NOTES ON THE EMBRYOLOGY AND LARVAL DEVELOPMENT OF TWELVE TELEOSTEAN FISHES

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Contribution from the United States Fisheries Biological Station, Woods Hole, Mass.

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INTRODUCTION.

Adequate measures for conservation of our fishery resources and the production of the maximum quantity of food with the minimum of expenditure through proper propagation methods require as their basis a reasonably complete knowledge of the life histories and habits of the fishes. The first step in this direction is the determination of the character of the eggs and young, so that they may be recognized at any stage of development. Many of our important marine food fishes—e. g., cod, haddock, hake, mackerel, and halibut—have floating eggs, which may be collected with an ordinary tow net with much less effort than is required to locate and capture the spawning fish. Thus this knowledge may serve to locate the spawning grounds and also the schools of spawning fish. The immediate value of knowledge of this character has been well illustrated by Dr. Hjort, of Norway. Knowing the character of cod eggs, he applied this method to the coast banks off northern Norway and thereby "succeeded in finding enormous shoals of cod on certain banks where no fishing was carried on, and where, as a consequence of our discovery, millions of cod were afterwards taken."

The present paper embodies the results of a study of the embryology and larval development of teleostean fishes taken in the region of Woods Hole, Mass., during July and August, 1915.

The majority of the species, especially the more important ones, common to this region spawn earlier in the season. Little is known of the breeding habits of the bonito (*Sarda sarda*), the menhaden (*Brevoortia tyrannus*), the butterfish (*Poronotus triacanthus*), and the hake (*Urophycis chuss*). Females of these species in which the eggs were nearly or quite mature and males from which the milt flowed freely were taken. However, all attempts at artificial fertilization failed. The eggs of the bonito and the hake were never taken in the plankton. With the exception of the menhaden, butterfish, and whiting, the eggs of all the species described herein were artificially fertilized and hatched in the laboratory. The eggs of the whiting were artificially fertilized, but all died during

early cleavage. Both eggs and young of all the species with pelagic eggs were taken in the plankton.

The embryology and early larval life of several species included in this paper were early studied by Agassiz [a] and Agassiz and Whitman.[b] The embryology of one species, viz, *Tautogolabrus adspersus*, is described and illustrated in great detail by these authors in their fundamental work on the development of osseous fishes.[b] Their observations on other species included in this paper are more or less fragmentary. The pelagic eggs and larvæ identified by them as *Cottus grœnlandicus* are doubtless *Prionotus carolinus*, as a comparison of their figures with the figures here presented of the eggs and larvæ of the latter species will show. The eggs and larvæ described by them as species allied to *Motella* are probably eggs and larvæ of the butterfish. Eggs apparently identical with the eggs described by them as those of the Sienna flounder were taken throughout July and August. They were taken in greatest abundance off Gay Head on August 24. These eggs were not identified by the present writers. Observations on the early development of one species (*Apeltes quadracus*) included in this paper are recorded by Ryder.[c]

The observations recorded herein were made almost exclusively on living material. It is not the purpose of this paper to discuss in detail the embryological development of each species studied, but rather by means of illustrations and descriptions to afford a ready means of identifying eggs or larval fishes at any time during embryonic or larval life. With this purpose in view, the inclusion of several species upon which more or less complete observations have been previously recorded seems justifiable.

Acknowledgments are due Homer Wheelon for the preparation of the majority of the illustrations and general assistance in the investigation and Vinal N. Edwards for assiduous collecting of material.

KEY TO EGGS OF CERTAIN FISHES.

As an aid to the identification of eggs which may be met with in the Woods Hole region during July and August, the following key is appended:

I. PELAGIC EGGS.
- *a.* Eggs without oil globules.
  - *b.* Eggs spherical.
    - *c.* Egg 0.75 to 0.85 mm. in diameter, highly transparent; pigmentation appears in embryos of 10 to 15 somites in form of small black chromatophores distributed over dorsal surface. *Tautogolabrus adspersus* (cunner).
    - *cc.* Egg 0.9 to 1 mm. in diameter; in all other respects egg and pigmentation of developing embryo resemble preceding ..... *Tautoga onitis* (tautog).
  - *bb.* Eggs ellipsoidal, yolk cortex segmented.
    - *d.* Major axis but little longer than minor axis, 0.65 to 0.75 mm. long, minor axis 0.1 to 0.3 mm. less ..... *Anchovia mitchilli* (anchovy).
    - *dd.* Major axis considerably longer than minor axis.
      - *e.* Major axis 1.15 to 1.25 mm. and minor axis 0.55 to 0.8 mm. in length; developing embryo within egg unpigmented ..... *Anchovia argyrophana* (anchovy).
      - *ee.* Major axis 1.2 to 1.5 mm. and minor axis 0.84 to 0.86 mm. in length. *Anchovia brownii* (anchovy).

[a] On the young stages of some osseous fishes (part III). Proceedings, American Academy of Arts and Sciences, vol. XVII, 1882, p. 271.

[b] The development of osseous fishes: I. The pelagic stages of young fishes. II. The pre-embryonic stages of development. Memoirs, Museum of Comparative Zoology, Harvard College, vol. XIV, no. 1, pt. I, p. 1, 1885; pt. II, p. 3, 1889.

[c] On the development of osseous fishes. * * * Annual Report, Commissioner of Fish and Fisheries, 1885, p. 489.

aa. Eggs with oil globules, spherical in form.

f. Egg with one (rarely two) oil globule.

g. Egg with very large perivitelline space; diameter of egg 1.4 to 1.6 mm., of yolk sphere 0.9 to 0.93 mm.; cortex of yolk sphere segmented; oil globule small, 0.12 to 0.14 mm. in diameter; pigmentation begins several hours after closure of blastopore; at time of hatching small black pigment spots are more or less closely aggregated on upper surface of head and body.....*Brevoortia tyrannus* (menhaden).

gg. Egg without large perivitelline space.

h. Egg 0.7 to 0.8 mm. in diameter; a single large oil globule 0.17 to 0.2 mm. in diameter or two smaller ones which later coalesce; in well-differentiated embryo black chromatophores are sparsely scattered over its entire surface, on extra-embryonic blastoderm and oil globule, being relatively large at time of hatching.
Poronotus triacanthus (butterfish).

hh. Eggs 0.85 to 1 mm. in diameter.

i. Oil globule transparent, small, less than 0.18 mm. in diameter.

j. Egg 0.85 to 0.9 mm. in diameter; pigmentation first observed in embryos of 15 to 20 somites; black and yellow pigment cells sparsely scattered over embryo and oil globule, and these increase in number and size; before hatching the yellow chromatophores have become aggregated to form heavily pigmented areas.....*Stenotomus chrysops* (scup).

jj. Egg 0.9 to 1 mm. in diameter; oil globule about 0.125 mm. in diameter (Sienna flounder of Agassiz and Whitman).....Species(?)

ii. Oil globule opaque, yellowish or brownish in color, 0.19 to 0.23 mm. in diameter; pigmentation appears shortly after closure of blastopore; black chromatophores become sparsely scattered over embryo and oil globule, those on posterior part of body later becoming aggregated in two vertical bands; yellow pigment behind eye, back of otocyst, along side of trunk anteriorly, and in the two vertical bands.....*Merluccius bilinearis* (whiting).

ff. Oil globules several to many.

k. Egg 0.7 to 0.8 mm. in diameter; one or more large oil globules and numerous small ones.....*Urophycis chuss* (hake).

kk. Egg 1 to 1.35 mm. in diameter.

l. Egg 1 to 1.15 mm. in diameter, slightly yellowish in color but highly transparent; 10 to 25 unequal oil globules present; numerous yellow and black pigment cells are present over entire surface of embryo and extra-embryonic blastoderm, before hatching becoming fewer and more scattered.
Prionotus carolinus (sea robin).

ll. Egg with two to five (rarely one) large oil globules and several smaller ones egg 1.15 to 1.35 mm. in diameter, transparent.....*Sarda sarda* (bonito);

II. DEMERSAL EGGS.

m. Eggs attached by adhesive threads arising from egg membrane.

n. Adhesive threads arising in a tuft from one point on egg membrane.

o. Egg yellowish, semiopaque, 1.1 to 1.2 mm. in diameter; 5 to 12 large oil globules of unequal size and numerous smaller ones present; black chromatophores become sparsely scattered over embryo and blastoderm, followed by yellow ones on embryo; later black ones become aggregated in a few areas on top of head, in series along base of ventral-fin fold, and a few at base of dorsal-fin fold posteriorly.....*Menidia menidia notata* (silverside).

oo. Egg tinted with yellow, more transparent than preceding, 0.9 to 1 mm. in diameter; one or two large oil globules and few smaller ones; fewer adhesive threads (four to six) in tuft than preceding.....*Menidia beryllina cerea* (silverside).

nn. Adhesive threads scattered over surface of egg membrane.

p. Egg about 1.5 mm. in diameter, yellowish, opaque; oil globules numerous, unequal, grouped together; roots of threads scattered over egg membrane. . *Fundulus heteroclitus* (common killifish).

pp. Eggs smaller, 1.1 to 1.4 mm. in diameter.

q. Egg 1.1 to 1.3 mm. in diameter, slightly yellowish, almost transparent, held together by a tangle of coarse adhesive threads; 12 to 20 unequal oil globules grouped together. *Lucania parva* (rainwater fish).

qq. Egg 1.2 to 1.4 mm. in diameter, yellowish, highly transparent, held together by a tangle of very minute adhesive threads; a single large oil globule and groups of minute oil globules present. . . . . *Cyprinodon variegatus* (short minnow).

mm. Egg membrane adhesive, no threads.

r. Egg about 1 mm. in diameter, yellowish, semitransparent, glutinous, with a relatively large perivitelline space after fertilization; oil globules small, unequal, scattered; embryo with very little pigment up to time of hatching. *Pomolobus æstivalis* (glut herring).

rr. Eggs larger, 1.5 to 1.7 mm. in diameter, clinging together in a rather rigid mass.

s. Egg 1.5 to 1.7 mm. in diameter, yellowish, semiopaque; oil globules numerous, very unequal in size, mostly clustered at upper pole of egg. *Gasterosteus aculeatus* (three-spined stickleback).

ss. Egg 1.5 to 1.6 mm. in diameter, darker and more opaque oil globules fewer in number and smaller than in the preceding. . . . *Apeltes quadracus* (four-spined stickleback).

TAUTOGA ONITIS (Linnæus). TAUTOG.

Spawning.—The principal spawning month for the tautog is June. Although the majority of the fish taken after July 1 were spent, eggs were abundant in the plankton as late as July 15. During the latter half of July they became gradually less abundant, but were taken in small numbers as late as August 20.

The tautog is prolific, but difficulty is experienced in obtaining eggs from captured fish in quantities sufficient for successful fish-cultural operations. Little difficulty, however, was experienced in obtaining and artificially fertilizing the eggs required for embryological study.

Eggs.—The eggs are highly transparent, spherical in form, and 0.9 to 1 mm. in diameter. The egg membrane is thin and horny. The yolk sphere contains no oil globule. The protoplasm which invests the yolk sphere in a very thin layer is finely granular and hardly perceptible until fertilization has taken place and the process of concentration that results in the formation of the blastodisc is initiated. As soon as fertilization has taken place a relatively small space, the perivitelline space, becomes apparent between the egg membrane and the delicate vitelline membrane which incloses the yolk sphere.

Blastodisc.—As soon as fertilization has taken place, the protoplasm becomes concentrated at one pole of the yolk sphere into a lenticular mass, the blastodisc. During this process the protoplasm slowly flows toward the pole of concentration. The "streaming" movements early described by Ryder [a] that occur in the protoplasmic

[a] Ryder, J. A.: A contribution to the embryography of osseous fishes * * * . Report United States Fish Commission 1882, p. 455-605.

layer during the process of concentration are less apparent in the eggs of this species than in the eggs of many other species of teleosts by reason of the extremely minute size of the protoplasmic granules. The process of concentration occupies less than one-half hour. The fully differentiated blastodisc (fig. 1, BD.) comprises nearly all the protoplasm contained in the egg. It is circular in outline and of nearly uniform thickness throughout the central area, thinning out abruptly near the periphery. At the periphery it thins out gradually into a very thin layer of protoplasm, which continues to invest the yolk sphere.

Segmentation.—The first act of cleavage occurs less than one hour after fertilization. Later acts of cleavage follow each other in rapid succession. Blastoderms in advanced stages of cleavage may be observed within four hours after fertilization.

As the moment of cleavage approaches, one axis of the blastodisc becomes somewhat longer than the other. The first plane of cleavage cuts the blastoderm at right angles to the longer axis (fig. 2). The second plane of cleavage cuts the first at right angles.

During the four-cell stage (fig. 3) the two axes of the blastoderm are approximately equal. The third planes of cleavage cut the blastoderm approximately parallel with the first (fig. 4). As the third act of cleavage occurs one axis of the blastoderm again becomes distinctly longer than the other (fig. 4). Typically, the eight blastomeres formed by the third act of cleavage lie in two symmetrical series of four cells each. As the fourth act of cleavage occurs, the two axes of the blastoderm again become approximately equal. The blastoderm now becomes more or less circular in outline and approaches true radial symmetry more and more closely as cleavage advances.

The first two or four blastomeres are usually approximately equal in size and quite symmetrical. As the third act of cleavage occurs, symmetry is usually disturbed. Early blastoderms of more than four cells show a marked lack of symmetry and frequently some disparity in the size of the constituent cells. However, blastoderms of 8, 16, and 32 cells are found occasionally which remain almost ideally symmetrical. Beyond the 64-cell stage symmetry or lack of symmetry in the arrangement of the cells is not easily observed. Blastoderms in advanced stages of cleavage usually appear radially symmetrical.

Formation of the periblast.—The cells at the margin of the blastoderm are not sharply limited peripherally, but remain continuous with the thin layer of protoplasm at the surface of the yolk. As segmentation advances this layer of protoplasm becomes concentrated at the periphery of the blastoderm into a somewhat flattened protoplasmic ridge that gives rise to the periblast (fig. 5, PB). Before this ridge of protoplasm has become fully differentiated, nuclei become apparent near the margin of the blastoderm and gradually become distributed throughout the entire protoplasmic ridge. The periblast nuclei as observed by Agassiz and Whitman,[a] doubtless are derived from the peripheral cells of the blastoderm. When fully differentiated the periblast consists of a flattened syncytial ridge of protoplasm with nuclei apparently like those of the cells in the blastoderm distributed throughout its entire extent.

Until nuclei are present throughout the peripheral area of the periblast it remains continuous with the peripheral cells of the blastoderm. As segmentation advances further the peripheral cells of the blastoderm become completely cut off from the peri-

[a] Agassiz and Whitman: On the development of some pelagic fish eggs. Proceedings, American Academy of Arts and Sciences, vol. 20. 1884.

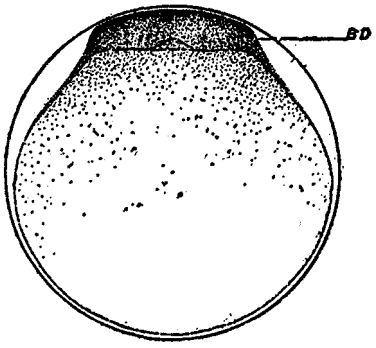

FIG. 1.—Fertilized egg with fully developed blastodisc (BD).

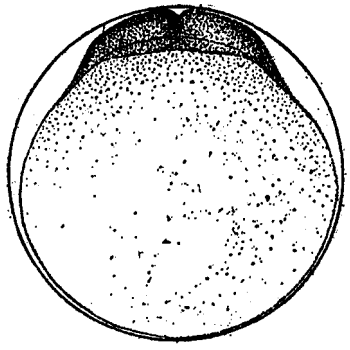

FIG. 2.—Egg with blastoderm of 2 cells.

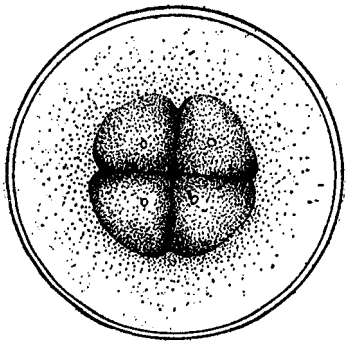

FIG. 3.—Egg with blastoderm of 4 cells.

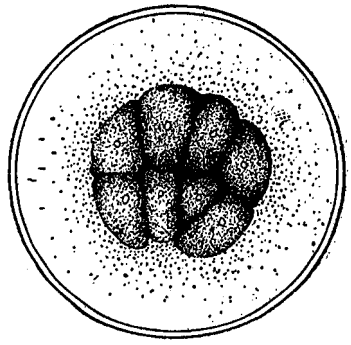

FIG. 4.—Egg with blastoderm of 8 cells.

