dark spots on the outer rays, whereas the inner rays are dark, except at the base and a dark bar crosses the middle of the fin and extends to the tip of the longest rays. Nichols and Breder (1928, p. 448) published a color plate of a fish 65 millimeters in standard length. While we have no specimen of exactly that size, our smaller, as well as larger ones, have much more dark color on the pectoral fins than shown in the color plate. The color of the ventrals is similar, but none of our specimens have dark spots or bars on the caudal fin, as shown in the color plate mentioned.

Specimens 90 millimeters and more in length.—A specimen 90 millimeters in length has rather short dermal appendages at the tip of the lower jaw which reach only a little past the anterior margin of the eye and are only about two-thirds as long as the eye. In color the body is plain, light brown with only a trace of the dark rings, described for smaller fish, remaining on the chest and abdomen. A specimen only slightly larger (95 millimeters) has no trace of dermal tentacles on the lower jaw. The ventral fins do not quite reach the base of the caudal and have attained the proportions of those of the adult. In color it is more uniform and without traces of dark bars or rings. The pectorals and ventrals, however, are very largely black. Two adult fish, respectively 135 and 140 millimeters in length, have no trace of dermal appendages on the lower jaw. Insufficient specimens are at hand to draw conclusions. However, the indications are that in this species as in *Parexocœtus mesogaster* (see p. 448) these dermal tentacles, which are not present in the very young, again are missing in the adult. No specimens with branched barbels, such as is figured by Fowler (1906, p. 288), are included in the present collection. Nor does the coloration of our specimens agree with Fowler's illustration. The dark markings on the pectorals probably vary. However, the ventral fins in all of our specimens of 35 millimeters and upward in length are blotched with black and in a specimen 90 millimeters long the characteristic pearly gray spot of the adult already is developed. Fowler's illustration shows the ventrals unmarked.

Very young *Parexocœtus mesogaster* and *Cypselurus furcatus* may be distinguished from each other by the generally lighter color and the much more profuse spotting with black chromatophores of the body in the latter. At a length of 10 millimeters the ventral fins in *C. furcatus* already are proportionately longer than in *P. mesogaster* and as the fish increase in size this difference becomes more pronounced. Due to the early development of the fins, the species can be separated even at a small size (5 to 10 millimeters) by the enumeration of the dorsal and anal rays, *P. mesogaster* usually having 11 dorsal and 13 anal rays, whereas *C. furcatus* usually has 14 dorsal and 10 anal rays.

DISTRIBUTION OF YOUNG

All of the specimens in the present collection from the vicinity of Beaufort, both adults and young, were caught at the surface. No nets suitable for taking the young on the bottom were used by the *Fish Hawk* which collected all the locally caught

specimens, exclusive of one. Since no collecting was done for bottom specimens in the areas where the young were common at the surface, it can not be definitely stated that they are present only at the surface. However, it seems very probable that this species is wholly pelagic throughout life.

It is pointed out in the preceding paragraph that the fish were taken only at quite a distance from the shores. On account of the failure to secure more than a single young fish during the systematic collecting carried on along the shores and out to sea for 12 to 15 miles from 1927 to 1929, and the rather numerous specimens taken farther out at sea by the *Fish Hawk*, it may be concluded that the young are fairly common, at least during the summer, from 20 to 30 miles or more offshore, and that they rarely enter the shore waters in the vicinity of Beaufort.

The rate of growth of this fish, its age at maturity, its range of flight, its food and feeding habits, and many other things concerning its life history remain unknown.

DECAPTERUS PUNCTATUS (Agassiz). Scad; cigarfish; round robin

The scad is known from Cape Cod to Brazil. Although common in a part of its range, as in Florida, it is not numerous enough to be of much commercial importance. The adults are rarely seen at Beaufort and the species was first recorded from that vicinity by Gudger (1913, p. 105), the record presumably being based on a specimen taken at Cape Lookout by the late Dr. Russell J. Coles. The same collector presented 3 fine specimens, all close to 8½ inches in length, to the Beaufort laboratory on August 9, 1913. These fish, also, were caught at Cape Lookout. In addition to the three adult fish, the laboratory collection contains hundreds of young, ranging from about 2 to 50 millimeters in length. Some of these specimens were taken off the coast of North Carolina by the *Albatross* in 1885, and others by the *Fish Hawk* from 1913 to 1915. However, the majority of them, including particularly the very small fry, were caught during the present investigation (1927 to 1929) when systematic collecting was carried on off Beaufort Inlet. Because of the abundance of the young in the local offshore waters (for the species has been taken only once within the harbor), it is believed that the adults must be fairly common, too, although rarely taken.

The adults of the scad are most readily recognized by the elongate, fusiform body, the long dorsal and anal fins (the dorsal with VII or VIII–29 to 30 and the anal with II–I, 25 to 27 rays), each followed by a single detached finlet, and by deep bony scutes in the posterior half, or straight part, of the lateral line. The scad probably is chiefly pelagic and the maximum size attained is about 12 inches.

SPAWNING

The eggs of the scad were not taken, or at least not recognized. Nor were adult fish with roe observed. The presence of the fry in the local waters, however, affords a fairly satisfactory means of determining the time, the duration, and the place of spawning. Very small fry, only about 2 to 4 millimeters in length, which obviously are very young, were taken from May to November. They were most numerous, however, in July, August, and September. It is evident, therefore, that spawning may take place throughout the summer, or from about May to November, but that it is at its height during July, August, and September.

The young were taken anywhere from the outer shores of the banks at Cape Lookout, and offshore to the Gulf Stream. The fry were secured within the harbor only once when they were caught immediately opposite the inlet. It is quite evident,

therefore, that spawning takes place at sea and probably anywhere from the shores to, and possibly beyond, the Gulf Stream. The smallest fry taken are only about 2 millimeters long, which suggests that the scad produces very small eggs.

DESCRIPTIONS OF YOUNG

The young fish in the present collection range from about 2 to 50 millimeters in length and within this range the series is fully complete, as all sizes are represented by numerous specimens. However, no specimens ranging from 50 to 175 millimeters in length are at hand. Therefore, young ranging upward of 50 millimeters are not described.

Specimens 2.3 millimeters long:—The head is excessively large and deep and somewhat compressed. The body tapers posteriorly to a sharp point. The dorsal profile of the head is deeply concave, the snout being directed upward. The mouth is large and nearly vertical, and the tip of the lower jaw is above the level of the upper margin of the eye. Comparatively large spines are present on the preopercular bones. (These spines disappear at an early age, or when the fish reaches a length of about 20 millimeters and the preopercular margin, thereafter, is smooth and entire.) Pectoral fin folds are prominent but the ventral fins are not evident at this size, nor in considerably larger specimens. The vent is prominent and is situated somewhat posterior to mid-body length. A few dark markings usually are evident along the dorsal and ventral outlines of the body at the base of the fin fold. Although the fish must be very young at this size, the yolk is all absorbed and the head is fairly well in line with the axis of the body. (Fig. 68.)

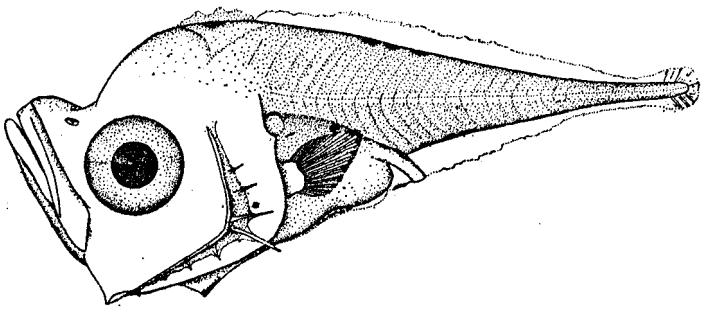

FIGURE 68.—*Decapterus punctatus*. From a specimen 2.3 millimeters long

Young of this size are remarkable on account of their deep heads, turned up snout, and long spines on the preopercular margin.

Specimens 3.5 millimeters long.—At this size the head is not as disproportionately large in comparison with the rest of the fish as in the 2.3 millimeter specimens, for the body has gained greatly in depth, except in the distal part of the tail which remains slender and pointed. The fish is quite strongly compressed and very unlike the adult in this respect. The concavity in the dorsal outline of the head is slightly less pronounced, and the mouth is a little less strongly oblique than in the smaller fish described. The fin fold remains complete and extends from the nape around the tail and forward to the abdomen. The dark chromatophores on the dorsal and ventral outlines of the body, especially on the caudal region, have increased in number and intensity. A few dark chromatophores, also, are present on the median line of the side, posterior to the vent.

The presence of dark chromatophores on the median line of the side are very helpful in recognizing young scad of this size and larger ones, for this row of black chromatophores persists and is prominent until a length of at least 10 to 12 millimeters is attained. At that size the fin rays are developed and identification can be based largely on adult characters.

Specimens 5 millimeters long.—The fish remains deep and compressed. The principal advancement over the 2.3-millimeter fish is the development of fins, for some of the anal, dorsal, and caudal rays are definitely formed. Posteriorly, the notochord is bent upward abruptly, giving the tail a pronounced heterocercal appearance. Preopercular spines are present but proportionately smaller than in younger fish. Chromatophores have increased in number, a few having appeared on the head, and some specimens have 3, others 4, longitudinal rows of black chromatophores on the side extending backward from the vertical of the vent. (Fig. 69.)

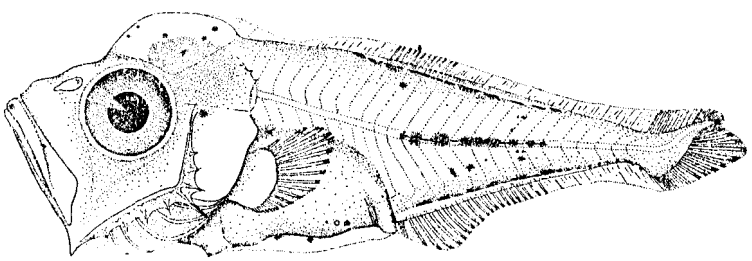

FIGURE 69.—*Decapterus punctatus.* From a specimen 5.2 millimeters long

Specimens 7 millimeters long.—The fish is much more regular in outline and more shapely than it is in the smaller sizes described. The concavity in the dorsal profile of the head, very pronounced in 2 and 3 millimeter specimens, is very slight at this size. The distal part of the tail has become deeper, much more shapely, and has lost its heterocercal character. However, the body remains deep and compressed. The fins are all developed. The ventrals are very small and were not noticed in smaller specimens. The vertical fins are fairly well developed. However, the spines in the dorsal and anal are scarcely distinguishable from the soft rays and the caudal fin has a round margin. Dark chromatophores have increased in number on the dorsal surface of the head. In other respects pigmentation remains much as in 5-millimeter specimens.

Specimens 10 millimeters long.—No pronounced advancement in the development, over 7-millimeter fish, is evident. The preopercular spines have become quite small, the mouth is noticeably less oblique than in the very young, and the dorsal outline of the head is regularly convex. The spinous dorsal is differentiated and separated from the soft dorsal by a notch. The spines in the anal fin too are well differentiated, and the caudal fin is slightly forked. A concentration of dark chromatophores has taken place on the head, making a black blotch on the occipital surface. A black line on the middle of the side on the caudal portion of the body is now visible to the unaided eye. This dark line is very characteristic of the young and serves as an early recognition mark. (Fig. 70.)

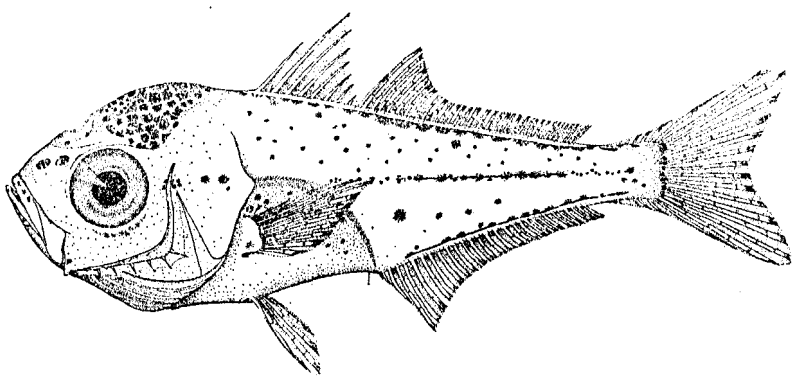

FIGURE 70.—*Decapterus punctatus.* From a specimen 10.5 millimeters long

Specimens 15 millimeters long.—The head is disproportionately large and deep in the smaller fish, being notably deeper than the rest of the body. At a length of about 15 millimeters the greatest depth of the head is equal to the greatest depth

of the body and is contained about 3 times in the standard length, whereas in 10-millimeter specimens the greatest depth of the head is contained about 2.5 times in the standard length. Preopercular spines, long and prominent in the very young, are not evident in 15-millimeter fish. The fins are well developed. The ventral fins, which first became evident in specimens 7 millimeters long, are long and prominent in 15-millimeter specimens, reaching to the origin of the anal. The first two spines of the anal are well separated from the rest of the fin, as in the adult, and the caudal fin is rather deeply forked. Preserved specimens of this size, when viewed with the unaided eye, have a brownish cast, especially along the back, a dark blotch over the head, and a dark lateral stripe. Under magnification the individual chromatophores, causing the coloration, are still visible. In life, specimens of this size are quite silvery.

Specimens 20 millimeters long.—The differences between fish of this size and those 15 millimeters long is not pronounced. The body, although still notably compressed, has become more elongated. Scales are not yet present but bony scutes in the posterior part of the lateral line are quite evident. The pores of the lateral line also are plainly visible. (Fig. 71.)

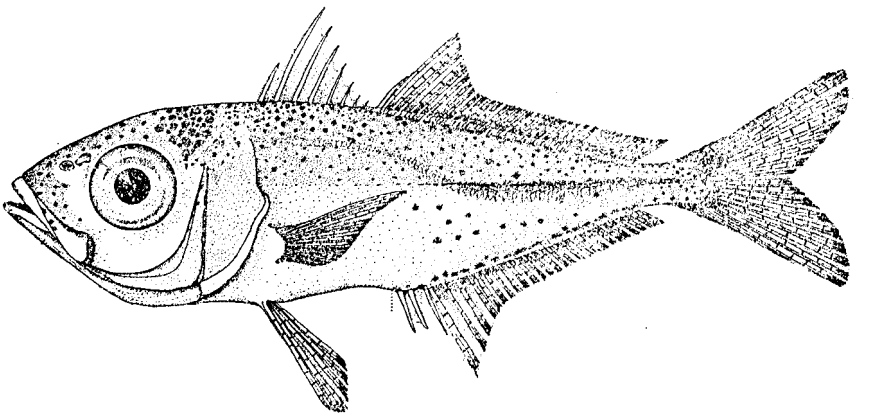

FIGURE 71.—*Decapterus punctatus.* From a specimen 20 millimeters long

Specimens 30 millimeters long.—The body is notably elongate but remains quite strongly compressed, the greatest depth being contained about 3.6 times in the standard length. The snout has become rather pointed, and the mouth oblique and terminal. The tip of the lower jaw is about on the same level as the middle of the eye, and the maxillary reaches to or slightly past the anterior margin of the eye. The mouth therefore has approached very nearly the shape and position occupied in the adult. The bony scutes in the lateral line are developed throughout its length. The scales, being very small, are not definitely visible. The ventral fins are proportionately shorter than in somewhat smaller fish and reach only to the vent. The last two rays of both the dorsal and anal, which are destined to form separate finlets, are united by membrane and entirely undifferentiated from the rest of the fin until a length of about 30 millimeters is attained. At that size a somewhat larger interspace is present between the second and third posterior rays of each fin than between the other rays, but generally a membrane still connects the last pair of rays with the rest of the fin and the finlets are not fully differentiated. The fish now is mostly silvery, the back being slightly brownish in preserved specimens, and the dark lateral stripe, characteristic of smaller fish, has disappeared.

