HABITS AND LIFE HISTORY OF THE TOADFISH (OPSANUS TAU)

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CONTENTS.

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MATERIALS AND METHODS OF STUDY.

The material on which this paper is based was collected and the notes were made while the author was a temporary assistant in the United States Fisheries Laboratory at Beaufort, N. C., during the summers of 1906, 1907, and 1908. The collections were made in all parts of the harbor, but the best collecting ground was a shoal lying directly in front of and not farther distant from the south front of the laboratory than 100 yards.

The "nests," consisting of tin cans, empty *Pinna* shells, pieces of board, etc., were brought in in buckets of water and placed in aquariums or in shallow pans under jets of running salt water, or in a large tank 3¾ by 7¾ feet, filled with fresh salt water to a depth of 6 inches. In some of these aquariums there were placed nests with guarding fish; in others nests without any fish; while in the tank there were always numbers of fish, both adults and half grown.

The nests thus placed were perfectly accessible and could be inspected at any hour of the twenty-four. Daily they were taken out, put in shallow pans of water, and minutely examined under a glass. Selected eggs and larvæ were put in killing fluids, careful notes were taken, and at intervals the eggs and nests were photographed.[a]

GENERAL DESCRIPTION OF ADULT TOADFISH.

For a description of this singular fish the writer can not do better than quote Doctor Gill (1907) and Miss Clapp (1899), since their descriptions leave little or nothing to be added. Doctor Gill says:

> They [the toadfishes] have an oblong form, a broad flattish head, restricted lateral gill openings, two dorsal fins, the anterior very small and with only two or three spines, the second very long, the anal moderately long, the pectorals broad, and the ventrals jugular and imperfect (1, 2- or 3-rayed).

[a] I am under obligations to Mr. Henry D. Aller, Director of the Beaufort Laboratory, for furthering this research in every way possible, and to Dr. H. E. Enders, of Purdue University, for taking the photographs from which some of the figures are made. The other figures are made from photographs taken by myself.

According to Miss Clapp:

There is something singularly grotesque in the appearance of the toadfish; and, as its name would imply, there is a superficial resemblance to the familiar batrachian. The sluggish disposition, the mottled brown and gray of the wrinkled, scaleless skin, the depressed head and toadish eyes do not suggest the typical teleost. The young fish are tadpole-like in their form and motions. * * * It will be seen that there are quite conspicuous projections of the skin on the head. Besides the paired flaps found in connection with the sense organs, there are other single, often longer projections to be found, which become laciniated in the older fish. These are especially prominent about the mouth, fringing the margin of the lower mandible and opercular regions, while over each eye rises a broad conspicuous flap, giving an owl-like facial expression. * * * The function of these skinny tentacles seems evidently to be for protection, as they strikingly resemble both in color and form the seaweed (*Fucus*) that abounds near their favorite haunts.

Toadfish are somewhat variable in color, but may, generally speaking, be grouped in three classes—those which are a muddy green, those with brown on the upper parts, and those which approximate yellow. I am inclined to think that the former are found largely in deeper water, the latter two classes in shallows. There is, it must be understood, no definite line of demarcation, since all degrees of gradation from class one to two and to three exist. Perhaps the greatest variation, however, is not so much in the ground color as in the markings and blotches which render one fish distinguishable from another. These markings, generally of darker color, are found on the head and fins, particularly the dorsal and caudal. One very large fish of particular marking comes to mind. This was a brown male with an enormous head, the whole right side of which was of a velvety black color, the bright eye with its St. Andrew's cross being near the center. This fish always recalled a bulldog with a black patch covering the right side of the head. It may be added that the toadfish has to a considerable degree the power of changing its color to correspond with the bottom on which it happens to find itself.

HISTORICAL ACCOUNT.

When one considers the abundance in which this fish is found along the Atlantic coast, the large size of the eggs, and the ease with which, owing to the nesting habits of the parents, the eggs can be obtained, one wonders that the embryology and habits of the toadfish have never been worked out. But, excepting two short papers by Ryder, there has been no attempt to study the life history of *Opsanus tau*. There are, however, several papers, long or short, dealing with the habits and with the development of particular organs, which will be referred to later. Since those particular points in the articles cited which touch upon this research are referred to at length in the body of this paper, the references in most cases taking the form of quotations, it will not be necessary here to do more than list the papers and give a general synopsis of their contents.

This fish was first described and named (*Gadus tau*) by Linnæus from a specimen collected by Doctor Garden, of South Carolina. The earliest figures of the toadfish that I have been able to find are in plate LXVII of Bloch's Atlas to his "Oeconomische Naturgeschichte der Fische Deutschlands," published about 1782. These figures, one a dorsal, the other a lateral view, are very good, the latter especially.[a]

The first American describer was Doctor Mitchill (1815), of New York, who allied it with the angler (*Lophius*) because of its large head adorned with skinny tentacles, and its cavernous mouth. His description is an excellent one.

Rafinesque in 1818 describes, under the name of *Opsanus cerapalus*, a toadfish from the south shore of Long Island. This, he notes, is found spawning along the shores during the summer but is not seen in winter. So far as the present writer knows, the first American ichthyologist to figure this fish was Le Sueur. His drawing, published in 1819, represents the fish in the attitude of swimming. This admirably drawn and thoroughly characteristic figure has been reproduced in Doctor Gill's (1907) paper, referred to later.

Le Sueur, following the lead of Mitchill, allies the toadfish, which he calls *Batrachoides vernullas*, to *Lophius*. In another paper the same author (1824), in describing what he thought were two new species of the toadfish, thus justifies the name *Batrachoides* which he first applied to this fish:

The name *Batrachoides* * * * is a very appropriate one, inasmuch as the form of the body of these fishes has considerable analogy with the larval or imperfect and exclusively aquatic state of the frog; this similarity exists in the large depressed head and wide mouth, the attenuated body edged with an almost continuous fin above and beneath, and, in fact, a general conformity which at once reminds us of the numerous family of Batrachians that are inhabitants of almost every country. This general resemblance is evident to the common observer and they are known by the name of toadfish to the inhabitants of Salem, Rhode Island, and Egg Harbor, and probably also Carolina.[b]

His first specimens were very small, consisting of two individuals of 5½ inches each and one of 2½ inches in length. This latter was taken from a living oyster, in which Le Sueur thinks it had taken refuge in alarm at the noise and motion of the oyster tongs.

In 1842, De Kay, following Cuvier and Valenciennes, gives the name *Batrachus tau* to the toadfish, but still retains it in the family *Lophius*. He

[a] In Marcgrave's (1648) Historiæ Rerum Naturalium Brasiliæ, on page 178, there is figured and described a fish "called Niqui by the Brasilians, and Pietermann by the natives." Both the figure and the description lead me to believe that the fish Marcgrave had was a toadfish. Jordan and Evermann (1898) make no reference to this fish in their description of North American forms. Since, however, in a footnote to page 2315, they refer to certain structures in "the Brazilian genus *Marcgravia cryptocentra*," one may be allowed to conjecture that this is the fish referred to above.

[b] Hargreaves (1904), writing of the pacuma, *Batrachus surinamensis*, of Guiana, says. "The head of the pacuma is exactly like that of a huge toad and has much the same color and markings as the common crapaud."

also describes another fish (1 inch long and undoubtedly the young of the above) as *B. celatus*. This latter he notes is frequently found in oysters, while in 1824 a shower of them fell in the streets of New York. De Kay gives two figures of the toadfish, but they are not to be compared to Le Sueur's splendid drawing. The present writer twice went over the plates of this paper without recognizing either figure as that of the fish in question. One figure has the caudal fin pointed, the other rounded.

Storer (1855) in his "History of the Fishes of Massachusetts," published about the middle of the last century, gives a very interesting but not wholly accurate account of the nesting habits of the toadfish. As the essential points in his paper will be discussed later, it will not be necessary to go further into it here than to say that he was the pioneer worker on the habits of this fish. He obtained his information chiefly from Dr. William O. Ayres, of East Hartford, Conn. This information must have been conveyed by letter, for in Ayres's paper published thirteen years before (1842) there is a very meager account of the general habits only and no reference whatever to the nesting habits. Ayres's paper will be referred to later.

Yarrow (1877), twenty-two years after Storer, in listing the fishes of Beaufort Harbor, speaks of finding a nest of toad eggs in an old boot leg. In 1881, Alexander Agassiz, in the course of an interesting article, "On the Young Stages of Some Osseous Fishes," describes the coloring of a half-grown larva and figures the heterocercal tail. In a popular article published in Harper's Magazine, C. F. Holder (1883) figures a toadfish in a nest amid seaweeds, and falls into the popular error of making the mother the guardian. With regard to the adhesion of the eggs, however, he merely says that the young are enabled to cling to the rocks by their yolk sacs, remaining until bold enough to swim away. Goode (1884), in dealing with the nesting habits and embryology of the toadfish, quotes Storer (1855) at length and gives the accurate and highly interesting observations of Silas Stearns, of Pensacola, Fla., all of which are quoted in detail further on.

In 1886 John A. Ryder published the first of a series of short but highly interesting papers on the habits and embryology of *Opsanus* (or, as it was then called, *Batrachus*) *tau*. These papers followed in rapid succession. The first appeared in 1886 and seems to have been an abstract of the but slightly longer article which appeared in 1887. This latter paper, which he calls a "Preliminary Notice," contains six figures, the first illustrations of toadfish embryos ever published so far as the writer knows. The third, last, and possibly most valuable of these papers is an oral communication to the Philadelphia Academy, on November 4, 1890, on "The Functions and Histology of the Yolk-Sack of the Young Toadfish." The striking points of these papers are all referred to later in the body of this article.

Miss Cornelia Clapp, in 1891, published an interesting paper entitled "Some Points in the Development of the Toadfish (*Batrachus tau*)." In this she figures segmenting blastoderms, illustrates and describes the closure of the blastopore and its relation to the forming embryo, and discusses the relation of the axis of the embryo to the first cleavage plane. She also briefly refers to the nesting habits.

Five years later Miss Clapp presented as a dissertation for the doctor's degree at the University of Chicago a paper entitled "The Lateral Line System of *Batrachus tau*," which was published in the Journal of Morphology, volume XV, 1899 This contained figures of early larvæ and gave an excellent description of the fish and of its nesting habits. In the same year and in the same journal one of Miss Clapp's students, Miss Wallace, published a short but valuable article on "The Germ Ring in the Egg of the Toadfish," reviewing and extending Miss Clapp's work. A third paper on the embryology of this fish appeared the same year. This is a reprint of a lecture delivered by Miss Clapp at the Marine Biological Laboratory at Woods Hole, during the previous summer, on the relation between the first cleavage plane and the axis of the embryo. Those points in all three of these papers which deal with matters pertinent to this research are taken up at length in the other parts of this paper.

The last article, so far as has come to the writer's knowledge, bearing on the habits and life history of this fish is Doctor Gill's (1907) "Life Histories of Toadfishes (Batrachoidids) compared with those of Weevers (Trachinids) and Stargazers (Uranoscopids)." This, as the liberal quotations from it in various parts of this paper show, has been a veritable mine of information to the present writer.

HABITS AND CHARACTERISTICS.

NESTING HABITS.

Nesting places.—The toadfish in accommodating itself to its environment has developed most interesting habits. The eggs are deposited in nests, which in the writer's observation have been old tin cans, a broken jug, floating boards, rotting logs lying more or less horizontally in the water, stones (ballast thrown overboard) with an exposed under surface, but especially the empty shells of a large fan-shaped lammellibranch (*Pinna seminuda*) which abound in the sandy shoals around the laboratory at Beaufort.

Miss Clapp (1899) says that—

> The fish resort in pairs to large stones, especially near low-water mark, and, scooping out a cavity beneath, remain for days in this retreat.

Again she notes that—

> The toadfish of the Eel Pond near the laboratory [at Woods Hole] seem to prefer the débris of civilization to the excavation beneath the rock—for example, tin cans, old boots, broken jugs, etc.

These points had been briefly stated by her in the earlier paper (1891) elsewhere referred to.

Ryder (1886) found that—

> The adult toadfish burrows a cavity under one side of a submerged bowlder and to the solid roof of this cavity the female attaches her ova in a single layer. The eggs are very adhesive and quite large, measuring about one-fifth of an inch in diameter. Like the male catfish, the male toadfish assumes charge of the adherent brood of eggs and remains by them until they are hatched and subsequently become free.

A year later (1887) he writes:

> They (the eggs) are dirty yellow, almost amber colored, and adherent to the surfaces of submerged objects, especially the undersides of bowlders, under which the parent fish seem to clear away the mud and thus form a retreat in which they may spawn. The ova are attached to the roof of the little retreat prepared by the adults, where the eggs are found spread out over an area about as large as one's hand, in a single layer, hardly in contact with each other, and to the number of about 200.

Yarrow (1877), writing of the Beaufort fish, tells, as already referred to, of a nest which was found in an old boot leg. Storer (1855), the first writer, so far as I can find, to describe the nesting habits, found the fish living in eel grass or under stones, to the latter of which eggs, several hundred in number, were found attached in June, July, and August. At Beaufort a more interesting, and for the collector more dangerous, place of abode is in holes dug by the stone crab (*Menippe mercenaria*) in sand flats covered with eel grass (*Zostera marina*). In short, the fish resort for egg laying to any place which is dark and which secures a protected abode to the hatching eggs and guarding parent.