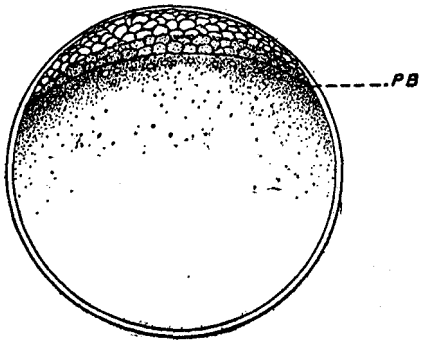

FIG. 5.—Egg with blastoderm in late cleavage stage. PB, periblast.

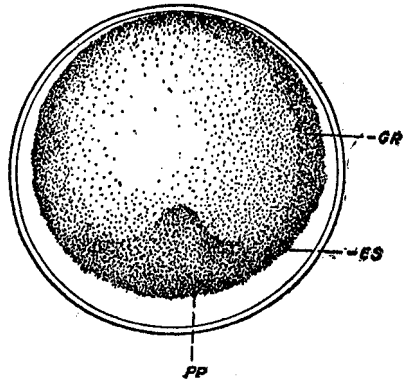

FIG. 6.—Egg with blastoderm showing germ ring (GR) fully differentiated and an early stage in the differentiation of the embryonic shield (ES). PP, posterior pole of blastoderm.

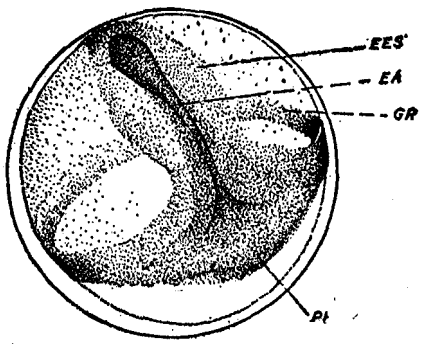

FIG. 7.—Egg showing advanced stage in differentiation of embryonic axis. EA, embryonic axis; EES, extra-embryonic area of embryonic shield; GR, germ ring; PP, posterior pole of blastoderm.

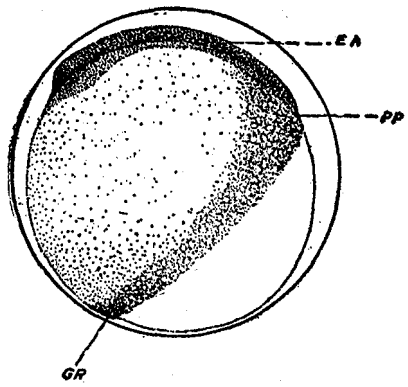

FIG. 8.—Same as figure 7, lateral view.

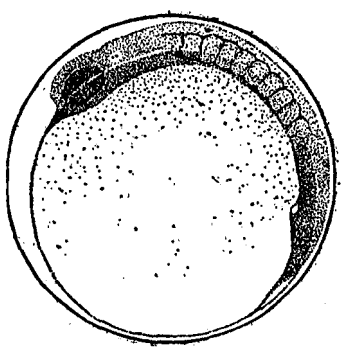

FIG. 9.—Egg with advanced embryo, with 8 somites.

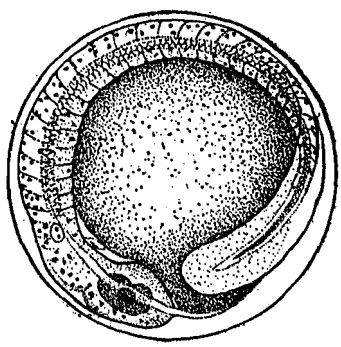

FIG. 10.—Egg with advanced embryo, shortly before hatching.

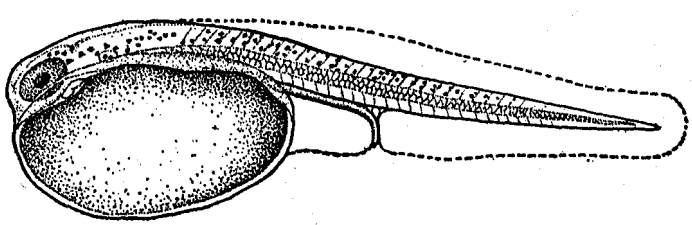

FIG. 11.—Newly hatched fish, actual length 2.1 mm.

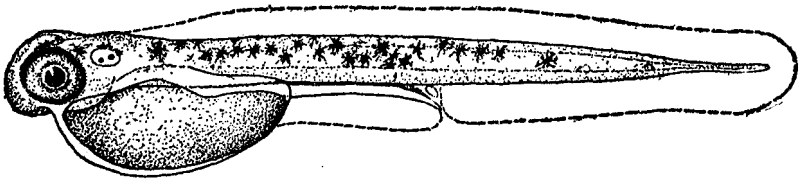

FIG. 12.—Larval fish, 1 day after hatching, actual length 2.9 mm.

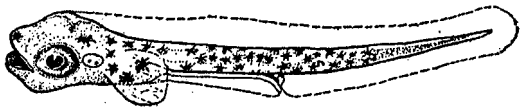

FIG. 13.—Larval fish 4 days after hatching, actual length 3.3 mm.

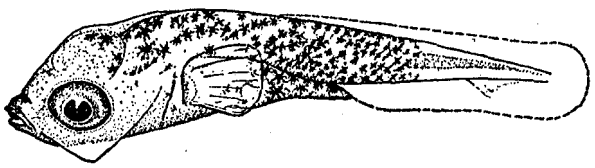

FIG. 14.—Young fish 5 mm. in length.

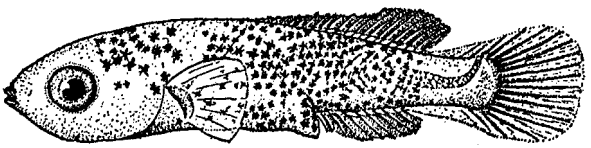

FIG. 15.—Young fish 10 mm. in length.

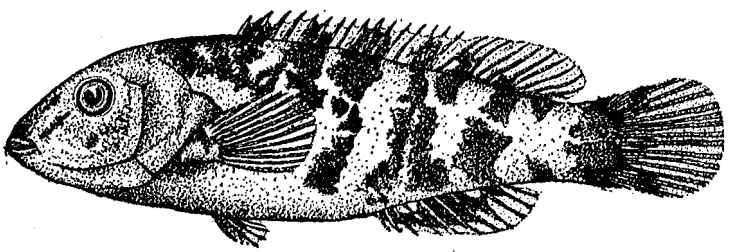

FIG. 16.—Young fish 32 mm. in length.

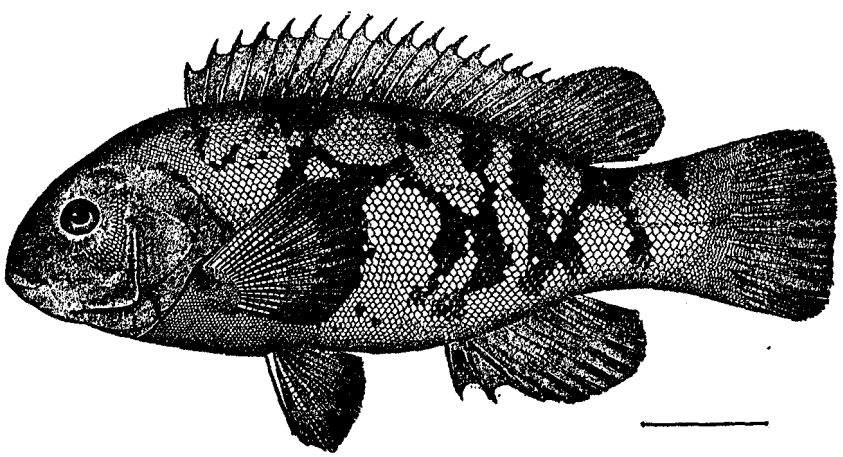

FIG. 17.—Adult fish.
TAUTOGA ONITIS.

blast. A thin sheet of protoplasm, the central periblast, which is also invaded by nuclei now advances centripetally from the periblast beneath the blastoderm.

During early cleavage the blastoderm is essentially a lenticular mass of cells. As segmentation advances, it becomes distinctly dome-shaped, leaving a cavity beneath its central area. This cavity, which is the cleavage cavity, now lies between the blastoderm and the central periblast.

Formation of the germ ring.—The germ ring, when fully differentiated, appears as a thickened peripheral zone of the blastoderm (fig. 6, GR). This zone becomes roughly outlined before the marginal cells of the blastoderm are completely cut off from the periblast. The thickening is at first more apparent than real, being due primarily to the thinning of the central area of the blastoderm, by reason of which its under surface becomes concave. After the blastoderm is completely cut off from the periblast, cells at the periphery grow inward (invaginate), thus adding somewhat to the thickness of the germ ring. Before invagination begins the cells forming the surface layer of the blastoderm become distinctly flattened. This layer plays no part in invagination. The cells which grow inward from the periphery are derived from the deeper layers. The full extent of the ingrowth of cells from the periphery of the blastoderm can not be determined in living material. For a detailed discussion of the rôle of invagination in the formation of the germ ring and the embryonic shield based on a careful study of histological sections the reader is referred to Wilson's paper on the embryology of the sea bass.[a] As the blastoderm gradually grows larger the germ ring, which in its earlier stages involves but a narrow zone, increases somewhat in width by the centrifugal growth of the blastoderm as well as by the invagination of the marginal cells.

Formation of the embryonic shield and differentiation of the embryo.—Before the germ ring is fully differentiated it becomes apparent that invagination advances more rapidly at one pole than round the rest of the periphery of the blastoderm. This is the posterior or embryonic pole (fig. 6, PP). At this pole a broad tongue of cells is pushed forward into the cleavage cavity. Viewing the blastoderm from above, there soon appears at the posterior pole a roughly triangular area which is obviously thicker than the adjacent areas. This triangular area marks an early stage in the differentiation of the embryonic shield (fig. 6, ES).

The blastoderm now increases in size more rapidly than in the earlier stages, and the germ ring gradually advances around the yolk sphere. As the blastoderm spreads over an increasingly greater area of the surface of the yolk, the embryonic shield grows larger and becomes more definitely outlined. Soon there occurs a linear thickening along its anteroposterior axis that marks the axis of the future embryo (fig. 7, EA). The embryonic shield is now differentiated into an embryonic and an extra-embryonic area. The further differentiation of the embryo begins in the anterior or head region and gradually advances posteriorly. Before the embryonic axis is well differentiated, the blastoderm covers more than half the surface of the yolk sphere, and the circumference of the germ ring is actually decreasing. As development advances much of the material contained in the germ ring becomes incorporated in the embryo. The part played in this process by concrescence in the sense of His[b] and confluence in the

[a] Wilson, H. V.: The embryology of the sea bass (*Serranus atrarius*). Bulletin United States Fish Commission, vol. IX, 1889, p. 209–277.

[b] His, W.: Zur Frage der Langsverwachsung von Wirbelthierembryonen. Verh. d. anat. Ges., 1891, p. 70–83.

sense of Sumner [a] can not be discussed in this paper. This entire process is doubtless but a part of a larger process by which much of the material contained in the embryonic shield becomes incorporated in the body of the embryo.

By the time the embryo is well formed the blastoderm covers approximately three-fourths of the surface of the yolk sphere. As development advances the blastoderm soon covers the entire yolk sphere and the blastopore is closed.

The closure of the blastopore occurs within 18 hours after fertilization. At this time the embryo extends approximately halfway round the circumference of the yolk sphere and segmentation of the body has already begun. Figure 9 illustrates an egg shortly after the blastopore is closed. The embryo remains highly transparent and shows no evidence of pigmentation. The beginning of pigmentation is observed in embryos with 15 to 20 somites. The chromatophores first appear as minute rounded black dots scattered over the dorsal aspect of the embryo. As the time of hatching approaches, the chromatophores become somewhat larger and show irregular pigmented processes. However, the embryo remains highly transparent (fig. 10). The extra-embryonic blastoderm remains free from pigment.

Larval development.—Incubation at laboratory temperature—i. e., in water at approximately 22° C.—occupied 42 to 45 hours. In the tidal hatching boxes at the same time incubation occupied approximately 48 hours.

The newly hatched larvæ (fig. 11) are approximately 2.2 mm. in length. The head is slightly deflected. The yolk sac remains relatively large. It is ovate-elliptical in form and free from pigment. The vent is located at some distance from the posterior margin of the yolk sac and a little more than half the length of the body from the anterior end. The depth of either dorsal or ventral fin fold is less than the depth of the body just posterior to the vent. The chromatophores have grown somewhat larger, but have not increased materially in numbers. They remain confined more or less closely to the dorsal and dorsolateral aspects of the body. The fin folds and the posterior caudal region of the body remain entirely free from pigment.

One day after hatching (fig. 12) the larvæ have grown to a length of 2.8 to 3 mm. The yolk sac is greatly reduced and the head is no longer deflected. The chromatophores have increased materially in size and show well-developed pigmented processes, but are apparently fewer in number than in the newly hatched larvæ. Individual pigment cells, doubtless, have become intimately associated with each other to form larger chromatophores. The larvæ now have a distinctly blackish color.

Four days after hatching (fig. 13) the larvæ have grown to a length of 3.2 to 3.5 mm. The yolk is completely absorbed. Larvæ kept in dishes of sea water as well as those hatched in the tidal hatching boxes now begin to die rapidly. The critical period for this species, therefore, comes about the fourth day after hatching. At this stage black chromatophores are more or less uniformly distributed over the dorsal and lateral aspects of the body. However, the posterior caudal region remains free from pigment.

Figure 14 illustrates a young fish 5 mm. in length taken in the plankton. In young fishes at this stage growth is indicated more especially by the increase in the depth and thickness of the body than by the increase in length. The distribution of pigment remains essentially the same as in larvæ four days after hatching. However, the chromatophores are larger and have increased materially in numbers.

[a] Sumner, F. B.: Kupffer's vesicle and its relation to gastrulation and concrescence. New York Academy of Sciences, Memoirs, vol. II, pt. II, 1900, p. 47-83.

In young fish 10 mm. in length (fig. 15) the dorsal, anal, and caudal fins are becoming well differentiated. The distribution of pigment remains essentially as in the early stages. However, the number of chromatophores, as well as the quantity of pigment, has materially increased.

As development advances the young fish gradually assume adult characters. Young fish 30 mm. in length (fig. 16) exhibit nearly all the diagnostic characters of the species. The depth of the body in proportion to its length is rapidly increasing and the back is becoming strongly arched. The ground color of the body at this stage is greenish. The black chromatophores have become aggregated to form heavily pigmented areas, which are roughly arranged in transverse bands and give the body the transversely banded appearance characteristic of the adult.

TAUTOGOLABRUS ADSPERSUS (Walbaum). CUNNER.

Spawning.—This species spawns in June and July. The majority of the fish taken after July 1 were spent. However, eggs were abundant in the plankton until July 15 and were taken in small numbers as late as August 15.

Eggs.—The eggs are transparent, spherical in form, and 0.75 to 0.85 mm. in diameter. They contain no oil globules and can be distinguished from the eggs of *Tautoga onitis* only by a slight difference in size, the latter having a diameter of 0.9 to 1 mm.

Embryology.—The embryological development of the eggs of this species is typical of pelagic teleostean eggs. It conforms in all essential details to the course of development as outlined for the eggs of *Tautoga onitis* and will not, therefore, be discussed in detail. Early and advanced stages of cleavage are illustrated in figures 18 to 21. Figure 22 illustrates an egg in which the embryonic axis is becoming well differentiated.

Pigmentation is first observed in embryos which show 10 to 15 somites. The earliest chromatophores appear as minute black dots distributed over the dorsal aspect of the body. The extra-embryonic blastoderm remains free from pigment. The distribution of chromatophores during the early stages is essentially the same as in embryos of *Tautoga onitis*, and the blastoderm does not undergo any material change until after hatching. However, in the latter species the chromatophores are more numerous and somewhat larger.

Larval development.—Incubation at laboratory temperature occupied approximately 40 hours. The newly hatched larvæ (fig. 24) are 2 to 2.2 mm. in length. The yolk sac remains relatively large, and the head is slightly deflected. The vent is located some distance from the posterior margin of the yolk sac and a little more than half the length of the body from the anterior end. The depth of either dorsal or ventral fin fold is greater than the depth of the body posterior to the vent. The chromatophores remain small and are limited almost entirely to the dorsal and dorsolateral aspects of the body. The posterior caudal region and the fin folds remain free from pigment.

