METHODS OF STUDYING THE HABITS OF FISHES, WITH AN ACCOUNT OF THE BREEDING HABITS OF THE HORNED DACE

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CONTENTS.

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I. METHODS.

The studies upon which this paper is based have been made in the field, on fishes in their natural environment. Captive fish have been used only when necessary to supplement field observations. As the result of this work, extending over somewhat more than fifteen years, there have been developed certain methods which it is the purpose here to describe. These are, of course, essentially field methods. The studies that produced them related to the natural history of the dogfish (*Amia calva* Linnæus), work begun in 1891 and published in 1903; the habits and development of the black bass (1903); the habits of coral-reef fishes at Tortugas, Florida, published in 1909; and more or less complete observations about ready for publication on *Lampetra wilderi*, *Catostomus commersoni*, *Catostomus nigricans*, *Moxostoma aureolum*, *Campostoma anomalum*, *Pimephales notatus*, *Semotilus atromaculatus*, *Rhinichthys atronasus*, *Notropis cornutus*, *Hybopsis kentuckiensis*, and half a dozen sunfishes of the family Centrarchidae. Work by the writer's students on the breeding habits of local fishes (Reeves, 1907, B. G. Smith, 1908) has also been utilized.

GENERAL PRINCIPLES IN FIELD STUDY OF FISHES.

Habituation of fish to observer.—When an observer approaches a fish for the first time it nearly always happens that the fish is disturbed by the sight of him or by some sound that he makes, and forthwith retreats into deep water or into some nearby cover. The inexperienced observer usually considers such a fish as lost to observation for good and very likely passes on in search of some less wary subject. In doing this he is governed by the popular impression that fish are rovers, not bound to any one locality, and that it would therefore be useless for him to await the return of this particular fish to the locality in which he first saw it. If it were a bird or a mammal he might at least follow it in its wanderings, but with a fish this is manifestly impossible.

In passing to a new subject for observation the inexperienced worker makes a fundamental error, for, save under exceptional conditions, fish are local in their habits. A fish frightened from a particular spot will ordinarily return to it if the observer have but the patience to wait. While waiting, he must not move, but must hold himself as immobile as a tree, so that to the fish, very likely watching from some lurking place, he becomes a part of the landscape. After a longer or shorter time the fish will return, but is likely to be again frightened by a nearer look at the intruder. His second return will follow after a shorter absence, and his third, if again frightened, after a still briefer time. Thus gradually the fish will become habituated to the presence of the observer and will take no further note of him. Then the observer may move about slowly. Let him not move even his head or his hand quickly or the fish will be again frightened, and the whole procedure will need to be recommenced. But if he is careful to begin with moderation he may gradually increase the range and rapidity of his movements until he has come quite near the fish and is moving at his accustomed rate. During this time he may talk or make other sounds in air, for sound waves in air do not disturb fish in water; but he must take care not to set up vibrations in any solid body so situated that these vibrations will be transmitted directly to the water. Thus, if he is in a boat or standing on a wharf he must not strike it violently. If on shore, he must do nothing to cause vibrations of the ground. If wading in the water, he must be careful to lift his feet slowly, so that there will be no splash or dribble, and to set them down with equal care. After a time he will find that the fish resumes the occupation in which it was engaged when first disturbed, and he may then observe it at his leisure; but the time that will be required before the fish will take no further notice of the observer, the nearness of his possible approach, and the extent to which he may expose himself to view or move about will vary with the kind of fish under observation and with its condition.

There is a very great difference in the readiness with which different species of fish become habituated to the presence of the observer, so that some may be said to be much more timid than others. This is well illustrated on the coral reefs. As an observer approaches such a reef by wading, all the many species which frequent it disappear at once into the shelter of the tortuous recesses of the reef. If the observer stands motionless and waits, the fish soon reappear, not all kinds together, but first the less shy species and last the more timid. Among the shyest of our local fishes are the suckers of the genus *Catostomus* and the black bass, while among the boldest are the common sunfish and related species. Not only does the rate of habituation to the presence of an observer vary from species to species, but, as I (1903) have had occasion to observe in the fresh-water dogfish, *Amia*, it may vary also from individual to individual. The successful observer of fish in their native haunts must therefore take account of this difference in shyness of different fishes and must be governed accordingly. In studying the suckers it is usually necessary to remain very quiet and hidden behind some suitable shelter; but if the suckers happen to frequent the neighborhood of a bridge where there is frequent passing they become gradually used to the presence of human beings, and may then be watched without observing any unusual precautions. The black bass may be observed only by taking the utmost care not to disturb it, while the common sunfish (*Eupomotis gibbosus*) may, under most circumstances, be approached without difficulty.

In addition to the differences between species with reference to the readiness with which they become habituated to the observer, there are differences in the same species at different seasons. The areas suitable for the breeding activities of most species are of limited extent. On these areas the individuals of the species congregate at the breeding season, and it is then that they are most readily approached. If in addition to frequenting a particular breeding ground a species is in the habit of building nests, its activities are then centered about areas of still smaller extent, and it becomes proportionately easy to observe them. The breeding season therefore offers the best opportunities for observing the habits of fishes, not only because the fish are then gathered into limited areas, but also because they are easily approached on these areas and readily return to them when frightened away.

The tie which binds breeding birds to the nest and young has been made use of by Herrick (1902) in his remarkable studies of the "Home Life of Wild Birds." He has sawed off the supporting branch and thereby transferred nests from inaccessible trees to places more convenient for observation. The parent birds after recovering from their brief fright returned to their duties, while he watched them from a tent set up within two or three feet of the nest. He found that this parental instinct which, like a chain, binds the bird to its nest and makes it follow wherever the nest is carried, varies in strength at different times and in different birds. The nest should be moved for purposes of study at that time at which the parental instinct is at its strongest.

The like is true of fishes. A fresh-water dogfish may be readily frightened from its nest before the eggs are laid in it, but is much less easily frightened after the nest has been filled with eggs or the young fish hatched. The common sunfish becomes so tame when it has eggs in the nest that, as Thoreau (1849) long ago found, one may stand astride of the nest, stroke the fish on the back, and feed it from the hand. One may even lift the fish from the water in the hand, and when it is returned it will resume its parental duties. In like manner Miss Reeves (1907) found of the breeding rainbow darter (*Etheostoma coeruleum*):

> They quickly become accustomed to one's presence and are not then disturbed by one's wading among them. I have touched them with my boot tips or stroked them with a small wire without their moving. It is then possible to stand directly over them and even to examine them with a hand lens without in any way modifying their normal behavior.

Determination of species.—When the fish have become habituated to his presence the observer must, of course, learn to distinguish unerringly the species which he is studying from other species with which it might be confused. Workers who distinguish alcoholic fish at a glance may be puzzled to separate species of living fish in the water. Here it is impossible to count scale rows, pharyngeal teeth, or fin rays. On the other hand, the colors of the fish and their mode of movement and the fact that species difficult to separate are not usually associated make it comparatively easy to distinguish living fish in the water. Yet the literature contains many instances of errors which have arisen from the wrong determination of fish in their natural habitat. Safety lies in much collecting and repeated comparison of the fish in the hand with that in the water. After a time the observer of fish acquires something of the skill of the field ornithologist, who recognizes by its method of flight the bird that is so distant as to be a mere speck in the sky or by the wag of its tail or the tilt of its head the one that is almost hidden in the bushes. So the ichthyologist finds that living fish present characters that make their field determination easy and that are not set down in the books. But he must discriminate, not only between species, but between male, female, and young, and this is a much more difficult matter. Lack of critical method in discriminating between the sexes has led to very many errors recorded in the literature of the breeding habits of fishes. Until very recently there was perpetuated the error that the female of the black bass builds the nest and cares for the young, and a like error existed in respect to the dogfish (*Amia*).