The toadfish of the Pacific coast, *Porichthys notatus*, which ranges from Alaska to Panama, has the habit, according to Greene (1899), of spawning during spring and summer in shallow water. Here "the eggs are cemented in a single layer to the under surfaces of stones, and, * * * the male remains with the brood until the young become free swimming." Hargreaves (1904) states that the pacuma (*Batrachus surinamensis*) of Guiana has the habit of hiding in holes in the mud flats, but the context does not indicate whether for the purpose of egg laying or for the sake of protection.

The eggs.—How the extrusion and fertilization of the eggs take place and how their fixation to the nest is effected I have not been able to ascertain, although considerable numbers of fish of both sexes were kept for months in the large tank (above referred to) well equipped with tin cans, jars, boards, and especially empty *Pinna* shells. The fish readily inhabited these receptacles, but laid no eggs. On one occasion I found in a shell out in the harbor a pair of fish presumably spawning, since there were a few eggs in very early stages adhering to the nest. Though both fish and nest were carefully brought in and placed in the tank, no more eggs were laid.

The egg is permanently oriented with the ventral pole of the yolk fixed to that part of the egg membrane which is fastened to the object acting as a nest. The part of the eggshell there attached is not, as Miss Clapp (1899–1899a) indicates, always opposite the micropyle, but generally so. So far as my observations go, in the great majority of cases the micropyle is opposite the point of attachment, but it may vary within a zone bounded by a circle about 30° away from the animal pole. The blastoderm, and consequently the embryo, as pointed out by Ryder (1886 and 1887) and Miss Clapp (1891 and 1899a), are at the animal pole opposite the point of attachment, though here we find the same variation as is noted for the position of the micropyle.

Just here it is worth while to correct an error into which nearly all those who have described this fish and its young have fallen. Storer (1855), more than a half century ago, in describing the habits of the toadfish, says:

> We may see the eggs, not larger than very small shot; a little later they are increased in size, and the young fish are plainly visible through their walls; a little later still the young have made their escape (i. e., have burst their eggshells), but are still attached to the stone. The attachment now, however, is accomplished in a different manner. The yolk, not being yet absorbed, occupies a rounded sac protruding by a narrow orifice from the abdomen, and the part of the sac near its outer border, being constricted, leaves external to it a disk, by means of which, acting as a sucker, the young fish adheres so firmly as to occasion difficulty in detaching it.

The error here occurs in the idea that there is any "sucker" at the basal portion of the yolk stalk. The egg is simply glued to its support in a manner to be explained presently. It should, however, be stated that Storer did not get his information at first hand, but expressly credits it to Dr. William O. Ayres, of East Hartford, Conn. This, as previously stated, must have been communicated orally or by letter, since it is not found in Ayres's paper (1842).

Jordan and Evermann (1898), in their great work, "The Fishes of North and Middle America," fall into the same error in describing "the young clinging to the rocks by a ventral sucking disk." And Jordan (1905), in his "Guide to the Study of Fishes" speaks of "the young clinging to stones by a sucking disk on the belly, a structure which is early lost." And, last in point of time, Smith (1907), in his "Fishes of North Carolina," says that "for some time after hatching the young remain attached by means of a special sucking disk."

Ryder (1886) was the first to call attention to this error and to explain that the attachment was due to an adhesion of the eggshell to the nest. Later (1887) he correctly describes and figures the eggs as attached by means of an "adhesive membrane," but does not refer to the origin of this. In 1890 Ryder quotes Jordan and Gilbert as to this voluntary adhesion of the young, expressly corrects their error, and goes on to show definitely how the eggs adhere to the membrane and how the membrane is glued to the nest. Miss Clapp, in the three papers previously referred to (1891, 1899, and 1899a), also refutes this error. In her first paper (1891) she says:

The adhesive disk * * * is about 3 millimeters in diameter. It is a transparent thickening on one pole of the egg membrane, at the time of oviposition, and by means of it the egg is glued firmly to the rock.

Later she writes more explicitly (1899):

The young fish do not attach themselves by a ventral disk which soon disappears, as has been supposed, but at the time of oviposition each egg is securely glued to the rock by means of a secretion on the membrane at the pole of the egg opposite the micropyle. After hatching, the embryo fishes still remain attached to the rock by the adhesion of the yolk sac to the inside of the egg membrane over the disk area until the yolk material has been entirely absorbed, a period of three or four weeks.

Again, she says (Clapp, 1899a):

The membrane of the egg has a peculiar adhesive disk, about 3 millimeters in diameter, which has a constant position, with the center of the disk at the vegetative pole, directly (?) opposite the micropyle. By means of this disk the egg is firmly glued to the supporting surface. * * * The disk consists of a transparent secretion, which becomes opaque and gluey on contact with water. It is of nearly uniform thickness, and is closely applied to the egg membrane everywhere, except for a narrow margin which projects all around as a thin rim. The disk is saucer shaped and only a little thicker than the egg membrane itself. I have been able to separate it from the membrane in the case of eggs hardened before attachment. As the egg is generally fastened to more or less plane surfaces, it appears strongly flattened on the side of attachment, as described by Doctor Ryder and as shown in figure 3.

This is correct, and Miss Clapp has been quoted at some length in order to give her the credit for discovering the disk and for refuting the errors above noted, and because her clear statement of the facts could not be improved on by me. I am pleased to say, however, that on June 22, 1908, I ascertained that the adhesive disk is to be found in place opposite the micropyle in ripe ovarian eggs when these are allowed to flow from the ovary into water, thus confirming Miss Clapp's statement (1891) that the disk is present at the time of oviposition. When the egg becomes fixed to some supporting body both the disk and the egg become very much flattened on the supporting side. The accompanying text figure[a] shows both these points clearly. *A* is a ripe egg

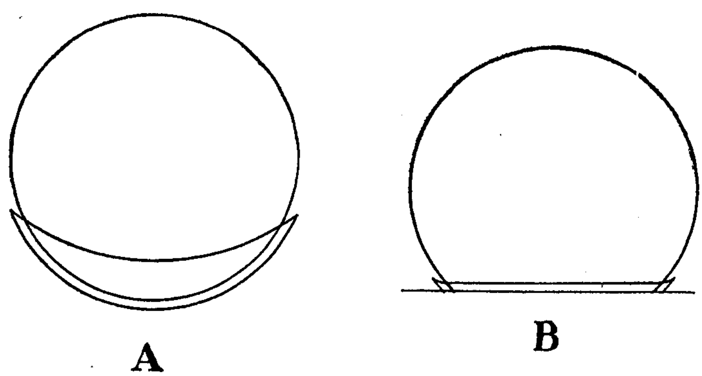

Diagram (after Miss Clapp) showing adhesive disk of toadfish egg. *A*, before, *B*, after attachment. (Much enlarged.)

[a] Copied from Miss Clapp (1899a). This is the "figure 3" referred to in the quotation above.

fresh from the ovary; *B* is the same after attachment. This attaching disk persists not only while the eggshell is intact but throughout larval life, until the yolk sac has been absorbed and until the little toad breaks away from the nest, leaves the disk behind, and takes up a free and independent life. This, however, will be referred to later.

Number of eggs in a nest.—The number of eggs found in nests varies within wide limits, these being from but few more than a score to several hundred, the numbers generally varying toward the upper limit. The smallest number which I have recorded is 22 in a *Pinna* shell, while the larger and more typical numbers are 181, 340, 361 in *Pinna* shells; 301 in another, 144 eggs on the right, 157 on the left valve; 624 in another shell, 381 being attached to the right valve and 243 to the left; 373 in an empty can; while on a piece of board 5 by 11 inches the amazing number of 723 was found. These are careful counts. On the under side of logs at the island elsewhere referred to two of us estimated that there were 350, 500, and 700 eggs in three nests, respectively. Other numbers might be given, but these are typical.

Where such large numbers of eggs as noted above are found, there is always more or less crowding. On a board, as elsewhere described, 723 eggs were counted in a space 5 by 11 inches. These eggs were very much jammed, some having the vertical diameter twice as great as the horizontal, and in some cases the eggs were piled up on top of each other like large shot stacked up two deep, and were adherent to each other instead of to the board. Figure 5, plate CIX, is a photograph of the board showing this crowding of the eggs. Here my observations are in direct contradiction to those of Ryder (1886 and 1887), who says "the female attaches her ova in a single layer," and again, "the eggs are found spread out over an area about as large as one's hand in a single layer, hardly in contact with each other, and to the number of about 200."

The fish polygamous.—By finding such large numbers of eggs and by noting the comparatively small size of the ovary of the adult females, I am led to conclude that several females have taken part in the laying of such enormous numbers of eggs. Figure 1, plate CVII, is a photograph (normal size) of the ovary of a female 9½ inches long. When we recall that the eggs average 5 millimeters (1/5 inch) in diameter, we arrive at the conclusion that one fish can at the most lay hardly more than 100 eggs. It is well known that domestic fowls lay many together in one common nest, and so it is with the toadfish. A fact that tends to confirm the matter is that eggs in nests are frequently found in two or three different stages of development, often rather near each other in time, but frequently as much as two or three days apart. For example, in a *Pinna* shell brought in on July 19, 1906, each valve had eggs in two stages. On the right valve 50 and on the left 88 eggs had embryos with the outline of the head just beginning to appear, while 183 eggs on the right and 60 on the left had embryos with black eyes and free tails. Instances of two or three stages in the eggs of a nest might be multiplied, but the general statement may be made that when such large numbers of eggs are found in a nest they are in more than one stage of development and have been laid by more than one female.

Orientation of the embryos.—Ryder stated (1887) that—

> The young adherent embryos are found tohave their heads directed toward the opening of their retreat and their tails toward its blind and dark extremity. This appears to be invariably the case, and it would seem that the direction from which the light comes, in this instance, at least, has a great deal to do in determining the direction of the axis of the body of the future embryo. This position of the young fishes is maintained as long as they are attached.

The last of these statements is correct, but the others are erroneous. In scores of nests which the writer has examined the embryos are found pointing in all directions. This is especially so in nests which are equally lighted from all sides, i. e., the board nest mentioned above. In a nest on the under side of a log projecting from a bank, eggs were found with the embryos pointing in all directions, but the majority had their heads turned more or less toward the point of greatest illumination. In *Pinna* shells, as shown in figure 7, plate CX, the embryos are almost always turned away from the opening of the shell toward the hinge. The writer is in position to state that only in a very general sense is it true that the embryos have any definite direction of axis, and not "invariably," as stated by Ryder. Figures 9 and 10, plate CXI, photographs of different nests, show this. Pieces of wood, 1 by 2 inches, from the log above mentioned have embryos pointing in as many as nine different directions. In her earliest paper (1891), Miss Clapp quotes Ryder, and adds:

> It was observed during the past summer that the embryos *within the egg membrane* do not have their heads all turned the same way, but in every possible direction, and it is only after the young toadfish are hatched that the heads of the whole brood are turned in the same direction.

That this latter statement is incorrect a glance at figures 7, 8, 9, 10, and 11, plates CX, CXI, and CXII, will show. Smith (1885), in the paper previously referred to, says on this subject:

> In the species of *Lepadogaster* the embryos show a marked irregularity of position; that is, the eggs are affixed to their station regardless of the future growth, which may develop with its head or tail in any direction with reference to the place of attachment.

In a paper published in 1890, Ryder, basing his argument on his (incomplete and erroneous) observations that all the embryos of a brood conform in direction to one axial plane, the heads pointing toward the light, declares that the polarity of the young is determined while the eggs are still in the ovisac of the mother. That this is not true the experimental work of Miss Clapp, as set forth in her papers of 1891 and 1899a, proves absolutely. If further evidence is needed, the reader is referred to the various photographs in this paper in which embryos early and late are shown.

Miss Clapp falls into error, however, in the first of the two papers to which reference is made where, in the passage above quoted, she states that "it is only after the young toadfish are hatched that the heads of the whole brood are turned in the same direction." During the larval period the yolk sac is attached to the inside of the egg membrane, and the possibility is suggested that the turning toward the light is effected at the time of hatching, when, according to Doctor Ryder, the attachment of the yolk sac may take place. In the second of the two papers above noted, Miss Clapp herself records the fact that the egg becomes attached at once to the egg membrane, hence such rotation is an impossibility.

Care of the nests.—When the place for the nest has been chosen and properly cleaned and the eggs laid and fertilized, the female departs, leaving to the male the sole care of the eggs and future young.

Storer (1855), quoting Ayres, says that it is the female which guards the nest. His statement is:

> That this is, in all cases, the mother of the young ones, and that she is there for the purpose of guarding them, we have no means of determining; we can only infer it.

On reading this one is led to wonder why he did not take a pair of scissors and by dissection ascertain the sex. Ryder (1886 and 1887), however, declares that—

> It is the male which assumes the care of the brood, and *seems* [italics mine] to remain in the vicinity until the young fish are hatched out and set free.

Miss Clapp (1899) confirms Ryder, and the writer can testify from scores of dissections that the guardian fish is always and only the male.