Soon after hatching the distribution of pigment undergoes a marked change. The chromatophores gradually become aggregated into compact masses, as illustrated in figure 25, in a larval fish less than one day after hatching. These masses of chromatophores become aggregated still further to form a heavily pigmented area in the dorsal region of the abdominal cavity, another just over the vent, and a third on the ventral aspect of the body approximately halfway from the vent to the tip of the tail. These pigmented areas are illustrated in figure 26 in a larval fish three days after hatching.

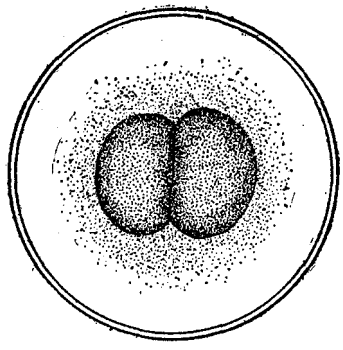

FIG. 18.—Egg with blastoderm of 2 cells.

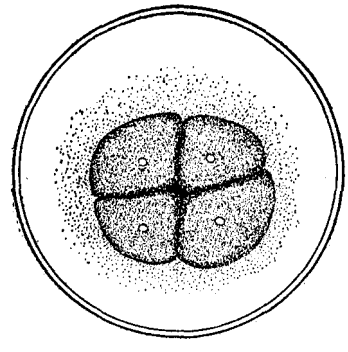

FIG. 19.—Egg with blastoderm of 4 cells.

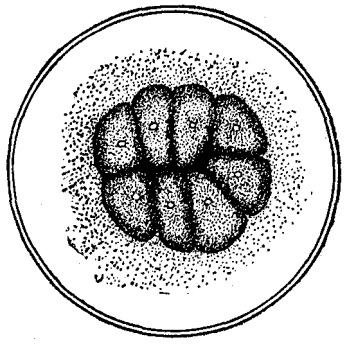

FIG. 20.—Egg with blastoderm of 8 cells.

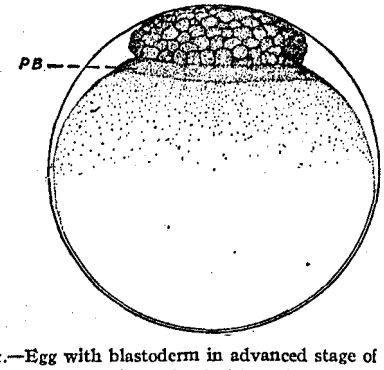

FIG. 21.—Egg with blastoderm in advanced stage of cleavage and periblast (PB) differentiated.

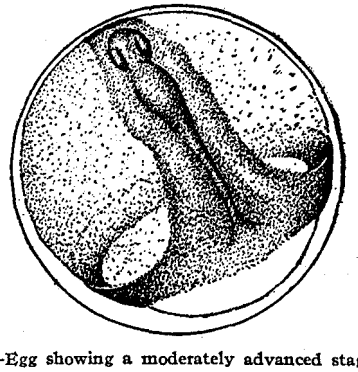

FIG. 22.—Egg showing a moderately advanced stage in the differentiation of the embryo.

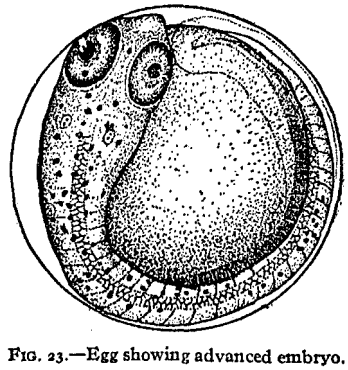

FIG. 23.—Egg showing advanced embryo.

TAUTOGOLABRUS ADSPERSUS.

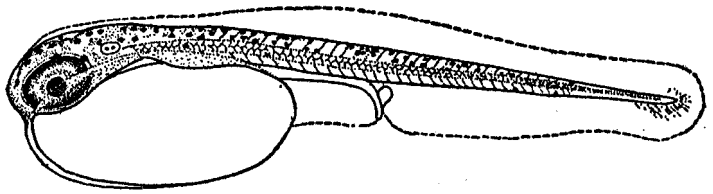

FIG. 24.—Newly hatched fish, actual length 2.2 mm.

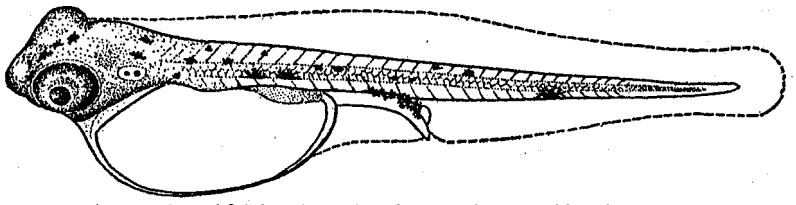

FIG. 25.—Larval fish less than 1 day after hatching, actual length 2.5 mm.

FIG. 26.—Larval fish 3 days after hatching, actual length 2.8 mm.

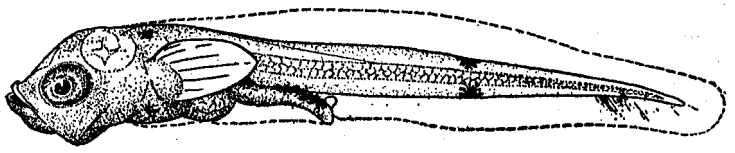

FIG. 27.—Young fish 4.2 mm. in length.

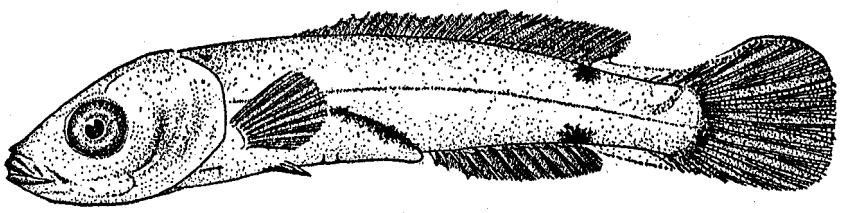

FIG. 28.—Young fish 8 mm. in length.

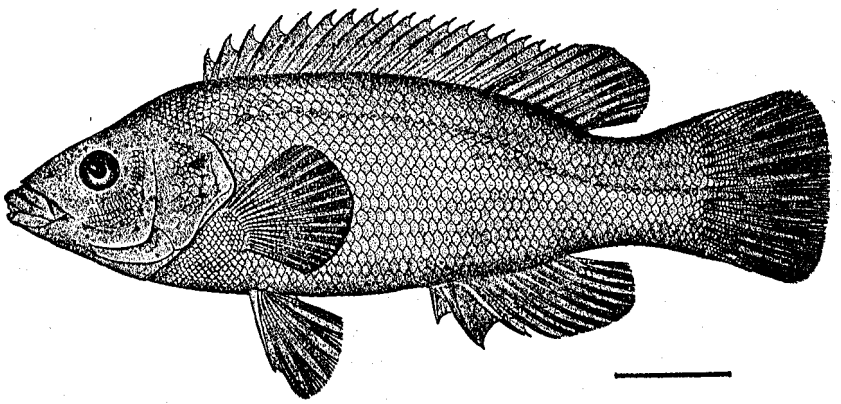

FIG. 29.—Adult fish.
TAUTOGOLABRUS ADSPERSUS.

At this time the yolk is completely absorbed and the larval fish have grown to a length of 2.8 to 3 mm.

During the fourth day after hatching, larval fish kept in dishes of sea water began to die rapidly. Few survived beyond the fifth day. The critical period comes somewhat earlier for this species than for *Tautoga onitis*.

As the young fish grow older, one or more small pigmented areas appear dorsally just posterior to the head, another on the dorsal aspect of the body opposite the one on the ventral aspect and halfway from the vent to the tip of the tail, and one or two very small areas at the base of the ventral-fin fold near the tip of the tail. These, in addition to the pigmented areas shown in figure 26, are illustrated in figure 27 in a young fish 4.2 mm. in length.

In young fish 8 mm. in length (fig. 28) the distribution of pigmented areas remains essentially as in the preceding stage. However, the two small areas which appear at the base of the ventral-fin fold near the tip of the tail now appear at the base of the caudal fin at the posterior end of the body. The dorsal, anal, and caudal fins are now well differentiated and the young fish are gradually assuming adult characters.

STENOTOMUS CHRYSOPS (Linnæus). SCUP.

Spawning.—As is well known, this species spawns largely in June. The majority of the fish taken after July 1 were spent. Eggs were not abundant in the plankton at any time during July, but were taken in small numbers as late as August 15.

Eggs.—The eggs are transparent, spherical in form, and 0.85 to 0.90 mm. in diameter. The yolk sphere contains a single oil globule which normally rests at the upper pole. The egg membrane is thin and horny.

Embryology.—The embryological development of this species, like that of the species above described, is entirely typical of teleosts with pelagic eggs. It conforms so closely to the course of development as outlined above for *Tautoga onitis* that a detailed description would be superfluous. The eggs being somewhat smaller than those of the last-named species, development advances somewhat more rapidly. In water at approximately 22° C. incubation occupied not over 40 hours.

Pigmentation is first observed in embryos showing 15 to 20 somites. Black and yellow pigment cells appear sparsely scattered over the embryo and the oil globule. As development advances, these pigment cells become larger and more numerous. In figure 31 yellow pigment on the embryo is indicated by coarse stippling, while the black is shown in solid color. As the time of hatching approaches, the yellow chromatophores become aggregated to form heavily pigmented areas. The extra-embryonic blastoderm remains free from pigment.

Larval development.—The newly hatched larvæ (fig. 32) are approximately 2 mm. in length. The head projects slightly beyond the anterior end of the yolk sac and is not appreciably deflected. The oil globule remains in the posterior end of the yolk sac. The vent is located a short distance from the posterior margin of the yolk sac, but less than half the length of the body from the anterior end. Small groups of black chromatophores remain sparsely scattered over the dorsal and dorsolateral aspects of the body. The yellow pigment is distributed as follows: A few small areas on the dorsal and lateral aspects of the head, a lateral area just posterior to the otocyst, a small area above the vent, another opposite the vent on the dorsal aspect of the body, and a

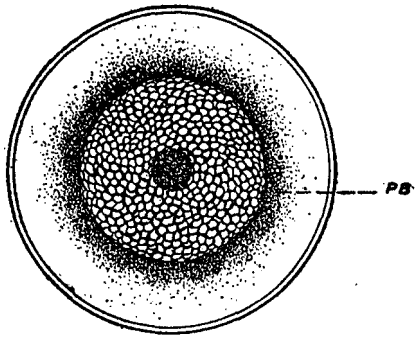

FIG. 30.—Egg with blastoderm in advanced stage of cleavage, periblast (PB) differentiated.

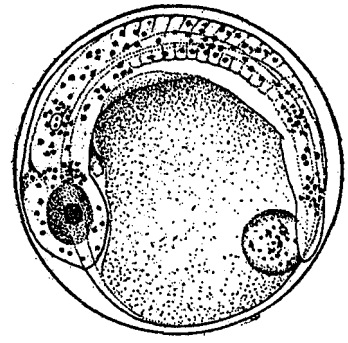

FIG. 31.—Egg showing advanced embryo.

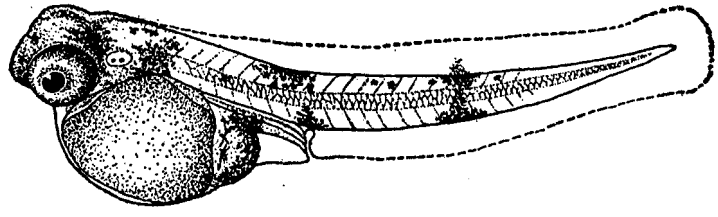

FIG. 32.—Larval fish several hours after hatching, actual length 2 mm.

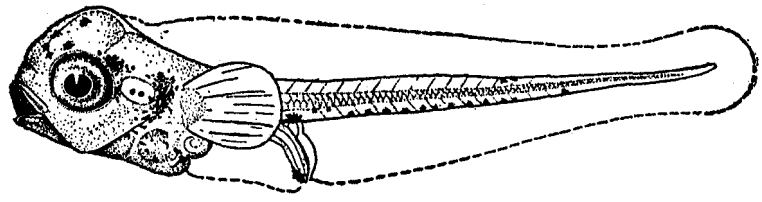

FIG. 33.—Larval fish 3 days after hatching, actual length 2.8 mm.

STENOTOMUS CHRYSOPS.

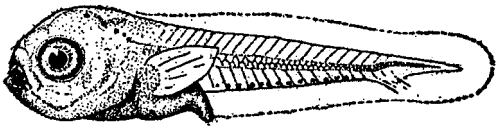

FIG. 34.—Young fish 5 mm. in length.

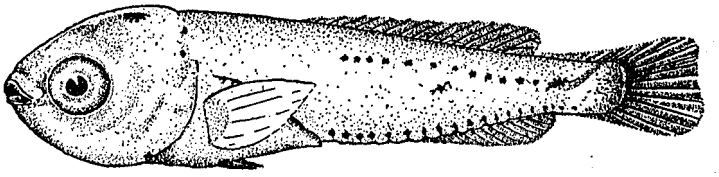

FIG. 35.—Young fish 10.5 mm. in length.

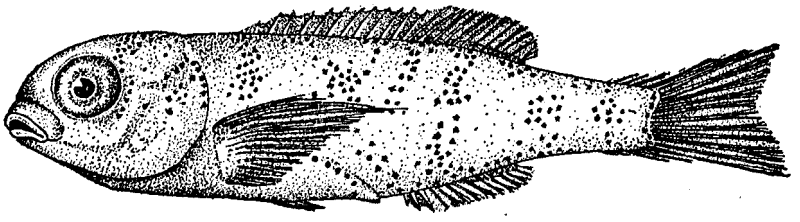

FIG. 36.—Young fish 25 mm. in length.

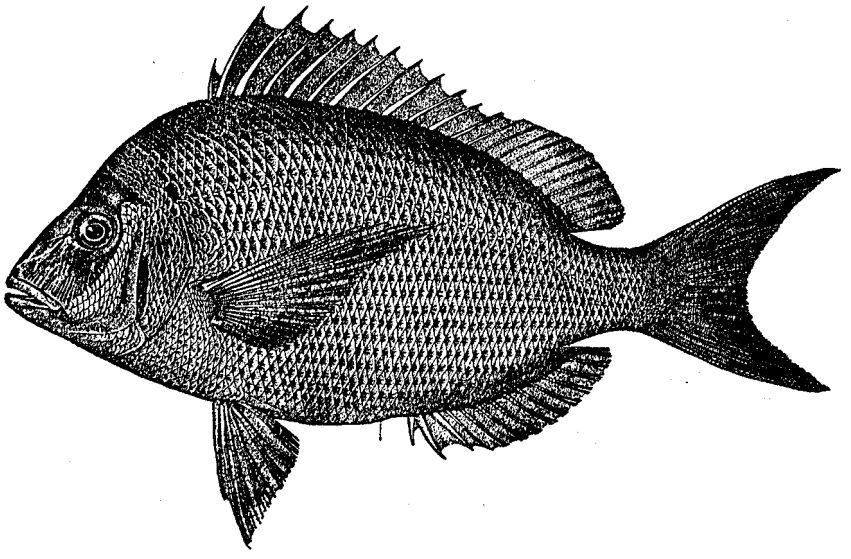

FIG. 37.—Adult fish.

STENOTOMUS CHRYSOPS.

transverse band approximately halfway from the vent to the posterior end of the body extending from the base of the ventral-fin fold onto the dorsal-fin fold. Both black and yellow chromatophores remain associated with the oil globule.

As development advances the transverse yellow band soon disappears. Before the close of the third day after hatching, when the larval fish are 2.8 to 3 mm. in length (fig. 33), the yellow pigment is greatly reduced. A small yellow area remains just back of the eye, another at the posterior margin of the opercle, and a third over the vent. A little yellow pigment also remains more or less diffusely scattered over the anterior region of the body. The distribution of black pigment also has undergone a marked change. A few small areas occur on the dorsal aspect of the head and the lateral aspect of the anterior region of the trunk. The young fish is marked further by a black spot at the anterior aspect of the vent and a series of black spots near the base of the ventral fin-fold posterior to the vent. At this stage the yolk is completely absorbed and the head is relatively large.

During the fourth and fifth days after hatching, the larval fish kept in dishes of sea water died rapidly. Few survived until the sixth day.