Analysis of observations.—When the observer of fish habits has successfully approached his subjects and has learned to distinguish between males, females, and young, he is usually confronted by such a bewildering maze of behavior that he sees but little clearly and is sorely tempted to patch out that little by conjecture as to the rest and to aid his patching by analogies drawn from other groups of animals. There is here but one safe rule of procedure, familiar enough in other fields of science, but too little applied in the field study of animal habits. It is that the observer must proceed analytically; he must take one element of the behavior at a time and study that until he can describe it accurately. What is the precise position of the male and female in a pair of spawning fish? To answer this question accurately the observer must ask himself many others. What is the position in each fish separately? In each sex, what is the position of the tail, the head, the dorsal fin, the anal fin, the pectoral fin, the pelvic fin? Each of these questions must be answered by a separate observation, many times repeated, and only when they have been answered and the answers put together does one know the position of the two sexes in the spawning pair. Only by securing answers to innumerable and apparently unimportant questions, only by constant "Fragestellung" does one make progress in the field study of animal behavior. Every accurate and complete account of such behavior is made up by putting together such answers.

Repetition of observations.—Many observations are necessary on each point. A single observation rarely suffices to answer any one of the many little questions that the observer puts to himself. The rapid movements of fishes in a more or less turbid medium, the surface of which is rarely wholly smooth, make observation difficult and increase the chances of error. The writer has in the case of some difficult points repeated his observations a hundred or more times before he has felt sure of their correctness.

Importance of field experimentation.—Field observations should be checked, wherever possible, by field experiments. The analysis of the problem, as advised in the third section above, sometimes brings to the front questions that can not be answered by direct observation, so that recourse must be had to experiment. Thus the building of the nest of *Amia* has never been observed, for the probable reason, as the observations of the writer show, that the work is done at night. In order to learn whether this work was done by the male or female, the writer introduced males into a considerable bay access to which was barred to the females by a net stretched across its mouth. By this device he learned that the nests are built by the males. In work on the breeding habits of *Lampetra* he has been able to make still more considerable use of the experimental method. There is no doubt that the use of the method may be extended to other forms.

Making of records.—Records of all observations should be made on the spot. It is not sufficient to observe what takes place and to write up notes in the evening or at some more remote convenient time. The memory can not be trusted to retain accurately the details of happenings so complicated as those that fall under the eyes of the observer of living fish. It would seem hardly necessary to insist on a precaution so obvious were it not that the observer of fish is placed under sore temptation to defer the writing of his notes. The scenes that he has before him are of absorbing interest and require his closest attention to follow them and unravel their complications. He is loth to spare any time to note taking. And not only does the taking of notes consume time; it causes the loss of observations, at least for the time being; for while the observer is recording one occurrence another follows it, and is lost to him. This loss can only be made good by repeated observation, and while the opportunity for such repetition may be long in coming, it is better to have an accurate record of a part of what has happened than to have an inaccurate record of the whole. Therefore, detailed notes should be made on the spot. There is another reason for this procedure, namely, that the writing down of an observation forces the conscientious observer to be accurate, and shows him wherein his observations are incomplete. A field note, once written, suggests some other query, so that the writing of such notes is not merely a record of what has been seen; it is in itself a guide and a stimulus to further observation.

Field records should be not only written, but, as far as possible, pictorial also. Both sketches and photographs should be made. The technique of such work is discussed in another place in this paper. One other point needs to be insisted on here—that it is impossible to make notes in too great detail. The experienced observer is apt to find his notes doubling in volume with each succeeding year, not only because he sees more, but because he learns the wisdom of making full notes. He finds that his first year's notes leave him in painful uncertainty about many points that he feels he should have made clear. Thereafter, in succeeding years, he increases the detail of his note taking.

Compilation of observations.—A connected account should be written immediately upon completion of the field observations. The experienced field observer will go into the field with a plan of observation in mind and will proceed in accordance with this plan to work out first one part of his plan and then another. It may seem that in the field one must take things as they come and record events in the order of their occurrence, and indeed it often is desirable to do this. Yet in the experience of the writer it is in most cases better to proceed according to some plan, to analyze the problem and to take up each part of it in turn. If the observer does this, he naturally neglects for the time being those happenings that do not fall in that part of the problem that he has immediately in hand. What he thus misses at one time he must get at another. Not only are the best results obtained in this way, but events often crowd so fast one upon another that there is no other possible mode of procedure.

If now the field observer proceeds in his work in accordance with a prearranged plan, he will find it of great advantage to write a connected account of his observations at the earliest possible moment. He should do this, if possible, before the period of observation has expired. In this way he will detect gaps in his plan and will be able to fill them in; he will perhaps find the plan itself defective and be able to modify it before it is too late. If it be here objected that the writer is laying down rules which ordinarily govern the laboratory worker, and that these rules are not at all applicable in field work, he can only reply that he has applied them in field work and always with the result of obtaining better results in shorter time.

TIMES AND PLACES OF OBSERVATION.

Allusion has already been made to the fact that the breeding season offers the best opportunities for the field observation of the habits of fishes. The fish are then congregated at the breeding places, which are usually areas of shallow water; their instincts often bind them strongly to a very restricted area; they become readily habituated to the presence of the observer. In addition to these advantages the habits of fishes are of more interest during the breeding season than at other times, and a knowledge of them is of the greatest consequence from the practical standpoint. At other seasons many fishes are in water so deep that they can not well be observed; or they are in other ways inaccessible. Nevertheless, in so far as fish are accessible outside of the breeding season, the principles that have been discussed in the preceding paragraphs may be applied.

Not only is it possible to observe the breeding habits of fishes in the field, but in the case of many species the breeding continues when the fish are confined in aquaria. In this respect there is a very great difference in species. In spite of repeated efforts I have never succeeded in observing any part of the breeding habits of dogfish (*Amia*) when the fish were under the least restraint. Dogfish that I confined in inclosures of netting on the natural spawning grounds refused to breed, even when the inclosures were 4 square rods in area. The Michigan grayling in its native waters did not breed, in the experience of the Michigan Fish Commission, when confined in a portion of the stream separated from the remainder by gratings at its ends, even when the part of the stream available for the fish was many rods in length. On the other hand, I have observed in aquaria the breeding operations of *Lampetra wilderi*, *Catostomus commersonii*, *Semotilus atromaculatus*, *Rhinichthys atronasus*, and *Eupomotis gibbosus*. It is well known that the European sticklebacks breed readily in aquaria, although I have never succeeded with our American *Eucalia*. Undoubtedly the most noteworthy work in observing the breeding habits of fish in aquaria was that of Carbonnier (1869, 1870, 1872, 1872*a*, 1874, 1875, 1876, 1876*a*, 1876*b*, 1879, 1881) at the aquarium of the Trocadero in Paris. A number of Indian, Chinese, and other exotic fishes bred there as though under no restraint.

To secure apparently normal breeding of fish in confinement the temperature of the water and the food of the fish must be regulated so as to be as nearly as possible that of the natural environment. Such regulation can be accomplished only approximately, so that the breeding habits of fishes in confinement are probably not quite normal. For this reason it is best to make observations on fish in their native waters wherever this is possible and to resort to fish in aquaria only when no other method is available, or for special purposes.

MEANS AND DEVICES FOR OBSERVATION.

Note-taking materials.—For taking notes the writer prefers the aluminum notebook covers, within which loose leaves of note paper are held by a spring. In addition to the well-known advantages of the loose-leaf system, the aluminum covers afford a hard surface for writing, and they keep the note paper from becoming crumpled in the pocket or wet by perspiration. Thus they are preferable for all sorts of field notes, but are of especial use about water, since they protect the notes from wetting. A fountain pen filled with a thin carbon ink affords a permanent and legible writing.