For the next few weeks the male gives himself up wholly, so far as the writer has been able to ascertain, to this parental duty. He leaves the nest, if at all, only to feed; and the strong probability is that he never absents himself during the period of incubation, getting the small amount of food necessary during this self-enforced period of inactivity by snapping up unwary minnows and crabs passing his retreat. In support of these conclusions the following facts are adduced:

While the males caught in the traps (to be described later) or found free in the water were always fat and well fed, those from nests, with the marked exception of one lot from a particular spot to which special attention will be called further on, while never emaciated nor showing signs of starvation, were not so well fed as the others. So much as to feeding while guarding nests. With regard to their not leaving the nests, the writer can affirm that he has never yet found a nest with eggs without a guarding male. The fish ordinarily resist being evicted from empty shells, but if the shells are occupied as nests with eggs, then the fish have literally to be driven out. The following incident is typical. A *Pinna* shell nest, with valves partly open, containing a guarding male, was turned upside down and the fish "poured out" twice. The first time he came out head foremost, but braced his pectorals against the valves so as to be dislodged with difficulty. The second time he appeared tail first, but catching again by his fins and, the shell being partly in the water, swimming with his tail, he actually tried to climb back into the shell. So vigorous is the resistance offered that not infrequently many of the eggs are ruined in getting the guardian out. I recall one particularly desirable lot of eggs in early segmentation in which over 50 had been crushed. My negro collector, when asked the cause, gave the explanation above.

One more illustration is so interesting that it can not be omitted. On one occasion I visited an oyster reef which was about a foot out of water at low tide. On this were many old broken-down piles which had once formed a part of a fish house. Beneath these the fish had excavated retreats, and to the under sides were attached larvæ and unhatched eggs. As the tide fell lower and lower the water in the little pools around these "chunks" seeped out through the sand and shells, but in the score of nests examined not a single one had been deserted. In some cases there were no signs of fish, nest, or water until the "chunk" was turned over. At extraordinarily low spring tides the fish must have been left for a short time with practically no more water than enough to moisten the under side of the body, but in no case was a deserted nest found. The writer has never seen a more marked case of devotion to its young on the part of any fish.

This guardianship, as has been stated, lasts until the young are not only freed from their place of attachment, but are able to fend for themselves. I have not infrequently found nests with young showing no trace of attachment of the yolk-stalk—i. e., with this completely absorbed into the belly—which were still attended by the male, who guarded them as devotedly as ever.[a]

At what age the fish become sexually mature I can not say, but not infrequently empty shells were found inhabited by fish from 2 to 9 inches long (averaging about 6 inches). At least one 6-inch specimen was a "ripe" male, while another, 5½ inches long, proved on dissection to be a female with ovaries filled with eggs of fairly large size. As no attempt to escape was made on the part of these fish, it seems probable that the shell-dwelling habit is formed early.

There has been neither time nor opportunity in the course of this research for the writer to go into any particular study of the extensive literature of nest building by fishes, but the following interesting account has come to notice and is in all ways so parallel to that given for the toadfish that it is worth repro-

[a] There is at Beaufort a blenny which lays its eggs in shells and guards them. One dissection showed that the guardian was a male.

ducing. William Anderson Smith (1885), writing of the British suckerfish (*Lepadogaster*), says that *L. decandolii* deposits its eggs under stones and that these are watched by the parents. Of another species he writes:

> I have scarcely ever taken the ova of *L. bimaculatus* except arranged in regular rows in the empty shells of scallops (*Pecten opercularis*).
>
> The eggs are generally accompanied by the parent, curled up inside of the shell watching the progress of her progeny [the context does not indicate that the sex was determined by dissection]; and if the dredge should bring up a shell thus supplied with ova from 8 to 12 fathoms off the scallop ground, if the fish is not in the shell it is almost sure to be in the other contents of the dredge, showing that it had either come out in the capture or been watching close by.

Cleaning the nests.—Connected with the manner of feeding, an interesting thing has been noted. If bits of food put in a *Pinna* shell occupied by a toad were not eaten, the fish would take them in his mouth and "blow" them out some distance from the shell.[a] This is one way in which the nests are kept clean. Another is by the action of the pectoral and caudal fins in "fanning out" all small particles. All nests in the harbor, even in muddy water, are perfectly clean and free from sediment, as well as larger nonfixed particles.

A bit of experimental evidence may properly be adduced here. Aquariums or pans containing shells with eggs were put under running salt water. Fish were put into some (they readily adopt nests other than their own) but not into others. The eggs in aquariums with fish were invariably freer from sediment and made better progress than those which had no guardians. The fanning action could not operate at the bottom of jars 8 inches deep, and so another explanation has to be sought for. Having observed that these fish give off large quantities of mucus which sometimes comes to the surface in visible masses, I have arrived at the conclusion that this mucus entangles the sediment and thus carries it off. Let the explanation be what it may, the facts are that nests with guardian fishes were always cleaner, the eggs showed fewer losses and developed better than those without care takers.

Perhaps it was this same instinct on the part of the fish, of getting rid of all débris, that led to a very curious action which may properly be related here. On July 30, 1906, one of two fish, in an aquarium measuring 8 by 10 inches, picked up in his mouth a sand dollar 4½ inches in diameter, rose to the surface, and tried to throw it out. As the water filled the aquarium to the brim, he would have been successful had not the iron rim by projecting inward one-fourth of an inch prevented. He persisted in his attempts, however, making six or eight trials in the course of two hours. On August 1 the same fish tried the same thing over and over again.

[a] It may be remarked in passing that the fish will not infrequently blow out the food to take it in again. From repeated observations, I am led to conclude that, since this generally takes place with pieces of fish, the toad is simply trying to get them endwise for easier swallowing.

Brooding and guarding the young.—Intimately connected with the foregoing is a habit which I have noticed repeatedly in this fish and which from its likeness to a similar action on the part of the hen may for want of a better term be called "brooding." The following incidents are transcribed almost literally from notes made at the time.

On July 9, 1907, a number of little fish detached themselves from a nest, in this instance a piece of board. At 11 p. m. the male in the aquarium with them was lying on the board and with spread-out pectorals was brooding the young which hovered under these fins and under his body. When I put in my hand he threatened to bite. On July 13 this board with a number of larvæ still adherent and with a good many free little fishes hidden in holes made by the shipworm, *Teredo navalis*, was removed for examination, whereupon the male stood up on his jugularly placed pelvic fins in a manner familiar in the blennies and young of the sea bass (*Centropristes striatus*), and looked searchingly around, the free young left behind playing under him and between his pelvic fins. On the following day, when the board with the young was again taken out, the adult again went through the same performance, but became perfectly quiet when the board was put back. On the succeeding day, when the board was taken out, the fish tried to bite me. Then he stood on his pelvic fins and literally glared at me with mouth open and teeth showing in a very vicious manner. At this time the toadlets were collected mainly under him and between his pelvics; some, however, were on his head, and one swam into his mouth and then out again.

The nesting habits of this fish and the fixation of the ova are undoubtedly brought about by the great size of the eggs. If these huge eggs were set free in the water, by virtue of their lack of any buoyant apparatus, they would at once sink to the bottom, where, because of their large size and striking (yellow) color, they would attract enemies without number. Further they must adhere to these nests, since the nests are found in shallow water where waves and tides, acting freely on them, would, because of their great bulk, if they were not attached, quickly carry the eggs out of the nest, and so they would be lost.

Correlated with this large size and fixed condition of the ova and larvæ are the large size and great activity of the young when set free. The salmon egg is about the same size as that of the toadfish, but the salmon larva when set free is burdened with a great mass of yolk, which hampers its movements and makes it an easy and attractive prey to its enemies. The little toadfish when detached differs from its parents in magnitude only, and by reason of its large size, finished body, and great activity, can at once begin an independent life.

Silas Stearns's observations (quoted by Goode, 1884) go further than the writer's in the matter of the fishes guarding the young. They are so interesting and circumstantial that they are given here.

When its young have been hatched, the older fish seems to guard them, and teach them the devices of securing food in much the same manner as a hen does her chickens. I have spent hours in watching their movements at this time, and was at first much surprised by the sagacity and patience displayed by the parent fish.

ATTITUDES AND MOVEMENTS.

In 1906, attitudes of standing on pelvic fins were seen to be assumed by fish which were not guarding nests. The fish previously referred to as trying to rid its aquarium of a sand dollar repeatedly postured in this fashion. At a little later date a number of fish assumed the same attitude. Again a large fish (not one of the above) not only stood up on his pelvics, but deliberately yawned, gaping his mouth widely. In the earlier instances cited, the taking of this attitude seems to have been in anger at the removal of the nest and for the better protection of the young by admitting them under the body; in the last case it was probably assumed as a part of the yawning action of the fish. (That fish yawn, the writer can testify from repeated observations; even larvæ with still adherent yolk sacs do so.) For the other instances no explanation is at hand.

Other curious attitudes also were assumed by the fish. One fish in a round aquarium was seen to lie for two hours on his side with his belly against the glass. On the next day the same fish stood on his tail between a large bottle and the wall of the aquarium, and, with his belly against the glass and his mouth nearly closed, breathed through the right gills only. This continued for some hours. The closest scrutiny could detect no motion whatever of the left operculum. This fish and his companions were quite tame and were handled with ease and safety. On the next day both stood on their tails, bellies to the glass, heads laid back, and gill covers barely moving. One of these fish (recognized by a spot on his dorsal) was the one whose yawning has just been described.

Again, two other fish in another aquarium, seven days later, stood vertically, resting on the roots of their caudal fins, clinging to the glass by the fleshy parts of their jugularly placed pelvics. Later, one of these stood on his tail (bent about midway between anus and caudal), and touched the glass with the barbels of his lower jaw only, occasionally moving his pectorals gently. Again, one of these two, some days later, stood vertically clinging with pelvics to the glass, with his caudal fin gently sweeping the floor of the aquarium. Many of the fish were given to lying with the caudal bent abruptly upward at an angle of at least 45 degrees. As to why these attitudes are assumed, the writer has no conjectures to offer.

I have seen a fish crawl into a tin can, seemingly only large enough for his head, and then turn around until both head and tail projected from the opening, the tail perhaps partly covering the head. The fish were fond of crawling into shells or empty Mason jars and then reversing ends until only the head was visible.

Sometimes they would back in until only the head remained uncovered. Storer (1855), probably quoting from Ayres, describes this attitude well. He says:

> If we approach this (cavity) cautiously, we shall probably distinguish the head of the toadfish very much in the position of that of a dog as he lies looking out of his kennel.

In nature the fish are solitary rather than social in habits, but in the aquarium they herd together and lie heads on each other like a lot of pigs. Gill (1907) has well described this habit, and I can not do better than quote him, as follows:

> Where many are together, they may congregate in a heap in some retired nook. The crowding together of many individuals just alluded to is a characteristic habit in aquaria at least. The toadfish is not a schooling or social animal as generally understood, but there are very few others who will associate as closely as it does. All the fishes in a toadfish aquarium may occasionally be found massed together in a regular heap, as close together as possible, in some selected corner, some on top of others. In such positions some may remain quite a long time (perhaps an hour even) and most of them scarcely move; there will be often some restlessness, nevertheless, and from time to time one or more may leave and swim about or possibly seek another corner.

This description is as accurate as a photograph.

Doctor Gill further writes:

> When at rest its attitude is quite characteristic; its head is somewhat tilted, sometimes supported by a stone, a sloping decline of sand or mud, or, it may be, on the body of a companion. The fins, unlike those of most fishes, are often maintained erect, the first as well as the second dorsal being completely upraised, while the caudal may be almost folded; the pectorals are near the sides, but with the lower edges everted and borne on the ground; a slow movement of inspiration and expiration is kept up, the jaws being very slightly open and moved, and the gill membranes slightly puffing and collapsing in harmony; otherwise the fish is motionless. Different individuals, however, may assume very diversiform attitudes, and some coil themselves up so that the tail touches the gills or, maybe, is tucked under a pectoral fin.

All of these attitudes I have seen scores of times.

To a very slight degree the toadfish moves by crawling, using its jugularly placed pelvic fins for this purpose. It may swim, using either pectorals or caudal, or both. When using the pectorals only, the caudal is held still and the motion is slow. The most common mode of progression is by the use of the caudal, helped by the long dorsal. With each right or left stroke of the tail an undulatory movement is set up in the dorsal, which aids materially in propelling the fish forward. This gives the whole body a wriggling motion, as is well portrayed in Le Sueur's (1819) figure, reproduced on page 394 in Doctor Gill's (1907) article.

FEEDING HABITS.

Food.—The toadfish is omnivorous; "all is grist that comes to his mill." But the pièce de résistance of his daily fare is crab, young molting blue crab preferred; any crustacean will do, however, or fish, or almost any kind of offal.

In 1907 a fish trap was hung off the wharf and kept baited for toadfish. There were caught, almost daily, numbers with bellies enormously distended with fish swallowed while in the trap. On being put into the tank the toads disgorged pieces of fish of such large size that one wondered how they could have been swallowed. One giant toad had his belly swollen balloon-fashion to such an extent that for two or three days his tail parts floated high in the water (nor could he get them down) while his nose rubbed the floor of the tank. He finally, however, got rid of both food and gas and seemed to be none the worse for his experience.

On the trip to the oyster rock holding the old log remains of a fish house, elsewhere referred to, large numbers of toads (about 25) were found under the rotting logs partly imbedded in the sand and shells. These fish all had distended abdomens, leading me to hope that some of them at least were ripe females; but under pressure they gave out blue crab remains either at one end or the other. Those that were brought in and dissected proved to be males, the distension in all cases being due to crabs. These were the only guardians I have ever found that were particularly distended with food. That they were so well fed is doubtless due to the fact that as the water receded the crabs sought shelter under the very logs which concealed the toadfish, their worst enemies.