In young fish 5 mm. in length (fig. 34) little yellow pigment remains. The black spot at the vent also has disappeared, but the characteristic series of black spots near the base of the ventral-fin fold has become more prominent. The young fish is relatively plump anteriorly and tapers gradually toward the posterior end.

Young fish 10 mm. in length (fig. 35) show increased pigmentation in the dorsal region of the abdominal cavity. The series of black spots on the ventrolateral aspect of the body still remains. In addition a series of black spots has become apparent along the lateral line over the posterior half of the body. Dorsal, anal, and caudal fins are becoming well differentiated.

Young fish 25 mm. in length (fig. 36) already show some of the diagnostic characters of the species. The body is relatively plump, but the back is not arched as in the adult, consequently the depth of the body is relatively small. The ground color of the body is brownish yellow. Black chromatophores have increased materially in numbers and are arranged in somewhat irregular transverse bands that give the young fish the transversely banded appearance characteristic of the young of this species.

PRIONOTUS CAROLINUS (Linnæus). SEA ROBIN.

Spawning.—This species spawns in June, July, and early August. Fish ripe for stripping were taken in small numbers during the first half of July. Eggs were abundant in the plankton throughout July and were taken in small numbers as late as August 24. The spawn is abundant, and no difficulty was experienced in obtaining and artificially fertilizing eggs for embryological study.

Eggs.—The eggs (fig. 38) are spherical in form and 1 to 1.15 mm. in diameter. They are slightly yellowish in color, but highly transparent. The yolk sphere contains a variable number (10 to 25) of oil globules of unequal size scattered over the surface. As development advances, some of these oil globules may become aggregated. Usually, however, they remain distributed more or less uniformly over the surface of the yolk. The egg membrane is thin and horny.

Embryology.—These eggs develop in a manner typical of pelagic teleostean eggs. They are somewhat larger than the eggs of *Tautoga onitis*, and therefore development

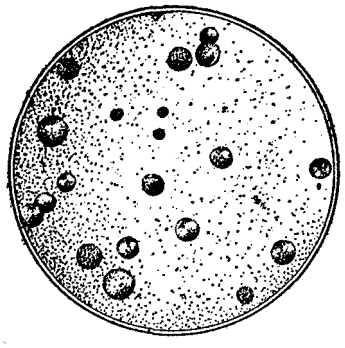

FIG. 38.—Mature unfertilized egg.

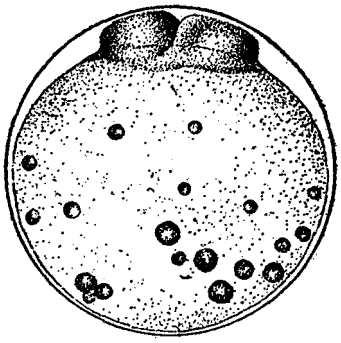

FIG. 39.—Egg with blastoderm of 2 cells.

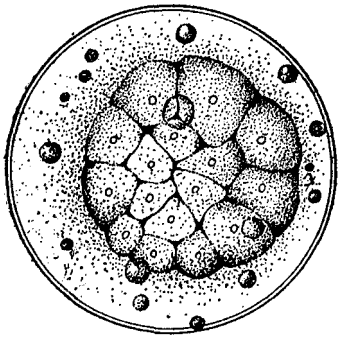

FIG. 40.—Egg with blastoderm of 16 cells.

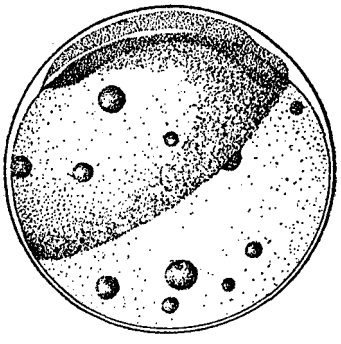

FIG. 41.—Egg showing early stage in the differentiation of the embryo.

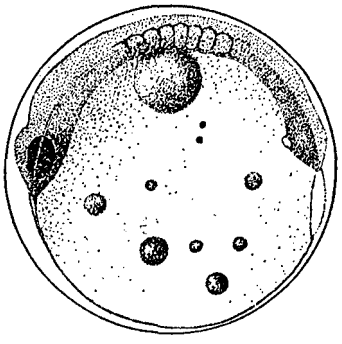

FIG. 42.—Egg with embryo well differentiated, blastopore, closed.

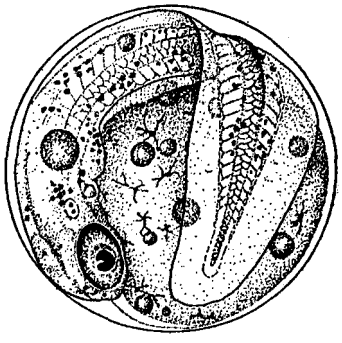

FIG. 43.—Egg with advanced embryo.

PRIONOTUS CAROLINUS.

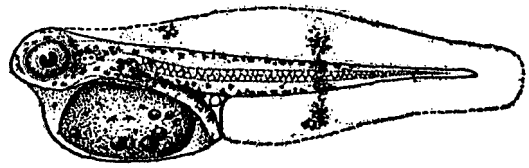

FIG. 44.—Newly hatched fish, actual length 2.8 mm.

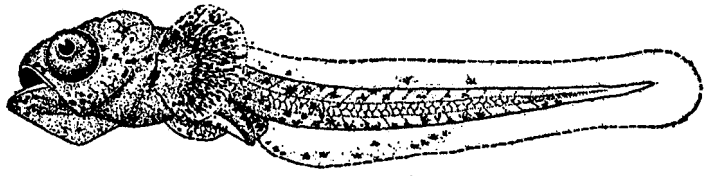

FIG. 45.—Larval fish 5 days after hatching, actual length 3.1 mm.

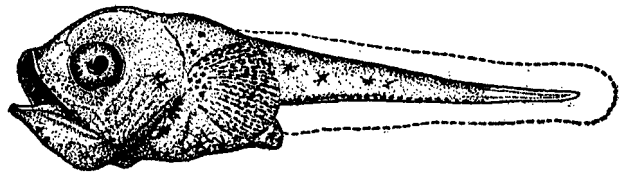

FIG. 46.—Young fish 4 mm. in length.

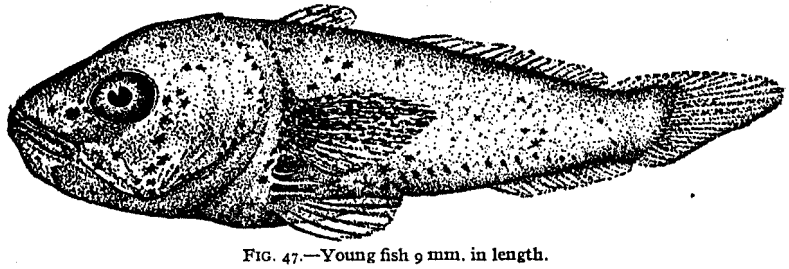

FIG. 47.—Young fish 9 mm. in length.

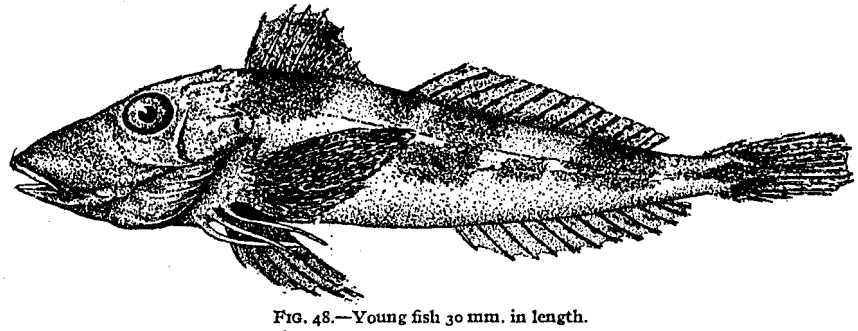

FIG. 48.—Young fish 30 mm. in length.

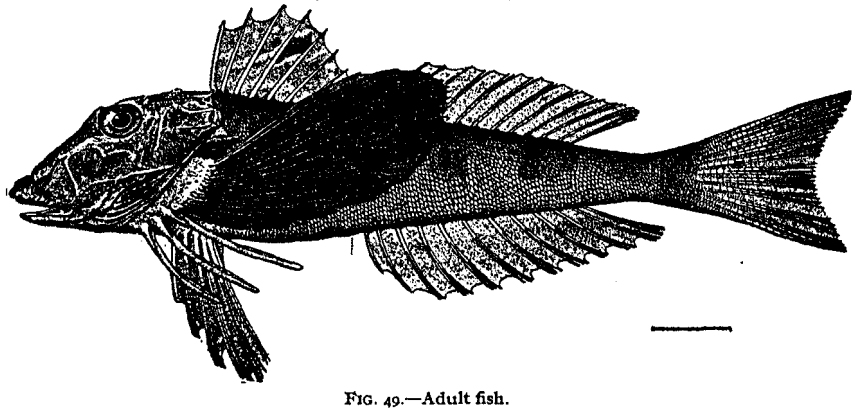

FIG. 49.—Adult fish.

PRIONOTUS CAROLINUS.

advances somewhat less rapidly. The volume of protoplasm in proportion to the volume of yolk is relatively small, yet the blastodisc is relatively thick; consequently, during the early stages of cleavage (fig. 39) the blastoderm covers a relatively small area of the surface of the yolk sphere.

The first act of cleavage occurs within 1.5 hours after fertilization. The successive acts of cleavage follow each other very regularly. The early blastoderms are usually more nearly symmetrical than are those of *Tautoga onitis* or either of the other species described. A blastoderm of 16 cells in which symmetry is somewhat disturbed is illustrated in figure 40.

Within 20 hours after fertilization (fig. 42) the embryo is well differentiated and extends halfway around the circumference of the yolk sphere. The blastopore is not yet closed. The embryo shows 10 to 12 somites and pigmentation has already begun. Numerous yellow and black pigment cells are present over the entire surface of the embryo and in the adjacent areas of the extra-embryonic blastoderm. Pigment cells arise earliest in the embryo and gradually become apparent in the remoter parts of the blastoderm. Yellow pigment arises somewhat earlier than black pigment in these embryos.

At 42 hours after fertilization (fig. 43) both black and yellow chromatophores are larger and fewer in number than during the earlier stages. They are now sparsely distributed over the surface of the embryo and throughout the extra-embryonic blastoderm.

Larval development.—Incubation in water at a temperature about 22° C. occupied approximately 60 hours. The newly hatched larvæ (fig. 44) are approximately 2.8 mm. in length. The yolk sac is relatively small and still contains oil globules. The head is not markedly deflected. The vent is located just posterior to the yolk sac. The pectoral fins are prominent: The depth of either dorsal or ventral fin fold is greater than the depth of the body posterior to the vent. Black and yellow chromatophores are sparsely scattered over the head, the anterior region of the trunk, and the dorsolateral and ventrolateral aspects of the trunk farther posteriorly. The body is marked further by two transverse yellow bands, one just posterior to the pectoral fins, the other approximately halfway from the vent to the posterior end of the body. These bands of pigment extend onto the fin folds. The general color of the head and pectoral fins is yellowish. In figures 44 and 45 black pigment is indicated by solid color, while yellow pigment is indicated by short lines.

As development advances a material reduction of the yellow pigment becomes apparent. Five days after hatching (fig. 45) the yellow markings characteristic of the newly hatched larvæ are no longer apparent. The head and the pectoral fins still show yellow pigment. Some yellow chromatophores also remain at the vent and at the former location of the posterior transverse band. Black chromatophores are sparsely scattered over the body and a few appear also in the dorsal and ventral fin folds. The posterior caudal region remains practically free from pigment.

Larval fish five days old have grown to a length of 3.1 to 3.4 mm. The head is relatively large. The pectoral fins are large and prominent. The critical period for this species is reached during the fifth or sixth day after hatching; when kept in dishes of sea water, few survived until the seventh day.

Young fish 4 mm. in length (fig. 46) are characterized by a very large head and relatively great depth of the body in the anterior region of the trunk. The ground color of

the body remains yellowish. Black chromatophores occur sparsely scattered over the dorsal and lateral aspects of the body and in a series along the ventrolateral aspect of the body near the base of the ventral-fin fold.

In young fish 8 to 10 mm. in length (fig. 47) the dorsal, anal, and caudal fins are becoming well differentiated, and the free rays of the pectoral fins characteristic of the species are already present. The general color of the body and the distribution of black chromatophores remain essentially as in the preceding stage.

In young fish 25 to 30 mm. in length (fig. 48) the general color of the body has become darker, and the trunk is marked by heavily pigmented areas that give it a transversely banded appearance. The fins are well differentiated. The head is long and somewhat pointed and shows the bony structure characteristic of the adult. The young fish are gradually assuming the appearance of the adults and already show many of the diagnostic characters of the species.

MERLUCCIUS BILINEARIS (Mitchill). WHITING.

Spawning.—Eggs of this species were present in small numbers in the plankton late in July and throughout August. Males ripe for stripping and females nearly ripe were taken in the traps in Menemsha Bight late in July. A few females apparently ripe for stripping were taken in the same traps on August 6. The eggs were successfully fertilized, but all died during early cleavage. The majority of the fish taken in these traps on August 16 were smaller than those taken earlier. Among them were found a number of spent females. but none ripe for stripping. Apparently the spawning period for this species is a protracted one and not all the eggs mature at one time.

Eggs.—The eggs are highly transparent, spherical in form, and 0.88 to 0.95 mm. in diameter. The yolk sphere contains a relatively opaque, yellowish or brownish oil globule 0.19 to 0.23 mm. in diameter. The protoplasmic layer is finely granular. The egg membrane is thin and horny.

Embryology.—The embryological development of this species is entirely typical and does not differ essentially from the course of development as outlined for *Tautoga onitis*. Early and advanced stages of cleavage are illustrated in figures 50 and 51.

Pigmentation begins soon after the closure of the blastopore. At this time the embryo extends approximately halfway around the circumference of the yolk sphere. Black chromatophores become sparsely scattered over the embryo and the oil globule. The extra-embryonic blastoderm remains free from pigment. The distribution of chromatophores several hours after the beginning of pigmentation is illustrated in figure 52.

As the time of hatching approaches (fig. 53), yellow pigment also becomes apparent on the embryo. Yellow pigment areas occur just back of the eye, back of the otocyst, in a series along the lateral surface of the anterior region of the trunk, and in two vertical bands on the posterior half of the body. The distribution of black pigment on the anterior half of the body remains essentially as in the earlier stages. Farther posteriorly all the black chromatophores have become aggregated in two vertical bands.

Larval development.—Incubation occupied not over 48 hours. The newly hatched larvæ (fig. 54) are approximately 2.8 mm. in length and relatively slender. The head is slightly deflected at the anterior end of the yolk sac. The vent is located immediately

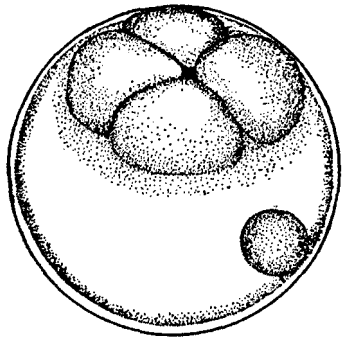

FIG. 50.—Egg with blastoderm of 4 cells.

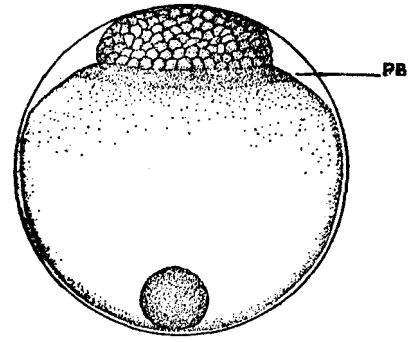

FIG. 51.—Egg with blastoderm in advanced stage of cleavage, periblast (PB) differentiated.

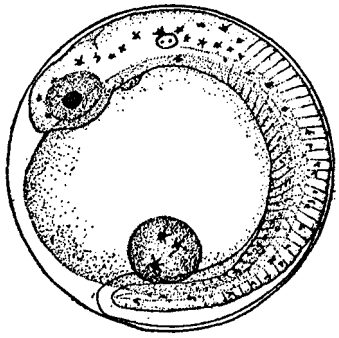

FIG. 52.—Egg with moderately advanced embryo.

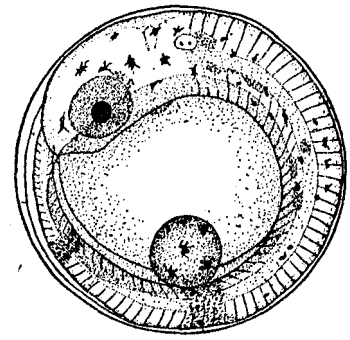

FIG. 53.—Egg with advanced embryo.