Specimens 45 millimeters long.—The difference between specimens of this size and 30-millimeter ones is not pronounced. The body remains proportionately deeper and much more strongly compressed than in the adult. The greatest depth at this size is contained about 3.8 times in the standard length, whereas in the adult specimens at hand the depth is contained about 4.5 times in the standard length. Scales are quite fully developed but are not shown in the accompanying drawing because of their extremely small size. The ventral fins reach about two-thirds the distance from their insertion to the origin of the anal, whereas in the adult they reach only about one-third of this distance. The single finlet, following the dorsal and anal fins, in each case is now fully differentiated. The color of preserved specimens remains almost wholly silvery. Although fish 45 millimeters or so in length differ in many respects from the adult, such diagnostic characters as the single detached finlet following each the dorsal and the anal; the deep scutes in the posterior part of the lateral line, the rather small oblique mouth, and the silvery color all are developed. It is not very difficult, therefore, to identify 50-millimeter specimens with the adult. (Fig. 72.)

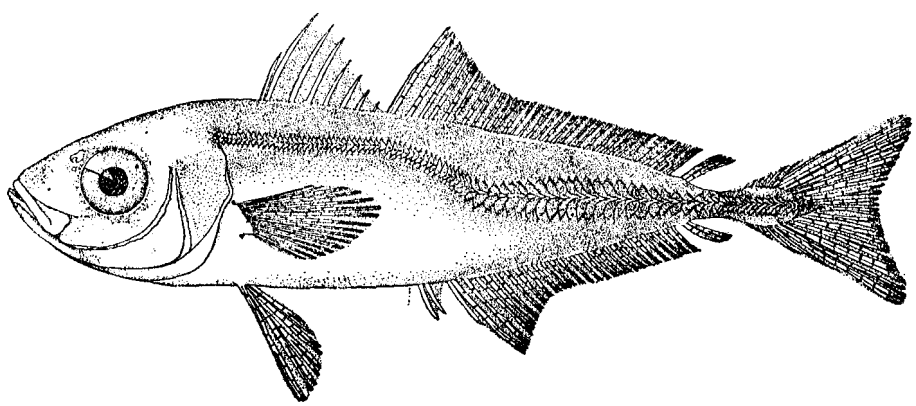

FIGURE 72.—*Decapterus punctatus.* From a specimen 44 millimeters long

DISTRIBUTION OF YOUNG

The young ranging from about 2 to 50 millimeters in length, of which numerous specimens were secured as stated in another section of this account, were nearly all taken at sea at numerous stations extending from the shores of the banks to the Gulf Stream. Only 3 fry were taken in the harbor, and these were collected near the inlet. The numerous specimens collected by the *Albatross* and the *Fish Hawk*, consisting mostly of fish ranging from 15 to 50 millimeters in length, so far as this information is given, were taken at the surface. It is not known that nets suitable for taking these small fish were hauled elsewhere than at the surface. However, during the systematic collecting with townets carried on from the Beaufort laboratory with smaller vessels from 1927 to 1929, when an approximately equal number of drags was made with two 1-meter nets hauled simultaneously—one at the surface and the other on the bottom—fry up to 25 millimeters in length were taken in the surface net 40 times and in the bottom net 49 times. The number of times the fish were taken on the bottom not only is larger but the number of specimens taken there is considerably greater.

It is evident from the collections that the young (up to 25 millimeters in length, at least) occur both at the surface and on the bottom, and it seems probable that

they can be taken at any depth (ranging down to 20 fathoms) within the area in which the recent townet collections were made. Evermann and Marsh (1902, p. 129) report the capture with a beam trawl of six young, about 2 inches in length, from near Porto Rico in 220 fathoms of water. It is quite certain from this record and the results of the present investigation that the young scad, at least, is not wholly pelagic.

It is pointed out on a preceding page (p. 453) that the young were secured from May to December. However, only a few were taken in May and June, many in July, August, and September, a few in October, and only a couple of stragglers in November and December. It is evident, therefore, that the fish leave the shore waters upon the approach of cold weather. This exodus from the shallower shore waters was expected, because the scad is principally a tropical species. It is not known, however, whether the fish hatched in the local shore waters during the summer migrate southward or whether they merely move offshore and possibly into the Gulf Stream.

The rate of growth can not be determined from the present collection. The largest specimens are only about 50 millimeters long and were taken in September and October. It is probable that these fish are representative of the largest young of the O class and that a length of 50 millimeters (2 inches), or so, is attained at an age of 4 or 5 months. The food and feeding habits remain largely undetermined. Beebe and Tee-Van (1928, p. 105) list copepods, numerous zoea, and ostracods for a fish 95 millimeters long. The stomach contents of the small fish in the present collection have not been studied.

SERIOLA DUMERILI (Risso). Amberfish; rudderfish

The amberfish, as here understood,[4] inhabits both coasts of the Atlantic, and on the American coast it ranges from Massachusetts to Brazil. It does not occur regularly in the vicinity of Beaufort and has no commercial value there. In 1915, for example, from 2 to 10 individuals, all of nearly uniform size (about 13 inches in length), were taken daily from May 17 to 29, in a pound net operated by the Beaufort fisheries station. These fish were shown to several local fishermen, who did not recognize the fish and could not remember that they had previously seen a fish that looked like it.

Smith (1907, p. 203) says, "A number of years ago, some New Jersey fishermen set pound nets off the beach near Nags Head and for some time caught numbers of fine, large amberfish, and 20 boxes of the fish were sent to market from Skyco, Roanoke Island. The steamer *Fish Hawk* caught a specimen about 28 miles off Cape Lookout, August 21, 1902." We have at hand two specimens, each about 15 inches long, taken with hook and line on the blackfish grounds, about 20 miles off Beaufort Inlet, by the *Fish Hawk* in 1913.

A considerable number of young amberfish, ranging from about 10 to 50 millimeters in length, were collected by the *Fish Hawk* in 1914 off Beaufort Inlet and principally on the blackfish grounds. This vessel collected in the same vicinity in 1913 and again in 1915, but no amberfish was taken those two years. Smaller fry were secured near Beaufort Inlet (once inside and several times outside of the inlet) in 1927. Although the towing operations of 1927 were repeated in the same locality

[4] Nearly all the specimens taken locally that are large enough to be pigmented belong to the barred form, *S. zonata* (Mitchill). However, after considerable study devoted to the genus some years ago, it was concluded that *zonata* are young *dumerili* and are so considered here.

and in the same way in 1928 and 1929, no small amberfish was seen during the last two years. The larger fish have not been taken since 1915. Of course, large spawning fish must have visited the coast in 1927 or the fry would not have been present. It may be assumed, from the information at hand, that the occurrence of the amberfish is rather irregular locally, and it is not known that the mature spawning fish enter the inside waters. At Key West, Fla., at least, the amberfish is pelagic in its habits, and it no doubt could be taken oftener off Beaufort Inlet by the employment of proper fishing methods.

The amberfish occurs in sufficient numbers and is important enough to find a separate place in the statistical records of the United States Bureau of Fisheries in Florida only, where 20,675 pounds were marketed in 1927. This fish is rather common at Key West, Fla., during the winter and is taken by trolling. It is considered a good game fish there, and individuals weighing from 50 to 70 pounds are not uncommon. The maximum weight attained is about 100 pounds.

The adults of this species are elongate shapely fish with somewhat compressed bodies. The soft dorsal and the anal fins are long, the former having 30 to 36 rays and the latter 19 or 20, and they are not followed by a detached finlet, as in some of the related species. (See *Decapturus punctatus*, p. 453.) The lateral line has a long, low arch anteriorly and has no bony scutes in the straight portion, as in many related genera, although a keel is present in the adult. The gill rakers are well developed but rather few in number—only 11 to 14 being developed on the lower limb of the first arch. Large individuals are amber colored from which the animal derives the name—amberfish. The young—that is, fish ranging from about 30 to 325 millimeters (1.25 to 13 inches) in length—are bluish-brown above and silvery on the sides, with black bars. The black bars in fish 13 inches or so in length when present in life are not especially distinct and generally fade quickly after death.

SPAWNING

The literature consulted contains nothing relative to reproduction in this species. No ripe fish were seen during the investigation. However, a female, 13 inches long, taken in May, 1915, has the ovaries somewhat distended and probably would have spawned within a few months. This shows that, although the fish reaches a large size, if correctly determined, it may be sexually mature at a length of only about 13 inches. Two larger specimens (15 inches long) taken on the blackfish grounds in September, 1913, have the sexual organs entirely collapsed as if spawned out recently. The eggs, if taken, were not recognized. Small young, ranging from 4 to 12 millimeters in length, were taken in August (1914) and September (1927). While the data are very incomplete, they do show that the spawning season on the coast of North Carolina occurs during the summer, probably from June through September. (See p. 463.) The fact that the fry were taken near Beaufort Inlet during only one season out of three, during which systematic collecting was carried on, seems to show that spawning does not occur there regularly.

DESCRIPTIONS OF YOUNG

Young Seriola are dark in color at a very early age, as seen with the unaided eye, this dark color being due to dark chromatophores variously distributed over the body. The mouth is large and oblique, and the body very early resembles in the general shape that of the adult, specimens 7 millimeters long already being elongate, shapely fish. Unfortunately no specimens of lengths between 14 and 30 millimeters

are at hand and, therefore, the development of the intermediate sizes can not be traced at this time.

Specimen 2.9 millimeters long.—The larva at this size is quite compressed, the head is deep, the mouth is slightly superior and strongly oblique, and a very pronounced angle in the ventral outline of the head is formed at the joints or hinge of the mandible. The eye is small for so young a fish and is scarcely longer than the snout. The abdomen is moderately prominent, and the vent is situated near mid-body length. The dorsal profile is quite convex, except for a slight concavity just in front of the eye. The tail tapers gradually and ends in a sharp point. Pectoral fin folds are rather prominent but no ventral fin folds are in evidence. The vertical fin folds either have been torn away or are very low. The specimen is rather dark in color and the only pigment spots evident in a preserved specimen are a few indefinite ones on the ventral outline. (Fig. 73.)

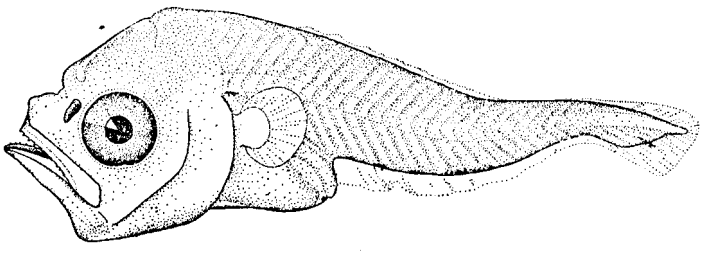

FIGURE 73.—*Seriola dumerili.* Drawn from a specimen 2.9 millimeters long

Young of this size resemble *Decapterus punctatus* somewhat; but the head is not quite as deep in comparison with the body, the snout is not curved upward to the same extent, the eye is proportionately much smaller, preopercular spines are wanting (although present at a somewhat larger size), and fin development has not progressed quite as far. (Compare figs. 68 and 73.) Another distinction is the absence of color markings along the dorsal outline in Seriola.

Specimens 5 millimeters long.—The body remains quite compressed as in smaller specimens. However, anteriorly it is not as deep as previously in proportion to the total length, and the tail, especially distally, is much deeper. The mouth is less strongly oblique, and the sharp angle at the joints of mandible, present in smaller specimens, has disappeared, the ventral outline of the head now becoming evenly convex. Fin rays are not yet very evident, except in the caudal fin. The notochord extends prominently into the upper part of the caudal fin giving the tail a decided heterocercal appearance. Pigmentation in the most distinctly marked specimens consists of a very narrow dark lateral stripe in addition to some large dark chromatophores irregularly distributed over the body. In some specimens the markings are much more diffuse than in the specimens described. (Fig. 74.)

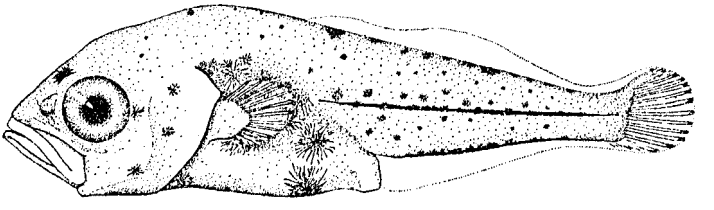

FIGURE 74.—*Seriola dumerili.* Drawn from a specimen 4.7 millimeters long

The absence of preopercular spines, the more regular dorsal outline of the head, and the less strongly oblique mouth distinguish this species from the scad at this size. The large black chromatophores on the side of the abdomen behind the base of the pectoral, too, are helpful, especially since the other color markings are largely similar to those of the scad of the same size.

Specimens 6 millimeters long.—The fish at this size have comparatively large spines on the preopercular margin (which disappear at a somewhat larger size).

Ventral fin folds now are slightly in evidence. The rays in the soft dorsal, caudal, anal, and pectorals are becoming differentiated, the ray development having progressed somewhat further in the pectoral and caudal fins than in the other fins mentioned. The notochord still is visible in the upper part of the base of the rounded caudal fin, but the tail has lost much of its heterocercal character possessed at a somewhat earlier stage. The spinous dorsal still remains largely undifferentiated. Pigmentation is more diffuse than in smaller fish, although some large and distinct chromatophores remain present much as in 5-millimeter fish. A dark lateral stripe is present on most of the caudal length of the body. Then there is also a concentration of color under the base of the dorsal and anal fins. We have specimens preserved since 1914 which are entirely without dark pigment. It is probable, though, that these fish have faded and that the general dark color described in the foregoing lines is normal (Fig. 75.)

The cluster of large, black chromatophores now present at the nape is of much value in recognizing amberfish of this size. This is especially helpful since the other color markings are largely similar to those of the scad of the same size. This cluster of black chromatophores persists until a length of at least 14 millimeters is attained. At that size fin rays are developed and identification may be based largely on adult characters.