Capture of food.—As to the manner in which the toadfish catches its prey, Silas Stearn's description, as quoted by Goode (1884), is so accurate as to leave nothing to be added:

> It secures its food rather by strategy and stealth than by swiftness of motion. Hiding under or behind stones, rocks, or weeds, or stealing from one cover to another, it watches its victims until the latter are near by, when it darts forth with a quickness quite astonishing, considering its usual sluggishness, and back again to its hiding place, having one or more fish in its stomach and on the alert for others.

Linton (1901) notes that its alimentary canal is chiefly filled with crustacean and molluscan remains and the bones and scales of fishes.

The mouth of the toadfish is eminently fitted for the catching and reception of the kind of food described above. The buccal cavity is enormous, as might be inferred from the size of the great, broad, blunt head. The gape of the mouth is very large and the powerful jaws are filled with bluntly conical teeth (as first noted by De Kay (1842) and later (1855) by Storer) with which the fish can inflict a rather severe and painful bite. Incidents to illustrate the action and utility of the mouth and jaws appear in the following paragraphs.

Disposition.—The toadfish is commonly credited with having a savage and even vicious disposition, an impression which is to some extent due to its unprepossessing appearance. After a somewhat intimate acquaintance with more than 100 individuals, however, I find that, like other animals, some are of good disposition and some of bad, and, moreover, that given individuals are even subject to moods, as incidents related below will show.

Toadfishes that have been teased always snap viciously at everything near them which moves. A 9-inch specimen after such treatment clinched his teeth so tightly on a bit of oyster shell that he was by it lifted out of the water and into a bucket. Ayres (1842) records a similar experience in the following words:

> One which I caught the last summer and kept for some time would snap fiercely at the finger or a stick held toward him and would sometimes allow himself to be lifted out of the water before he would loose his hold.

I have several times been bitten by these fish so that the blood came slightly; but the teeth are not sharp enough to draw blood ordinarily. Toadfish never hold on when they bite, but snap and let go. Though very sluggish, in biting they move faster than the hand and almost faster than the eye.

Some of the toadfish always remained vicious, others, after being in captivity awhile and fed by hand, became quite tame, some so much so that I could handle them with impunity. Those guarding the nests were more apt to bite than the nonguardians. If the nest, e. g., the shell with the affixed eggs, was taken from the aquarium, the fish was apt to become restless, and if the hand was put in the aquarium, he was likely to snap viciously at it. I have a note of a particular case in which this happened, but immediately thereafter the fish let himself be taken up in the naked hand and transferred to another aquarium. Another fish kept for some time in a tank 3¾ by 7¾ feet became so tame that he allowed me to handle him freely, to carry him in my naked hands to the camera 40 feet away, and to adjust him under it.

While these examples are specimens of the conduct of the fish in general, it is necessary to say that some were vicious, always snapped if they got a chance, and if not, always showed their teeth ready to bite if one came near. Goode (1884) formed a very favorable opinion of the fish, for he says:

> Although it is armed with by no means insignificant spines, which are capable of inflicting serious cuts, when touched they show no disposition to bite, but erect their opercular spines in a very threatening manner.

Feeding in captivity.—Nowhere do the varying dispositions of these fish show more plainly than when they are being fed. Considerable numbers of them were kept, and it was necessary to feed them when one could, for, in captivity, because of their inactivity, they mostly feed sparingly and at irregular intervals. Some, however, fed eagerly, swimming out from their retreats when oysters or bits of fish were thrown into the tank. For those not so tame a different method had to be pursued or some would probably have starved. These would snap a piece of fish held before their mouths in a pair of forceps. Some, however, could only be induced to eat by rapping them over the nose with the forceps, at which they would snap and take the oyster or piece of fish. One fish, after several days of this kind of experience, would gently close his mouth on the end of the forceps and pull the meat off, or finding none there would (especially if his head had been stroked or tickled with the forceps) close his mouth gently and let go without manifesting irritation.

To sum up the whole matter, my experience is that even such vicious fish, as many of these are, can in the majority of cases be tamed, if they are not teased or otherwise unnecessarily disturbed, if they are fed regularly and by the same person, and if they are not handled roughly and punished when they bite. Further, confinement and hunger are factors which must play a great part in taming fish. Fish guarding shells with eggs are much more likely to bite than those in empty shells, even though ordinarily they may be handled with impunity.

Fighting tendencies.—The toads are very much given to fighting among themselves. On one occasion a big fellow twice tried to swallow one slightly smaller than himself, and had gotten him down as far as back of the eyes, when by catching each by the tail I separated them. After the second separation they remained quiet, the smaller seeming not much worse for the experience. Six days later my attention was attracted by a great commotion in the tank, and I found that a large fish had clinched a smaller one as above described, and so determined was he that he let go only when struck repeatedly on the head with a piece of iron pipe. These were presumably the same pair as the above. Linton (1901) records a similar occurrence as follows:

> I have seen a toadfish in the aquarium in the act of swallowing another of its own species but little smaller than itself.

He also notes finding a partly digested toadfish in the stomach of another.

Just in proportion as the fish were well fed their propensities for fighting increased. During the first week in July, 1907, quite a number were in the large tank elsewhere referred to and were a lively lot. They were especially active at night after the lights were out and the laboratory was deserted. On coming in late at night, not infrequently a tremendous splashing could be heard, and, on striking a light, the fish could be seen fighting all over the tank. Morning after morning the floor around the tank would be wet with water thrown out in their struggles. So far as observations went, there was no attempting to swallow, but simply clinching and breaking away. This was again noted the last week in the same month.

DISEASES.

So far as the writer has been able to ascertain, the toadfish, because of his retiring manner of life, has both few enemies and few diseases. The latter are chiefly due to parasitic worms, entozoa. From their omnivorous habits the fish are especially subject to these. About 40 per cent of the 48 examined by Professor Binford in 1908 were infected with *Ascaris*. Linton (1905) in his "Parasites of the Fishes of Beaufort" reports the examination of 135 toadfish. From these he obtained more than 190 nematodes, about the same number of cestodes, and more than 100 trematodes. The nematodes are all of one species (*Ascaris habena*), the cestodes of five genera and as many species, and the trematodes (so far as identified) of three genera and three species. Examination of Linton's other publications will show that toadfish in other localities are similarly infested.

In the course of this research it was not infrequently noticed that some of the toadfish kept in confinement had "pop-eye." Whether these fish were thus affected when captured, or whether the trouble originated in confinement, can not be stated, but it should be noted that other fish, kept in the same tank at the same time, and large numbers of various kinds of fishes kept in running water under the writer's care during the five preceding summers, showed no symptoms of this disease.

Direct evidence is at hand, also, to show that wild fish have the same trouble. On July 7, 1907, there was taken in the trap hung off the wharf a large toad which had either the conjunctiva or cornea [a] of its eyes enormously distended, projecting one-half to five-eighths inch in front of the iris. One other fish caught at the same time showed a slight distension of the eye covering, while others had eyes perfectly normal in this respect. Pressure applied by means of a pencil to the eye showed that whatever caused the distension gave the membrane great firmness. Neither the distension nor the pressure of the pencil seemed to cause the fish discomfort, for only after an appreciable length of time did he move away, and then in an undisturbed manner. This was not that form of exopthalmia in which the whole eye is pushed out of the socket. The distending substance was evidently between the eye proper and its outer covering.

On July 10, 1907, two fish were taken from the trap at the wharf. Both these had their caudal fins blood red in those parts where the pigment was not so dense. Whether or not this indicates disease the writer can not say, but it is not an altogether uncommon phenomena among fishes, as he has noticed it in other forms, *Lepisosteus*, for example. At the time it was thought that maybe it indicated sexual maturity, as noted in *Lepidosiren* by Kerr (1900), and dissection showed that one, a male, was breeding, while the other, a female, had eggs nearly ripe enough to flow from the ovary.

[a] I unfortunately did not dissect to ascertain which.

VITALITY.

The vitality of toadfish is extraordinary, almost equal to that of the Reptilia. Incidents might be multiplied, but two will be sufficient to make clear this assertion. Before dissecting them it was my custom first to cut through backbone and spinal cord back of the head, and sometimes in addition to "pith" them. On June 28, 1907, this double operation was performed on a number of fish, which nevertheless during the operation and afterwards opened and closed their mouths, erecting their spinous dorsals, expanded their pectorals, and gave forth the curious sound made by the air bladder, which may be most nearly rendered "oonk" or "koonk." This sound was made by one or more fish while the air bladder was being removed.

While the above paragraph was being written, a toadfish whose spinal cord had been cut, whose belly had been ripped up, and whose stomach had been opened, was brought to me. It was put in a dry dish and set aside. When opportunity offered, some three or four hours later, I took it up and began examining its mouth to get the exact shape of its teeth; whereupon it snapped at my fingers half a dozen times. Goode (1884) remarks on this subject:

> They are very hardy, and when taken from the water will lie for many hours, and soon recover their ordinary activity when restored to the water.

Ayres (1842) had one live for twenty-four hours without water after it had been taken with the spear.

WINTER HABITAT.

What becomes of the toadfish during the winter the writer can not say. According to Ayres (1842) they go into deeper water, bury themselves in the mud, and remain in a torpid condition until spring. Goode (1884) says:

> The bottom temperature of the water frequented by these fish would appear to range from 50° F. to 90° F. In the more northern regions throughout which they are distributed they appear to become torpid or nearly so in winter, and it is stated by Storer (1855) that they are frequently found in the mud by men spearing eels.

SOUNDS.

As indicated in the paragraph on vitality, the toadfish makes a definite sound which may be fairly rendered verbally by "oonk" or "koonk." These sounds are produced by the contraction and relaxation of muscles connected with the air bladder, which has been figured and its structure described by Sörensen (1884). This paper the writer has not had an opportunity of consulting, but Doctor Gill (1907) reproduces the figure and translates from Sörensen, as follows. (The air bladder is small, U-shaped, and hence nearly doubled, the paired limbs of the U projecting anteriorly.)

Above, the division extends backward half as far again as on the underside. The inner surface of the air bladder presents no projecting membranous partitions or the like. The outer membrane is strong, tough, fibrous, and rigid; the inner somewhat thicker than usual. On the sides of the air bladder are found a couple of large muscular bands, especially thick behind, which cover more than half the surface of the organ. On the underside they do not extend as far toward the middle as on the upper surface, where they meet behind. The muscular fibers run transversely but at the same time somewhat obliquely backward (on the ventral side beginning at the middle, on the upper side toward the middle); toward the hinder end of the organ the fibers gradually run transversely. The pleura is strong, but rather thin; it is, however, thicker on the back side, where the muscle bands meet.

With this air bladder the fish is enabled to make the sound above noted, and which is variously rendered as "oonk," "koonk;" or "ung," "kung." The note or sound is always given twice, "koonk-koonk." The fish in the laboratory rarely make this sound, which has considerable carrying power, save at night or when caught and carried about (generally wrapped in a towel for precaution's sake).

ECONOMIC VALUE.

Those who have eaten this fish pronounce the flesh not unpalatable. Rafinesque (1818) says that the fishermen "don't reckon it good to eat, and often throw it away on the beach, yet it is as good as the different species of Phycis or Cusk." De Kay (1842) affirms that it "finds no favor with the fishermen, on account of its unsightly appearance; its flesh, however, when properly cooked, is well flavored."

Storer (1855) writes on this subject as follows:

The toadfish is not commonly employed as an article of food. Its generally repulsive aspect causes it to be looked upon rather with disgust. That its flesh is delicate and good, however, can scarcely be questioned, though the small size which it attains and the fact that it is never taken in any large quantities prevents it from being of any economic value.

Goode (1884) took a more optimistic view of the commercial possibilities of this fish. He writes:

The toadfish may be regarded as constituting one of the undeveloped resources of our waters, and it can scarcely be questioned that in future years it will be considered as much more important than at present. No estimates can be given as to the quantity now yearly entering into consumption, and, since it is almost never offered for sale, no price quotations can be presented. Professor Baird also bears testimony to the fact that its flesh is very sweet and palatable, and Mr. Stearns states that its flesh is highly esteemed by many of the Gulf fishermen.

Bean (1891) does not seem to think so highly of it as a food fish, for he dismisses the subject by saying:

The species is not an attractive one, and although the flesh is sweet and palatable, it is never eaten.

Gill (1907) found it good eating.

So far as the writer knows, this fish is never eaten at Beaufort. In July, 1908, he had some served at the laboratory mess and, discounting prejudice resulting from the unprepossessing appearance of the fish, its flesh was not only not unpalatable but was distinctly good, as good as or better than the majority of bottom fish caught in the harbor. But however good its flesh, Goode's prophecy for this fish can never be realized, because of the small size of the individuals, the limited numbers in which it is caught, and not least because of the great number of bones due to the presence of the long dorsal and ventral fins.[a]

LIFE HISTORY.

The life history properly begins with the formation of the male and female germinative products, the sperm and the egg, but before describing them it will be best to describe the organs of reproduction, the testis and the ovary, respectively, as found in the adult "ripe" fish at the other end of the life history.

ORGANS OF GENERATION.

The ovary.—This is fashioned after the ordinary teleostean type, as may be seen in figures 1 and 2, plate CVII, both of which are natural size. Figure 1*C* is of an unripe ovary which had been preserved in alcohol and photographed in the same. Figure 2 is a ventral view of an ovary excised from a pithed fish and photographed in water *alive*. Anteriorly it is bifurcated into two lobes, which join behind to form the short oviduct by which the eggs are carried to the exterior through the genital pore opening just behind the anus. In figure 1 the anus is shown and to the left of it one of the paired halves of the urinary bladder.