Field glasses.—Field glasses may with great advantage be used where the shyness of the fish precludes a too near approach of the observer. Even prism glasses (stereo-binoculars) may be used, and the writer has found those magnifying about six diameters to be admirable. Field glasses are not only often indispensable for viewing fish from a distance, but they are very useful in studying them near at hand, for then they act as magnifiers, by means of which small fish may be very considerably enlarged and the details of larger ones brought out.

Water glasses.—A very useful form of water glass is that in use on the Florida reefs. It consists of an ordinary wooden pail the bottom of which has been replaced by a circle of ordinary window glass luted into place with hard paraffin. A more convenient form of water glass for many purposes is that designed by the writer and described in his "Photography of Aquatic Animals" (1908). This is essentially a shallow box of galvanized iron into which there is cemented a bottom of plate glass. The rim of the box has an outwardly projecting lip, which lessens the slopping in of water. A bail of band iron is attached by the ends to the inside of the box in such a way that it can be folded down into the interior when not in use. Stout wires soldered across the corners of the box on the inside serve for the attachment of cords. A cover of galvanized iron fits over the plate glass on the outside and serves to protect it during transportation. The whole device is shown in figure 1, plate CXIV, with the cover at the left. This pattern the writer has used in sizes of 1, 2, 3, and 4 feet on a side. Under ordinary circumstances the water glass is allowed to float and the observer then has both hands free for taking notes or for using his field glasses. The bail serves as a means of carrying the apparatus about, and in the smaller size fits conveniently over the shoulder, so that the glass may be carried on the back, while the observer wades with both hands free. It serves the further purpose of supporting a shade of black cloth, as shown in figure 2, plate CXIV. A shade of this sort cuts off the light reflected from the sky into the eye of the observer and makes it possible for him to see much more clearly than would otherwise be possible. Where the water is so shallow that the heavy glass would sink so as to strike the bottom or interfere with the fish beneath, it may be supported on legs, as shown in figure 2. These legs are rods of iron which run through thimbles at the corners of the box and may be set at any height and held in place by thumb screws. The figure shows an observer studying the habits of the brook lamprey by the aid of such a water glass. The lampreys (*Lampetra wilderi*) were engaged in nest building and spawning beneath the glass and were not only studied but photographed by its help.

Of the various sizes of this type of water glass, that of 1 foot square is most convenient for ordinary field work where it must be carried from place to place by the observer, but this size is too small for photographic work. For this purpose the 2-foot glass shown in figure 2 is better adapted and is still not too burdensome to be carried by hand. The larger sizes are suitable only for special uses, as on the coral reefs or where it is desired to photograph a considerable area of the bottom from a considerable distance.

The reflecting water glass designed by the writer (1909) offers some advantages over the ordinary form of water glass for certain kinds of work. It is a rectangular box of galvanized iron (fig. 3, pl. cxv), about 2 feet long and 6 inches by 8 inches at the ends, which are closed. Within the box at each end, as shown in accompanying diagram, is a mirror placed at an angle of 45 degrees with the long axis of the box and firmly fixed in a metallic setting. The reflecting surfaces of the two mirrors are parallel and directed toward each other. The box is heavily weighted with lead at one end so that when placed in water it floats in an upright position, with about 10 inches of the upper end projecting above the surface. Opposite the lower mirror in the side of the box is an opening filled by plate glass bedded in aquarium cement (fig. 3, pl. cxv). Through this window light enters from objects outside the box and these objects are reflected in the lower mirror. At the upper end of the box, on the side opposite the first window, is an opening through which the observer may look at the surface of the upper mirror, and in this mirror he sees reflected the surface of the lower mirror with the objects on the outside of the box shown in it. The observer may thus stand upright in the water, holding the water glass in front of him, and by looking into the upper mirror see submerged objects as he would see them if his head were beneath the surface. He sees the submarine landscape as it appears to a fish or to a diver through the glass window of his casque A handle soldered to either side of the box enables the operator to turn it in any direction and to hold it steady. Into the opening at the upper end of the box there may be fitted a plate of metal to which are attached two tubes lined with chamois skin and of such a size that the objective end of a pair of field glasses fit snugly into them (fig. 3, pl. cxv, right). By inserting field glasses into these tubes the observer may examine with them the objects shown in the upper mirror. Except for the limits set by the opacity of the water, fish may thus be studied from a distance as birds are studied in air. It should be added that the use of field glasses is rarely necessary with this form of apparatus, as the observer is usually

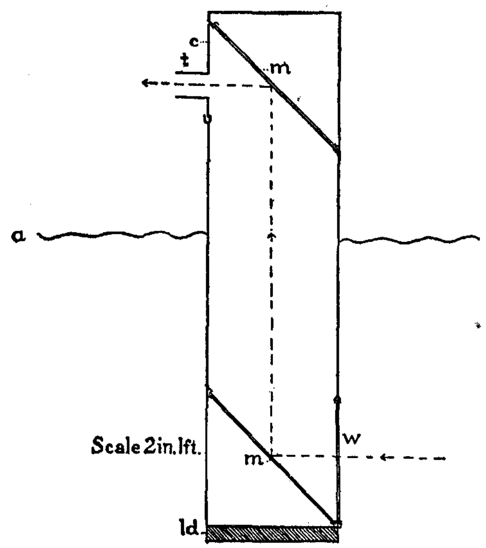

FIG. 1.—Longitudinal section of the reflecting water glass designed by the writer. *w*, Window on one side of the submerged part; *m*, mirrors; *c*, cover over the upper opening; *t*, tube for field glasses; *ld*, lead weight. The dotted line with the arrowheads shows the course of light from an external object to the eye. The line *a*—*b* represents the water's surface.

able to approach near enough for purposes of accurate observation with the naked eye. If field glasses are used the mirrors in the reflecting water glass should not be ordinary glass mirrors silvered on the back, since these produce double images which interfere to a slight extent with the working of field glasses. They should be of metal or of glass silvered on the surface, yielding a single image.

The principle of the reflecting water glass is shown in the diagrammatic figure 4, in section from the narrower side. The glass is seen entire in figure 3, plate II.

Photographic methods.—The writer has elsewhere (1908) described fully the methods which he and others have devised for the photography of aquatic animals and need here only outline these.

Photographing fish in aquaria is a method often of great value in obtaining records of their habits. The method is fully described in the papers cited in Reighard, 1908. Figure 4, plate CXV, shows the male of the common shiner (*Notropis cornutus*) with the details of scales, fin rays, and pearl organs clearly brought out. It was made with a reflecting camera from a specimen in an aquarium. Other examples of such work are figures 10 to 16, plates CXVIII, CXIX, and CXX.

Fish and fish habitats may also be photographed, by the methods already described by the author (1908), while the fish remain in their natural surroundings. To accomplish this two modes of procedure are available, as follows:

(*a*) The camera may be pointed from the air at the object beneath the surface of the water and the photograph taken through the surface of the water. In order to accomplish this it is nearly always necessary to cut off by a suitable screen the light reflected into the camera from the sky and other distant objects. This light is usually stronger than that which comes from the subject to be photographed, and if it enters the camera it affects the photographic plate in such a way as to obliterate the image formed on it by any object beneath the water's surface. One method of using such a screen and the results are shown in figure 5, plate CXVI. Here a dark screen stretched on a wooden frame is held by hand in an oblique position, so as to cut off the reflected light from the sky while allowing the full sunlight to fall on the object to be photographed. The object is in this case the nest of a small-mouth black bass. The large stones which form the bottom of the nest are shown clearly within the reflected image of the screen. Outside this image the reflected light from the sky has entered the camera so that in the picture almost nothing is visible beneath the water's surface.