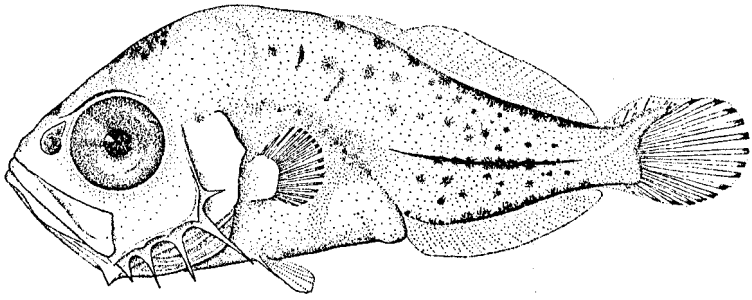

FIGURE 75.—*Seriola dumerili.* Drawn from a specimen 5.7 millimeters long

Specimens 10 millimeters long.—The body is regular in outline, elongate, compressed, and shaped much as in the adult, except that it is less robust. The fins are all fully differentiated and the soft rays are well developed. It is still difficult to enumerate the rays in the dorsal and anal, because of the crowded condition. The anal spines are short and distinct. The spines in the first dorsal, however, are not fully differentiated and the fin, although connected with the second dorsal, is distinct because it is lower. The caudal fin, round in somewhat smaller fish, has an almost straight margin at this size. In the specimens at hand, preserved in 1914, the body is quite dark brownish in color with scattered darker chromatophores. The dark lateral stripe or line of smaller fish has become less distinct and the concentration of black chromatophores at the base of the dorsal and anal fins are no longer pronounced. The dorsal surface of the head is profusely dotted with black.

Specimens 12 to 14 millimeters long.—The changes since a length of 10 millimeters was reached are not pronounced. At a length of 12 to 14 millimeters the rays of the dorsal and anal fins, although crowded, have become distinct enough for enumeration, and the caudal fin is decidedly concave. Preopercular spines are still prominent although proportionately smaller than in somewhat smaller fish. In specimens stained and mounted the vertebræ may be fairly accurately enumerated, the number being 11+14 to 16. This count agrees fairly well with the single adult dissected which had 10+14 vertebræ. The last caudal vertebra (hypleural) in 12-millimeter fish is not yet fan shaped as in the adult, for it is pointed and curved upward distally, therefore retaining in a measure the heterocercal character of younger fish. The color remains essentially as in 10-millimeter fish. (Fig. 76.)

Specimen 30 millimeters long.—A single specimen of this size is at hand. It does not differ greatly in shape from specimens 12 to 14 millimeters long. Preopercular spines, large and prominent in fish ranging from 6 to 14 millimeters in length, are missing and the preopercular margin now is entirely unarmed. The dorsal spines remain rather short but are pungent. The first two anal spines are well separated from the rest of the fin and are short and strong. The lateral line with distinct pores is fully developed and scalation is complete. Dark bands (six in the speci-

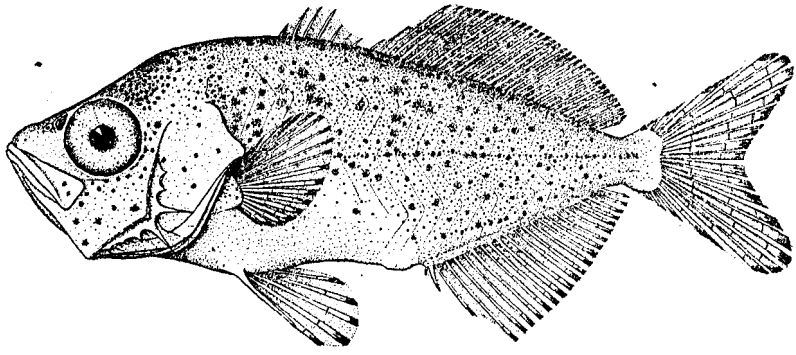

FIGURE 76.—*Seriola dumerili.* Drawn from a specimen 14 millimeters long

men at hand) apparently are just forming, for they are not nearly as distinct as in larger specimens. The bands or bars plainly are the result of the concentration of the dark chromatophores already present in much smaller fish. The bars are all vertical, except the first one which extends obliquely backward from the eye to the occiput. Dark chromatophores are sparingly distributed over the body between the crossbars. No trace of the dark lateral band or line, prominent in smaller fish, remains. (Fig. 77.)

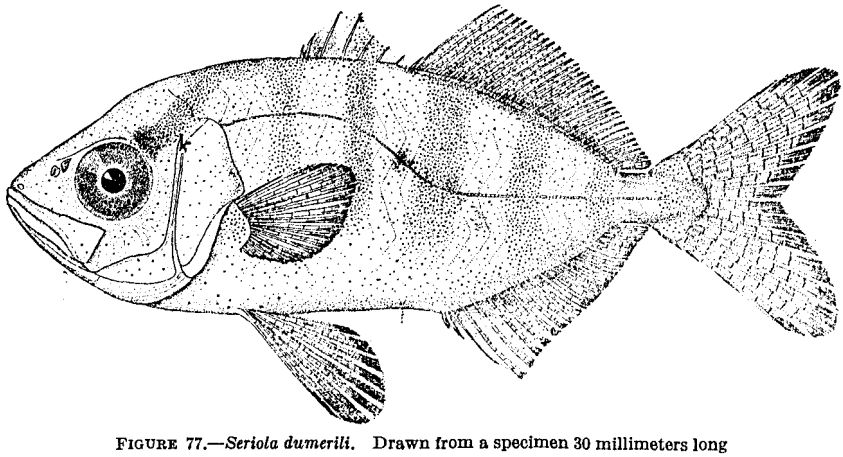

FIGURE 77.—*Seriola dumerili.* Drawn from a specimen 30 millimeters long

Specimens 40 millimeters long.—The difference between the 30-millimeter specimen and those that are 40 millimeters long is not pronounced. The caudal fin is somewhat more deeply forked, and the dark crossbars are more sharply outlined, and rather narrower and darker. The number of bars present in three specimens at hand of this size vary from 6 to 8. (Fig. 78.)

Specimens 110 millimeters long.—The difference between specimens of this size and those 40 millimeters long is comparatively slight. The body remains quite

strongly compressed, much more so than in specimens 13 inches long and, of course, very much more compressed than in large fish. The caudal fin is somewhat more deeply forked than at a length of 40 millimeters, yet it is not deeply lunate as in the adult. The ventral fins at this size, as in smaller fish, reach the vent, whereas in large fish they reach only about a third of the distance from their insertion to the vent. A slight keel is evident in the posterior part of the lateral line, which, although lower and less pronounced, corresponds with that of the adult. The upper parts of the body are brownish in preserved specimens and the sides are largely silvery, which in general corresponds with the color of the adult. However, the body is still crossed with several (about 6 to 8) dark brown or black bars, extending on the dorsal and anal fins, which are wanting in the next larger size at hand, namely, specimens 13 inches long. It may be noted, however, that the larger fish had dark bars in life which quickly faded after death.

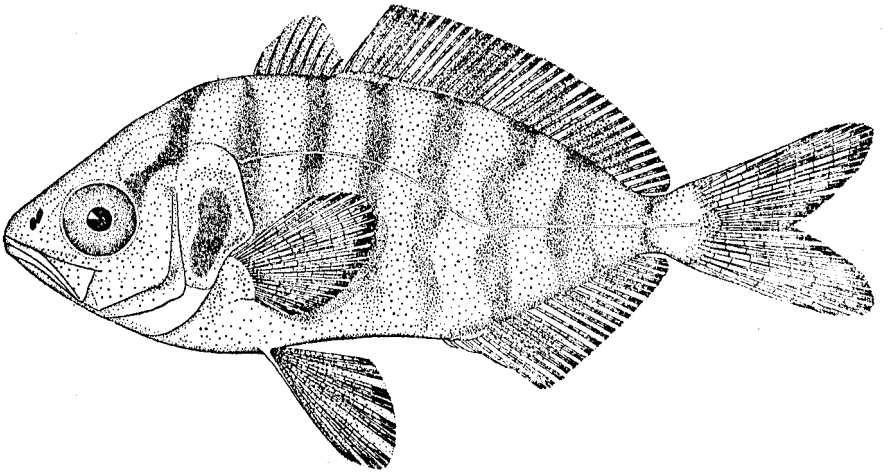

FIGURE 78.—*Seriola dumerili*. Drawn from a specimen 40 millimeters long

Although specimens 110 millimeters (4.4 inches) long differ in many respects from larger fish, as shown in the foregoing paragraph, sufficient adult characters are developed to make identification comparatively easy.

DISTRIBUTION OF YOUNG

Fry ranging from a little less than 3 and up to 10 millimeters in length were taken in 1927 from June 28 to September 24. Other specimens, ranging from about 6 to 10 millimeters in length, were taken by the *Fish Hawk* in 1914 on August 10, 11, and 12. It is evident from the collections of fry, totaling about 75 in number, that spawning takes place during the summer—probably from June through September—for the smallest fry in the collection (2.9 millimeters long) was taken on September 28, 1927.

Specimens collected by the *Fish Hawk*, so far as the records give this information, were taken at the surface. In fact, no nets suitable for catching the fry on the bottom seem to have been used. In the collections made near Beaufort Inlet in 1927, in an equal number of bottom and surface hauls, made simultaneously with two 1-meter townets, the fry were taken 6 times, 2 times at the surface and 3 times on the bottom. This information was missing for the other collection.

All the specimens in the collection, exclusive of one, 5 millimeters long taken just inside Beaufort Inlet, were collected offshore. Those taken by the *Fish Hawk* in 1914 were mostly secured on the blackfish grounds, about 20 miles offshore, and the others taken in 1927 were collected near the shore, at the most not over 15 miles from Beaufort Inlet.

It is evident, therefore, that the fry in the vicinity of Beaufort occur chiefly at sea where spawning no doubt takes place during the summer. Since the young sometimes were taken on the bottom, they probably are not as strictly pelagic as larger fish. Lewis Radcliffe, naturalist aboard the *Fish Hawk* in 1914, states in his notes, "Wherever sargassum weed makes its appearance they (young Seriola) may be found accompanying the weed and at such times are quite common." Elsewhere (p. 459) it is stated that the adult amberfish is caught at Key West chiefly by trolling. It is probable, therefore, that the fry are less strictly pelagic than the older fish.

GROWTH AND FOOD

Almost nothing concerning the rate of growth or the foods eaten appears to be contained in the literature. The present collection obviously is not extensive enough to yield much information on these subjects. Therefore, these phases of the life history of the amberfish remain for future investigation.

PARALICHTHYS DENTATUS (Linnæus) and PARALICHTHYS ALBIGUTTUS, Jordan and Gilbert. Summer flounder; southern flounder

Three nominal species of summer flounders,[5] namely, *Paralichthys dentatus* *P. albiguttus*, and *P. lethostigmus*, are recorded from Beaufort, N. C. However, the present writers are unable to separate the representatives of this genus, occurring locally, into more than two groups (species ?), and not infrequently individuals are seen that are confounding and difficult to identify with either one of the groups into which most specimens are separable. The characters employed in identifying adult summer flounders, namely a combination of gill-raker and fin-ray counts and color markings, are not all developed in the young, or at least are so indefinite that they can not be seen clearly until a considerable size (about 20 to 25 millimeters, or even much larger for color markings) is attained. No characters have been found by means of which the young can be separated into species until the adult characters mentioned above are developed. It is for this reason that we are obliged to treat all the small Paralichthys at hand as one group.

Although this paper is not intended to give a taxonomic account of the flounders, it seems desirable to show the close relationship of the locally represented forms as a guide to future investigators, in order that the reader may understand the difficulty involved in identifying these flounders, also to show more clearly why the young are treated as a single group in this paper.

Considerable time was devoted to the study of the adults for the purpose of ascertaining definitely the number and relationship of the species represented and with the view of finding characters that could be used in identifying the larvæ. In the latter object we failed; and as to the former, we found bewildering variations but no third species. In other words, two species, with certain doubtful intermediate as well as extreme specimens, certainly are present. One of these unquestionably is

[5] These fish are known locally only as "flounders." The designation "summer flounder" is used in the northern part of the range of Paralichthys in order to distinguish these fish from the "winter flounder" *Pseudopleuronectes americanus*. These designations are used in this paper for the sake of convenience and to avoid the frequent repetition of the scientific names.

dentatus, while the other remains in doubt. We provisionally use for this entire group the name *albiguttus*, which is older than *lethostigmus*, because of the possibility that a further study, especially of specimens from the type localities, Pensacola and Jacksonville, Fla., may show the two to be identical. In which case *albiguttus*, having priority, would stand.

The most reliable character for separating the two locally represented forms which are recognized by us, is the number of gill rakers present on the lower limb of the first arch. That is, *dentatus* nearly always has a higher number of gill rakers than *albiguttus*—the usual range for the first-named species being from 14 to 17 and for the latter 8 to 12. However, some overlapping occurs between the two ranges given, for some specimens which evidently are *dentatus* have only 13 or occasionally only 12 gill rakers, whereas specimens, which appear to be *albiguttus*, sometimes have 12 and rarely 13 gill rakers. (See fig. 79.) The length and shape of the gill rakers generally

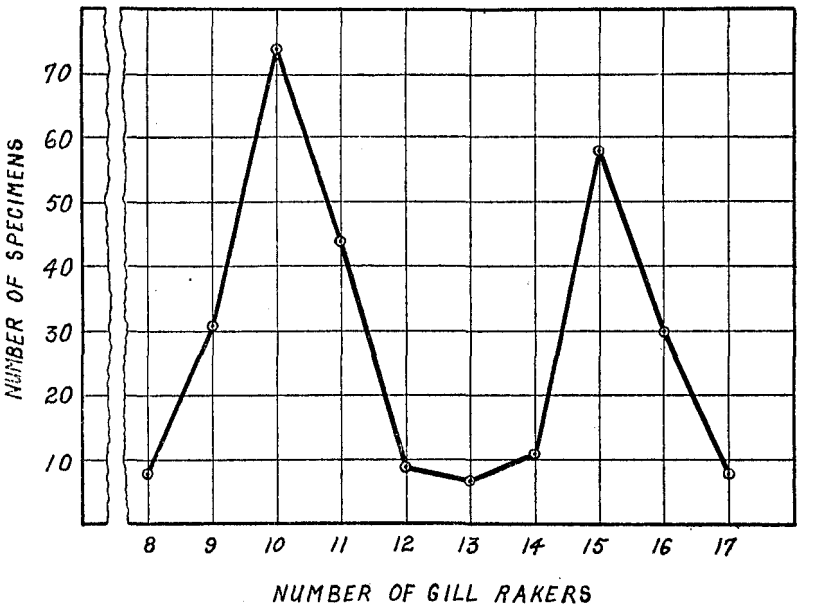

FIGURE 79.—Frequency distribution of gill rakers on the lower limb of first arch in 277 specimens of Paralichthys. Graph based on Table 11

are of help in separating the specimens in which the counts overlap, for *dentatus* has longer, more slender and smoother gill rakers which are equal to one-half to two-thirds the diameter of the eye, whereas those of *albiguttus* usually are notably shorter, coarser, and dentate.