When the eggs are ripe, the ovarian walls are very much distended and semi-transparent, as shown in figure 2, where the large eggs are plainly visible, as are also the small ova—probably of next year's crop—lying between. The fine dark lines running over the ovary are blood vessels with which this organ is abundantly supplied. Extending lengthwise of the left lobe is a strand of tissue which seems to be a raphe. At the anterior end of each lobe are to be seen the remnants of the tissues by which the ovary is tied to the other organs. Internally each lobe is a hollow tube the walls of which are covered with ovarian eggs.

The ovarian eggs are inclosed each in its own short-stalked follicle, which is richly vascularized. When the process of spawning takes place, the eggs burst the follicles and fall into the lumen of the ovary and thence pass to the

[a] Hargreaves (1904), writing of the allied *Batrachus surinamensis* of British Guiana, says that although its outward appearance is very much against it yet it "has the reputation of being the most delicately flavored fish in the whole colony."

exterior as described above. The eggs when extruded have the adhesive disk by which they become affixed to the nest. The formation of this disk and the manner of fixation of the eggs are points on which the writer is unfortunately able to give no information. The eggs are very large, measuring from 4 to 6 millimeters in diameter, the average being about 5 millimeters, as stated by Miss Clapp (1891 and 1899) and by Ryder (1886 and 1887).

The testis.—This organ, like the ovary, consists of paired elongated glands lying in the posterior dorsal part of the body cavity. They are confluent behind to form the sperm duct, which opens in the same place and manner as the oviduct. *A* and *B*, figure 1, plate CVII, show the dorsal and ventral surfaces of the ripe spermaries of a full-grown toadfish and are natural size. The long lobulated organs are the testes, the roundish dark structures are the paired lobes of the bladder, while the short whitish bodies (placed posteriorly and reaching right and left) are accessory glandular structures whose function is not known.

The spermatozoan is very large. The head is round in front, nearly as broad as long, flat behind where it joins the middle piece, which is almost as large as the head. The tail is not very long and the motion relatively slow. The sperms resemble nothing in the world so much as tadpoles with very large heads, and bodies but little smaller, behind which extend thin tails several times longer than the head and body combined.

FERTILIZATION AND EMBRYONIC DEVELOPMENT.

Natural fertilization.—The manner in which fertilization is effected in nature is not known, but it is interesting to note here the correlation between the size of the micropyle and the sperm. The former is so large as to be visible to the naked eye.

Artificial fertilization.—Neither Miss Clapp (1891 and 1899a), in her experimental work on the egg of the toadfish at Woods Hole, nor Miss Wallace (1898) had any trouble in artificially fertilizing the eggs, since ripe males and females were readily obtainable. At Beaufort scores of fish were dissected by the writer in the course of this research during 1906 and 1907, but while ripe males were abundant not a single ripe female was obtained. Fish were caught all over the harbor, the extreme points of capture being 3 to 3½ miles apart. On July 18, 1906, in a tank of fishes from Cape Hatteras, I received 12 toadfish. Two were given away, the sex of one could not be determined macroscopically, nine were males, and one was a female with immature ovaries. At Woods Hole females are more abundant than males, I am informed by Mr. Vinal N. Edwards.

During the summers of 1906 and 1907 not a single ripe female was captured, and but two with ovaries anywhere near maturity. One of these ovaries is shown in figure 2, plate CVII. The other was in about the same stage. On June 22, 1908, Prof. Raymond Binford, of Guilford College, N. C., in searching for *Ascaris*, killed a 6¾-inch toad which on dissection proved to be a female with ripe ovaries containing about 40 eggs. The ovaries were opened and the eggs were run into fresh salt water. A ripe male being at hand it was quickly opened and the testis was minced up and parts put into the same dish with the eggs. After about ten minutes the water with the minced-up testis was poured off and the eggs covered with fresh clean water.

Fertilization was effected about 12 noon. The eggs at 6 p. m. were in the 4-celled stage. Segmentation must have begun about 5, possibly as early as 4.30. At Woods Hole, Miss Clapp (1891 and 1899a) found that segmentation began seven hours after fertilization (artificial) was effected. In the above experiment, segmentation began within four and one-half or five hours after the eggs were impregnated. The explanation is undoubtedly to be found in the great difference in the temperature of the water. Miss Clapp does not give the temperature for her experiments, but at 3.15 p. m. on the day referred to a thermometer hung in running sea water in the Beaufort laboratory registered 81° F. In this difference in temperature of the harbor water at Woods Hole and Beaufort is also to be found the explanation of the ease with which Miss Clapp could get ripe females and of the difficulty I experienced in getting even one.

Owing to the low temperature at Woods Hole the breeding season for the toadfish is restricted to a comparatively short time. Dr. Raymond C. Osburn, of Columbia University, at my request, has carefully gone over the Woods Hole records. He writes me that they show that spawning goes on during the month of June only (except of course in some few sporadic cases), beginning sometimes as early as the first week in June. He writes that the most extensive and authentic records have been made by Mr. J. T. Patterson, who notes that in 1906 the spawning period extended from June 12 to June 25. Speaking for himself, Doctor Osburn says:

> It is my own experience that the eggs are mostly hatched by the first week in July; that is, they have broken the egg membranes. I know this because I have often looked for them here after coming the first of July, and I have never yet succeeded in finding eggs that were entirely fresh at that time.

In a letter to the present writer, dated July 24, 1906, Vinal N. Edwards, the veteran collector of the Fisheries Laboratory at Woods Hole, says that he does not find any toadfish with eggs after the first of July. He adds, however, that in the fall, when he sets his fyke nets, he catches large numbers of large fish full of spawn, but they carry it all winter.

Some older records for the Woods Hole region are as follows: Storer (1855) found eggs or young in June, July, and August; Goode (1884), at Noank, Conn., in 1874, founds eggs on July 14, and young one-half inch long on July 21, which had, on September 1, reached a length of 1 inch. Ryder (1886) says:

> Oviposition occurs about the middle of July in the latitude of Woods Hole. How long it lasts has not been determined, but judging from the condition of the roes and milt of the adults at that time, it seems probably that they do not spawn later.

According to Bumpus (1898):

> Oviposition occurs as early as June 3, and it may occur at any subsequent time throughout the month.

The higher temperature at Beaufort, however, allows the breeding season to be long drawn out. I have found advanced embryos the first week in June and eggs in segmentation late in August. Thus the spreading out of the time of oviposition makes it easy to find spent females and correspondingly hard to find ripe ones. I may add that no other ripe females have been found this season (1908).

Formation of the germ disk.—The germ disk was quite definitely formed as a fairly distinct white patch about three hours after impregnation. The streaming of the protoplasm to form this was in part preceded and in part accompanied by the collecting of yellow oil globules at the micropylar region. These oil drops, some large and some small, form in a layer under and visible through the germ disk in just the same fashion as the writer found in the egg of the pipefish, and as has been reported for a large number of teleosts. For a discussion of the matter see Gudger (1905). Miss Wallace (1898) also reports oil globules in the egg of this fish. The streaming of the protoplasm continues after the segmentation has begun, thus the germinal disk grows constantly larger for awhile by these additions of protoplasm. Ryder's (1886 and 1887) error in saying that there are no oil drops in the eggs of the toadfish is hard to explain save on the supposition that they disappear by the time those stages on which he worked are reached.

Segmentation.—As already stated, segmentation begins seven hours after fertilization at Woods Hole, five hours after that act at Beaufort. The germinal disk divides in a vertical plane into two cells, then along another plane, at right angles to the second, into eight cells. The segmentation into two and four cells results in blastomeres about equal in size and symmetrical in place. But beginning with eight cells and continuing on until division is ended, the segmentation is very irregular, growing more so with each division.

Notwithstanding the large size of the yolk, the blastoderm never piles up high with a clearly defined circumference as is found in the Salmonidæ, whose eggs are about the same size, and as the writer found to be the case in the pipefish (Gudger, 1905), whose eggs are only one-fifth (1 mm.) as large. On the contrary, even during the early stages of segmentation—8, 16, and 32 cells—the blastoderms flatten out, the cells on the periphery presenting an appearance which can only be likened to that taken by a pellet of soft mud when thrown against a smooth wall. To say that the blastoderms present an extraordinarily irregular appearance, but feebly expresses the fact. In some cases it looks as if the segmentation had begun at the center and worked outward, as Watase (1891) has shown in the squid. The explanation of the whole matter is to be found, I think, in the fact that segmentation begins before the flow of the protoplasm into the germinal region has ceased.

To the best of the writer's knowledge, the only work other than experimental done heretofore on the segmentation of the egg of the toadfish is to be found in Miss Clapp's paper published in 1891. Here she figures stages from two to sixteen cells, inclusive, the later blastoderms being very irregular.

Figure 3, plate CVIII, shows the right valve of a *Pinna* shell containing eggs in segmentation one-half natural size. This reduction was made in order that this half of the nest might be shown in its entirety. The photograph portrays a nest typical in all respects, the irregular manner in which the eggs are affixed, the crowding together—some eggs being on top of others as cannon balls are piled—and last, but by no means least, the fact that the eggs are in two stages. For the most part they are in late segmentation, but on the upper right-hand part of the shell some two dozen are still in early division, as the small size and somewhat rounded outline of the germinal disk show. Figure 4, plate CVIII, shows another nest with eggs in segmentation intermediate between the two stages shown in the previous figure. Here the eggs are shown twice their natural size in order to bring out details more clearly. Recalling to the reader's attention the fact that the micropyle is practically always found opposite the point of attachment of the egg, it is interesting to note that some of the blastoderms are not "opposite the point where the ovum is attached" as Ryder (1887) states, although this is generally true. Of especial interest is the fact that there are in this nest some half dozen eggs with divided blastoderms. Should these have come to maturity it is my opinion that they would have formed twins. (For a much magnified figure of such a blastoderm see the writer's paper on the pipefish, 1905, plate VI, figure 26, and for the histology of the same, plate VIII, figure 54, and plate IX, figure 55.) Miss Clapp, in the paper referred to in the preceding paragraph, figures such a divided blastoderm in the 8-celled stage.

Invagination.—The next stage in the history of the eggs whose development we are studying is that in which, segmentation having ended, the blastoderm flattens out into a thin cap of cells covering about one-fourth the upper half of the egg. Shortly thereafter it is the rule in teleost eggs that the edges of this protoplasmic cap begin to turn in under the cap and between it and the yolk. Technically this is called invagination, the in-pushing cells making a distinct rim to the edge of the cap and inclosing a clearer space known as the segmentation cavity. This condition of things, however, does not seem to exist in the egg of the toadfish.

Miss Wallace (1898) has shown in a short but highly interesting paper that there is no true invagination in this egg, but that the apparent thickening, the appearance of a germ ring or invaginating blastoderm, visible as the protoplasmic cap grows down over the yolk, is due in part to an ingrowth of cells from the ectodermic layer, but chiefly to the greatly thickened periblast filled with giant nuclei.

The writer regrets that he can present no photograph of this stage, as these structures can only be brought out clearly in eggs killed for the purpose, while his photographs are all of living eggs. He has had no opportunity to verify by means of sections the conclusions above stated. Eggs properly "killed" seem to show a very distinct germ ring, and, had he had not been aware of Miss Wallace's work, the writer would, from surface views, unhesitatingly have described the condition as a case of invagination.

Formation of the embryonic shield.—The cap of cells described above continues to spread over the upper hemisphere of the egg, growing thinner all the while. Presently at one point on the rim there appears a slight flattening tangential to it, causing the cap to become bilaterally symmetrical in one plane only, this plane being the axis of the future embryo. According to Miss Clapp (1891), the notch or bay described below is formed at the central point of this flattening during this stage. So far, however, as I have examined my material I have found nothing to corroborate her statement. No photograph of this stage is presented for the same reason as given above.

Differentiation of the embryo.—During all the events described above the blastoderm has been growing larger and extending over the yolk. After passing the equator of the egg, the opening, the morphological blastopore, grows smaller and eventually closes. Growth seems to go on less rapidly at the posterior end of the axial thickening—i. e., that connected with the rim of the blastoderm, the anterior free end extending out into the center of the cap—which results in the formation of a little bay at the hinder end of the forming thickening. Then, as the spreading of the cap over the yolk continues, the blastoderm grows backward away from the embryonic rod, leaving it connected with the edge of the cap by a slender cord of cells. This formation of the embryo is, I believe, peculiar to the toadfish. It was first demonstrated from surface views by Miss Clapp (1891), whose work was verified and extended by her pupil, Miss Wallace (1898), who cut sections of the egg in this stage.

At Woods Hole the axis of the embryo first becomes visible on the seventh day, according to Miss Clapp (1891). Miss Wallace (1898), however, detected an "axial thickening" on the fourth or fifth day. Artificial fertilization not having been effected at Beaufort, I can not give the time definitely; but from three separate broods of early eggs found in the harbor it can be stated that between forty-eight and sixty hours after impregnation the embryonic axis begins to form.

These structures are for the most part too delicate to be shown in photographs of living eggs. Figure 5, plate CIX, shows the board nest frequently referred to. It contains eggs in two stages of development, spreading blastoderms and rod-like embryos, and likewise the crowding always found in the eggs of a large nest. The board and eggs are natural size and all the eggs are shown save a few at each end. If studied with so low magnification as that afforded by even an ordinary reading glass, the young embryos, as yet possessing no trace of fishlike characters, may be seen as axial rods. Close scrutiny will reveal the fact that one end—the future head end—is slightly larger than the other.