Figure 6, plate CXVI, is from a photograph obtained by this method and shows brook lampreys in the act of spawning. Sometimes it is necessary to use not only a screen to cut off the reflected light, but at the same time a water glass for the purpose of rendering the surface of the water smooth enough for a photograph to be made through it. Figure 2, plate CXIV, shows such a combination of water glass and screen as used for photographing the lampreys of figure 6. The broad white bands in figure 6 are the edges of the water glass. It is to be noted that within these bands the picture is clear while outside them it is not clear. The lack of clearness in that part which lies outside the borders of the water glass is due to the running water, which is there much disturbed, as shown in figure 2, plate CXIV.

(*b*) The second method of photographing objects beneath water in their natural environment is to inclose the camera in a water-tight box and immerse this, and for this purpose a reflecting camera should be used. The principle of such an instrument is illustrated in the accompanying figure, which shows it in longitudinal section. The light entering the camera is reflected by a mirror, *m*, to a ground glass, *gl*, in the top of the camera and the image formed by it is viewed by the photographer as he looks down through the hood, *hh'*, on top of the camera. This image is of full size, and owing to the action of the mirror is erect. While looking at it the operator may focus the camera and thus keep the image always sharp, no matter how much the object may move. The mirror is hinged at its upper edge at *x*, and the operator can, by pressing a release button, cause it to swing upward until it reaches the position *m'*. It then covers the lower surface of the ground glass in such a way as to prevent the entrance of light through it. The light, hitherto reflected upward from the mirror, now passes backward and may form an image on the sensitive plate, *p*. In front of the sensitive plate there is a shutter, *s*, of the focal-plane type. This is essentially a roller shade of black cloth which may be wound on an upper roller, *r*, and made, by the action of a spring, to unwind very rapidly from the upper roller and wind on a lower roller, *r'*. In passing from one roller to the other the curtain passes in front of the plate. In one place in the curtain is a transverse slot and through this the light falls upon the sensitive plate as the slot, *sl*,

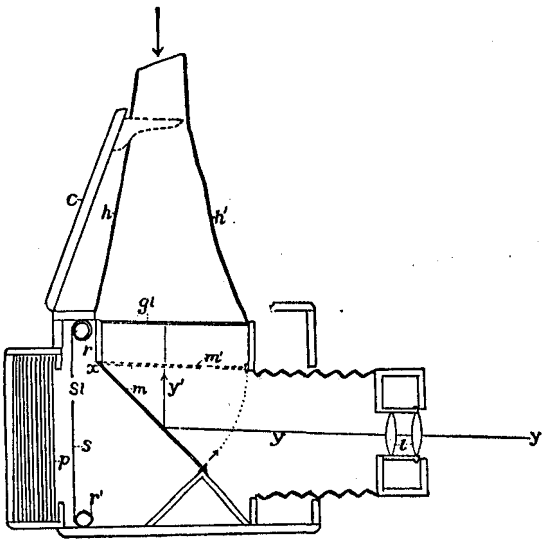

FIG. 2.—A reflecting camera shown in section, with magazine plate holder attached. *gl*, Ground glass; *h h'*, hood; *l*, lens; *m*, mirror in position during focusing; *m'*, mirror, showing position during exposure; *p*, sensitive plate; *r* and *r'*, rollers of focal plane shutter; *s*, the shutter; *sl*, slot in shutter; *x*, hinge on which mirror turns; *y y y'*, ray of light traversing the lens and reflecting from the mirror to the ground glass.

passes across its face. The rate at which the curtain moves and the width of the slot may be regulated. When the operator with the mirror set at *m* has focused the object and brought it into the desired position on the ground glass, he presses the button which releases the mirror. At the instant the mirror reaches the position *m′* it releases the mechanism which actuates the shutter, and the roller with its slot travels across the face of the plate, so that the exposure is made. It is unnecessary to dwell here on all the advantages of this form of camera. The feature of importance is that the camera permits the object to be kept in focus up to the instant of exposure and then permits the exposure to be made without removing the ground glass and inserting the plate, as is necessary in the ordinary form of camera.

In using this form of camera for photographing objects under water the writer inclosed it in a water-tight box of galvanized iron. This box, shown in figure 7, plate CXVII, is provided at one end with a plate glass through which the picture is taken. In the top of the pyramidal portion of the box which covers the hood of the camera there is a second plate of glass which does not show in the figure and through which the operator looks into the hood of the camera and examines the image on the ground glass. The camera is focused from the outside with the right hand by means of a milled head, from which a stem extends through a water-tight stuffing box to connect with the focusing screw of the camera. The exposure is made by pressing a pin which is on the opposite side of the box from the milled head shown in the figure and which also extends through a stuffing box to the interior of the water-tight box, where it actuates the mechanism by which the mirror of the camera is set in motion. The top of the box is held in place against a rubber gasket by eight thumbscrews by the use of which the joint between the box and the lid is rendered water-tight. When the box is in use its bottom must be heavily weighted with lead to submerge it.

In figure 8, plate CXVII, is shown the method of using the reflecting camera when inclosed in the water-tight box. The photographer is wading near a coral reef. The body of the box inclosing the camera is submerged, but the pyramidal top of the box inclosing the hood of the camera projects above the surface of the water. Through the glass in the top of the hood the photographer is viewing the image on the ground glass, while he focuses the camera with the right hand and is prepared to make the exposure with the left hand. When the exposure has been made the water-tight box must be taken from the water and opened in order to change the plate before making a second exposure.

If the water-tight box is made strong enough to resist the pressure of the water the photographer may descend in a diver's suit and may, with the apparatus described, make photographs at considerable depths. If the camera box is set on a tripod time exposures may be made with an apparatus of this type, but some changes would then be necessary in the mechanism by which the shutter is operated from the outside of the water-tight box.

II. ILLUSTRATIVE EXAMPLE OF METHODS OF OBSERVATION.

BREEDING HABITS OF THE HORNED DACE (*Semotilus atromaculatus*).

In the selection of the horned dace, rather than commercial or otherwise more important fishes, to illustrate the present discussion, chiefly two considerations have controlled: (1) That the matter here presented has not hitherto been published, and (2) that the behavior of the horned dace is so complicated that it affords an excellent illustration of the methods the writer has found successful in the study of the behavior of fishes in the field. The horned dace is, however, not without economic importance. It is sometimes eaten, but its chief value lies in the fact that, more than any other fish in the region in which it occurs, it furnishes bait to the angler. The present account of its breeding habits embodies the results of the observations of many years, or rather of many seasons, but the record is not a final one. It is an outline or sketch, a preliminary account from which details are purposely excluded.

There is no published description of the breeding habits of the horned dace, although its conspicuous nests must often have been observed. Kendall and Goldsborough (1908) publish notes prepared by Superintendent Charles G. Atkins, of the United States Bureau of Fisheries Station at Craig Brook, Maine, on the breeding habits of *Semotilus bullaris*. They report that they have themselves seen the nests of this form and give a diagrammatic picture of such a nest with the fish on it. More detailed observations are greatly to be desired, especially since the nest-building behavior described for *Semotilus bullaris* appears to be intermediate between that described in this paper for *Semotilus atromaculatus* and that observed by the writer in *Hybopsis kentuckiensis* and not yet published.