TABLE 11.—*Frequency distribution of dorsal rays, anal rays, and gill rakers on the lower limb of the first arch, of respectively 277, 249, and 277 specimens of Paralichthys*

DORSAL RAYS

Number	Frequency	Number	Frequency	Number	Frequency
72	2	80	19	88	13
73	5	81	19	89	29
74	7	82	9	90	8
75	24	83	19	91	3
76	13	84	6	92	4
77	15	85	8	93	6
78	10	86	15	94	
79	16	87	25	95	2

TABLE 11.—*Frequency distribution of dorsal rays, anal rays, and gill rakers on the lower limb of the first arch, of respectively 227, 249, and 277 specimens of Paralichthys*—Continued

ANAL RAYS

Number	Frequency	Number	Frequency	Number	Frequency
54	2	60	16	66	21
55	4	61	16	67	18
56	13	62	5	68	29
57	20	63	6	69	17
58	14	64	12	70	15
59	22	65	16	71	3

GILL RAKERS

8	8	12	9	15	58
9	31	13	7	16	30
10	74	14	11	17	8
11	44				

Correlated with the high number of gill rakers in *dentatus* is a high fin-ray count for both the dorsal and anal. While there is much overlapping between the two

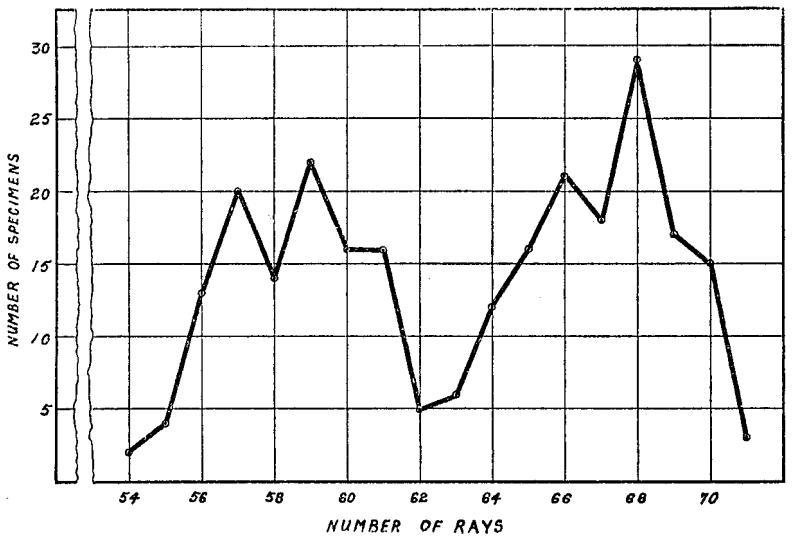

FIGURE 80.—Frequency distribution of anal rays in 249 specimens of Paralichthys. Graph based on Table 11

species, the average differences are pronounced. The range in the dorsal rays for *dentatus* in 107 specimens enumerated is 80 to 95 with an average of 87.3 rays. The range for the rays in this fin for *albiguttus* is much greater, reaching from 72 to 95 (therefore occupying the entire range of *dentatus*, as well as extending far below it) in the 173 specimens enumerated, but the average is only 79.5. The range in the number of rays in the anal in *dentatus* is 60 to 71 in 95 specimens enumerated and the average is 67.1. In 148 specimens of *albiguttus* the range again is much greater (therefore extending through the entire range of *dentatus* and much lower), reaching from 54 to 71, with an average of 60.7 rays.

The extremely great range in the number of fin rays in *albiguttus* suggests that two species may be confused, and it is on this character, chiefly, that the two nominal species *albiguttus* and *lethostigmus*, have been held to be separate and distinct. However, as already indicated, the large number of specimens of Paralichthys examined with respect to the dorsal and anal rays, give no indication of a third species, for when the counts are plotted, as to frequency (see figs. 80 and 81), two modes are

evident, for the anal, but not a third one, and no definite modes are shown for the dorsal. The width of the interorbital, too, has been used as a distinguishing character. The variations in the interorbital width are extremely great. The writers are unable, however, to find any correlation between this character and fin-ray counts, and it is believed that the differences probably are only individual variations.

Color markings generally are helpful in separating *dentatus* from *albiguttus*, yet they are not infallible and must not be relied upon too strongly. Usually *dentatus* bears ocellated spots, the three posterior ones being the most distinct. Furthermore, they form an almost perfect equilateral triangle. One of the three ocellated spots is situated on the lateral line and forms the anterior apex of the triangle, and the other two spots, respectively, are situated under the bases of the dorsal and anal and in each case about twice the diameter of the eye from the posterior end of the fins. However, not infrequently the ocellated spots are missing, and specimens of *dentatus* resemble *albiguttus* in color. Rarely the reverse is true, for now and then specimens are seen with definite ocellations, which upon the examination and enumeration of the gill rakers and fin rays appear to be *albiguttus*.

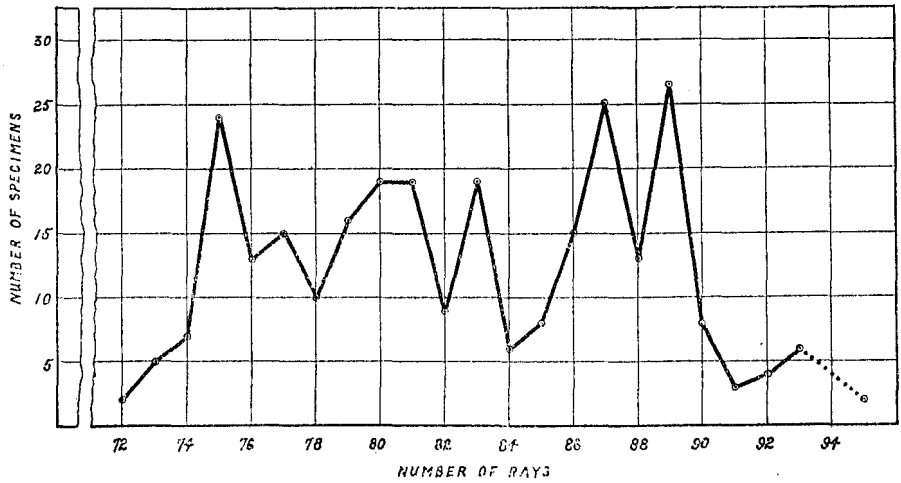

FIGURE 81.—Frequency distribution of dorsal rays in 277 specimens of Paralichthys. Graph based on Table 11

It is evident from the foregoing discussion that the separation of the local species of summer flounders, even with adult specimens, sometimes is difficult. It is not surprising, therefore, that the young (larvæ) are even more difficult and, according to the present studies, inseparable.

The species of the genus Paralichthys known as summer flounders, or southern flounders are recorded from the Atlantic coast of the United States from Maine to Texas. *P. dentatus* ranges farthest northward and is recorded from Maine (occurring only as a straggler north of Cape Cod), and it probably ranges to Florida, its southernmost range not having been definitely determined. The other locally represented form has been recorded by several authors under the name *lethostigmus* from as far north as New York. However, Fowler (1906, p. 395), who states that *dentatus* is the most important flounder on the coast of New Jersey, does not record any other species of Paralichthys from that State. Hildebrand and Schroeder (1928, pp. 165–167), who examined large catches of Paralichthys from Chesapeake Bay, found *dentatus* only, notwithstanding that an earlier author (Smith, 1907, p. 388) had reported *lethostigmus* as common in Chesapeake Bay. The northernmost records of *lethostig-*

mus, therefore, appear to be in need of verification. Whether one or two species are represented on the Gulf coast seems to us uncertain and in need of further study. It is impossible to give at the present time the southernmost range of the local form, which is referred to in the present paper as *albiguttus*.

The relative abundance and economic importance of the two or more species of summer flounders inhabiting the Atlantic coast of the United States from New York to Texas is not known, as the fish are not separated in the market because of their close similarity and statistical reports treat them as a single species. Furthermore, in Chesapeake Bay and northward to New York the winter flounder, *Pseudopleuronectes americanus*, enters into the catch which is listed simply as "flounders" in the statistical reports of the United States Bureau of Fisheries. The bulk of the catch, however, quite certainly consists of summer flounders. As the winter flounder does not occur in commercial numbers south of Chesapeake Bay, the catches reported southward from Virginia consist wholly of summer flounders. It is probable, furthermore, that *dentatus* is not included in the catches from the Gulf coast.

The total annual catch of flounders from the Atlantic and Gulf coasts of the United States, reported in the most recent statistical records of the United States Bureau of Fisheries, amounts to 11,775,046 pounds, valued at $711,224. These data are based on the 1926 canvass of the Middle Atlantic States, the 1925 canvass of the Chesapeake Bay States, and the 1927 canvass of the South Atlantic and the Gulf States. North Carolina produced 348,978 pounds, valued at $23,009. Other States with large catches are New York, 7,352,158 pounds (a considerable part of this catch probably consists of winter flounders); New Jersey, 2,921,714; Delaware, 66,040; Maryland, 118,078; Virginia, 1,581,817; Florida, 131,104; Mississippi, 92,930; and Texas, 77,580.

The summer flounders are not as numerous in the vicinity of Beaufort as several other species of fishes. However, they are of much commercial importance, for they are caught virtually throughout the year, they are well flavored, and always bring a fairly good price. Locally these flounders are caught principally with drag nets, hauled over sandy and muddy bottom. However, quite a few are taken at night by a method known locally as "floundering." A torch with a tank for holding kerosene is placed in the bow of a flat-bottomed skiff. A long pipe with a burner is connected with the kerosene tank in such a way that the burner projects a few feet beyond the bow of the boat, placing the light well in advance of the skiff. Formerly "lightwood" or pine knots were used in a "fire basket" for flounder lighting, but this kind of light has been replaced largely by kerosene torches. On calm nights and on low or a rising tide, skiffs equipped with a torch are slowly poled along the beach in shallow water, while the fisherman keeps a close watch for flounders. The fish often are nearly buried in the sand and only the general outline can be seen and, therefore, they are easily overlooked. When a flounder is found, it is gigged or speared. "Floundering" is successful only on calm nights, as ripples on the water interfere with vision.

The two forms recognized in this paper appear to be about equally common at Beaufort as indicated by market catches examined and by the fact that among 566 fish caught with various collecting gear and brought to the laboratory occurred 289 specimens identified as *dentatus* and 277 identified as *albiguttus*. The size attained also seems to be about equal. The largest specimen of *albiguttus* that we have seen was 29 inches long and weighed 12¾ pounds, whereas the largest specimen of *dentatus* measured by us was 20 inches long. However, somewhat larger ones have been observed in the market. The maximum size attained by *dentatus* is reported as 3 feet

and a weight of 10 to 25 pounds. No definite record of the maximum size reached by *albiguttus* (or *lethostigums*) has come to our notice. It is probable that the 29-inch specimen, mentioned in the foregoing lines, is the largest fish of this form of which there is a definite record.

A slight migration away from the harbor and adjacent estuaries no doubt is made by the summer flounders during late autumn. Both species are present during the winter, although in reduced numbers, and the migration certainly is less pronounced than in the pigfish, spot, croaker, and many other species.

SPAWNING

Summer flounders with roe have been observed infrequently during the present investigation. A few female *Paralichthys albiguttus* with large roe were seen in October and November and a few *P. dentatus* in November with one in February. However, no ripe, or nearly ripe, males were seen. Neither have the eggs been taken, or if secured (which is highly improbable) they have not been recognized.

During two successive autumns adult flounders were confined in aquarium tanks and held throughout the winter. The tanks were furnished with a screened overflow and a small stream of running water from a storage tank into which water from the harbor was pumped daily. It was hoped that the fish would develop roe and cast eggs in the tanks. Although the animals appeared to be healthy and took food (cut fish) regularly, they failed to develop spawn, and our efforts to obtain the eggs for study in this way failed, as did all efforts to obtain them in nature. It seems probable, therefore, that the summer flounders, like the spot, will not spawn in captivity under the conditions provided at Beaufort.

Very small fry, including some slightly under 3 millimeters in length that evidently had been hatched very recently, were taken many times and in considerable numbers, as shown by Table 12. The duration of spawning no doubt is fairly accurately shown by the presence of the larvæ in the collections. However, since two species of flounders very probably are included among the fry (which we are unable to separate), the duration of the spawning season for each species can not be determined. Although the reproductive periods of the two species overlap, as shown by the presence in November of nearly ripe females of both species, it is possible that they do not begin or end simultaneously. However, Table 12 shows only one main uninterrupted period when the larvæ were numerous in the collections, indicating either that the spawning periods of *P. albiguttus* and *P. dentatus* occur simultaneously, or that only one species is represented.

It will be seen from Table 12 that small fry are numerous in the collections only in November and December, notwithstanding that a few were taken in September, several in January and February, and a few more in March, April, and May. These data, then, indicate that some spawning takes place from September to May and that the height of the season occurs in November and December. This period of spawning coincides with the observation of several ripening females in October and November and one in February, as reported in a preceding paragraph.

Spawning probably takes place chiefly, if not wholly, at sea. This conclusion is arrived at from the distribution of the very small fry which were taken much more frequently off Beaufort Inlet than within the harbor, as shown subsequently (p. 474.)

The literature contains very little information concerning the spawning habits of Paralichthys. Hildebrand and Schroeder (1928, p. 166) state that specimens of *P. dentatus* taken in Chesapeake Bay during October had comparatively large gonads.

From this fact and the size of the young secured during the spring and summer, these authors conclude that the eggs quite certainly are cast during the winter.

TABLE 12.—*Length frequencies of 1,151 young summer flounders, indicating that spawning probably begins in September and ends in April or May*

Length in millimeters	Sept.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Length in millimeters	Sept.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
0–4	10	87	98	14	25	6	3	1	----	40–44	----	----	----	----	----	----	1	----	1
5–9	3	270	237	39	45	17	8	5	----	45–49	----	----	----	----	----	----	----	1	----
10–14	----	8	97	60	44	13	3	----	----	50–54	----	----	----	----	----	----	----	----	1
15–19	----	----	----	----	3	35	----	----	----	55–59	----	----	----	----	----	----	----	2	1
20–24	----	----	----	----	----	9	----	----	----	60–64	----	----	----	----	----	----	----	----	----
25–29	----	----	----	----	----	1	----	----	----	65–69	----	----	----	----	----	----	----	----	----
30–34	----	----	----	----	----	----	1	----	----	70–74	----	----	----	----	----	----	----	----	1
35–39	----	----	----	----	----	----	----	----	1										

DESCRIPTIONS OF YOUNG

Ample specimens are at hand to show all the stages in the development of the larvæ. The following descriptions and drawings have been prepared with the view of conveying to the reader a fair idea of the important stages in their development.

Specimens 2.5 millimeters long.—The recently hatched fish is compressed, deep anteriorly, and the caudal portion is relatively long and slender ending in a sharp point. At a size of 2.5 millimeters the head is decidedly deflected and proportionately very large, having a prominent hump, situated over and slightly behind the eyes, inclosing the brain. The mouth is large, strongly oblique to nearly vertical, and the joint of the mandible forms a sharp angle with the ventral outline. The visceral mass projects prominently, is loosely attached to the body, and the hind-gut is plainly visible posterior to the main visceral mass. A few very small dark chromatophores are visible along the ventral outline of the caudal portion of the body, and at a slightly larger size they appear on the visceral mass. An interesting structure is the relatively large pectoral-fin fold which becomes proportionately smaller as the fish grows, resulting finally in a comparatively small fin. It is interesting to compare this pectoral-fin development with that of the tonguefish, *Symphurus plagiusa*. The larvæ of the tonguefish, too, have a rather prominent pectoral-fin fold, which, however, disappears entirely at a size of 10 to 12 millimeters. (Fig. 82.)