FIG. 54.—Newly hatched fish, actual length 2.8 mm.

MERLUCCIUS BILINEARIS.

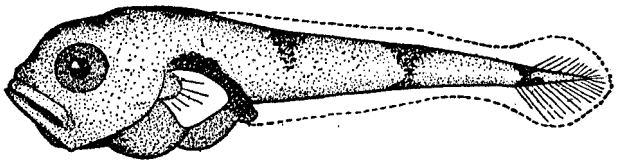

FIG. 55.—Young fish 6.5 mm. in length.

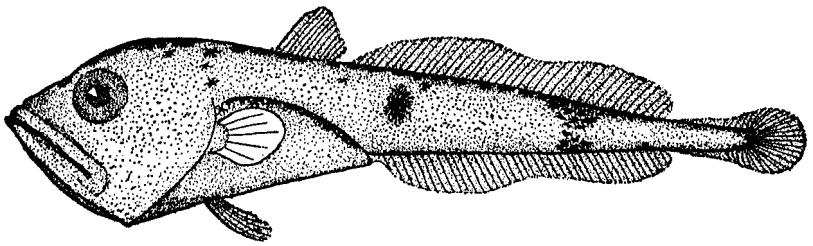

FIG. 56.—Young fish 11 mm. in length.

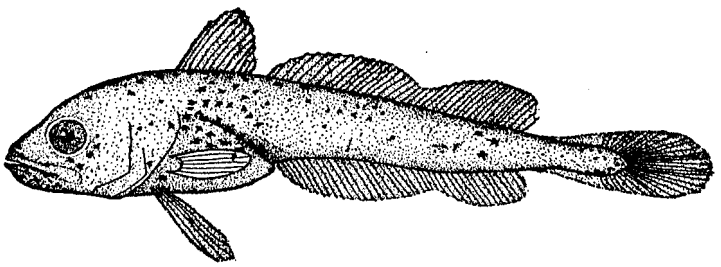

FIG. 57.—Young fish 23 mm. in length.

MERLUCCIUS BILINEARIS.

posterior to the yolk sac, not at the margin, but laterally near the base of the ventral-fin fold. The depth of either dorsal or ventral fin fold is greater than the depth of the body posterior to the vent. Black chromatophores occur sparsely scattered over the head and anterior trunk region and on the oil globule. Two small groups occur also near the margin of the dorsal-fin fold. A small yellow area occurs laterally just posterior to the otocyst. Farther posteriorly the body is marked by two vertical bands of black and yellow pigment, one of which is located a short distance posterior to the vent and the other somewhat more than half the distance from the vent to the posterior end of the body.

All the newly hatched larvæ kept in the laboratory died within 24 hours. Neither were larvæ of this species taken in the plankton. The later stages here described were selected from specimens taken by W. W. Welsh at or near the surface at the Grampus station 10258, August 25, 1914, about 20 miles south of Marthas Vineyard, Mass.

A young fish 6.5 mm. in length is illustrated in figure 55. At this stage the head is relatively large, and the body tapers gradually toward the posterior end. The lateral position of the vent is still apparent. The dorsal region of the abdominal cavity is heavily pigmented. Large black chromatophores occur on the dorsal aspect of the head and the anterior region of the trunk. The body is marked further by a vertical band just posterior to the vent, another approximately halfway from the vent to the posterior end of the body, and a third near the posterior end of the body.

In young fish 11 mm. in length (fig. 56) the head remains relatively large. The dorsal, anal, and caudal fins are becoming well differentiated. The dorsal region of the abdominal cavity remains heavily pigmented. Large black chromatophores now occur along the entire dorsal aspect of the body except in the caudal region. The three vertical bands described above are still present but are less distinct than in the earlier stages.

In young fish 20 to 25 mm. in length (fig. 57) the pigmentation characteristic of the earlier stages is no longer apparent. The dorsal and dorsolateral aspects of the body are more or less uniformly, but only lightly, pigmented. The head is long and the body is relatively slender. The young fish are now gradually assuming the general appearance of adults and already show some of the diagnostic characters of the species.

PORONOTUS TRIACANTHUS (Peck). BUTTERFISH.

Spawning.—The spawning habits of this species are practically unknown. The data available indicate that these fish leave the inshore waters during the spawning season. In the Woods Hole region, there is a run of fish in June, lasting a week or longer. After this relatively few butterfish are taken in the inshore waters until about September 1, when they again become abundant. During the first half of July, 1915, adult butterfish were taken in considerable numbers and daily examinations made. The majority of the males were ripe for stripping, and many of the females were apparently nearly ripe. However, mature eggs could not be obtained. After July 15 the catch gradually fell off until relatively few butterfish were taken. The majority of these were smaller than those taken early in July. About August 15 fish of larger size again were taken, but these were spent. At this time schools of butterfish were reported offshore.

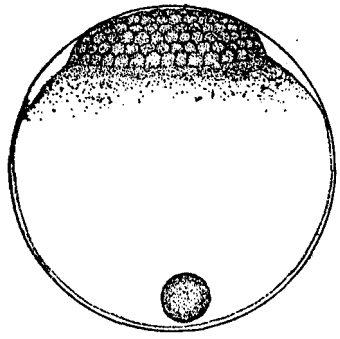

FIG. 58.—Egg with blastoderm in advanced stage of cleavage.

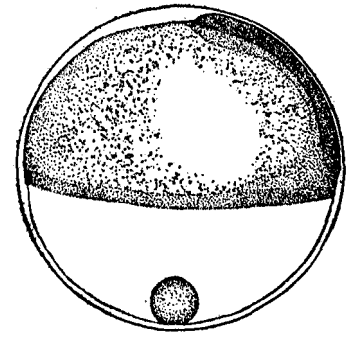

FIG. 59.—Egg showing advanced stage in differentiation of embryonic axis.

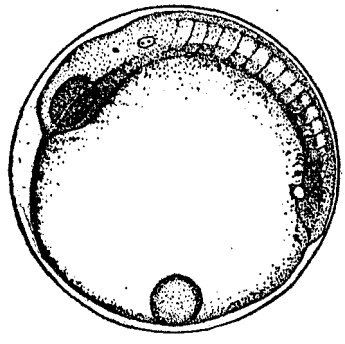

FIG. 60.—Egg with embryo showing 12 to 14 somites, blastopore closed.

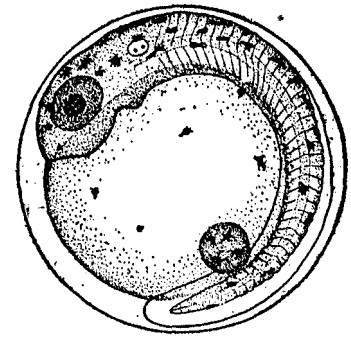

FIG. 61.—Egg with advanced embryo.

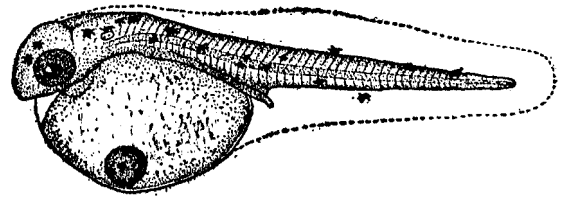

FIG. 62.—Newly hatched fish, actual length 2 mm.

PORONOTUS TRIACANTHUS.

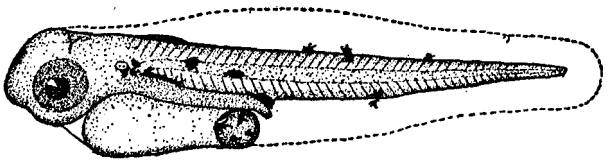

FIG. 63.—Larval fish 1 day after hatching, actual length 2.1 mm.

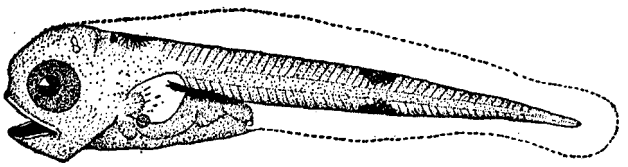

FIG. 64.—Larval fish 3 days after hatching, actual length 2.3 mm.

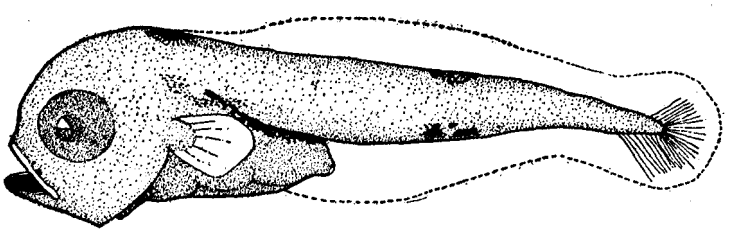

FIG. 65.—Young fish 3.2 mm. in length.

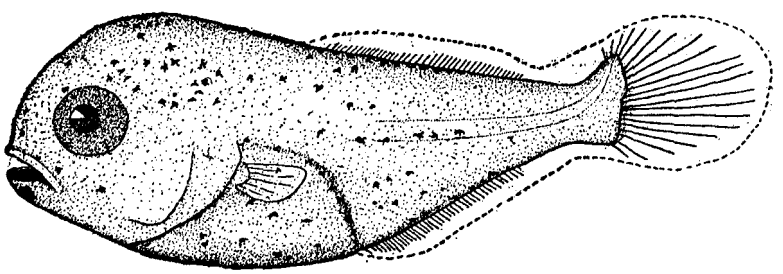

FIG. 66.—Young fish 6 mm. in length.

PORONOTUS TRIACANTHUS.

Eggs were first taken in the tow in Muskeget Channel on July 30. They were present in the plankton off Gay Head throughout August, being especially abundant on August 20. Larval fish 2 to 3.2 mm. in length were taken at this point on August 12 and again on August 16. On August 7 a young butterfish 6 mm. in length and on August 14 another 7.5 mm. in length were taken in Woods Hole Harbor. Eggs or newly hatched larvæ were never taken in the harbor. These larger young fish show many of the diagnostic characters of the species and can be positively identified. Although young fish between 3.2 and 6 mm. in length were not taken, it is believed that the eggs and smaller larval fishes here described are this species.

The authors have since learned that at the Gloucester, Mass., fisheries station, from July 15 to 31, inclusive, 609,000 eggs were secured and somewhat over 60 percent hatched. This is believed to be the first successful attempt at taking the eggs from the parent fish.

Eggs.—The eggs are transparent, spherical in form, and 0.7 to 0.8 mm. in diameter. The yolk sphere usually contains a single transparent oil globule 0.17 to 0.20 mm. in diameter. Eggs with two oil globules of smaller size are not uncommon, but as development advances these coalesce. The egg membrane is thin and horny.

Embryology.—These eggs develop in a manner typical for pelagic teleostean eggs. An advanced cleavage stage is illustrated in figure 58. Figure 59 illustrates an advanced stage in the differentiation of the embryonic axis. Figure 60 illustrates an egg shortly after the closure of the blastopore. At this time the embryo extends approximately halfway around the circumference of the yolk sphere.

As soon as the embryo is well differentiated, black chromatophores appear sparsely scattered over its entire surface as well as in the extra-embryonic blastoderm and on the oil globule. As the time of hatching approaches (fig. 61) these chromatophores become relatively large.

Larval development.—Incubation occupies less than 48 hours. The newly hatched larvæ (fig. 62) are approximately 2 mm. in length. The head is slightly deflected at the anterior end of the yolk sac. The vent is located just posterior to the yolk sac, not at the margin, but laterally, considerably above the margin of the fin fold. Large black chromatophores are sparsely scattered over the body and the oil globule. A small group of chromatophores also remains in the posterior region of the yolk sac.

Soon after hatching, a small amount of yellow pigment becomes apparent. Small yellow areas appear on the head and the dorsal surface of the body, another at the vent, and a few on the oil globule. The black chromatophores, as illustrated in figure 63, in a larval fish one day after hatching, gradually become aggregated into small groups. By the close of the third day after hatching (fig. 64) these groups of chromatophores have become aggregated still further to form a heavily pigmented area on the nape, another in the dorsal region of the abdominal cavity, a third on the ventral surface of the body less than half the distance from the vent to the tip of the tail, and a fourth directly opposite the third on the dorsal surface of the body. At this time the yolk is completely absorbed and the larvæ are approximately 2.3 mm. in length. The larval fishes kept in sea water died before the close of the fourth day.

In young fish 3.2 mm. in length (fig. 65) the head is relatively large and the anterior region of the trunk relatively deep. The distribution of pigment remains essentially as in the preceding stage.

In young fish 6 mm. in length (fig. 66) the depth of the body in proportion to its length has increased materially. Black chromatophores are sparsely scattered over the anterior two-thirds of the body, being most abundant in the area corresponding to and adjacent to the heavily pigmented areas in the preceding stage.

Figure 67 illustrates a young fish 15 mm. in length. The dorsal, anal, and caudal fins are now well differentiated, and the young fish is gradually assuming the general appearance of the adult.

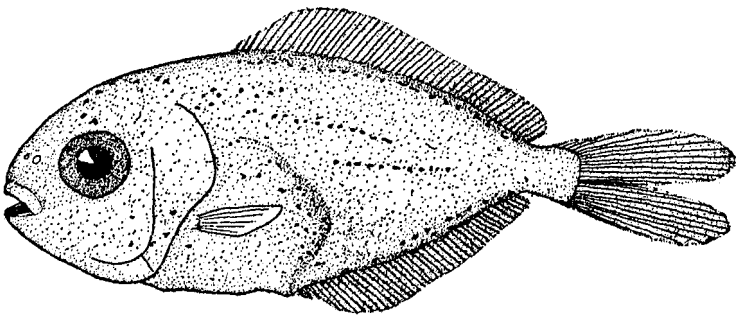

FIG. 67.—Young fish 15 mm. in length.

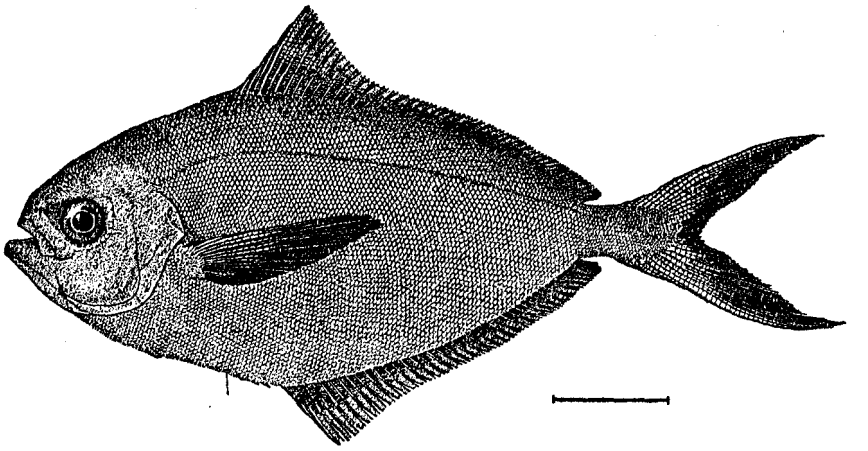

FIG. 68.—Adult fish.

PORONOTUS TRIACANTHUS.

ANCHOVIA ARGYROPHANA (Cuvier and Valenciennes). ANCHOVY.

Spawning.—The eggs of this species were present in small numbers in the plankton off Gay Head throughout August. They were at no time abundant, and none were taken in Woods Hole Harbor. The species probably spawns in offshore waters. Spawning probably occurs regularly in the evening. Eggs taken at the same hour on successive days were in approximately the same phase of development. Newly spawned eggs were not observed.

During the latter half of August adult fish were taken occasionally. Some of these were spent and none were found ripe for stripping.

Eggs.—The eggs are highly transparent and ellipsoidal in form, having a major axis of 1.15 to 1.25 mm. and a minor axis of 0.55 to 0.80 mm. The yolk is broken up by refraction planes, giving it the appearance of being made up of large cells. The eggs of this species resemble those of *Anchovia brownii* more closely than those of *Anchovia mitchilli.*[a]

Embryology.—The embryological development of these eggs differs from that of the pelagic eggs here described only in a few unimportant details. The protoplasm becomes concentrated to form the blastodisc at one pole of the major axis. As the blastoderm grows round the yolk, its posterior pole does not remain at a relatively fixed point, as is the case in many spherical teleostean eggs, but recedes as the anterior pole advances. The center of the blastoderm, therefore, remains at one pole of the major axis. (Figs. 69 and 70.) The blastopore finally closes at the opposite pole.