Figure 6, plate CIX, shows half natural size another board nest of large size. The embryos here are considerably older than the preceding. The head end has noticeably enlarged, the ventricles of the brain are visible (under a low power), the eye vesicles are forming, the pectoral fin buds are not visible but are clearly marked off at this stage. In short, the embryonic fish is outlined.

Even a momentary glance at the positions of the embryos will completely negative Ryder's (1886 and 1887) statements that the embryos "invariably" point in one direction.

By taking the nests out of the aquariums and examining them from day to day the development can be followed step by step. The eye vesicles are formed, the blastopore closes, the pectoral fins grow in size, the tail becomes free, the heart is formed and begins to beat, a vascular system is formed and spreads over the yolk, and, finally, growing dissatisfaction with its narrow quarters is expressed by the little fish through writhings and shiftings of the tail from side to side.

THE LARVAL TOADFISH.

Early stage.—The condition of things described in the preceding section is not destined to continue longer. Presently the time arrives when, the shell having grown weak (rotten is the way my notes put it in numerous cases), the little fish bursts that part over its head and, taking in a mouthful of salt water, passes this back over its gills and is ushered into a new world as the just-hatched larva of the toadfish.

Usually the shell bursts first over the head and back, setting the head parts free; then the split, continuing backward, sets the tail free. Sometimes, however, the shell bursts over the tail first. In this latter event one will see a wildly waving tail, which by its lashings continues the split forward and uncovers the head. Eventually the shell splits down in several directions and not only uncovers the embryo but the upper half of the yoke as well.

As clearly as I can determine (artificial fertilization not having been possible), the bursting of the shell takes place eleven days after fecundation. Ryder (1887) says that on Chesapeake Bay the incubatory period lasts from ten to fifteen days. According to Patterson (quoted in Osburn's letter to the writer): "In 1906 young fish at Woods Hole broke the capsule in twenty-six days." The difference in the time of hatching at Woods Hole and Beaufort is plainly due to the difference in temperature of the water, the higher temperature at the latter place greatly hastening development.

Figure 7, plate CX (one-half natural size), shows one-half of a nest of eggs in the early larval stage. Whether it is a photograph of the shell shown in figure 3, plate CVIII, I can not say positively, since my records are not clear on this point, but I believe that it is. The tadpole-like appearance of the young spoken of by writers is very apparent. As in most shell nests at this stage the embryos point in one general direction, but toward the hinge rather than the opening of the shell, and consequently away from instead of toward the light, as Ryder (1886 and 1887) positively asserts.

Figure 8, plate CX, shows the same board nest shown in figure 5, plate CIX, and represents the larvæ in natural size and in a stage of development slightly older than the preceding. Here the embryos point in all directions, as stated in the first part of this paper. The tadpole-like structure is very apparent, due to the broad, flat head with its opercular flaps, just back of which are the pectoral fins, the largest organs with which the fish is provided at this stage of its development.

There may be plainly seen in this figure the empty shells still adhering to the nest. The eggs have either died and been removed to prevent the spread of disease or they have been taken away for preservation in alcohol for further study. The empty shells with the adhesive disks are very resistent to decay, but finally the gluey substance by which they are affixed becomes loosened and they may readily be removed.

The pectoral fins have been referred to. Their formation precedes in time and position the formation of the pelvics. These latter originate at this period as two folds just back of the pectorals. As the fish develops these become "translocated," as Ryder (1886) puts it, to their permanent jugular position. Both Ryder (1887) and Miss Clapp (1899) have figures of the just-hatched toadlet which show these fins and also make clear the fact that there is no definite caudal fin at this stage. Miss Clapp's admirable drawing of this stage has, however, three serious defects, i. e., the larva has neither mouth nor gill slits, both of which in a very rudimentary condition are present, and the extremity of the tail turns downward instead of upward, as Ryder correctly shows.

Under favorable conditions the embryos make steady progress. The head and mouth parts grow more perfect, the gill covers and pectorals become more thoroughly functional, the vascular system spreads over the yolk and brings in digested food with the concomitant rapid enlargement of the embryo, the pelvic fins rapidly grow forward to their permanent position, and the other fins, dorsal and caudal, are formed. Presently the bands and markings begin to appear faintly. The embryos, which at the beginning of this stage looked more like tadpoles, larval frogs, than larval fish, now begin to look not merely fish-like, but decidedly toadfish-like.

Late stage.—There is no marked event to set apart the early and late larval stages as the bursting of the shell delimits the former from the purely embryonic forms. So for the sake of convenience I will (somewhat arbitrarily) choose the appearance of the color bands as making the distinction, since their appearing does to some degree divide the larval life into fairly definite stages.

These markings first appear in the tail region as three faint bands of grayish color, one at the root of the caudal and two across the median portion of the tail. A little later a fourth band appears in the region of the spinous dorsal, and finally a smaller band running transversely to the rays of the caudal adds much to the appearance of that organ. The two transverse bands on the tail gradually extend into the long dorsal and ventral fins and, aided by the diversified coloring of the head and by the St. Andrew's crosses in the iris of the eyes, give the little fish a really beautiful appearance. An inspection of figure 13, plate CXIII, numbers 1 to 7, will make clear all these points. In this photograph the larvæ, specially "killed" and preserved in alcohol, are enlarged two diameters.

Figure 9, plate CXI, represents a nest of late larvæ twice natural size. Unfortunately the fish at this stage were almost the color of the nest (a *Pinna* shell), and they do not show up very clearly. The growth of the larvæ, however, from the stage shown in the preceding paragraph is very apparent.

Somewhat older are the toadlets shown in figure 10, plate CXI, which is an instantaneous photograph (natural size) of the nest shown in figures 5 and 8. Not only is the focus better than the preceding photograph, but the contrast between the color of the board and that of the young is so strong as to bring out the latter very distinctly. Both the mottlings on the head and the bands across the body are very distinct. The larvæ are very toadfish-like with their broad heads and large pectorals. In passing it should be noted that the heads of the fish point in all directions. The young are very active, lashing right and left with their tails continually, and in this observation I am in disagreement with Ryder (1887), who says that, while the young are still adherent, the little fish keep up a rapid motion of the pectorals, to aid in carrying away the water from the gills, while the tail is comparatively still. I find that the pectorals rarely show any motion, while the tails are more frequently in motion than at rest, until the last few days before the young detach themselves. At this late period their tails are more frequently still than in motion, while the pectorals keep up a slow but continual fanning motion, broken at intervals by a few impatient strokes.

Figure 11, plate CXII, is an instantaneous photograph (natural size) of the nest shown in the preceding and in other photographs. Here the young are ready to break away. They are in continual motion, lashing with their tails, swinging back and forth, even twisting in their efforts to break loose from their anchorage. This is apparent in the figure in the blurred effects, which are due to the motion of the little fish while the plate was being exposed. While one is looking one or more little fish may break loose and swim rapidly away, seeking at once a place of safety under the board or in holes in it. As best I can determine, at Beaufort detachment is effected twenty-four to twenty-six days after fertilization. An allowance of two or three days must be made for variations in the temperature of the water, the degree of virility of each little fish, and external stimuli, such as fear or some mechanical shock, exciting the larvæ to greater action. Ryder (1887) approximates the fixed condition at from three to four weeks at Cherrystone, Va. At Woods Hole the young became free in 1906 on the forty-second day, according to Patterson's notes forwarded to the writer by Osburn.

I am satisfied that these larvæ begin to feed before they detach themselves from the nest. Small crustacea, and indeed anything which would serve as food for them, would be drawn into their mouths by the action of the opercula and, being caught by the gillrakers, would be passed down their gullets to the stomach.

A curious phenomenon found only, so far as the writer's knowledge goes, in the young of the toadfish, must now be described. The egg remains spherical so long as the egg membrane exists intact, but immediately after the larva bursts this the yolk begins to elongate and presently a constriction appears. This constriction appears at first to be due to the yolk pouring over the torn shell, but as time passes and the shell is burst wide open, it is apparent that it is due to other causes.

Before going into the explanation of this curious constriction, it will be proper to give a fuller description of the phenomenon itself. On looking at some eggs but a few hours after hatching, at say 5 p. m., to make a hypothetical case, we find the little embryo sitting on top of the rounded yolk; some hours later we find it on the summit of a pyriform eminence, to use Ryder's (1887) expression; next morning we may find the yolk-sac still elongated but having a slight constriction at or near the middle (like a pillow or bolster with a rope tied around it), or drawn out into a pillar-like body sometimes as long as or even longer than the embryo itself. Later still the yolk may round up and then again go through the same series of changes described above, not necessarily, however, in the same sequence, but with the order perhaps varied or some steps in the series omitted. The changes in form of the yolk bag are, however, more or less rythmical.

Finally, about the time that the color bands make their appearance, the yolk sac takes a certain very definite appearance. The constriction appears at the upper part of the yolk and divides it into a small upper and a large lower bulb (Ryder, 1886). The lower bulb sits inside the remnants of the egg shell, the upper is partly inclosed in the down-growing body walls. As the fish grows larger and can accommodate within its body more yolk, the constriction travels toward the base or point of fixation of the egg. Presently the yolk sac takes on the hour-glass shape to which Ryder (1887) refers and which he figures so well. Finally all the yolk has been driven into the body of the larval fish and there is nothing left save the placenta-like mass of blastoderm filled with blood vessels. Figure 13, plate CXIII, numbers 1 to 6, shows the various changes in the yolk sac as the constriction travels toward the base. This photograph is made from "killed" eggs in alcohol.

The explanation—the only one, so far as I know, ever proposed—is to be found in a little-known oral communication of Ryder to the Philadelphia Academy of Natural Sciences on November 4, 1890. In this he makes known the notable discovery that in the yolk sac of the young *Opsanus tau* there is a layer of *smooth* (italics mine) muscle fibers underlying the epidermis and presumably originating from the splanchnic mesoblast. This muscular layer in turn is composed of layers of spindle-shaped fibers. One layer runs around the yolk bag in equatorial fashion, the fibers of the other run at right angles to the first. Given these facts, the explanation of the changes taking place in the form of the yolk sac is at hand. This is a most interesting point, and, in so far as the writer knows, nothing like it has ever been discovered in any other fish, and great credit is due Ryder for working it out. Ryder surmises that possibly it may have a double function, i. e., not merely that of forcing the yolk into the abdomen of the embryo, but likewise of strengthening the yolk bag so that no injury results from the energetic movements of the fish in its attempts to set itself free. To the present writer this seems to be beyond question the correct interpretation.

THE FREE-SWIMMING YOUNG TOADFISH.

The little toads which have just torn themselves away from their anchorage, if looked at from above, appear to differ from adults only in size; but if viewed on the ventral surface they show the placenta-like stalk to which reference has been made in the preceding paragraph, and to which not infrequently the adhesive disk is still attached. In a few days the disk (if present) drops off, the placenta-like stump is absorbed, leaving only a knob-like projection in the jugular region. Later this disappears and our little fish is no longer a larva but a toadfish, differing from its parents only in size and the stage of development of its reproductive organs. Numbers 5, 6, and 7, figure 13, plate CXIII, show the various stages in the final absorption of the yolk, the formation and disappearance of the lower yolk bulb or placenta-like stump. The fish are enlarged two times.

Figure 12, plate CXII, is from an instantaneous photograph of part of the brood from the board nest of which a series of photographs has been shown. These toadlets (natural size) are in the stage described above, and, in their markings, their bendings of the tail, and their crowding together, show the typical toadfish characteristics.

THE ADULT TOADFISH.

What is the rate of growth in the toadfish? How long is required for it to reach maturity? What is the normal and what the maximum sizes of the fish? These are questions pertinent to this research, but unfortunately not so easily answered as asked.

The little toads at hatching at Beaufort are from 16 to 19 mm. long (⅔ to ¾ of an inch). Storer gives a length of ½ or ¾ of an inch for those at Woods Hole. Greene (1899) says the young of the Pacific form, *Porichthys notatus*, are about 1 inch long when they become free-swimming. According to Smith (1907), on March 26, 1904, a specimen 1.37 inches long was taken in a seine at Beaufort. This must have been hatched late in the preceding season. I have taken them in June and July about 2 inches long. Not infrequently specimens 3 to 6 inches in length are taken in *Pinna* shells. Goode (1884) gives the length of the season's brood in September at 1 inch and adds: "Individuals, apparently of the second year's growth, were also common, and would average three-fourths of an inch in length." Doctor Gill (1907) says of this, "A statement contradicted by the context and probably a *lapsus calami* for 3 or 4 inches." For myself I am thoroughly satisfied that the 3 and 4 inch individuals met with are of the preceding year's brood.

A very incomplete series of measurements of specimens taken at Beaufort in seines by the writer in 1903 and 1904 runs from 3½ to 8 inches in length. These, however, are smaller than those previously referred to as caught and made use of in this work. The following are recorded in my notes because of their unusual size: Males, one 10, one 11½, and another 12½ inches in length; females, one 10, another 10½, a third 12 inches long; sex not determined, one 12-inch specimen. It is greatly to be regretted that a complete list of measurements of all specimens was not kept. The writer's judgment, however, is that they would measure 7 to 12 inches from tip of nose to end of caudal, with an average of about 9 inches.