Specimens of Paralichthys of this size are most readily recognized by the deep, compressed body, long slender tail, and large hump on the head. The row of dark spots, usually present along the ventral edge of the caudal portion of the body, also is helpful.

Specimens 4 millimeters long.—The advancement in the development over the 2.5-millimeter specimen described in the foregoing paragraph is not pronounced. The head in the 4-millimeter fish is slightly less deflexed, the occipital hump is somewhat smaller, and the mouth probably is a little less oblique. The dark chromatophores of the smaller fish have increased in size and number on the abdominal mass, and a few are now present on the back. The eyeball is slightly concave above and below and a little longer than deep in specimens of this size, as well as in smaller and in somewhat larger ones, as shown in the accompanying drawing. The base of a small fin at the nape (more fully developed at a slightly larger size) is just appearing in specimens 4 millimeters long. (Fig. 83.)

The row of dark spots along the ventral edge of the abdomen, mentioned for the smaller stage, is now quite evident and, in combination with black chromato-

phores on the visceral mass, aids identification. Another recognition mark is the base of a small fin just becoming evident at the nape. This fin develops rays at a slightly larger size, which still later became produced and separate (that is, without interradial membranes) and persist until the right eye crosses the ridge of the head at a length of 10 to 12 millimeters. Through all the stages of the fish intermediate of a length of 4 to about 12 millimeters this fin, therefore, serves as a recognition mark.

Specimens 6 millimeters long.—At this size the head is quite fully in line with the axis of the body, the occipital hump inclosing the brain, described in the smaller fish, no longer is present and the brain is now inclosed in the cranium through which it is plainly visible.

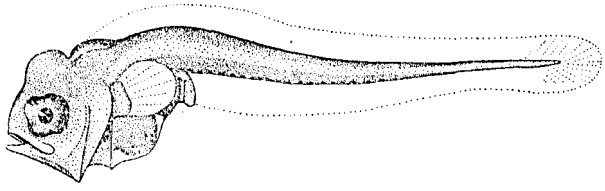

FIGURE 82.—*Paralichthys sp.* From a specimen 2.75 millimeters long

External symmetry remains complete. A decrease in the proportionate depth of the anterior part of the body has taken place. The visceral mass projects less prominently than in the smaller fish described and it is more firmly attached, the body wall having thickened and definitely enveloped it. The small fin at the nape, of which the base only is present in a 4-millimeter specimen, is now well developed. Rays in the caudal fin, below the upward curve of the notochord are just beginning to appear. In pigmentation no changes worthy of note have taken place. Although chromatophores are not shown on the abdomen in the accompanying drawing, they are present in some specimens of this size. (Fig. 84.)

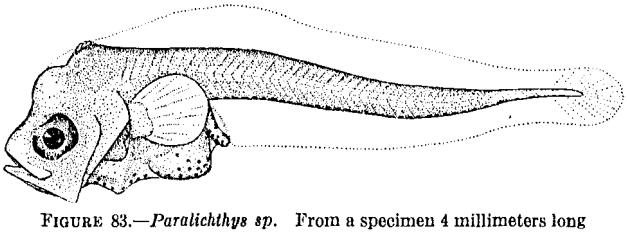

FIGURE 83.—*Paralichthys sp.* From a specimen 4 millimeters long

Specimens 7 millimeters long.—The fish is becoming more definitely compressed. This is especially true of the caudal portion of the body, which also has increased greatly in depth since a length of 5 to 6 millimeters was attained. Symmetry no longer is complete, as the right eye is situated slightly higher than the left one. A notable depression in the dorsal profile of the head is now present over the eyes. The mouth is less strongly oblique than in smaller specimens. The caudal fin is rather fully developed and rays are appearing in the dorsal and anal fins, and the small fin at the nape, described in somewhat smaller specimens, is merging with the long dorsal. Pigmentation remains much as in 5 and 6 millimeter fish, except that the markings have become more distinct and a dark spot is present at the occiput near the origin of the dorsal. (Fig. 85.)

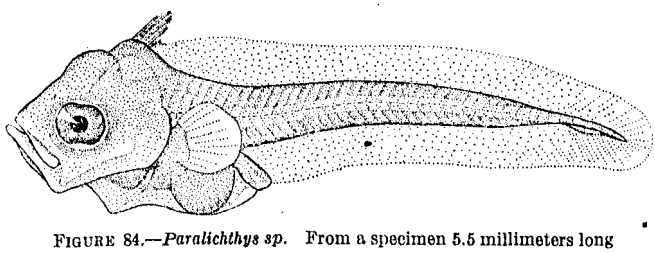

FIGURE 84.—*Paralichthys sp.* From a specimen 5.5 millimeters long

Specimens 8 millimeters long.—The fish has become much more compressed and "flounder shaped." The normal number of fins, including ventrals, are present. The finlet at the nape, described for smaller fish, has become definitely merged with the dorsal. A few of its rays are longer and larger, however, than the other rays of the dorsal. The right eye has made considerable progress in its migration, for it

is near the dorsal ridge at the greatly depressed point in the profile described in the 7-millimeter specimen, and it is in part visible from the left side. Pigmentation has not changed greatly from that of somewhat smaller fish. The markings are only a little more definite and a few chromatophores are now present on the sides of the body. At this size the color markings are identical and equally developed on both sides of the fish. (Fig. 86.)

Specimens 11 millimeters long.—The right eye is situated on the ridge of the head and is "looking up." Specimens of this size were stained, cleared, and mounted, making the vertebræ, or at least their projections, visible. A range from 9 or 10+26 to 30 was found in the number of vertebræ in 17 specimens enumerated. The number of vertebræ is not a distinctive character, however, as the number present is almost identical with several other locally represented species of flounders. Pigmentation has progressed rather rapidly on the left side since a length of 8 millimeters was attained, and it is no longer identical on both sides, as the markings of the right side remain as in the somewhat smaller fish described in the foregoing paragraph. The new chromatophores of the left side are principally so placed as to suggest crossbars. The upward curve of the notochord, prominent in smaller specimens, is scarcely visible at this size, and the tail has lost it heterocercal appearance. (Fig. 87.)

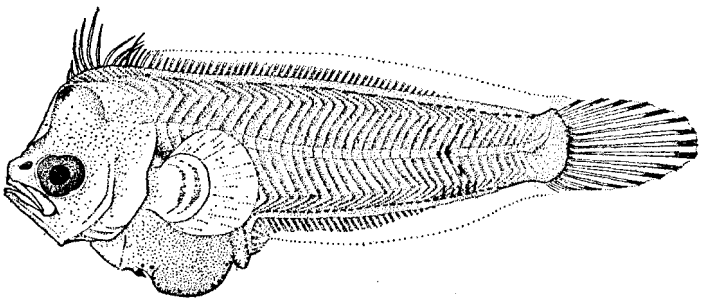

FIGURE 85.—*Paralichthys sp.* From a specimen 7 millimeters long

The fish is now plainly shaped like a Paralichthys, and the fin rays in the dorsal and anal are well enough developed to admit a fairly accurate enumeration. A further aid in identification is the presence of dark chromatophores on the sides arranged so as to suggest crossbars.

Specimens 16 millimeters long. — The form and shape is approaching that of the adult at this size. However, the caudal portion is still a little too slender and the ventral outline has not yet become rounded as in the adult. The chest, with the pelvic bones, is well separated from the gill covers, leaving a vacant space. The right eye is well across the ridge of the head, and both eyes are situated on the left side of the head. Numerous chromatophores are present on the left side, both on the body and on the fins. Many are arranged in clusters, forming diffuse spots. On the blind side a row of dark dots remains along the dorsal and ventral peripheræ. Although pigmentation has progressed rapidly since a length of 11 millimeters was reached, it is not general. Live fish of 16 millimeters, and considerably larger ones, remain surprisingly transparent and are extremely difficult to see and no doubt

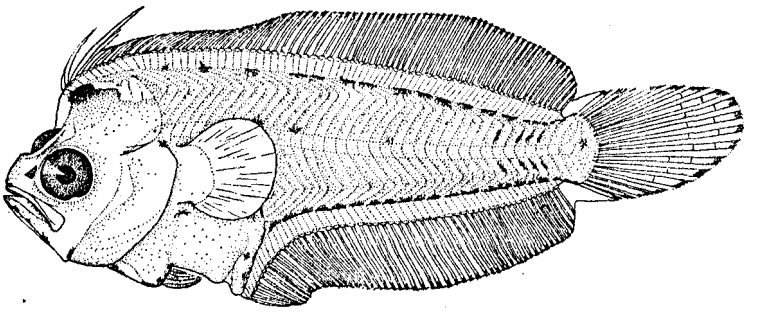

FIGURE 86.—*Paralichthys sp.* From a specimen 8 millimeters long

frequently are overlooked in collecting nets. The gill rakers on the lower limb of the first arch can be fairly accurately enumerated at this size and, as the specimen from which the drawing was made appears to have only about 10, it probably is *P. albiguttus*. (Fig. 88.)

Specimens 26 millimeters long.—At this size the shape of the body is very nearly as in the adult. The ventral outline, however, is not yet as evenly rounded as it will be later. The eyes are situated virtually as in the adult, the upper (right one) being a

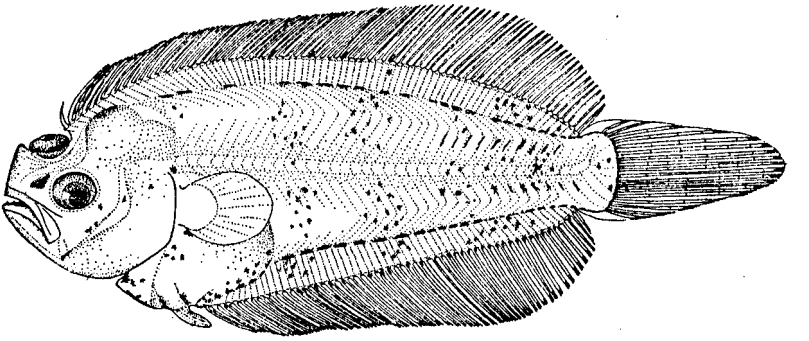

FIGURE 87.—*Paralichthys sp.* From a specimen 11 millimeters long

little in advance of the lower one. Although still proportionately larger than in grown fish, a notable proportionate decrease in size has taken place since a length of 16 millimeters was reached—the diameter being about equal to the length of the snout, whereas it was much longer than the snout in 16-millimeter specimens. The body, exclusive of the head, is rather fully scaled. Pigmentation has become quite general on the left side, while only a few dark dots along the dorsal and ventral periphera of the body remain on the blind side. The concentration of chromato-

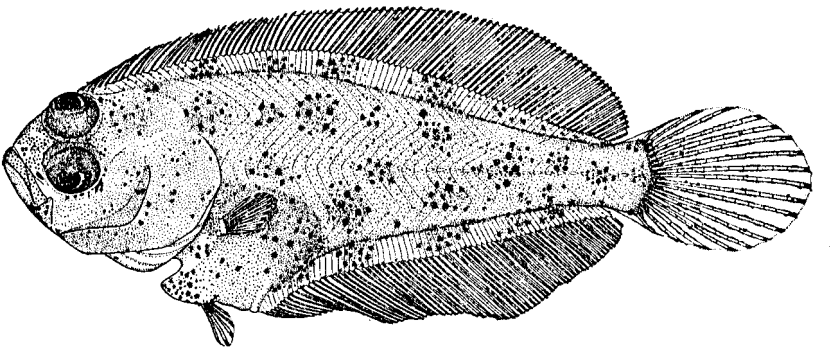

FIGURE 88.—*Paralichthys albiguttus* (?). From a specimen 16 millimeters long

phores on the "eyed side" has increased, and rather definite dark spots are present on the body and on the vertical fins. The specimen drawn has only 9 gill rakers on the lower limb of the first arch and, therefore, quite probably is *P. albiguttus*. (Fig. 89.)

Specimens 77 millimeters long.—The shape and form of the adult has been fully acquired; the body is completely scaled, and pigmentation is general. The eye has decreased further in proportionate size, and the mouth has acquired the characteristic upward and forward curve. The color at this size is very variable as in the adult, some specimens being almost plain brownish with traces of dark spots. Others are variously speckled and spotted. The particular specimen drawn, which is *Para-*

lichthys dentatus, is a profusely spotted one, having the typical ocellations of that species. (Fig. 90.)

DISTRIBUTION OF YOUNG

Very small fry, 3 millimeters and under in length, were taken only at sea. Somewhat larger fish up to 5 millimeters in length, although taken within the harbor

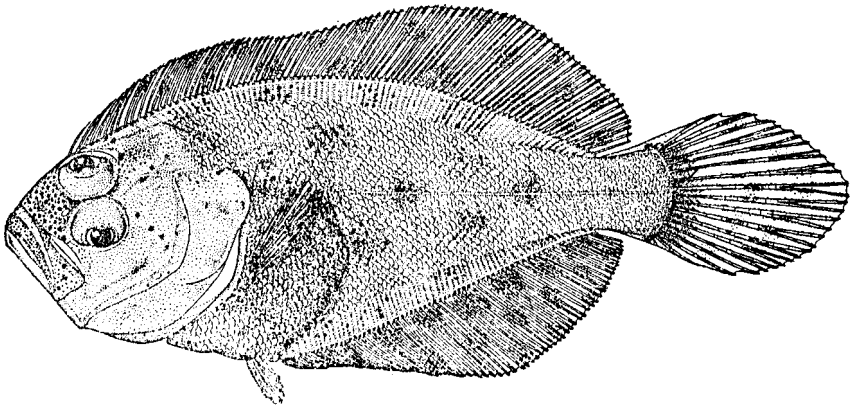

FIGURE 89.—*Paralichthys albiguttus*. From a specimen 26 millimeters long

near Beaufort Inlet a few times, certainly are much more numerous outside. Sizes ranging from 6 to 10 millimeters in length were taken both inside and outside, and judging from the number of specimens contained in the collections they seem to be about equally distributed over the entire area in which collections were made, extending from 12 to 15 miles offshore through Beaufort Harbor and near-by portions of the adjacent sounds, and 6 to 7 miles into the estuaries of Newport and North Rivers.