Observing the fish at nest-building time.—The observer who approaches one of the gravelly brooks of southern Michigan during the latter part of April or in May is likely to have his attention attracted by certain elongated heaps of gravel scattered at intervals along the bottom of the stream (fig. 9, pl. CXVIII, and fig. 3, text). These catch the eye, because the stones that compose them are clean, as though scoured, and show their blotches of bright colors. The heaps consequently stand out in sharp contrast to the surrounding bottom, which is everywhere covered with a uniform brown ooze. Each of these heaps has the form of a low, rounded ridge, commonly a foot in width and 2 or 3 inches high, but varying in length from a foot to 16 or 18 feet. The ridges run with the stream, and at the down-stream end of each is an oval pit (*P.*) 2 or 3 inches deep and as wide as the ridge. Below the pit again is seen a trail of clean sand, which at its beginning is as wide as the pit, but as it is followed downstream gradually narrows to a point (*S. T.*, in fig. 9, pl. CXVIII, and fig. 3, text).

As the observer approaches one of these structures he may see the flash of a fish departing from the pit, and he is then apt to move on in the belief that nothing more is to be seen. But if he lies prone on the bank and keeps perfectly still the fish will return. This may happen after ten or fifteen minutes, or it may not happen for an hour, and during all this time the observer must remain motionless, not moving so much as a hand or foot, for if he moves the fish at once flees to shelter and does not reappear for some time. It again departs if the movement is repeated, but each absence is shorter than the preceding, and after a time, if the movements are not too abrupt, the fish remains on the nest in spite of them. For him the observer has become a part

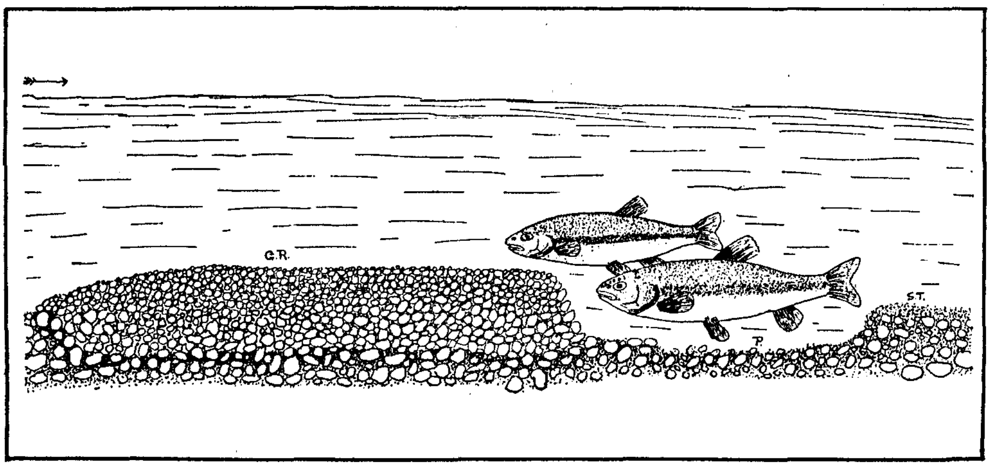

FIG. 3.—Showing in longitudinal section the nest of a horned dace with the male and female fish on the nest. The stream flows in the direction indicated by the arrow at the upper left corner of the figure.

of the landscape, to which he pays no more attention than to a tree. The fish that returns (fig. 10, pl. CXVIII) is usually 8 or 10 inches long, of a beautiful apple-green color above and of a rose red below. If a small fish, there may be a stripe of dark brown between the two colors, where they join along the middle of his side. At the base of the dorsal fin in front is a black spot (fig. 12, 13, pl. CXIX), and above this an orange spot, while the caudal and paired fins are yellow. If the observer is very near, or if he uses field glasses, he may see along the sides of the head above the eye and nostril a row of 4 or 5 white horn-like spines (fig. 10, pl. CXVIII, and text fig. 5, p. 1130). These are pearl organs, so called because in some related forms they have the rounded glistening look of pearls (see fig. 4, pl. CXV, on the snout). By them and by its colors the observer may recognize the fish as the male of the horned dace.

The nest-building process.—Presently the fish will be seen to put its head to the bottom of the pit and by vigorous movements of its tail appears to try to force its way into the bottom, as in figure 11, plate CXIX, in which it is seen to have seized a pebble. Presently it rights itself and is then seen to have picked up a good-sized stone from the bottom of the pit (fig. 12, pl. CXIX). With this it swims to the lower end of the ridge of gravel and there drops it (fig. 13, pl. CXIX), so that it falls on the end of the ridge or rolls down into the pit. In either case it helps to lengthen the ridge. Sometimes a stone too large to be taken into the mouth is pushed along the bottom (fig. 14, pl. CXIX). The fish now carries stone after stone in this way until the ridge is visibly lengthened. Sometimes instead of a single larger pebble the fish takes into its mouth a mass of smaller pebbles, with a considerable amount of sand. When this happens, he does not drop his burden on the end of the ridge, so as to lengthen it, but proceeds some little distance farther upstream, until his head at least is well above the ridge. Then with a movement of his head first to one side and then to the other he distributes the mouthful of small pebbles over the top of the ridge, so as to form a top dressing. As the pebbles leave his mouth it may be seen that the sand which was taken up with them is washed downstream and falls to the bottom below the nest, where it forms the trail already seen (fig. 4, text, at right). This trail is added to by the sand stirred from the bottom of the pit by the fish whenever he picks up a stone. As the ridge lengthens it slowly encroaches on the pit and tends to fill it. But as this occurs at the upper end of the pit the fish slowly pushes his excavation downstream, lengthening the pit at the lower end, so that it does not become filled. The whole ridge thus lies in a long trench, which has been excavated as the fish slowly drops downstream and has been filled by the ridge as fast as made. Only the pit in which the fish lies has been left unfilled at the lower end of the ridge. If the observer is fortunate enough to arrive as the dace is beginning its nest, he may see it dig a little pit in the level bottom and pile the stones on its upstream edge (fig. 13, pl. CXIX). By gradually lengthening this pit and at the same time filling it he completes his nest.

The structure of the completed nest is shown in perspective in figure 9, plate CXVIII, and as it appears in longitudinal section in the diagrammatic figure 3, page 1126. At the right of text figure 4, page 1128, it appears in plan. The bottom of the stream is here composed of gravel, with sand intervening between the stones. In this the long trench has been excavated and partly filled with the stones that have been removed in digging it. These stones may be distinguished from those that still remain undisturbed in the bottom by the fact that they are clean and the sand has been washed from between them. They form a low ridge, which projects from the trench somewhat above the level of the bottom. The unfilled part of the trench—the pit in which the fish are seen—lies at the lower end of the ridge. The sand washed by the current from between the stones that have been moved in making the ridge collects in a trail below the pit and is seen there in the figures.

As the fish continues to work at the nest the observer may slowly, very slowly, raise himself into a sitting position, and if he is careful the fish will not be frightened by this. Then, after a time—a half hour, perhaps—he may slowly rise to his feet, and in the course of time may slowly approach the nest until he is within 8 or 10 feet of it. How much of this he may do and how rapidly he may do any of it can only be learned by trial in each case, for it depends on the individuality of the fish and upon the particular stage of his activities. To the fish the relatively immobile observer becomes, after a time, a part of the landscape and no attention is then paid to him.