Mitchill (1815), the first American describer of this fish, says the length is about 12 inches, breadth about 4, depth 2. Yarrow, writing of Beaufort toadfish, in 1877, says that a length of 4 to 8 inches is the most common. Le

Sueur (1824) could find no specimens longer than 5½ inches. De Kay (1842) gives the average size as 6 inches, but had seen them up to 1 foot long. Goode (1884) says of the "northern variety" (*Batrachus*, now *Opsanus*, *tau*) that it rarely exceeds 10, 12, or at the most 15 inches in length, and quotes Silas Stearns, that the southern species (*Batrachus*, now *Opsanus*, *pardus*) frequently attains the length of 18 inches. Jordan and Evermann (1898) give the length as 15 inches, meaning, I take it, that this is the maximum. Miss Clapp (1899), writing of the Woods Hole toadfish, says that a specimen 12 inches long is seldom met with. Smith (1907) fixes the maximum size for Beaufort specimens at 15 inches. The writer's experience is that a 12-inch specimen is rather rare, and that the average length of sexually mature fish is from 7 to 10 inches. Hence if a fish in one year attains a length of from 3 to 4 inches it will probably require two to three years to attain sexual maturity and three to four years (since growth takes place more slowly as the fish becomes older) to attain the average maximum size.

The largest fish of this species ever seen by the writer was 14½ inches long, a veritable giant of his kind. He was anesthetized and carefully measured. These measurements are herewith reproduced: Length, tip of nose to end of caudal, 14½ inches; width across head, 4⅞ inches; width between eyes, 1¾ inches; girth of head, 4⅞ inches; girth of body at anterior base of pectorals, 11⅞ inches; girth of body at posterior base of pectorals, 11½ inches; girth of body at anus, 6¾ inches; mouth (wide open) width, angle to angle, 3¼ inches; height, top to bottom, 2⅝ inches.

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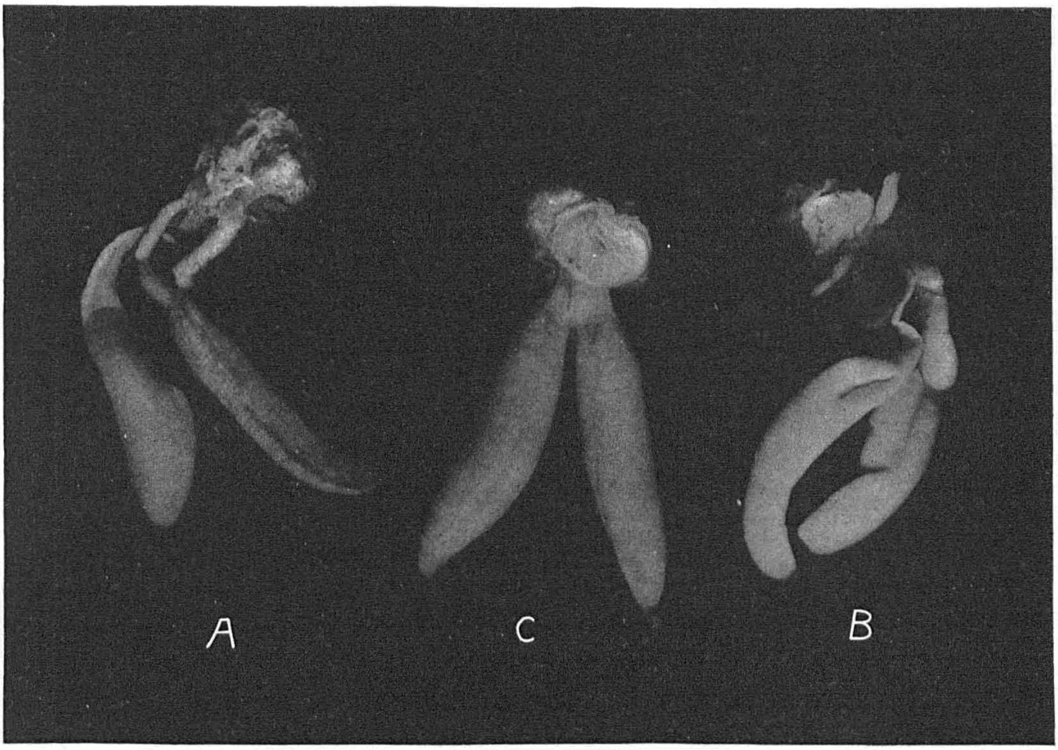

FIG. 1.—Reproductive organs of the toadfish. A, dorsal; B, ventral aspect of ripe testis from adult male; C, dorsal view of immature ovary. Photographed in alcohol.

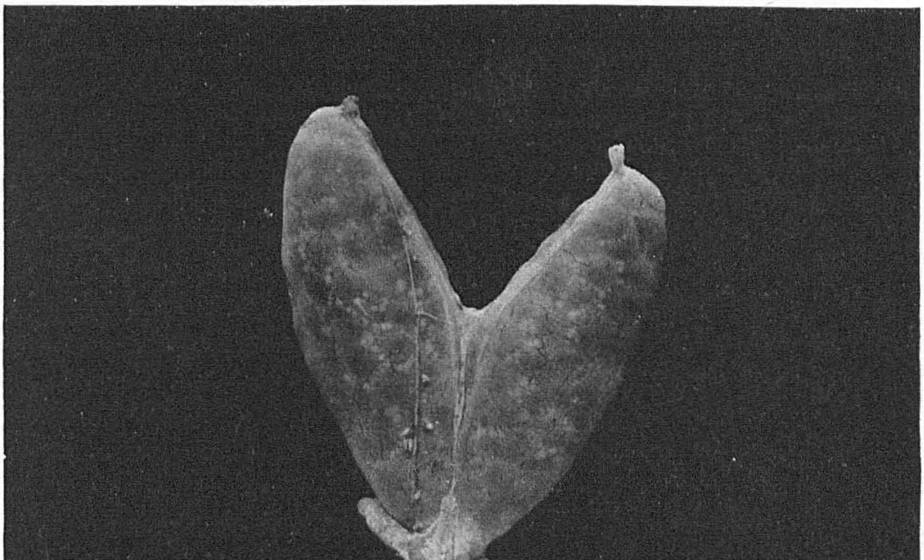

FIG. 2.—Ventral aspect of living ripe ovary of toadfish. Photographed in water.

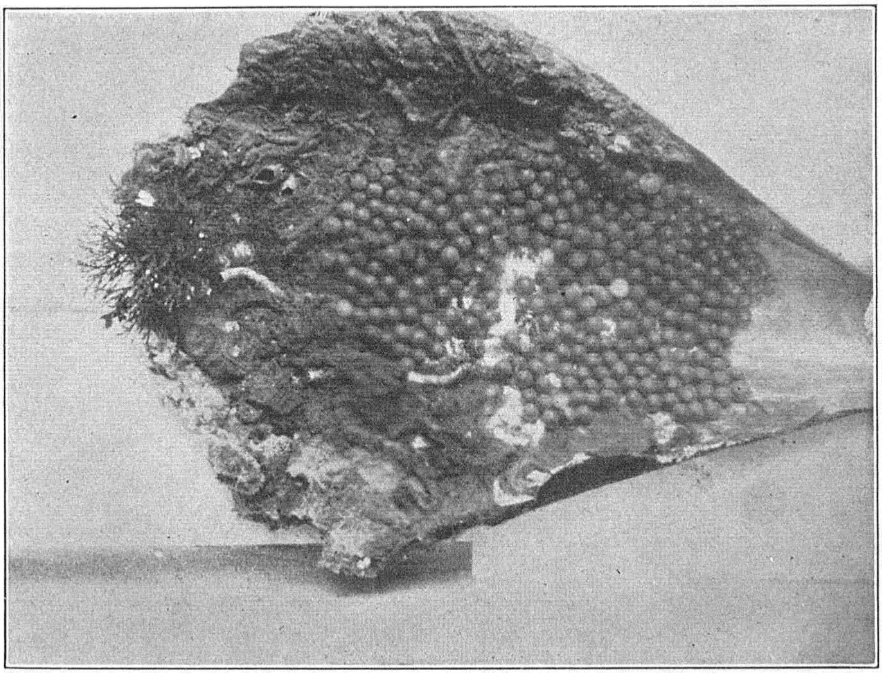

FIG. 3.—One-half of *Pinna* shell nest, showing live eggs in segmentation. ×½.

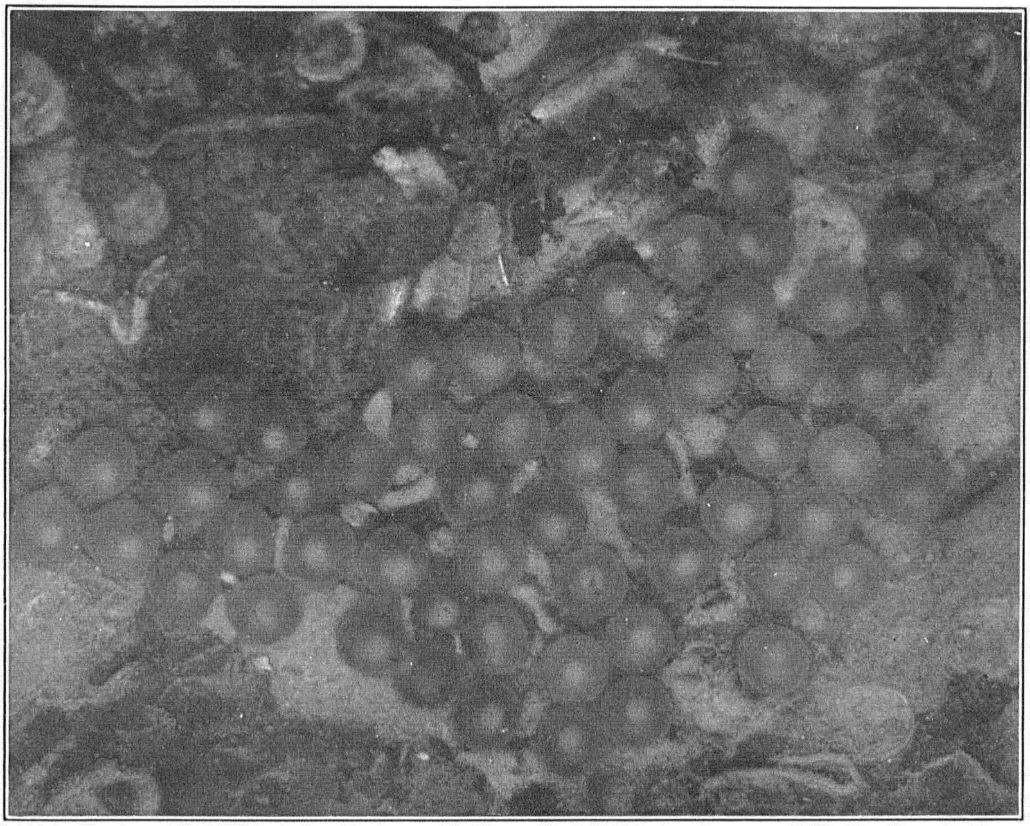

FIG. 4.—Eggs (×2) in late segmentation. Photographed alive in water.

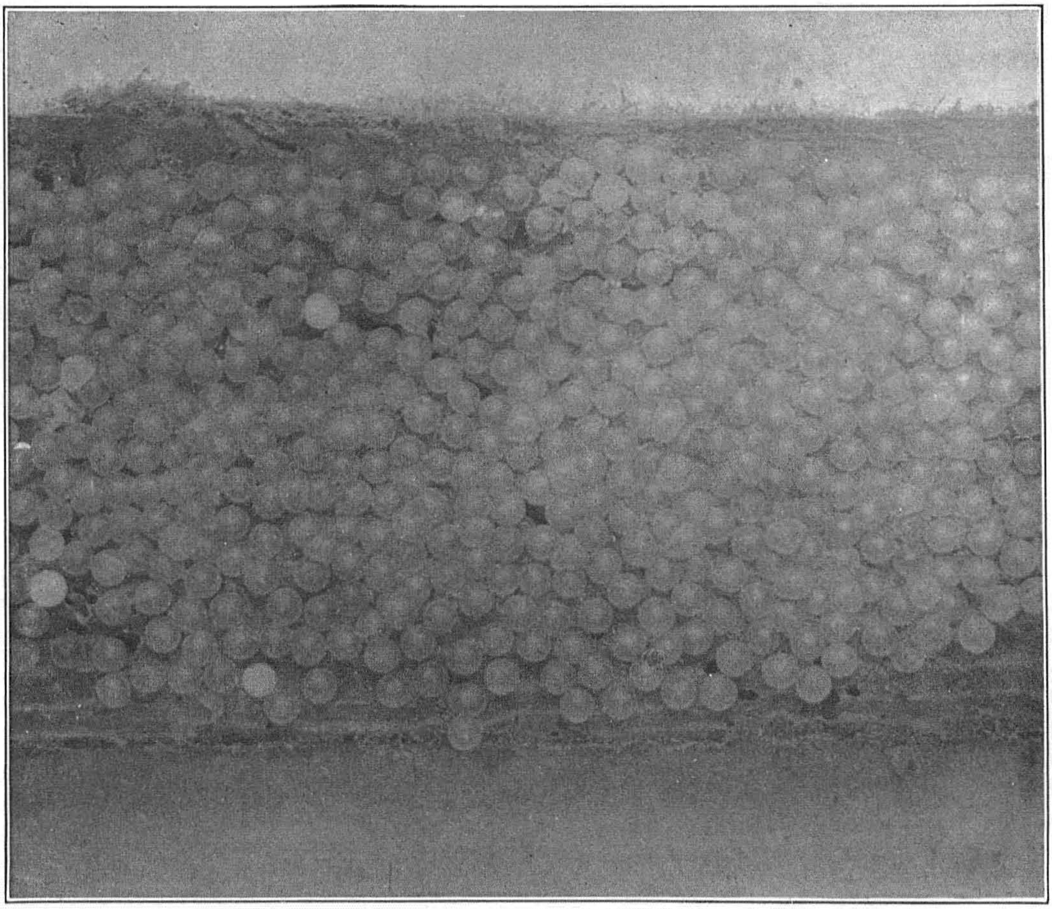

FIG. 5.—Board nest, eggs with late blastoderms and early embryos. Natural size.