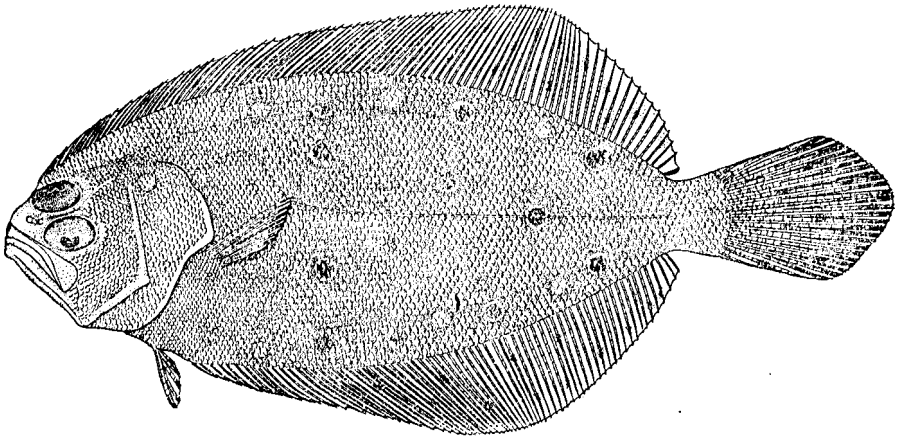

FIGURE 90.—*Paralichthys dentatus*. From a specimen 77 millimeters long

Fish exceeding a length of 10 to 12 millimeters are rarely taken with 1-meter townets. Since much less collecting with apparatus designed to capture the larger young was done in outside than in inside waters, the comparative abundance of these fish in these areas is uncertain. However, the indications are that young fish ranging upward of 10 millimeters are more numerous inside, and especially in the estuaries, than off Beaufort Inlet. Furthermore, a migration toward brackish and fresh-water creeks and ditches of fish ranging upward of about 15 millimeters, is indicated by

limited collecting in such waters. It is quite certain that the larger young ranging from about 15 to 100 millimeters or so in length, are scarce in those areas where the smaller ones are obtainable in considerable numbers and that they must be sought elsewhere. In the light of our present limited information, it seems probable that the larger young may live principally in the brackish and fresh water creeks and ditches.

The distribution of the young over time and season has been shown in part under the head "Spawning" (p. 469). Small fry, ranging from about 2 to 4 millimeters in length were taken from September to May but were numerous only during November and December. Somewhat larger fish, 5 to 14 millimeters long, were common in the collections from November to March. Larger young, ranging from 15 to 25 millimeters in length are comparatively scarce and were taken only in February and March. Still larger ones, ranging upward to about 125 millimeters are sparingly represented and fish coming within this range were taken only in April, May, and June.

Adult Paralichthys, of course, live almost wholly on the bottom. It is evident from the present investigation that the fry also inhabit the bottom, for in an approximately equal number of hauls made with two 1-meter townets, hauled simultaneously at the surface and on the bottom, the larvæ were present in 119 bottom and in only 10 surface collections. Since the eggs have not been taken, it is not known, of course, whether they are of the demersal or the pelagic type. It is quite certain, however, that if the eggs hatch at the surface the young go to the bottom very quickly. The rather constant presence on the bottom of recently hatched fry (only 2 to 3 millimeters long, with deflexed heads) and their almost total absence at the surface, suggests that the eggs may be demersal.

It is evident from the foregoing discussion relative to the distribution of the young that spawning very probably takes place exclusively at sea from September to April or May, but principally in November and December. It is indicated, furthermore, that the young move shoreward and into the inside waters at an early age and that at a somewhat later age, still, they enter brackish and fresh water. It is shown, also, that the fry, like the older and the adult fish, live almost exclusively on the bottom.

GROWTH

Insufficient specimens of the proper sizes have been obtained to show the rate of growth, and this part of the life history must remain unsolved until the habitat of the young fish, ranging from about 25 to 125 millimeters in length, is more definitely located and a much larger number of specimens is collected.

Hildebrand and Schroeder (1928, p. 166) working with fish from Chesapeake Bay, where *P. dentatus* alone is represented, state that their specimens indicate a length of 120 to 180 millimeters (4.7 to 7.1 inches) at one year of age, a length of 200 to 250 millimeters (7.9 to 10.2 inches) when 1¾ years old, and around 270 to 280 millimeters (10.6 to 11 inches) when 2 years old. However, these authors had limited data and their results are not conclusive.

The age of these flounders at sexual maturity, of course, can not be given as their rate of growth is not well enough known. The individuals with large roe that have been observed, invariably, were large ones and ranged in length from 16½ to 29 inches. It seems probable that sexual maturity is not reached at an early age if it be true that the fish first must attain a length of about 16 inches, for our meager data do not suggest a rapid rate of growth.

FOOD AND FEEDING HABITS

It has been shown in that section of this paper dealing with the distribution of the young of the summer flounders, that the fry like the larger young and the adults live on the bottom. Since they habitually dwell on the bottom it follows that they must acquire their food there. No study of the stomach contents of small fish has been made during the present investigation. A considerable number of large flounders has been examined, however, and their food consisted almost wholly of fish, supplemented sparingly by crustaceans. Hildebrand and Schroeder (1928, p. 166) report fish as the principal food, supplemented by squids, shrimp, crabs, and Mysis for specimens from Chesapeake Bay.

Flounders frequently are seen in shallow water, partly covered with sand or mud, and in color they resemble the background. That is to say, if the fish happen to be on sand of a light color, for example, the body is light in color and generally profusely speckled and spotted, thereby more closely resembling the sand. However, if the background consists of dark mud the fish are dark and quite uniform in color. In other words, these flounders are able to simulate to a remarkable degree the color and pattern of the bottom. (See Mast, 1916, pp. 177–238, pls. XIX–XXXII.) Thus concealed from easy vision, they lie in wait for their prey. Although generally rather sluggish fish, they are able to dart from their partial concealment with remarkable rapidity to seize their prey, and they strike with great force. These feeding habits of the summer flounders are easily observed by confining the fish in aquarium tanks, for the fish live well and feed readily in captivity. The senior author once kept about a dozen flounders for nearly two years in a tank supplied with a small stream of running water for the purpose of watching their behavior. The fish lost all fear of a person in several months time and would strike at a man's finger when inserted in the tank just as readily as at a minnow. A laborer who was cleaning the tank, for example, suffered a painful injury one day when a fish struck his hand at a moment when he was offguard.

It is of interest to note that this lot of fish, held in confinement for a long time, when finally liberated apparently had lost the sense of self-preservation. The fish were placed in the water on a sandy beach at high tide but failed to follow the water with the receding tide, remaining on the beach where they had settled upon liberation. When it became evident that they would remain there to die, they were placed in deeper water. It is not known, however, whether these animals again learned to cope with nature and shift for themselves or whether they perished. While color and pattern simulation of the bottom and partial concealment in sand and mud no doubt at times serve the fish as protection from enemies, it very probably is far more important as a concealment from its prey until the critical moment comes when it is time to strike.

SYMPHURUS PLAGIUSA (Linnæus). Tonguefish; sole

The tonguefish is known from Chesapeake Bay southward to Florida, occurring on both coasts of the Florida peninsula. It is common to numerous at Beaufort, N. C., but rare farther northward. Hildebrand and Schroeder (1928, p. 178) say, "It is a rare fish in Chesapeake Bay and unknown to most of the fishermen." It seldom attains a length of 7½ inches, and the usual length of adults is only 4 or 5 inches. It has no direct commercial value and appears to enter into the food of commercial fish only occasionally. Therefore, its economic value appears to be very slight.

The fish is readily recognized by its tongue shape from which it derives its common name. The dorsal and anal fins are continuous with the caudal; pectorals are wanting in the adult; and the single ventral that is present is situated on the ventral edge, slightly in advance of the anal. The skin is very tough and slimy. The slime makes the fish very slippery and difficult to hold with the hand. It is thought that the abundance of slime and the toughness of the skin may serve the fish as protection against enemies.

The literature, as far as known to us, contains almost nothing concerning the habits and life history of this sole.

SPAWNING

Ripe fish have not been observed at Beaufort, nor have the eggs been taken, or if taken they at least have not been identified. Eggs removed from a ripe, or nearly ripe, tonguefish, taken in Chesapeake Bay on July 26, 1916, have been examined by the present writers. Several different sizes are present, indicating that the eggs are not all cast at one time. The ova before spawning are round, and the largest ones in the specimen examined were only about one-half millimeter in diameter.

Although ripe fish were not observed nor eggs obtained, the spawning season nevertheless has been quite accurately determined by the collection of the fry. During nearly four years, townet collections were made quite consistently at about weekly intervals, with the result that tonguefish fry (5 millimeters and under in length) were taken from the last week of May to the first week of October. The larvæ were taken more frequently and in larger numbers in June than at any other time. It may be concluded therefore, that the spawning season extends from May to October and that it probably is at its height in June. From the distribution of the young, as explained on page 481, it seems rather certain that nearly all spawning takes place at sea.

DEVELOPMENT OF YOUNG

The development of young flatfishes always is interesting. The stages of the tonguefish described and figured in these pages are believed to be complete and comprehensive enough, except for one missing stage, to give the reader a fair idea of the development from a recently hatched larva, only about 2 millimeters long, until the fish virtually acquires all the characters of the adult.

Specimens 2.0 millimeters long.—The body is very deep anteriorly, the caudal portion is comparatively long and tapers posteriorly, ending in a rather sharp point. The forehead is high, with a slight concavity above the eyes. The chin is deep and strongly angled. The abdomen is large and protrudes downward prominently and the coils of the alimentary canal are visible in preserved specimens through the thin walls. The mouth is large, oblique, and extremely close to the relatively large eye. Over the head, or at the occiput, are two long filaments. The notochord is visible almost throughout the length of the body as a pale streak. The pigment present consists of three slightly elongated dark spots situated on the back, over the middle part of the body, and in some specimens a dark line is evident on the ventral edge of the caudal portion at the base of the fin fold. At this size the body externally is entirely symmetrical, the eyes being opposite and equally distant from the mouth. (Fig. 91.)

The strongly protruding visceral mass and the large oblique mouth placed very close to the eye are outstanding characters. However, the most evident recognition mark is furnished by two long filaments on the median line of the occiput. These

filaments increase in number with age, some of them becoming bifid, and they persist until a length of at least 10 millimeters is attained. The high number of vertebræ (about 43 to 47), as shown by the muscular rings, is helpful in separating the tonguefish from the other flatfishes of the vicinity of Beaufort.

Specimens 3.0 millimeters long.—The body has increased in depth at this size. The forehead is scarcely as prominent as in a 2-millimeter specimen, the chin is less strongly angled, but the abdomen is larger and protrudes even more strongly. The intestine remains visible through the abdominal walls, as in smaller specimens. The mouth remains close to the eye and strongly oblique. Instead of 2 filaments at the occiput, as in the smaller specimens, 3 or 4 are now present. Indications of fin rays have appeared within the fin fold on the distal part of the tail, and a pectoral fin is becoming visible. The elongated dark spots on the back, described in the 2.0-millimeter specimens, are more evident and more elongated, and in some specimens an indication of a fine dark line between them is present. A finely dotted line is now plainly evident along the ventral edge of the caudal portion of the body. The body remains entirely symmetrical and the slight pigmentation just described is identical on both sides of the fish. (Fig. 92.)

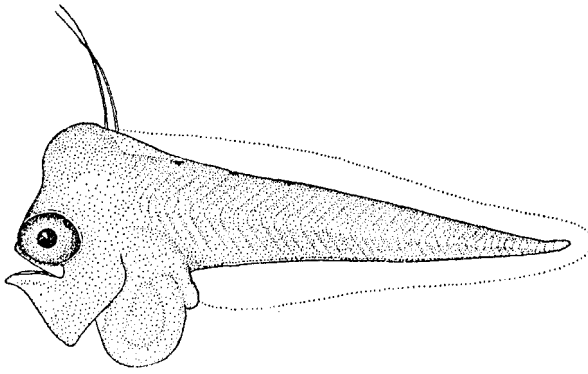

FIGURE 91.—*Symphurus plagiusa.* From a specimen 2 millimeters long

Specimens 5.0 millimeters long.—The caudal portion of the body is much deeper than it is in a 3.0-millimeter specimen, but the anterior portion has decreased in depth and the abdomen protrudes much less prominently. The forehead is now much lower; the eye is proportionately smaller, and the mouth is much farther removed from it. The course of the alimentary canal remains only faintly visible through the abdominal walls. The margin of the opercle is becoming visible, branchiostegals are evident, and the maxillary and premaxillary are well outlined. The filaments on the head have increased still further in number, four to seven now being present. They are unequal in length and in some specimens the longest ones are bifid. Fin rays of the dorsal, caudal, and anal fins are well developed, and the pectoral fin is distinct. Pigmentation differs only slightly from that of a 3.0-millimeter specimen. The notochord remains visible throughout as a pale streak. Symmetry remains perfect in all external characters, except that the vent is situated to the right side of the anterior rays of the anal fin. (Fig. 93.)

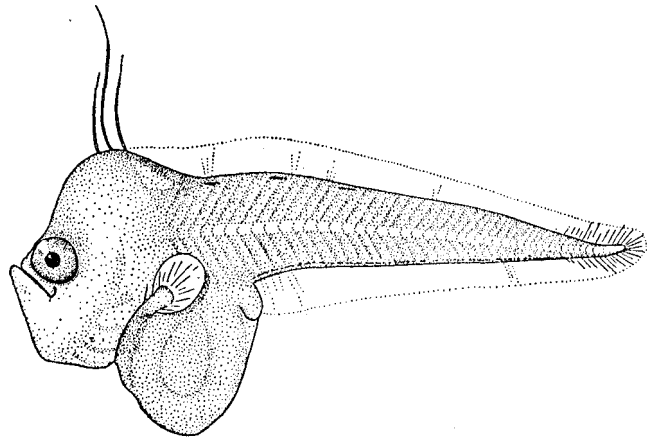

FIGURE 92.—*Symphurus plagiusa.* From a specimen 2.7 millimeters

Specimens 7.0 millimeters long.—Development has proceeded regularly since a length of 5.0 millimeters was attained but the changes are not pronounced. The

body has become more shapely; that is, it has acquired more nearly the form of the adult. The abdomen still protrudes quite prominently and, through its walls, the alimentary canal remains faintly visible. The filaments on the head are proportionately shorter and are becoming definitely merged with the dorsal fin, forming the anterior rays thereof. Color markings are less distinct than in smaller specimens. The eyes are proportionately much smaller in size and symmetry no longer is complete, for the right eye is about one-half an eye's diameter higher than the left one and also slightly in advance of it. The relative position of the eyes can be seen plainly because of the transparency of the head. In all other respects the symmetry apparently remains as complete as in 5-millimeter specimens. A fairly accurate count of the vertebræ may be made at this size by staining and clearing specimens. In 11 specimens, 7 millimeters in length and somewhat larger ones, the body vertebræ were constantly 9 and the caudal ones ranged from 34 to 38. Since no other flatfish known from the vicinity of Beaufort has such a large number of caudal vertebræ this character is distinctive. (Fig. 94.)