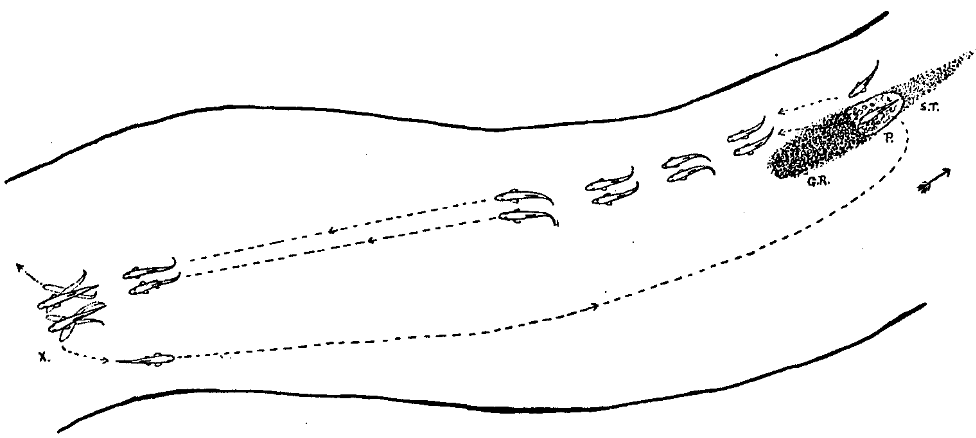

FIG. 4.—Showing the ceremonial behavior of the horned dace when a strange dace approaches the nest. The owner of the nest is seen in the pit, *P*. Above this is the gravel ridge, *G. R.*, and below it is the sand trail, *S. T.* The direction of the current is indicated by the arrow at the right. The course of the two fish upstream to the point *X* and the return of the owner to his nest are indicated by the broken lines with the arrowheads. The heavy lines indicate the banks of the stream.

Protection of the nest against other fishes.—Other fish approach from time to time as the dace works at his nest. Minnows of other species frequently attempt to enter, but if smaller than the dace they are pursued and driven out. Frequently other male dace approach the nest. If these are smaller than the nest builder they are pursued and then invariably flee. Such small males are distinguished from the larger ones by the presence of a dark lateral stripe (fig. 11 to 16, pl. CXIX and CXX). If the male dace that approaches the nest is of the same size as the nest occupant a battle frequently ensues. The two strike at each other with their heads in apparent efforts to inflict wounds with the sharp pearl organs. They often struggle together fiercely in these encounters, but neither fish appears to suffer any injury. The sole result seems to be to produce temporary discomfort in the fish that is hooked, and this usually results in the departure of the intruder.

The attempt of a male to appropriate the nest of another fish of equal size does not always result in an encounter. Frequently it happens that as the strange male approaches the nest the occupant ranges himself alongside and the two fish swim upstream with great deliberation for a distance of 15 or 20 feet (text fig. 4). In their course they move slowly and swing their tails from side to side in unison, as though keeping step with them. At the end of their course they settle to the bottom and bring their heads together gently, as though bowing to one another. They then usually separate their heads and bring their tails together, as though about to swim away from one another. They then commonly again bring their heads together and finally separate, the owner to return to his nest, his companion to some near-by shelter. This performance, which with some variation is so often seen that it must be regarded as a part of the normal behavior, may be interpreted as a deferred combat. The two fish move along side by side, like two boys threatening each other but each afraid to strike. When they have gone a certain distance they approach each other and make certain threatening movements in unison and then they separate. This mode of behavior, which has the appearance of a ceremonial, is illustrated diagrammatically in text figure 4, where the nest is seen from above with its owner in the pit. The outlines of the stream are represented by the heavy black lines, while the direction of the current is indicated by the large arrows. The nest shows the gravel ridge, the pit at its lower end, and the sand trail below the pit. The movements of the two fish in their upstream course, as well as after they have stopped, and the return of the owner to the nest, are represented by the successive outlines, and their direction is indicated by arrowheads.

Spawning behavior of male and female.—While the male dace is building his nest the females are waiting in some near-by shelter. At any time during the progress of the nest building they may be seen to approach the nest, usually one at a time, but sometimes in troops of three or four. The females may be distinguished from the males by their smaller size (fig. 10, pl. CXVIII), for while they may be as long as the males they are nearly always smaller and frequently not more than one-fourth as long. They are further distinguished by the absence of the bright colors on the body and of the black and orange spots in the dorsal, as well as by the absence of pearl organs. From larger males they are distinguished by the presence of the lateral stripe. In all these respects they resemble young males, but from these they may be told after a little practice by the fact that their abdomens are distended with eggs (fig. 10). As a female approaches the nest for the first time the male turns toward her and she then usually flees without actually entering the nest. Presently she returns, again approaches the nest and comes a little nearer, but again flees as the male turns toward her. As female after female thus approaches the nest their coyness gradually diminishes, until one, bolder than the rest, enters and does not flee as the male approaches. She gives no assistance in building, for that is the work of the male. As she enters the nest the male first turns toward her and then, as she comes nearer, takes up his position at the bottom of the pit at the lower end of the gravel ridge, as shown in figure 3, page 1126. He lies usually nearer the bottom of the pit than shown in the figure and often turned somewhat on one side, and in this position he waits until the female has taken a position just above him or at his side. Even when the female has come so far she often again flees, and in that case is pursued by the male, who attempts to bite or hook her. Usually when she has come near enough the male gets his head and his expanded pectoral fin of one side beneath her, and then with a movement often too rapid to be followed by the eye he tosses her into an upright position and at the same time encircles her body with his own. When this has happened the two fish are in the position shown in figure 15, plate CXX, and text figure 5, page 1130. Then the male immediately straightens his body and releases the female. The length of time required for the male to clasp and release the female varies, but is always very brief. It appears to take about as long as is required to close and open the hand when that movement is performed as rapidly as possible. This seems to be usually one-tenth of a second, but is often more.

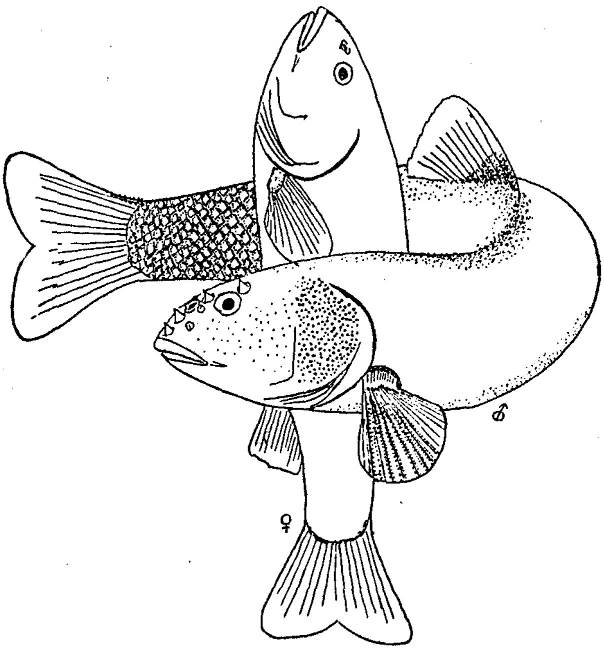

FIG. 5.—Male and female horned dace during the spawning act. On the male, which is the fish with the body curved, are shown above the eye and in line with the nostril, four spine-like pearl organs and below these two smaller spines. Small organs are seen on the operculum and dorsal surface of the pectoral fin and on the caudal edges of the scales on the tail.

When the two fish are in the position shown in text figure 5, the surface of the opercle of the male is seen to be pressed against one side of the female, while the side of his body back of the dorsal fin is pressed against her other side. At the same time the upper surface of his pectoral fin of one side is pressed against her ventral surface. The female always has her head up and her tail down as shown in the figure, but the positions of her dorsal and ventral surfaces with reference to the body of the male may be the reverse of that shown. The movements of the fish are so rapid that it requires many observations on each part of each fish before the observer can be sure of accuracy.