FIG. 6.—Nest showing embryos having a marked enlargement at one end. ×½. (White eggs to right are dead.)

FIG. 7.—*Pinna* shell nest, showing tadpole-like larvæ. ×½.

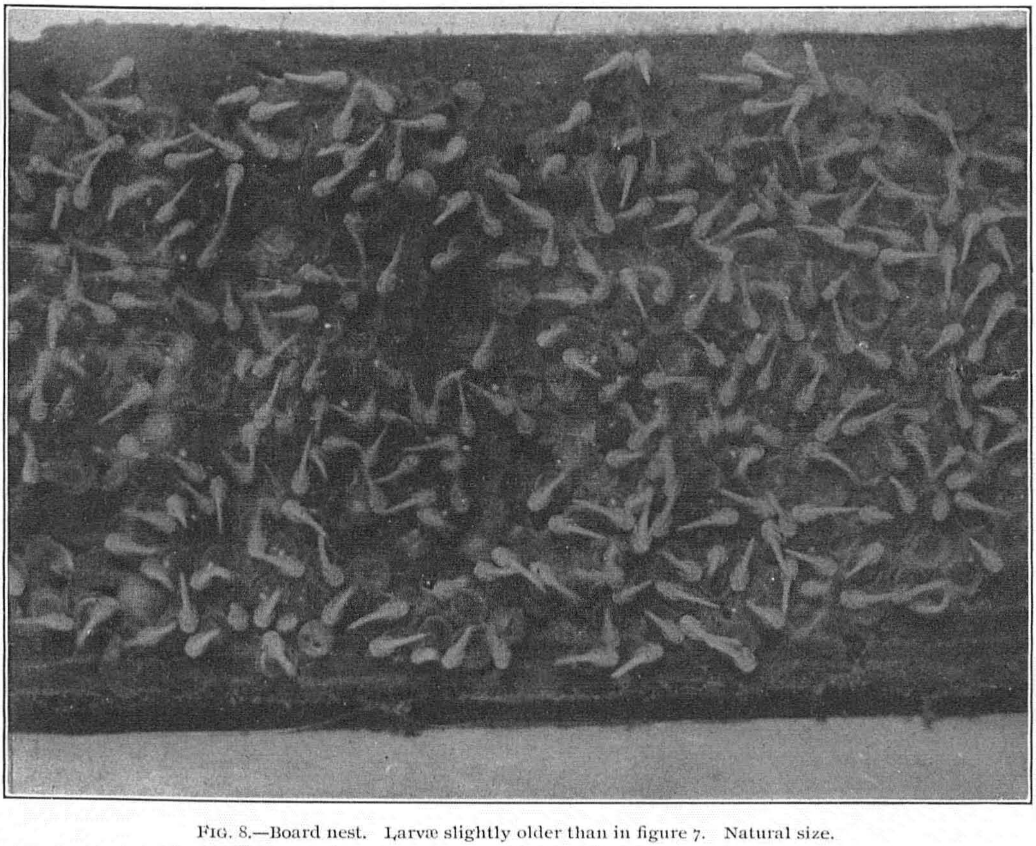

FIG. 8.—Board nest. Larvæ slightly older than in figure 7. Natural size.

FIG. 9.—*Pinna* shell nest, late larval toadfish. ×2.

FIG. 10.—Late larval toadfish, showing color markings. Natural size. Same nest as figure 5, plate CIX, and figure 8, plate CX.

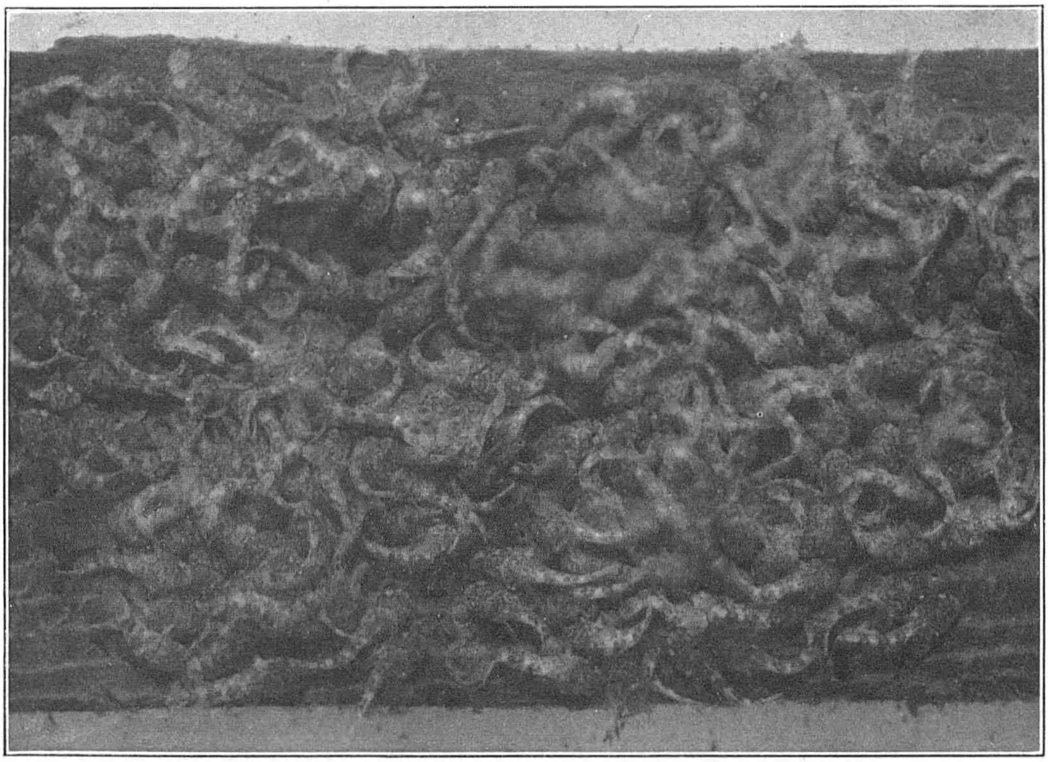

FIG. 11.—Same nest as figure 10, plate CXI. The young are nearly ready to break away.

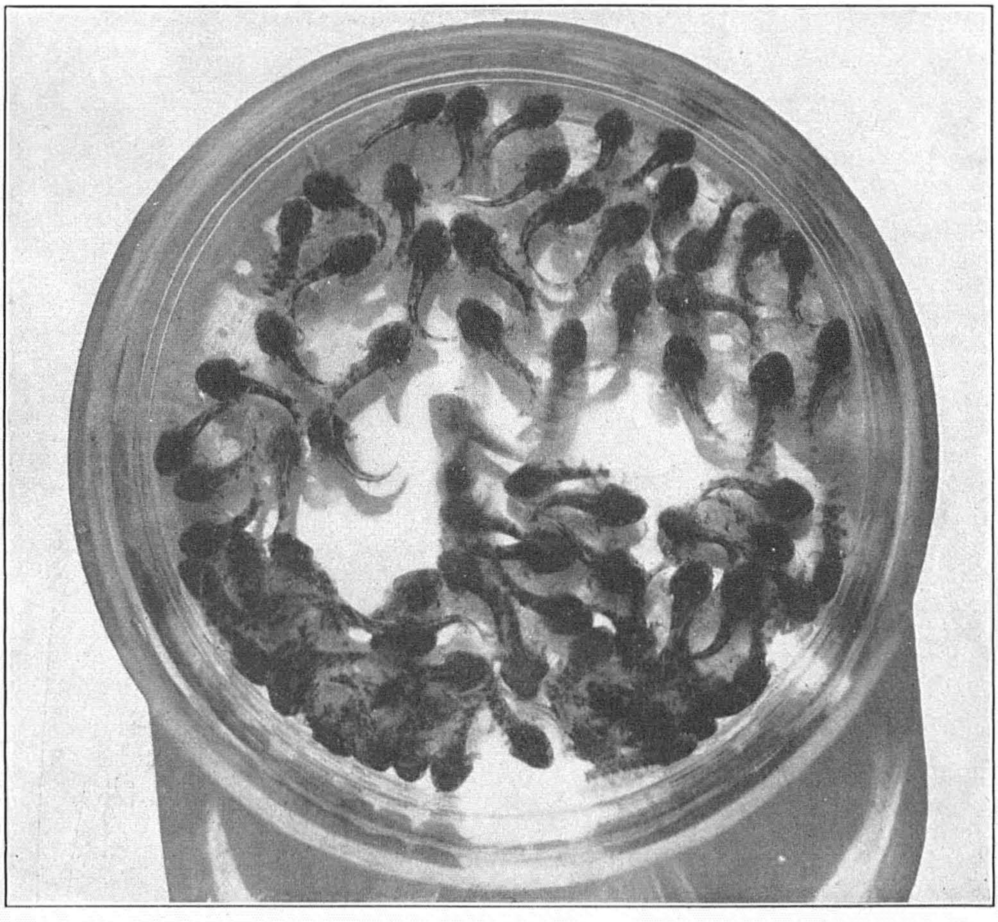

FIG. 12.—From an instantaneous photograph of free-swimming young toadfish in water.

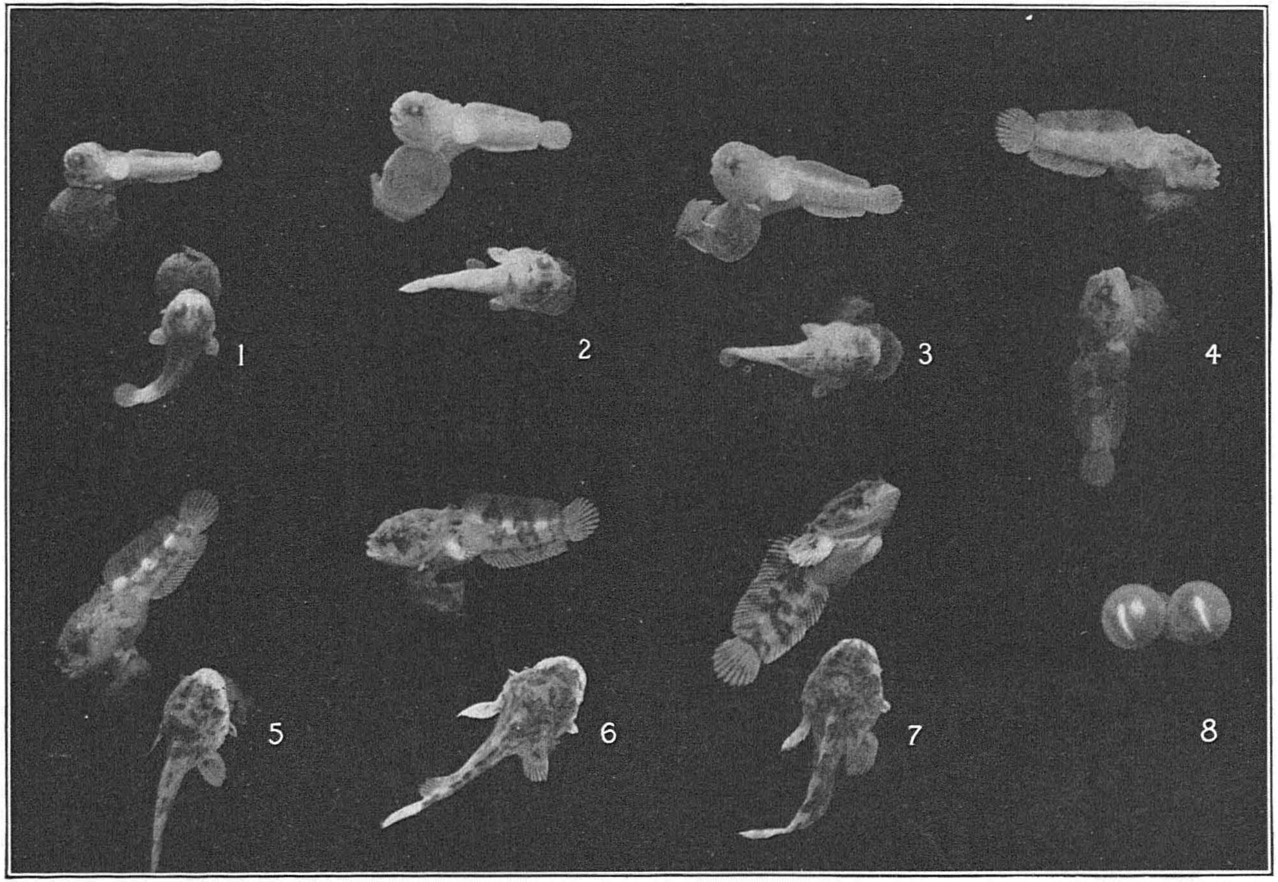

FIG. 13.—Larval toadfish (×2), showing formation of the color bands and disappearance of the yolk. Photographed in alcohol.