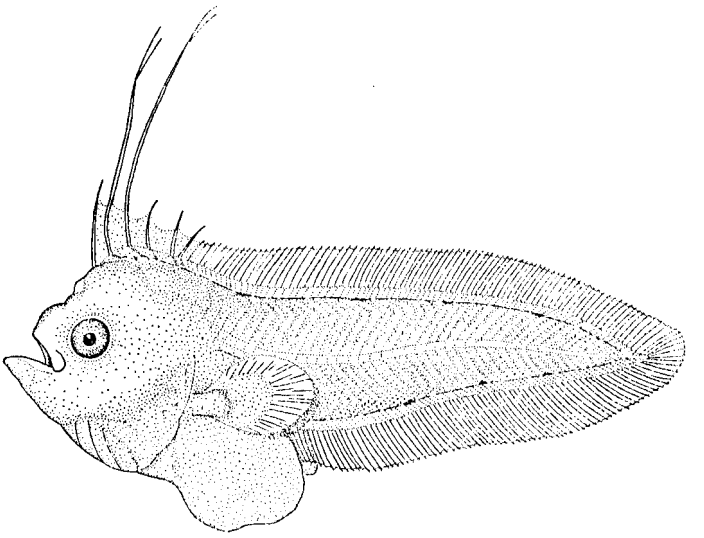

FIGURE 93.—*Symphurus plagiusa.* From a specimen 4.75 millimeters long

Specimens 10 millimeters long.—No pronounced differences between fish of this length and those of 7.0 millimeters are evident. The eyes still are on opposite sides of the head, and although the right one is situated higher than the left one comparatively little advancement is evident in this respect over 7.0-millimeter fish. The abdomen still protrudes rather prominently and the body in general is proportionately deeper than in somewhat older fish. A few filaments with bifid tips remain on the head. The mouth is terminal and only a little less oblique, and the characteristic curve of the premaxillaries of the adult is faintly developed. In fin ray and pigment development, no changes of importance are evident. A few scattered, dark spots, however, are present on the posterior part of the body. (Fig. 95.)

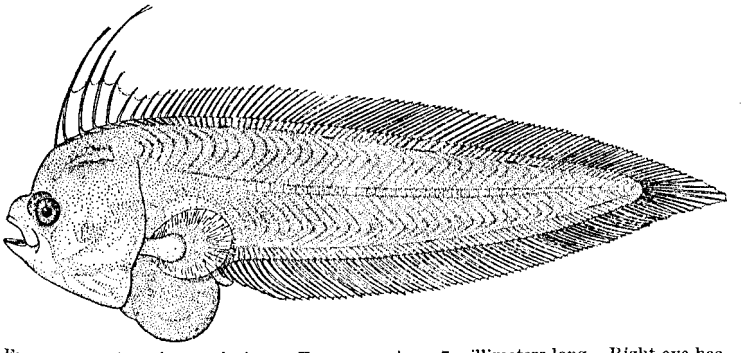

FIGURE 94.—*Symphurus plagiusa.* From a specimen 7 millimeters long. Right eye has begun migration. Its position is indicated in drawing

Specimens 13 millimeters long.—The differences between 10 and 13 millimeter specimens are pronounced. In the larger specimens the eyes are close together on

the left side of the head, as in the adult; the abdomen no longer protrudes; the body has definitely acquired the shape of the adult and is completely scaled; the anterior rays of the dorsal fin are no longer filamentous; the rudimentary pectoral fin has disappeared almost completely; a ventral fin in advance of the anal is evident for the first time; the mouth is horizontal and slightly inferior; the premaxillaries have acquired a pronounced curve as in the adult; and pigmentation has become general, distinctive color markings consisting of dark bars. Our material suggests a sudden metamorphosis soon after a length of 10 millimeters is reached or perhaps that no

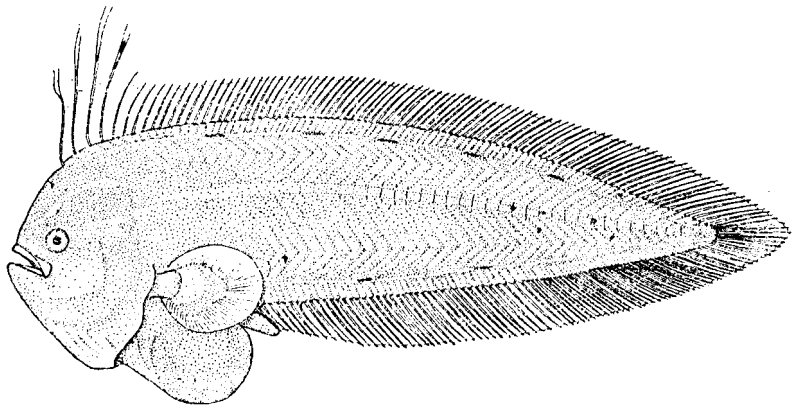

FIGURE 95.—*Symphurus plagiusa*. From a specimen 10 millimeters long

increase in the length takes place during this critical stage. For example, a specimen fully 10 millimeters long still has the eyes on the opposite sides of the head, the right one being situated only a little higher and slightly in advance of the left one; the abdomen protrudes, much as in smaller larvæ; and the anterior rays of the dorsal are still filamentous. An 11-millimeter specimen, on the other hand, has virtually all the characters of the 13-millimeter specimens described in the foregoing lines. It is quite probable, of course, that some variation in the length at which adult characters are acquired occurs among individuals. It is expected, that in some indi-

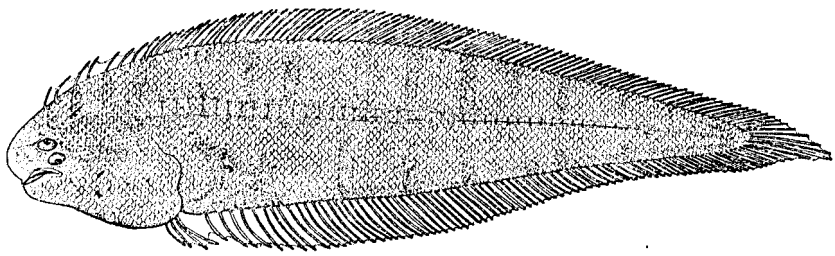

FIGURE 96.—*Symphurus plagiusa*. From a specimen 13 millimeters long

viduals the eyes, for example, will become situated on one side of the head at a somewhat smaller size than in others. Insufficient material is at hand, however, to show the exact variations, for we have comparatively few specimens ranging from 7 to 15 millimeters in length. These specimens also fail to show the complete migration of the right eye to the left side of the head, notwithstanding that one or a few specimens are at hand for each 1-millimeter group, ranging in length from 8 to 15 millimeters (the range in size during which the metamorphosis takes place). In 10-millimeter specimens, as already explained, the migration of the eye appears to have

just begun, whereas in an 11-millimeter specimen, and larger ones, it has been completed. (Fig. 96.)

Specimens 35 millimeters long.—The fish has acquired virtually all the characters of the adult at this size. It is proportionately more slender, the depth being contained about 3.5 times in the length, whereas in the adult the depth is contained in the length about 3.0 times. The differences between fish 13 to 35 millimeters long are not pronounced. It is evident, however, that the rays in the anterior part of the dorsal and anal fins have become more crowded in the larger specimens and the characteristic dark bars of the smaller fish sometimes, although not always, become quite indefinite. Considerable variations in color are evident, however, in fish of this size and larger ones; some specimens being quite plain brownish gray, others paler gray, and some are without spots or bars, whereas others are indefinitely barred and variously specked or spotted. Fish 35 millimeters in length, and even smaller ones, are readily recognized by anyone familiar with the adult. (Fig. 97.)

DISTRIBUTION OF YOUNG

Small fry, 5 millimeters and under in length, were taken in only 2 collections made within the harbor, whereas they occur in 46 collections made off Beaufort

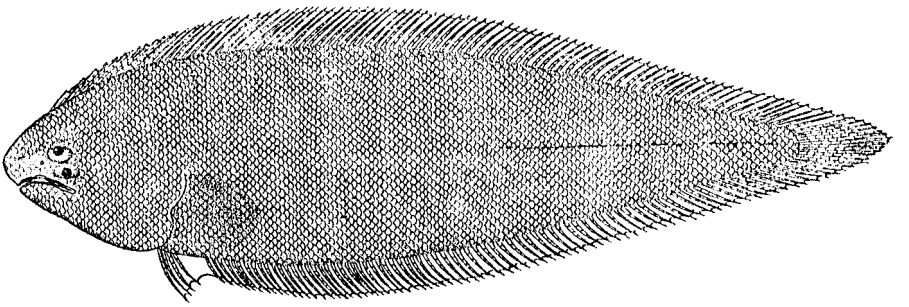

FIGURE 97.—*Symphurus plagiusa*. From a specimen 35 millimeters long

Inlet, some of the stations at which the collections were made being as much as 12 to 15 miles offshore. Somewhat larger fish were taken a little more frequently within the harbor, but they remain more numerous at sea. It may be concluded from the distribution of the fry that spawning takes place principally at sea.

Young fish ranging from about 10 to 75 millimeters in length are few in our collection, very probably because of the method of collecting. Fish of this size are too big to be caught readily in 1-meter townets, yet too small to be held by the ordinary collecting trawl. A method of collecting fish of this size was not developed until toward the close of the investigation. The fish of these larger sizes contained in the collection, with a single exception, were taken within the harbor. It must not be concluded, however, that these young are more numerous in the harbor than at sea, as much less collecting with the recently devised apparatus was done at sea than within the harbor. The data do show, however, that the larger sizes (10 to 75 millimeters) are more common within the harbor and adjacent estuaries than the smaller ones.

The adult tonguefish, of course, is strictly a bottom-dwelling form. It is evident from the townet collections at hand that the young, too, live almost entirely on or near the bottom, for in an approximately equal number of drags made with two 1-meter townets, hauled simultaneously, one at the surface and the other one

on the bottom, the fry were taken in 56 bottom collections and in only 3 surface ones. It seems evident from the results of collecting that the fry, if hatched from floating eggs (which is probable, as the other species of sole occurring locally, as well as one or more European species, are known to produce pelagic eggs), resort to the bottom at a very early age, as the great majority of the numerous specimens taken there are less than 7 millimeters long.

It may be concluded from the foregoing discussion, therefore, that the small fry locally occur almost entirely out at sea, where spawning no doubt takes place, and that the larvæ, like the adults, dwell almost exclusively on the bottom.

GROWTH

Insufficient specimens were taken to show the rate of growth, as individuals from about 10 to 75 millimeters in length are sparingly represented in the collections. We have several specimens, however, which evidently belong to the O class, taken in January, February, and March, when about 6 to 9 months old, ranging from 34 to 68 millimeters in length. It is believed that these specimens probably are representatives of the larger fish of the O class. If that be true, the rate of growth is not very rapid.

MONACANTHUS HISPIDUS (Linnæus). Foolfish

The foolfish is known from Nova Scotia to Brazil, and it is recorded also from the Canaries and Madeira in the eastern Atlantic. It is rather rare on the American coast north of Cape Cod and common southward. It is common at Beaufort during the summer, but certainly not abundant. During the winter it has not been seen. It is principally pelagic in its habits, living chiefly among plant growth along the shores and among floating plants and débris at sea.

Color simulation is highly developed, for the fish are bright green when found among vegetation of that color, or brownish if that happens to be the color of the plants among which the fish are taken, and so forth. The fish probably has need of the protection it derives from color simulation, as it is a sluggish fish and a poor swimmer. When caught in a net it makes no effort to escape, and not infrequently it even fails to swim away for some time after the net is removed. This seems so foolish to the fishermen that they have named this species, as well as its relatives which behave similarly, foolfish.

This foolfish is recognized by its short, deep body; in the adult the depth at the vertical from the vent generally being contained less than two times in the length of the body. It has a rough, spiny skin; a single high dorsal spine with barbs; and a rough ventral spine, beyond which a skinny, ventral flap does not extend, as in a related species. The foolfish is of no direct economic importance, as it is not eaten and its value indirectly, as food for commercial species, probably is slight. The literature contains very little information concerning the life history of this fish.

SPAWNING

The eggs of the foolfish have not been taken, or if so, they have not been recognized. Neither have fish with large roe been observed. In fact, few individuals exceeding a length of about 5 to 6 inches have been caught, although this fish is said to reach a length of 10 inches. The rather small individuals, commonly taken locally, probably are sexually immature. All that has been learned during the pres-

ent investigation about spawning in this species, has been derived from the collection and the study of the young. It has been possible, however, in this way to obtain fairly accurate data relative to the place, time, and duration of spawning.

Very small young, 4 millimeters and under in length, were taken in townet collections from May to September and a few scattering ones, slightly larger in size, were taken in October, November, and as late as December 6 (1927). The fry were common from June to September, and the largest number was taken during July. The records of these collections, therefore, indicate that spawning may take place from May to about November, that the chief spawning season extends from June to September, and that it probably is at its height in July.

The distribution of the young, as shown on p. 486, indicates that in the vicinity of Beaufort spawning takes place entirely at sea. This would be expected because extensive collecting within the harbor and adjacent inside waters has yielded very few large foolfish; that is, fish over 5 or 6 inches in length, among which no individuals with developing roe have been observed. It is probable, therefore, that the mature fish live almost entirely at sea where they carry out the reproductive processes.

The extremely small size of the most recently hatched fry taken, which are only about 1.7 millimeters long, suggests that the foolfish produces a very small egg. Since the smallest fry, that is larvæ 4 millimeters and under in length, were nearly all taken in bottom hauls, although the larger ones were collected almost exclusively at the surface, suggests that the eggs may be demersal.

DEVELOPMENT OF YOUNG

The foolfish acquires adult characters and is readily recognizable as a foolfish at an extremely early age. This interesting fact is shown by the descriptions and drawings which follow.

Specimens 1.7 millimeters long.—Two specimens of about this size are at hand, only one of which is in good enough condition for an accurate description and illustration. The fry at this size have a robust body and a long, slender, pointed tail. The head is blunt anteriorly and extends only slightly beyond the large eye. The mouth is small and terminal. Fin folds extend around the entire caudal portion of of the body and are present for the pectorals and for *two* ventral fins. The last-mentioned fins fail to develop and are represented in larger fish by a single spine, attached to the pelvic bones. A spine, about equal in length to the diameter of the eye, already is present over the head, as in the adult, and at once identifies the larva as a foolfish. The spine is very slender at this age and without barbs or serrations. Dark pigment is present on the head, extending along the upper surface to the base of the dorsal spine. Similar dark pigment is present on the ventral fin folds and extends from thence along the upper margin of the abdomen to the vent and then as a row of somewhat larger dots along the ventral edge to the tip of the tail. (Fig. 98.)

The presence of the dorsal spine in combination with the deep body aid identification at this and all other ages.

Specimens 2 millimeters long.—The principal change in the structure, since a length of 1.7 millimeters was attained, is in the loss or union of the ventral fin membranes, for the two tufts of membrane present at the smaller size have disappeared and now a single flexible membranous fin is situated on the median line of the abdomen. It is not evident from the specimens at hand whether the pair of membranous tufts, resembling ventral fins, present in the very young are lost, or whether they

become united to form the single membranous fin now present on the median line of the abdomen. This membranous appendage on the abdomen will soon develop into a strong spine. (Fig. 99.)