A close examination of a breeding male of the dace is necessary to show the means by which he retains his brief hold of the female in spite of the slipperiness of the skin of both fishes. If he be so examined, it is found that those parts of his body which are in contact with the body of the female during the embrace are beset with minute, sharp pearl organs, and are thereby rendered rough, like a piece of sandpaper (fig. 5, text). The opercular region, covered with close-set pearl organs, has a shagreen-like feel. The sides of the body and tail from the caudal edge of the dorsal fin backward are provided with minute organs which occur in rows along the slightly everted edges of the scales and roughen the surface over which they are found. Finally the upper surfaces of the pectoral fins are provided with close-set organs of moderate size which form rows along the fin rays. By means of these organs the male, whose body would otherwise be smooth and slippery, is enabled to make effective his brief hold of the female. This is the more necessary to him since his scales are devoid of the tooth-like points which occur along the free edges of the scales (ctenoid scales) of many fishes and render their bodies rough to the hand.

While the female is held in the embrace of the male she emits a few eggs, and with field glasses these may often be seen falling slowly through the water until they rest on the gently sloping end of the gravel ridge or on the adjacent bottom of the pit. Probably not more than 25 to 50 eggs are emitted at one time. The released female then floats for a moment belly up as though dead, while the male appears to examine the falling eggs. (Fig. 16, pl, cxx.) The female now speedily recovers and disappears along the neighboring bank, but after a short time returns to the nest and repeats the spawning. She continues this intermittent egg laying until all her eggs have been deposited. She may thus place her eggs in one nest, but more often she deposits a part of them in one nest and a part in another. Meantime, during her absences, other females have entered the nest and laid their eggs, so that when the eggs of any nest are examined they are found to be of several different sizes corresponding to females of different sizes that have entered the nest.

When the females are not in the nest the male continues to carry stones and thus lengthens the gravel ridge. The eggs that have fallen on the end of the ridge or into the pit just at its base are thus covered by the added stones and included in the ridge. As one female succeeds another and as the gravel ridge at the same time lengthens, it becomes filled with eggs. The position of these eggs is shown in figure 3, page 1126, by the black dots among the stones of the gravel ridge. The eggs are undoubtedly fertilized at the moment they are laid, but owing to the fact that the seminal fluid of the male is colorless its emission can not be observed.

Security of nest structure.—The structure of the nest (fig. 3, p. 1126) is such as to afford the eggs protection, for, as already pointed out, the base of it is composed chiefly of larger stones, which the male drops directly on the end of the ridge, so that they roll down toward its bottom. Among these larger stones the eggs are lodged. The surface of the ridge is, on the other hand, composed chiefly of smaller pebbles which there fill the chinks between the larger stones. By this arrangement the eggs in the spaces between the larger stones in the base of the ridge are separated from the free water above by the fine gravel which closes these spaces at the top and are thus protected.

When the nest of the horned dace has been completed it is a conspicuous object on the bottom of the stream, because the pebbles that compose it are clean and stand out in sharp contrast to the ooze-covered pebbles of the surrounding bottom. But within a very few days the sediment from the stream covers the nest pebbles also and the nest becomes then almost indistinguishable. Meantime the builder of the nest, now that his breeding ardor has run its course, has abandoned his work, and the nest with its contained eggs is left to its fate. Here the eggs undergo their development, and after a time, which varies with the temperature of the water, the young fish hatch from them. The eggs or the newly hatched fish may be obtained at any time by scooping up a part of the nest gravel and agitating it with water, when the eggs, which float for a moment in the agitated water, may be poured off. The newly hatched dace do not differ greatly in their general features from the adult, but no accurate description of them has been made. How long they remain in the nest is not known, nor has their method of exit from it been observed. They must soon make their way out through the spaces between the pebbles and through the overlying ooze, but the precise time and method of accomplishing this are not known. Very small dace and those of every intervening size up to the adult are found in the same streams with the parent fish and differ from them apparently only in the smaller size of the prey which they capture and in occupying a slightly different habitat.

The nest of the dace affords an absolute protection of its eggs and young against the smaller carnivorous fishes, and this protection arises from two sources. The presence of the male dace on the nest keeps these little enemies at bay while the eggs are being laid and while they are being covered by pebbles. This protection extends over some days at least. Besides this the covering of stones over the eggs effectually excludes small fish after the male dace has left the nest.

At the same time the top covering of small stones filters out much of the sediment which would otherwise sift down upon the eggs and smother them or carry to them the fatal spores of fungus.

The horned dace and the other minnows that build stone nests are relatively small fish, toothless, and without spiny fin rays, so that they have no effective means of repelling the attacks of their enemies. They would therefore be unable to protect their eggs by guarding them in open nests after the manner of the larger and more formidable fresh-water dogfish and black bass. By building stone nests which inclose and protect their eggs, certain of these minnows, including the horned dace, seem to have followed the most effective method open to fish which are physically incapable of personally defending their offspring.

Destructive agencies.—Yet the nests of the horned dace are not impregnable castles. Against the smaller carnivorous fishes they afford ample protection, for the stones of which they are built are too heavy to be moved by *Rhinichthys, Pimephales, Etheostoma,* and the like. On the other hand, the nests may easily be disturbed and even robbed by larger fishes. *Campostoma* and *Catostomus* habitually uproot small stones in the process of feeding, and it is possible that in this way they uncover and devour the eggs of the horned dace, though I have not observed this. But there is another way in which the structures built by the horned dace are frequently torn to pieces and their contained eggs probably devoured, and that is by the nest-building operations of other fish. When a horned dace nest has been completed by its builder and abandoned, a second dace frequently selects the same site for his nest and proceeds to build with the materials used by his predecessor. Or a *Campostoma* may use the gravel ridge of a horned dace nest as a suitable place in which to excavate his pit, or a *Hybopsis* may carry away some of the dace materials in building his nest. These fish all build at about the same time, and their pits, ridges, and stone piles occur on the same areas. By this process of the repeated occupation of the same area by other fish of the same and other species, the nests of the horned dace are often disturbed, and in such cases the contained eggs are probably in part destroyed. The extent to which this happens varies in different streams. In certain streams areas which I have kept under observation have been utilized as nesting sites two or three times in succession, and the first dace nests built in them have been thereby wholly or in part destroyed. In other streams most of the dace nests have been left undisturbed. Again the top dressing of fine gravel by no means suffices to exclude all sediment. Sediment and fungus spores reach the eggs. In many of the nests that I have examined, living eggs were found in the new-built parts, while the older parts contained only dead eggs matted together and covered by fungus.

SUMMARY OF OBSERVATIONS OF THE BREEDING HABITS OF THE HORNED DACE.

1. The horned dace breeds in southern Michigan from late April to early July.

2. Breeding males are distinguished from females by their larger size, brighter colors, the presence of pearl organs, and abdomen not distended as in the female.

3. The breeding takes place in clear streams, which vary in width from 1 or 2 feet to 4 or 5 rods, on bottom of coarse gravel, and usually at the heads of rapids.

4. The male fish builds nests without assistance from the females.

5. The nests are constructed, each chiefly by an individual male, by picking up and carrying stones in the mouth.

6. Each male thus excavates, parallel to the course of the stream, a long trench, usually a foot wide and 2 or 3 inches deep, but varying in length from 1 to 16 or 18 feet.

7. As he excavates this trench he fills it with the gravel removed in making it, so as to form a ridge of gravel which extends 2 or 3 inches above the top of the trench.

8. The trench and ridge are extended downstream, and the fish always occupies the unfilled portion of the trench at the lower end of the ridge. This I have called the pit.

9. The sand washed from between the stones in moving them accumulates in a trail below the pit.

10. In forming the ridge most of the coarser gravel is deposited so as to form its base, while the finer gravel is used chiefly as a top dressing on the surface of the ridge.

11. The male guards the completed nest, and often defends it by giving battle to other males.

12. Frequently when the nest of one fish is approached by another male dace of equal size there ensues, not a combat but a "ceremonial" which may be interpreted as a deferred combat.