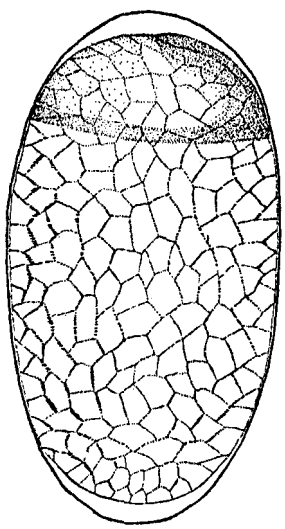

FIG. 69.—Egg showing an early stage in differentiation of embryonic axis.

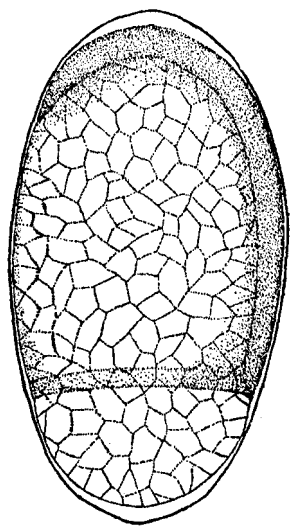

FIG. 70.—Egg showing a late stage in differentiation of embryonic axis.

ANCHOVIA ARGYROPHANA.

When the embryo is fully differentiated, it lies approximately parallel with the major axis of the egg, the head being strongly deflected at the end of the yolk mass. (Fig. 71 and 72.)

Larval development.—The newly hatched larvæ are approximately 3 mm. in length. The yolk sac remains relatively large and tapers to a point at the posterior end. The body is relatively slender, and the vent is located less than one-fourth the length of the body from the posterior end. Black chromatophores occur in a series along the intestine posterior to the yolk sac and at the base of the ventral-fin fold posterior to the vent. Figure 73 illustrates a larval fish approximately eight hours after hatching.

One day after hatching (fig. 74) the larvæ have grown to a length of approximately 3.4 mm. The yolk is largely absorbed. The distribution of pigment remains essentially as in the newly hatched larvæ, but the chromatophores have increased materially in size.

[a] Kuntz, A.: The embryology and larval development of *Bairdiella chrysura* and *Anchovia mitchilli.* Bulletin Bureau of Fisheries, vol. XXXIII, 1913, p. 14.

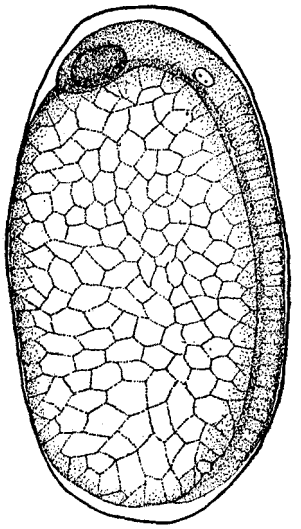

FIG. 71.—Egg with embryo well formed, shortly after closure of blastopore.

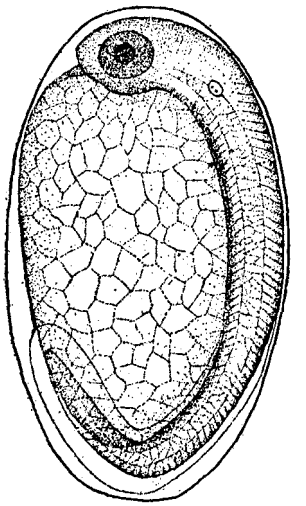

FIG. 72.—Egg with advanced embryo.

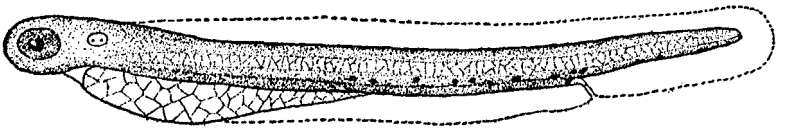

FIG. 73.—Larval fish several hours after hatching, actual length 3.2 mm.

FIG. 74.—Larval fish 1 day after hatching, actual length 3.4 mm.

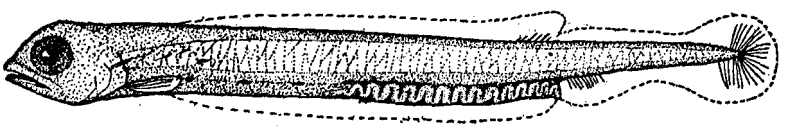

FIG. 75.—Young fish 5.2 mm. in length.

ANCHOVIA ARGYROPHANA.

In young fish 5.2 mm. in length (fig. 75) the dorsal and anal fins are becoming differentiated. In the posterior abdominal region the intestine is convoluted, as is characteristic of the young of many clupeoid fishes. The body remains almost colorless. The chromatophores along the intestine and at the base of the ventral-fin fold are less conspicuous than in the earlier stages.

BREVOORTIA TYRANNUS (Latrobe). MENHADEN, POGY.

Spawning.—For years data on the spawning habits of the menhaden have been sought with little success. Observations on the movements of the schools and examinations of the reproductive organs lead to the belief that in New England spawning takes place in late spring or early summer and that from Chesapeake Bay southward the season is late fall or early winter. Some reasons have been advanced for believing that in the Chesapeake region, at least, there are two spawning seasons. A very important addition to our knowledge of the life history of this species has recently been made by W. W. Welsh, of the Bureau of Fisheries, in identifying the larvæ. His specimens were about 24 mm. long, taken in St. George Sound, Carabelle, Fla., January 15, 1913. On February 22, 1914, examples about 30 mm. in length were taken near the mouth of the Potomac River, off Piney Point, Md., by the junior author, and on October 21, 1914, specimens about 20 mm. in length were collected in Woods Hole Harbor.

Observations made at Woods Hole this season indicate that the main body of fish spawn in June and that spawning continues throughout July and August and apparently later, as the *Grampus* obtained eggs and larvæ to the westward of Marthas Vineyard and in Nantucket Sound the last week in October, 1915. About June 30 larvæ were common in the plankton in the harbor and were not rare as late as July 20. The young, with most or all of the adult characters, were not infrequently taken in abundance between July 10 and August 10. For several days about July 21 adult fish were present in Vineyard Sound. Examinations of the reproductive organs of some of these fish indicated that they were about ready to spawn, and others were spent. Some of the males had enlarged testes with active spermatozoa, and the ovaries of some of the females were greatly distended.

Individual eggs were occasionally taken in the tow in the harbor throughout July. On August 20 they were quite abundant in the plankton off Gay Head and were still present on the 24th.

Eggs.—The eggs are highly transparent, spherical in form, and 1.4 to 1.6 mm. in diameter. The perivitelline space is very large. In this respect these eggs resemble the eggs of the shad and the European pilchard. The yolk sphere is approximately 0.9 mm. in diameter and contains a transparent oil globule 0.12 to 0.14 mm. in diameter. The egg membrane is thin and horny.

Embryology.—The embryological development of these eggs does not differ essentially from the course of development as outlined above for the eggs of *Tautoga onitis*. An advanced stage of cleavage is illustrated in figure 76. Figure 77 illustrates an advanced stage in the differentiation of the embryonic axis. Figure 78 illustrates an egg shortly after the closure of the blastopore. The embryo is relatively long and slender and at this time extends more than two-thirds around the circumference of the yolk sphere.

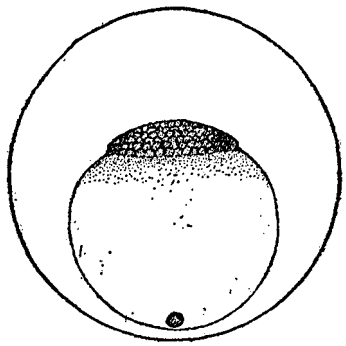

FIG. 76.—Egg with blastoderm in advanced stage of cleavage.

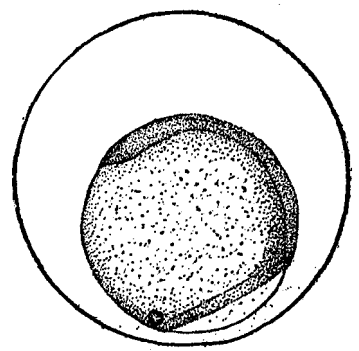

FIG. 77.—Egg showing advanced stage in differentiation of embryonic axis.

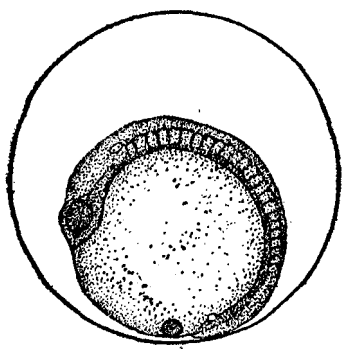

FIG. 78.—Egg showing embryo with 22 to 24 somites, blastopore closed.

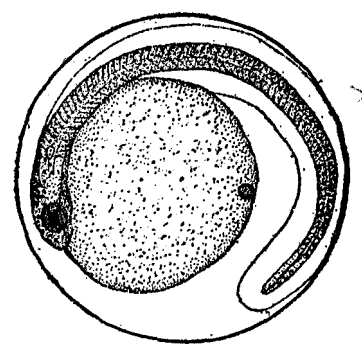

FIG. 79.—Egg with advanced embryo.

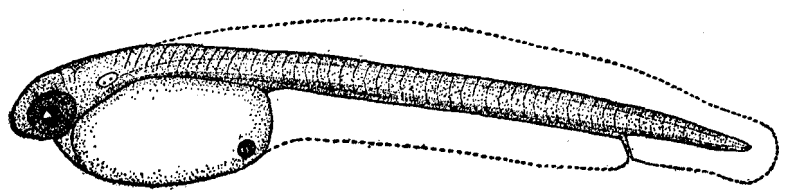

FIG. 80.—Newly hatched fish, actual length 4.5 mm.

BREVOORTIA TYRANNUS.

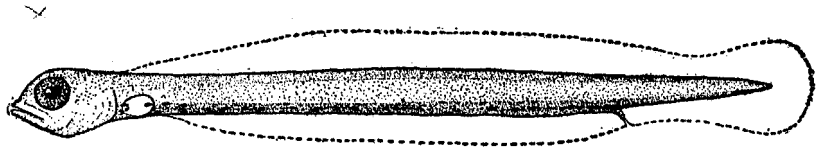

FIG. 81.—Larval fish 4 days after hatching, actual length 5.7 mm.

FIG. 82.—Young fish 9 mm. in length.

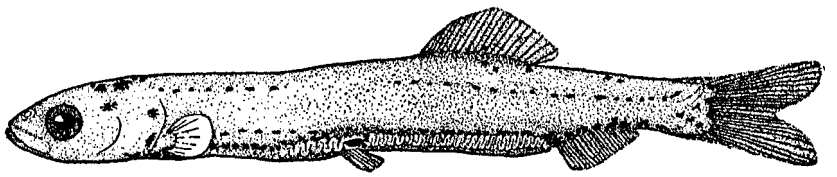

FIG. 83.—Young fish 23 mm. in length.

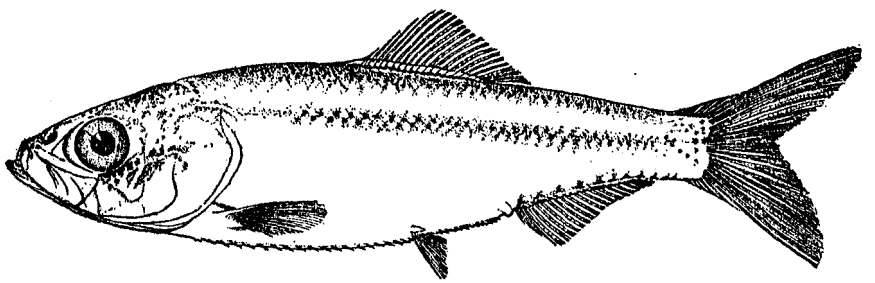

FIG. 84.—Young fish 33 mm. in length.

BREVOORTIA TYRANNUS.

Pigmentation begins within several hours after the closure of the blastopore. Before the time of hatching (fig. 79) small black chromatophores appear more or less closely aggregated on the dorsal and dorsolateral aspects of the embrvo. The extra-embryonic blastoderm remains free from pigment.

Larval development.—Incubation occupies not over 48 hours. The newly hatched larvæ (fig. 80) are approximately 4.5 mm. in length and relatively slender. The head is slightly deflected at the anterior end of the yolk sac. The vent is located less than one-fifth the length of the body from the posterior end. Pigment is less abundant than before hatching. Small black chromatophores now occur on the dorsal aspect of the

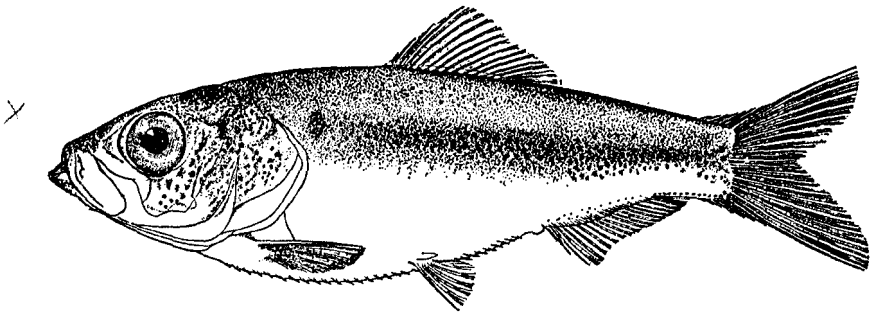

FIG. 85.—Young fish 41 mm. in length.

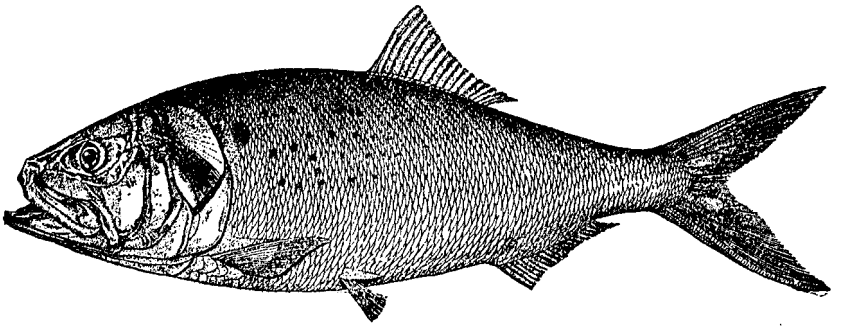

FIG. 86.—Adult fish.

BREVOORTIA TYRANNUS.

body near the base of the dorsal-fin fold and on the ventral aspect of the body posterior to the vent.

Four days after hatching (fig. 81) the larvæ have grown to a length of approximately 5.7 mm. Pigment is no longer apparent on the dorsal aspect of the body except near the tip of the tail. A small group of chromatophores occurs in the caudal region, also on the ventral aspect of the body. Black chromatophores are now present in a series along the digestive tube from the level of the pectoral fins to the vent.

In young fish 9 mm. in length the dorsal fin is becoming differentiated. In the posterior abdominal region the intestine is already distinctly convoluted. The distribution of pigment remains essentially as in the preceding stage.

In young fish 23 mm. in length (fig. 83) all the fins are well differentiated. The body remains relatively slender. Black chromatophores now occur superficially on the nape, along the margin of the opercle, near the base of the dorsal, anal, and caudal fins,

and in small groups posterior to the dorsal fin and just ventral to the pectoral fins. Black pigmented areas occur internally along the dorsal wall of the abdominal cavity and in a series at the dorsal level of the notochord.

Figure 84 is an illustration of a specimen 33 mm. long. Scales are present, the back is becoming pigmented, there is a distinct lateral stripe of dark pigment, and black chromatophores are present on dorsal and caudal rays. At this stage the fish is more slender than the adult. In a specimen 41 mm. long (fig. 85) the characters of the adult are more apparent. The body is deeper and more heavily pigmented than the preceding, and the black blotch on shoulder is distinct.

POMOLOBUS AESTIVALIS (Mitchill). BLUEBACK, GLUT HERRING.

Spawning.—This species spawns in fresh and possibly in very slightly brackish water. In some localities, at least, the spawning season appears to be an extended one. The reason, in part at least, for this is believed to be that young fish coming to maturity may ripen their eggs at a somewhat later date from the regular run of fish. Among the fish taken during July in small ponds with an outlet to the ocean the majority of the females were spent, a few females and many small males were ripe for stripping, and a considerable number of both males and females were still unripe. Young fish 30 to 60 mm. in length were present in the same ponds in abundance.