Specimens 3 millimeters long.—The body has become considerably deeper, especially in the anterior portion of the caudal region. Posteriorly the tail remains slender and pointed. The snout now projects rather prominently in advance of the eye and is becoming slightly conical, while the mouth is small and terminal, as in the adult. The dorsal spine is high and prominent, being equal to about two-thirds the depth of the body, and from its anterior and posterior margins project a few spiny barbs, variable in size. The ventral spine has become strong and rigid. The soft dorsal, caudal, and anal are becoming slightly developed with traces of rays, and small prickles are beginning to appear on the body covering. Dark pigment is present on the head and generally extends on the back. The ventral periphera, including the ventral spine, usually is slightly pigmented with black. Similar pigmentation occurs on the side above and behind the abdomen. (Fig. 100.)

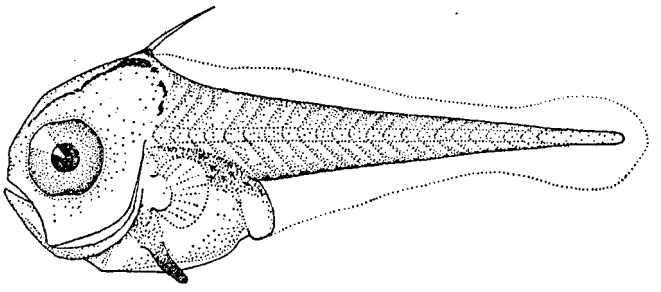

FIGURE 98.—*Monacanthus hispidus.* Drawn from a specimen 1.7 millimeters long

Specimens 5 millimeters long.—The body is shaped very much as in the adult. The tail now is moderately deep and it supports a well-developed, rounded caudal fin. The soft dorsal and anal, too, are fairly well developed. The barbs on the dorsal spine have increased in number and size, and the skin is now quite generally beset with prickles. Pigmentation in preserved specimens consists principally of dark dots scattered over the body.

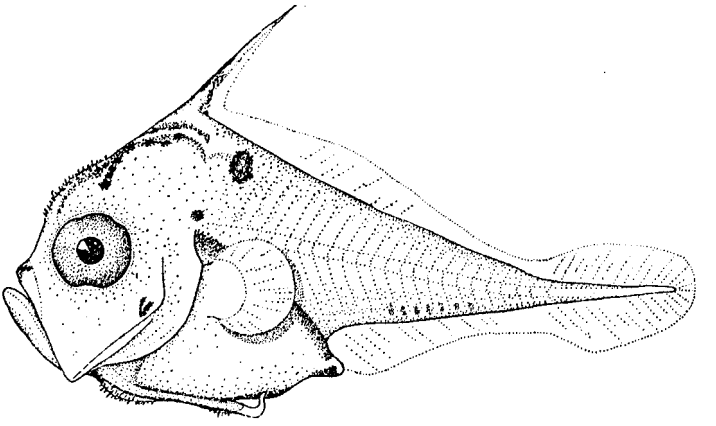

FIGURE 99.—*Monacanthus hispidus.* Drawn from a specimen 2 millimeters long

Specimens 8 millimeters long.—Specimens 8 millimeters long are very similar to the adults in shape. The snout, however, remains much shorter and blunter. The dorsal spine still has large barbs on both the anterior and posterior margins; the ventral spine is very prickly and largely free, the membranous flap which later ties it to the abdomen being mostly undeveloped. The other fins are all well developed and shaped as in the adult. Pigmentation consists principally of brownish spots with dark centers, present everywhere on the body, exclusive of an area behind the eye and around the gill opening. (Fig. 101.)

Specimens 15 millimeters long.—In shape and form the body is now identical with the adult, except that the snout remains too blunt and does not project as

prominently as in grown fish. The barbs on the dorsal spine, especially those on the forward margin, have become proportionately much smaller since a length of 8 millimeters was attained; the ventral spine is prickly and is now attached to the abdomen by a membranous flap which is much more fully developed than in 8-millimeter specimens. Brownish spots with dark centers are present everywhere on the head and body. When seen with the unaided eye the body shows indications of dark marblings. The fins are almost colorless, as in the adult. Fish 15 millimeters long have acquired so many of the adult characters and are so similar to the fully grown fish that they are readily recognized by anyone familiar with the adult.

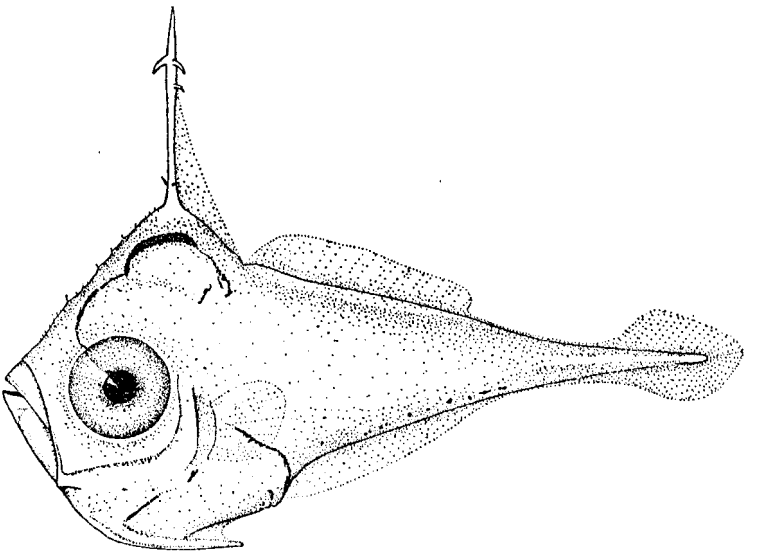

FIGURE 100.—*Monacanthus hispidus*. Drawn from a specimen 2.8 millimeters long

As the fish increases in length the snout continues to become more pointed and the dorsal profile over the snout gets more strongly concave. This lengthening of the snout continues even after the fish has reached a length of 75 millimeters. The barbs on the anterior margin of the dorsal spine gradually become smaller as the fish grows and generally are quite small or have disappeared when a length of 40 to 50 millimeters is reached. The ventral flap, situated between the ventral spine and the abdomen, varies somewhat in size among individuals of the same length, but generally increases in size with age, failing to reach the tip of the spine until a length, of

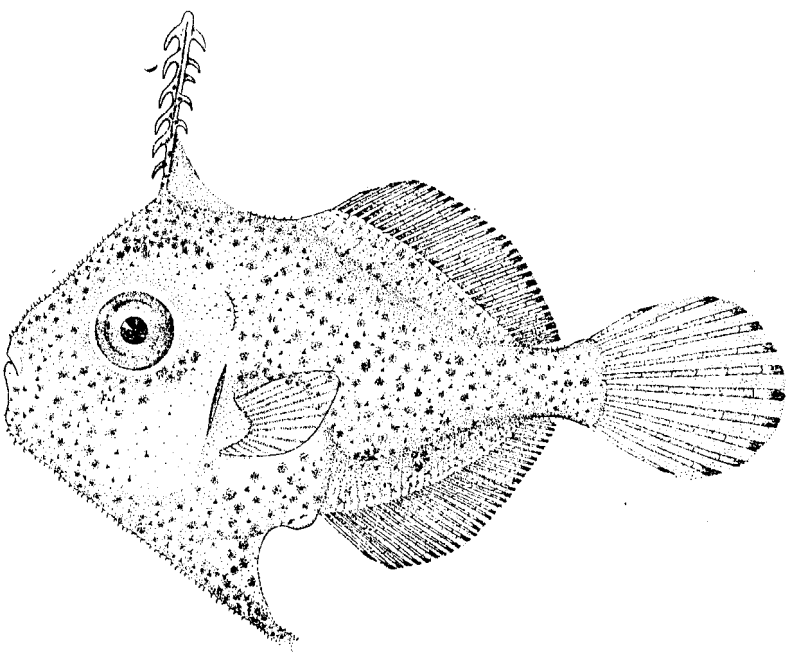

FIGURE 101.—*Monacanthus hispidus*. Drawn from a specimen 8 millimeters long

at least 75 millimeters is attained. The margin of this flap rarely extends slightly but never prominently beyond the tip of the ventral spine.

DISTRIBUTION OF YOUNG

The fry first appeared in the tow in May when only a few were taken and three young—5, 7, and 10 millimeters long—were collected as late as December 6 (1927). The last-mentioned specimens certainly may be considered stragglers, for they are the only foolfish of any age or size taken in December. Young foolfish were common in June, July, August, and September. They were most numerous, however, in July. These data are interpreted to indicate, then, that spawning may occur from May to about November, that the principal spawning season extends from June to September and that it probably is at its height during July. Neither the young nor the adults have been found in the local waters during the winter.

Small fry were not found in the inside waters. Only three specimens, all over 7 millimeters in length, were taken in townets within Beaufort Harbor and adjacent waters, all the others (over 300 specimens) having been secured outside. It is quite certain, therefore, that nearly all the young, locally, are hatched at sea.

The young were never taken in large numbers in any one haul. They were caught frequently, however, and generally only one or a few at a time. This seems to show that the young, like the adults, are solitary.

The young, exclusive of the very smallest ones, were taken at the surface much more frequently than on the bottom. For example, in an approximately equal number of hauls made with two 1-meter townets, hauled simultaneously, one at the surface and the other at the bottom, specimens of foolfish were taken in 80 surface towings and in only 12 bottom ones. Since the bottom net remained open as it was hauled in, it is quite possible that some of the specimens contained in this net were not caught on the bottom. It is interesting and worthy of note, however, that of the smallest larvæ secured—that is, fry of 3 millimeters and less in length, of which about 15 specimens are at hand—only 1 individual was taken in a surface haul, whereas only 9 larger ones were caught in bottom hauls. The results of this collecting appear to indicate that the recently hatched young occupy the bottom but come to the surface at a very early age.

Foolfish are rather infrequently taken locally in otter trawls, a type of net that fishes the bottom, and generally is hauled in water at least several feet deep. Individuals ranging from 25 millimeters upward are common in shallow grassy areas in the harbor during the summer, and they are also seen at sea swimming about or among floating plants. It is evident from the foregoing facts that the foolfish acquires its surface-dwelling habit at a very early age. It appears to retain this habit throughout life.

GROWTH

Measurements for the determination of the rate of growth have not been made and little information on this subject has been secured. Fish ranging from about 15 to 60 millimeters in length are common in collections made with seines in Beaufort Harbor during September. It is believed that the larger individuals, namely, those ranging from about 50 to 60 millimeters (2 to 2½ inches or so) in length are representatives of the earliest and largest young of the season. Upon the approach of cool weather in the autumn the fish withdraw from the shallow shore waters and

comparatively few appear to return the next summer. Therefore, nothing has been learned about their growth after the first summer, nor has the age at which maturity is reached been determined.

BIBLIOGRAPHY

BEEBE, WILLIAM, and JOHN TEE-VAN.

1928. The Fishes of Port au Prince Bay, Haiti. Zoologica, Vol. X, No. 1, 1928, 279 pp., text figs. New York.

EVERMANN, BARTON WARREN, and MILLARD CALEB MARSH.

1902. The Fishes of Porto Rico. Bulletin, United States Fish Commission, Vol. XX, Pt. I, 1900 (1902), pp. 51–350, 112 figs., 3 maps, 49 pls. Washington.

FOWLER, HENRY W.

1906. The Fishes of New Jersey. Annual Report, New Jersey State Museum, Pt. II, 1905 (1906), pp. 35–477, 103 pls., text figs. Trenton.

1907. The Amphibians and Reptiles of New Jersey. Annual Report, New Jersey State Museum, Pt. II, 1906 (1907), pp. 23–408, 122 pls., text figs. Trenton.

GUDGER, E. W.

1913. Natural History Notes on Some Beaufort, N. C., Fishes, 1912. Proceedings, Biological Society of Washington, Vol. XXVI, 1913, pp. 97–110. Washington.

HILDEBRAND, SAMUEL F., and WILLIAM C. SCHROEDER.

1928. Fishes of Chesapeake Bay. Bulletin, United States Bureau of Fisheries, Vol. XLIII, Pt. 1, 1927 (1928), 388 pages, 211 figs. Bureau of Fisheries Document No. 1024. Washington.

JORDAN, DAVID STARR, and ALVIN SEALE.

1926. Review of the Engraulidæ, with Descriptions of New and Rare Species. Bulletin, Museum of Comparative Zoology at Harvard College, Vol. LXVII, No. 11, pp. 355–418. Cambridge.

KUNTZ, ALBERT.

1914. The Embryology and Larval Development of *Bairdiella chrysura* and *Anchovia mitchilli*. Bulletin, United States Bureau of Fisheries, Vol. XXXIII, 1913 (1915), pp. 3–19, 46 figs. Bureau of Fisheries Document No. 795. Washington.

MAST, S. O.

1916. Changes in Shade, Color, and Pattern in Fishes, and Their Bearing on the Problems of Adaptation and Behavior, with Especial Reference to the Flounders Paralichthys and Ancylopsetta. Bulletin, United States Bureau of Fisheries, Vol. XXXIV, 1914 (1916), pp. 173–238, Pls. XIX–XXXVII. Bureau of Fisheries Document No. 821. Washington.

NICHOLS, J. T., and C. M. BREDER, Jr.

1928. An Annotated List of the Synentognathi. Zoologica, Vol. VIII, No. 7, 1928, pp. 423–448, figs. 156–176. New York.

PEARSON, JOHN C.

1929. Natural History and Conservation of the Redfish and Other Commercial Sciænids on the Texas Coast. Bulletin, United States Bureau of Fisheries, Vol. XLIV, 1928 (1929), pp. 129–214, 44 figs. Bureau of Fisheries Document No. 1046. Washington.

RADCLIFFE, LEWIS.

1914. The Work of the U. S. Fisheries Marine Biological Station at Beaufort, N. C., During 1913. Science, N. S., Vol. XL, 1914, pp. 413–417. New York.

SMITH, HUGH M.

1898. The Fishes Found in the Vicinity of Woods Hole. Bulletin, United States Fish Commission, Vol. XVII, 1897 (1898), pp. 85–111. Washington.

1907. The Fishes of North Carolina. North Carolina Geological and Economic Survey, Vol. II, 1907, xi, 453 pp., 21 pls., 188 figs. Raleigh.

TAYLOR, HARDEN F.

1916. The Structure and Growth of the Scales of the Squeteague and the Pigfish as Indicative of the Life History. Bulletin, United States Bureau of Fisheries, Vol. XXXIV, 1914 (1916), pp. 285–330, Pls. L–LIX, 8 text figs. Bureau of Fisheries Document No. 823. Washington.

TOWERS, IRVING L.

1928. Embryology of the Pigfish. *In* Progress in Biological Inquiries in 1926, by Elmer Higgins. Appendix VII, Report, United States Commissioner of Fisheries, 1927 (1928), pp. 622–624. Bureau of Fisheries Document No. 1029. Washington.

WELSH, W. W., and C. M. BREDER, Jr.

1923. Contributions to the Life Histories of Sciænidæ of the Eastern United States Coast. Bulletin, United States Bureau of Fisheries, Vol. XXXIX, 1923–24 (1924), pp. 141–201, 60 figs. Bureau of Fisheries Document No. 945. Washington.