Eggs.—The eggs are demersal and somewhat adhesive, semitransparent, and yellowish in color. When water-hardened they are spherical in form with a diameter of approximately 1 mm. (fig. 87). The egg membrane is relatively thick, and its inner surface appears finely corrugated. After fertilization has taken place a relatively large perivitelline space becomes apparent.

Embryology.—The volume of protoplasm in proportion to the volume of yolk is considerably greater in these eggs than in the pelagic eggs already described. In the unfertilized egg the protoplasm is disposed in a layer of uniform thickness investing the yolk sphere. It is distinctly granular in structure; consequently, after fertilization has taken place, the protoplasmic movements involved in the formation of the blastodisc may be readily observed. The fully differentiated blastodisc (fig. 88 BD) is relatively thick and covers a relatively large area of the surface of the yolk sphere. Near the periphery it thins out abruptly and then fades away gradually into the very thin layer of protoplasm that remains at the surface of the yolk. The yolk sphere now shows apparent lines of cleavage that give it the appearance of being broken up into large cells. This structure in the yolk is less apparent in these eggs than in the eggs of *Anchovia* and certain other teleosts.

Cleavage takes place very regularly and in a manner typical for teleostean eggs. The volume of protoplasm being relatively large, the early blastomeres are correspondingly large and show a marked tendency to assume a spherical form (figs. 89 and 90).

As cleavage advances the radius of the blastoderm gradually increases. This peripheral growth of the blastoderm becomes apparent before the periblast is well differentiated (figs. 91 and 92). After the periblast is well formed the blastoderm grows round the yolk more rapidly. When the germ ring is well differentiated the blastoderm covers more than half the surface of the yolk. Figure 93 illustrates an egg in which the germ ring is fully formed and the differentiation of the embryonic shield is well started. The embryonic shield becomes relatively long and narrow. The embryonic axis, when

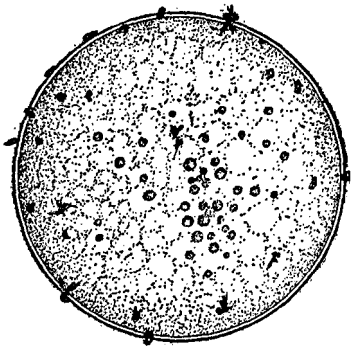

FIG. 87.—Mature unfertilized egg.

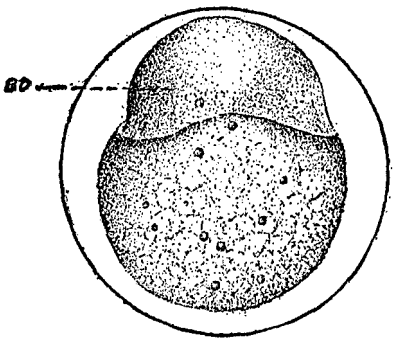

FIG. 88.—Egg with blastodisc (BD) fully differentiated.

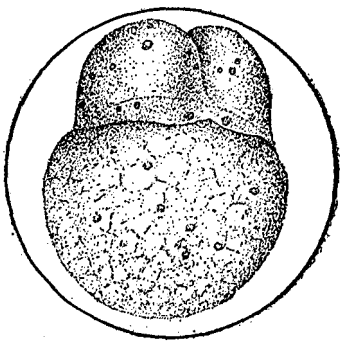

FIG. 89.—Egg with blastoderm of 2 cells.

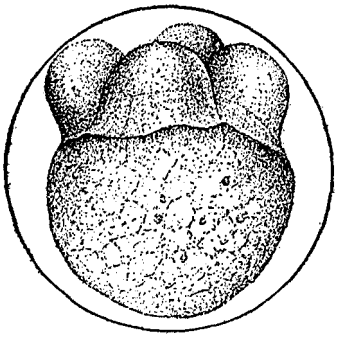

FIG. 90.—Egg with blastoderm of 4 cells.

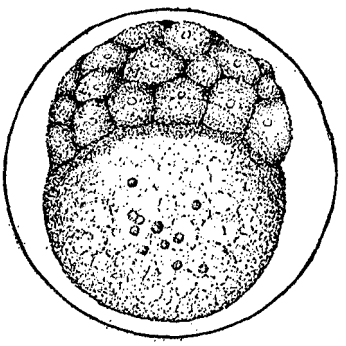

FIG. 91.—Egg with blastoderm of 64 cells.

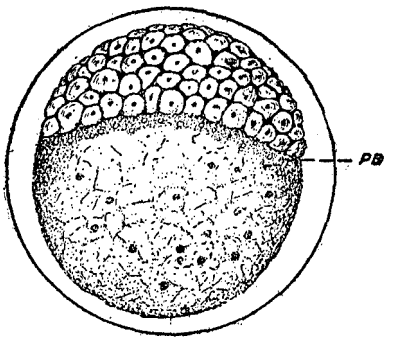

FIG. 92.—Egg with blastoderm in moderately advanced stage of cleavage, early stage in differentiation of periblast (PB).

POMOLOBUS ÆSTIVALIS.

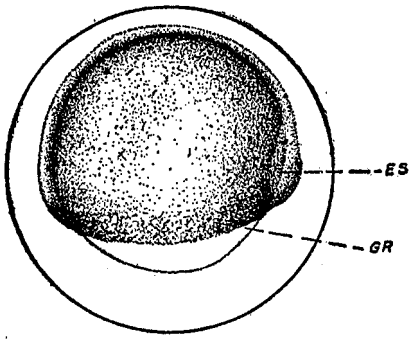

FIG. 93.—Egg showing an early stage in the differentiation of the embryonic shield (ES), germ ring (GR).

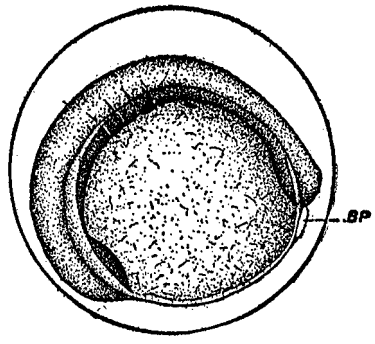

FIG. 94.—Egg with embryo well differentiated, blastopore (BP) nearly closed.

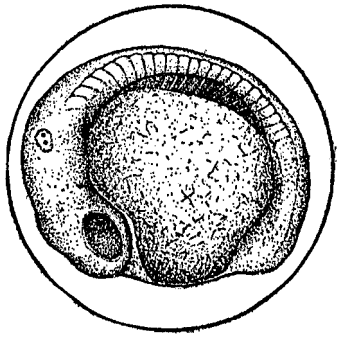

FIG. 95.—Egg with embryo showing 24 to 26 somites.

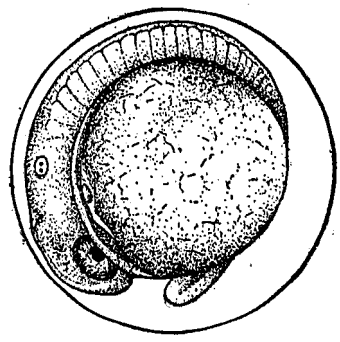

FIG. 96.—Egg with advanced embryo.

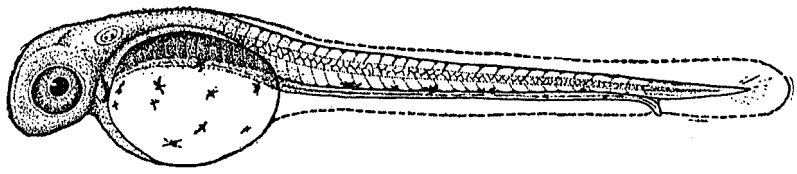

FIG. 97.—Newly hatched fish, actual length 3.5 mm.

POMOLOBUS ÆSTIVALIS.

fully differentiated, extends more than halfway around the circumference of the yolk sphere. Although the blastoderm early covers a large portion of the surface of the yolk, the blastopore does not close until the embryo is well formed and segmentation of the body has begun (fig. 94). The closure of the blastopore occurs within 16 hours after fertilization. At this time the embryo extends fully two-thirds around the circumference of the yolk sphere. Figure 95 illustrates an egg shortly after the blastopore is closed.

As the time of hatching approaches the embryo increases in length until it makes more than a complete turn within the egg membrane. It becomes relatively opaque but shows very little pigment.

Larval development.—Incubation at laboratory temperature occupied approximately 50 hours. The newly hatched larvæ (fig. 97) are approximately 3.5 mm. in length and relatively slender. The head is somewhat deflected at the anterior end of the yolk sac.

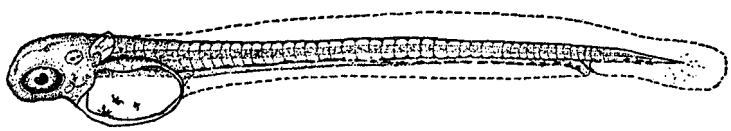

FIG. 98.—Larval fish 1 day after hatching, actual length 4 mm.

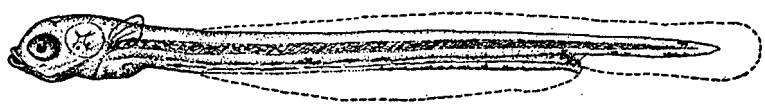

FIG. 99.—Larval fish 4 days after hatching, actual length 5.2 mm.

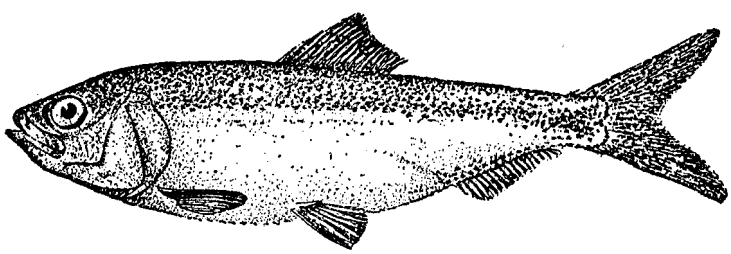

FIG. 100.—Young fish 30 mm. in length.

POMOLOBUS ÆSTIVALIS.

The vent is located near the posterior end of the body. Black chromatophores occur sparsely scattered over the yolk sac and in a series along the intestine.

One day after hatching (fig. 98) the larvæ have grown to a length of 4 mm. The greater part of the yolk is absorbed and the head is no longer deflected. The general appearance of the larva has not changed materially, although the series of chromatophores along the intestine has become more marked and a few chromatophores appear at the base of the ventral-fin fold posterior to the vent.

Four days after hatching (fig. 99) the larvæ have attained a length of 5 mm. or over. The yolk is completely absorbed. The distribution of pigment remains essentially as in the earlier stages.

Figure 100 illustrates a young fish 30 mm. in length. Young fish 30 to 50 mm. in length, as indicated above, were present in abundance during July in the waters in which adult fish were found spawning. Young fish of this size have the general appearance of adults and show all the diagnostic characters of the species.

MENIDIA MENIDIA NOTATA (Mitchill). SILVERSIDE.

Spawning.—This species spawns in June and July. The height of the spawning season is reached, doubtless, before July 1. The great majority of the fish taken early in July were already spent.

Eggs.—The eggs are spherical in form, 1.1 to 1.2 mm. in diameter. They are demersal and are held together in ropy clumps by a tangle of adhesive threadlike processes, a tuft of which arises from the membrane of each egg. The yolk sphere contains 5 to 12 large oil globules of unequal size and numerous smaller ones. The larger oil globules may or may not be aggregated; the smaller ones are distributed more or less uniformly over the surface of the yolk. The eggs are yellowish in color and semi-transparent. The egg membrane is thick and the micropyle relatively large (fig. 101). These eggs are very similar to those of the related species, *Kirtlandia vagrans*, described in an earlier paper,[a] but are somewhat larger.

Embryology.—These eggs, being somewhat larger and much more heavily laden with yolk material, develop much less rapidly than do the pelagic eggs here described. In all other essential respects their embryological development follows a course practically identical with that as outlined for the eggs of *Tautoga onitis*. Successive stages in the process of cleavage and the differentiation of the embyro are illustrated in figures 102 to 106. The embryo is well differentiated and shows 20 to 24 somites within 40 hours after fertilization (fig. 106).

The beginning of pigmentation is observed during the third day of incubation. Black chromatophores become sparsely scattered over the embryo and the extra-embryonic blastoderm. Yellow chromatophores appear only on the embryo. As development advances, black chromatophores become aggregated in a few areas on the dorsal aspect of the head and in a series at the base of the ventral-fin fold. A few black chromatophores appear at the base of the dorsal-fin fold near the posterior end of the body. The black chromatophores in the extra-embryonic blastoderm gradually become arranged along the extra-embryonic blood vessels. Small yellow chromatophores remain sparsely scattered over the embryo for some time, but gradually become less conspicuous.

Larval development.—Incubation at laboratory temperature occupied 8 to 9 days. The newly hatched larvæ (fig. 109) are approximately 5 mm. in length and relatively slender. The yolk is largely absorbed before hatching. The vent is located just posterior to the yolk sac. From this level the body tapers gradually toward the posterior end. Black and yellow chromatophores are aggregated on the dorsal aspect of the head and in the dorsal region of the abdominal cavity. Black chromatophores are present on the ventral aspect of the yolk sac, in a series at the base of the ventral-fin fold, and in a few small groups at the base of the dorsal-fin fold toward the posterior end of the body.

Five days after hatching (fig. 110) the larvæ have grown considerably, but the majority of them do not exceed 5.5 mm. in length. The yellow pigment is materially reduced. Black chromatophores have become more abundant on the dorsal aspect of the head and anterior trunk region. The body is marked further by a series of black chromatophores at the base of the ventral-fin fold and another at the ventral level of the notochord.

[a] Kuntz, A.: Notes on the embryology and larval development of five species of teleostean fishes. Bulletin, Bureau of Fisheries, vol. XXXIV, 1914, p. 420.

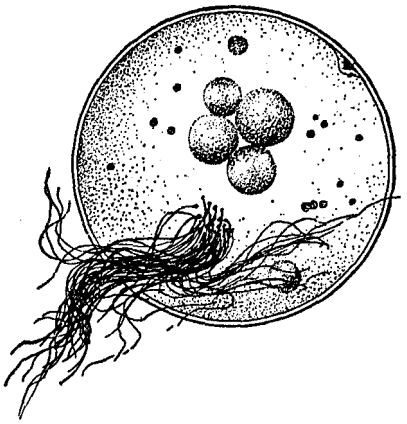

FIG. 101.—Mature unfertilized egg.

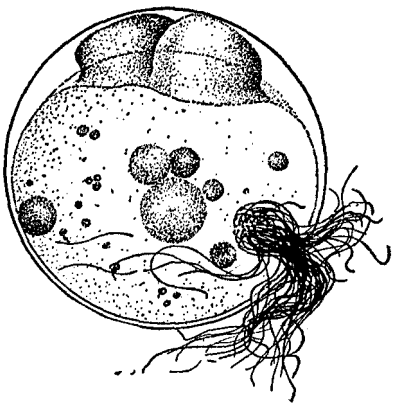

FIG. 102.—Egg with blastoderm of 2 cells.

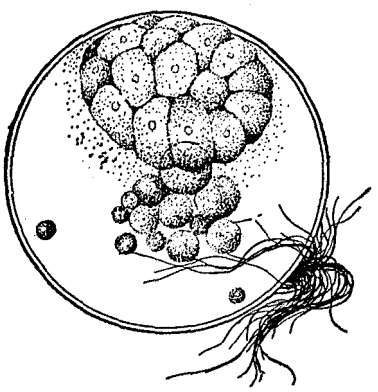

FIG. 103.—Egg with blastoderm of 16 cells.

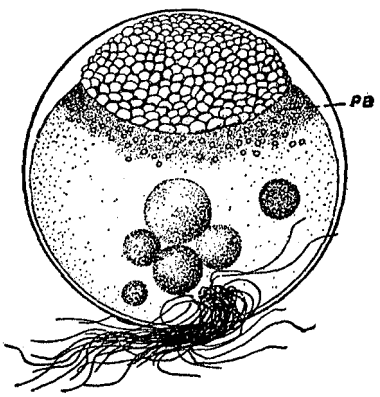

FIG. 104.—Egg with blastoderm in advanced stage of cleavage, periblast (PB) differentiated.

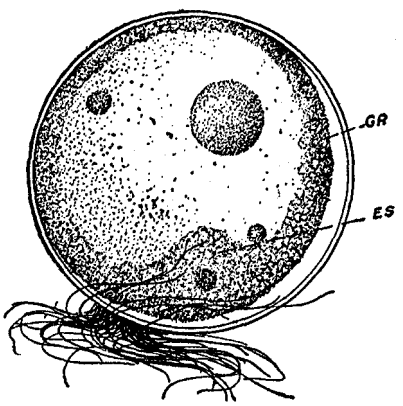

FIG. 105.—Egg showing germ ring (GR) well differentiated and early stage in differentiation of embryonic shield (ES).

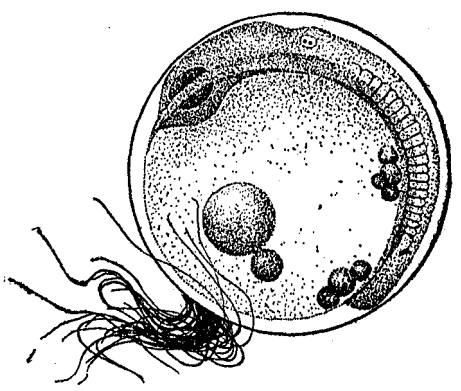

FIG. 106.—Egg showing embryo with 22–24 somites.

MENIDIA MENIDIA NOTATA.

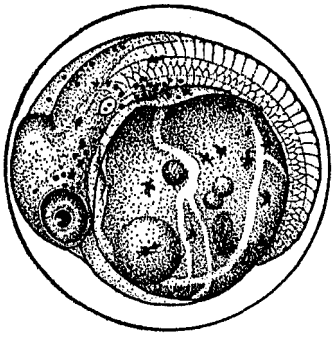

FIG. 107—Egg 6 days after fertilization.

FIG. 108.—Egg 8 days after fertilization.

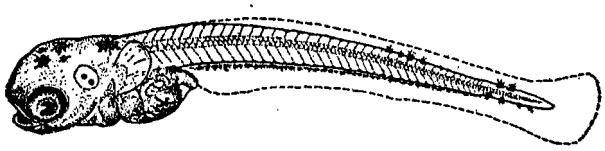

FIG. 109.—Newly hatched fish, actual length 5 mm.

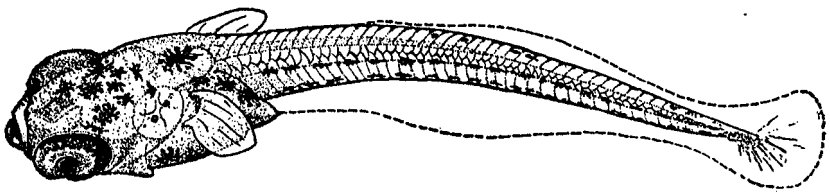

FIG. 110.—Larval fish 5 days after hatching, actual length 5.5 mm.

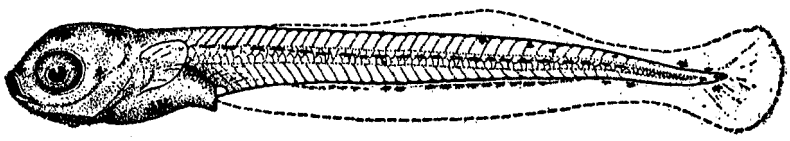

FIG. 111.—Young fish 8 mm. in length.

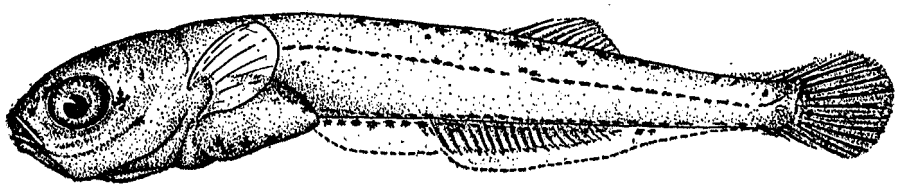

FIG. 112.—Young fish 13 mm. in length.

MENIDIA MENIDIA NOTATA.

Young fish 8 mm. in length (fig. 111) do not differ essentially in their general appearance from the young fish 5 days old just described. The distribution of pigment also remains essentially the same.

In young fish 12 to 15 mm. in length (fig. 112) the distribution of pigment observed in the earlier stages is still apparent; however, black chromatophores are becoming more abundant on the dorsal aspect of the body. The silvery lateral band characteristic of the species is not yet well differentiated. The dorsal, anal, and caudal fins are well formed, and the young fish are gradually assuming adult characters.

GASTEROSTEUS ACULEATUS Linnæus. THREE-SPINED STICKLEBACK.

Spawning.—The spawning season of this species begins in May (Edwards) and continues until late in July. Females ripe for stripping were taken as late as July 24. Males ripe for stripping were not secured. Fertilization was accomplished by macerating the testes of the male in the water into which the eggs were stripped.

Eggs.—The eggs are demersal and adhere firmly in small clumps. They are somewhat irregular in form when stripped from the female, but become spherical as soon as they become water-hardened. If they adhere closely, adjacent surfaces may remain somewhat flattened. They are yellowish in color, semiopaque and have a diameter of 1.5 to 1.7 mm. The egg membrane is thick and apparently smooth, but strongly adhesive, The yolk sphere contains numerous oil globules of unequal size, which are usually aggregated more or less closely. Very minute oil globules also occur sparsely scattered over the surface of the yolk sphere (fig. 113).

Embryology.—The eggs of this species develop typically. The volume of protoplasm in proportion to the volume of yolk is comparatively small; consequently the blastodisc (fig. 114 BD), as well as the early blastoderm (fig. 115), covers a relatively small area of the surface of the yolk. Early development advances quite rapidly. Within 24 hours after fertilization the embryo is well differentiated and the blastopore is closed (fig. 116).

Before the close of the third day of incubation the embryo extends nearly around the circumference of the yolk sphere (fig. 117). The head is relatively broad, and the body tapers gradually toward the posterior end. Circulation may be observed throughout the entire extra-embryonic blastoderm. Small black chromatophores are present on the dorsal surface of the anterior region of the trunk and in the adjacent areas of the extra-embryonic blastoderm.

As the time of hatching approaches, the embryo grows larger and the yolk becomes materially reduced (fig. 118). A close-meshed network of blood vessels becomes apparent over the entire surface of the yolk sphere. Chromatophores have become larger and more numerous. They are now present over the entire dorsal surface of the embryo, in the adjacent areas of the extra-embryonic blastoderm, and in a series along the ventrolateral aspect of the body posterior to the vent.

Larval development.—Incubation at laboratory temperature occupied approximately six days. The newly hatched larvæ (fig. 119) are 4.2 to 4.5 mm. in length. The vent is located a short distance posterior to the yolk sac and more than half the length of the body from the anterior end. The general color of the body is yellowish. Diffuse yellow pigment and small yellow chromatophores occur over the entire body. Large black chromatophores are more or less closely aggregated on the dorsal surface of the body,

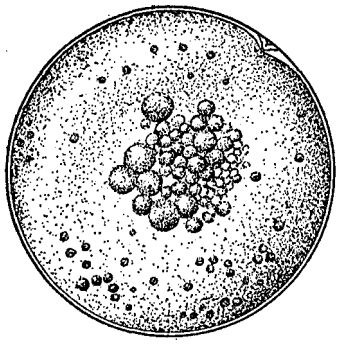

FIG. 113.—Mature unfertilized egg.

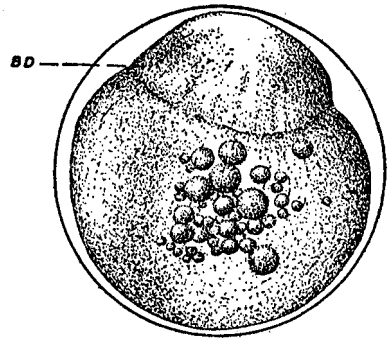

FIG. 114.—Egg with fully differentiated blastodisc (BD).

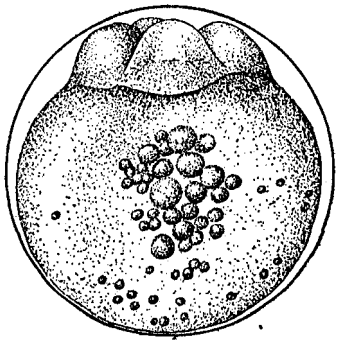

FIG. 115.—Egg with blastoderm of 4 cells.

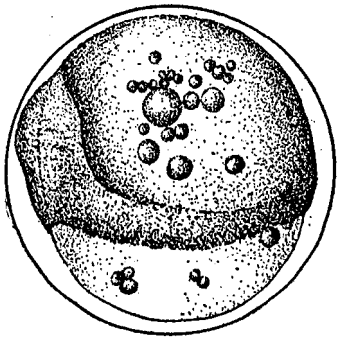

FIG. 116.—Egg 24 hours after fertilization.

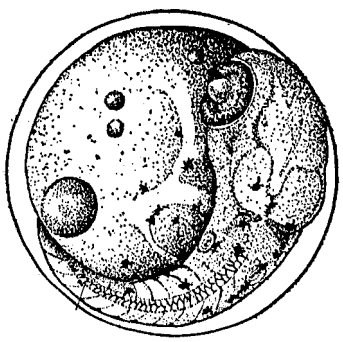

FIG. 117.—Eggs 68 hours after fertilization.

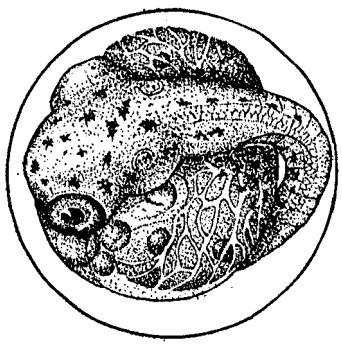

FIG. 118.—Egg 4 days after fertilization.

GASTEROSTEUS ACULEATUS.

on the surface of the yolk sac adjacent to the body, and on the ventrolateral aspect of the body near the base of the ventral-fin fold.

Three days after hatching (fig. 120) the young fish have grown to a length of 6.2 to 6.5 mm. The general color of the body remains yellowish, and the distribution of black pigment remains essentially as in the newly hatched larvæ. However, the chromatophores have increased materially in number.

Eight days after hatching (fig. 121) the young fish have attained a length of approximately 7 mm. The general color of the body is now darker than in the earlier stages. Black pigment has become more abundant, and the yellow pigment is materially reduced. Black chromatophores are present over the entire surface of the body but are closely aggregated only on the dorsal and dorsolateral aspects.

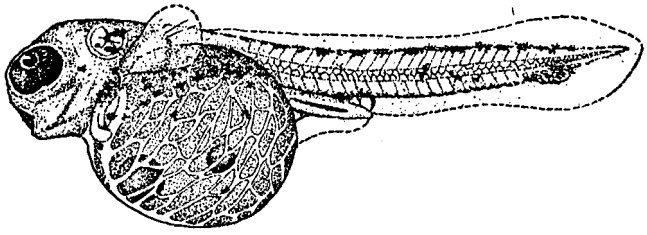

FIG. 119.—Newly hatched fish, actual length 4.3 mm.

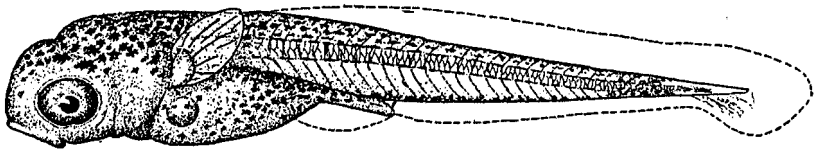

FIG. 120.—Larval fish 3 days after hatching, actual length 6.3 mm.

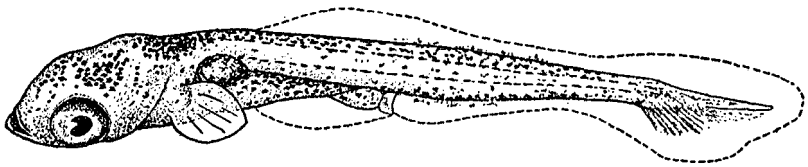

FIG. 121.—Larval fish 8 days after hatching, actual length 7 mm.

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APELTES QUADRACUS (Mitchill). FOUR-SPINED STICKLEBACK.

Spawning.—This species is known to spawn in May and June (Sumner). The spawning season continues until late in July. Females ripe for stripping were taken as late as July 24. A considerable number of females were taken on August 3 but all were spent. As in the case of *Gasterosteus aculeatus*, males ripe for stripping were not secured. Fertilization was accomplished by macerating the testes of the male in the water into which the eggs were stripped.

Eggs.—The eggs are demersal and adhere firmly in small clumps. They are similar to the eggs of *G. aculeatus* here described but more intensely yellowish and consequently more opaque. They are somewhat irregular in form when stripped from

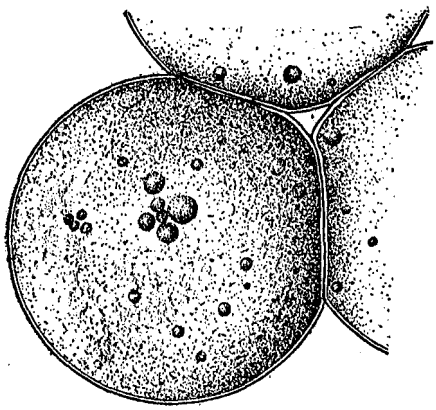

FIG. 122.—Mature unfertilized egg.

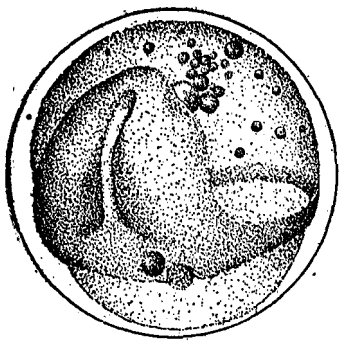

FIG. 123.—Egg showing advanced stage in differentiation of embryonic shield.

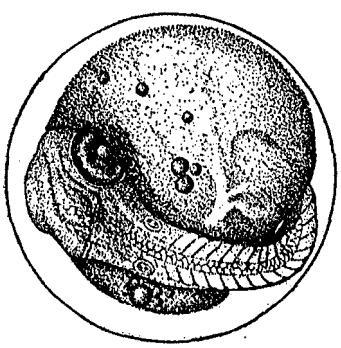

FIG. 124.—Egg 48 hours after fertilization.

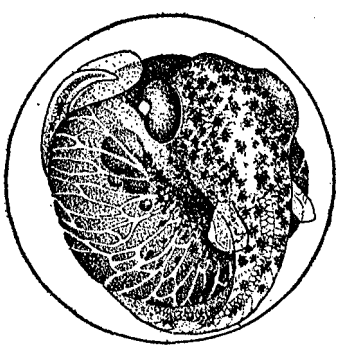

FIG. 125.—Egg 4 days after fertilization.

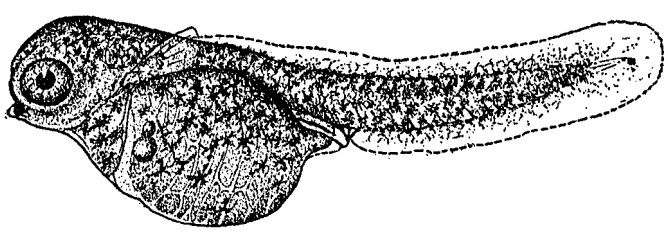

FIG. 126.—Newly hatched fish, actual length 4.3 mm.

APELTES QUADRACUS.

the females but become spherical as soon as they become water-hardened. Contiguous surfaces may remain slightly flattened. The average diameter is approximately 1.6 mm. The yolk sphere contains a few oil globules of unequal size which may be aggregated more or less closely or widely scattered (fig. 122).

Embryology.—The eggs of this species present essentially the same pictures during early embryological development, as do the eggs of the related species *G. aculeatus*. Their development is entirely typical and need not be discussed in detail.

Pigmentation begins relatively early, and pigment is developed rapidly. Four days after fertilization (fig. 125) large black chromatophores are present over the entire surface of the embryo as well as in the adjacent areas of the extra-embryonic blastoderm. Small yellow chromatophores also occur scattered over the surface of the embryo but are not conspicuous.

Larval development.—Incubation at laboratory temperature occupied approximately six days. The newly-hatched larvæ (fig. 126) are 4.2 to 4.5 mm. in length. The vent is located a short distance from the posterior end of the yolk sac and slightly more than half the length of the body from the anterior end. The general color of the body is dark brown. Yellow pigment remains sparsely scattered over the body but is obscured by the greater abundance of black pigment. Large black chromatophores are closely aggregated over the entire surface of the body and the upper half of the yolk sac. The newly hatched fish is similar to the newly hatched larva of *G. aculeatus*, but much more heavily pigmented.