13. The females may enter the nest and lay their eggs at any time during the process of nest building, and the eggs thus laid are covered in the subsequent operations of the male. Consequently they are included in the gravel ridge and this ridge is filled with the eggs of many females.

14. When a female enters the nest to spawn, she is thrown by the male into a vertical position and encircled by his body; in this spawning attitude the head of the female is always up and the opercle and pectoral fin of the male are pressed against one of her sides while his tail behind the dorsal fin is pressed against her other side.

15. The embrace of the female by the male lasts for a fraction of a second, during which a small number (probably 25 to 50) eggs are laid and fertilized.

16. The female when released usually floats belly up for a moment, and in all cases leaves the nest. She subsequently returns many times to the same nest, or enters another nest, and on each occasion deposits a small number of eggs. This continues until her eggs, laid in one nest or several, are all deposited.

17. The sharp pearl organs on the head of the male are used as weapons, while the smaller organs on his operculum and on the sides of his tail, together with those on the dorsal surface of his pectoral fin, are used in retaining his grasp of the female during the act of spawning.

18. When the male has completed his nest he deserts it, and it rapidly becomes covered with silt and not easily distinguished from the surrounding bottom.

19. The eggs hatch within the nest, and the young make their way out through the chinks between the stones.

20. The nests of the horned dace are of advantage to the species in affording protection to the eggs against sediment and against the attacks of the smaller carnivorous fishes.

21. The nests of the horned dace are often destroyed by the nest-building activities of other dace and of other species of larger minnows (*Campostoma anomalum*, *Hybopsis kentuckiensis*), and the eggs are frequently attacked by fungus.

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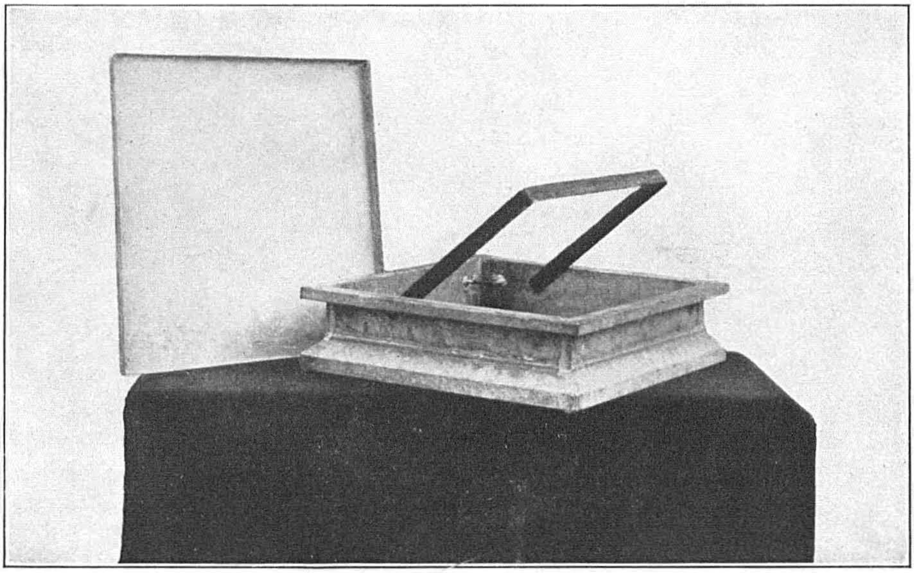

FIG. 1.—Water glass designed by the writer to be used for observation or photography of objects under water. The cover is shown at the left.

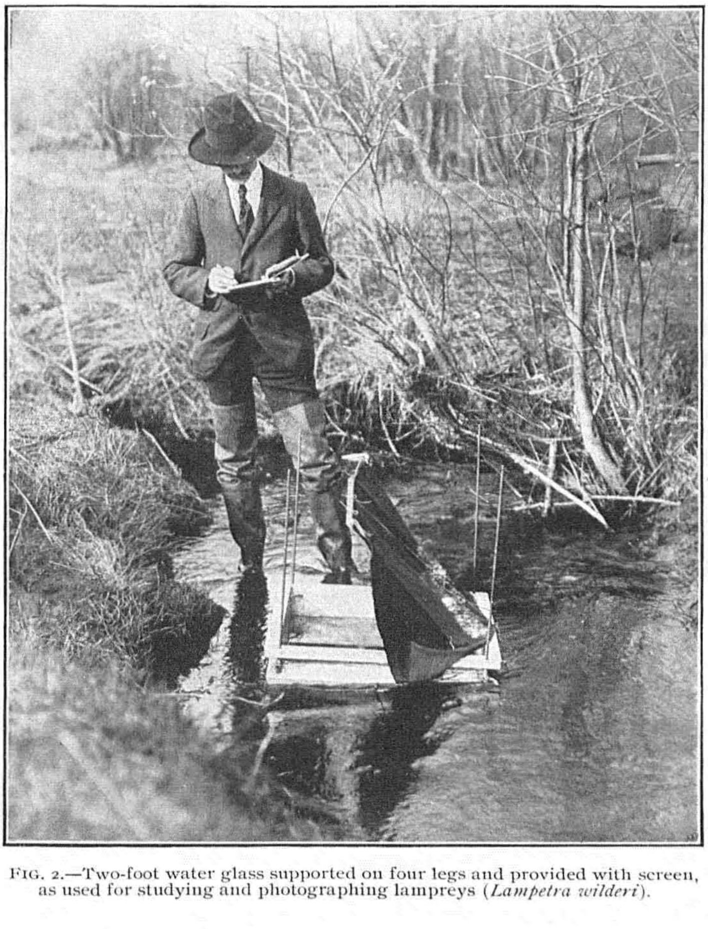

FIG. 2.—Two-foot water glass supported on four legs and provided with screen, as used for studying and photographing lampreys (*Lampetra wilderi*).

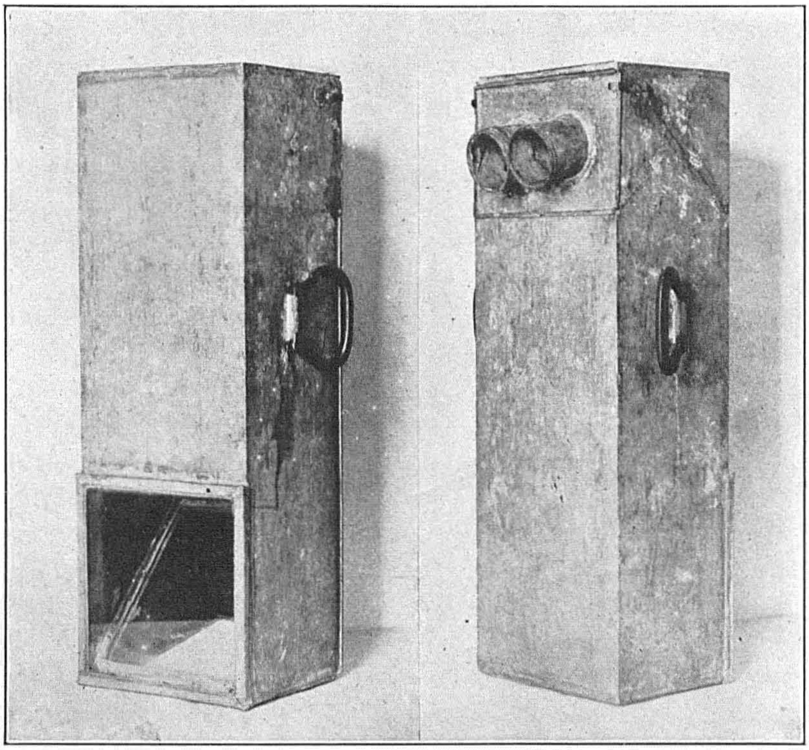

FIG. 3.—Reflecting water glass used by the writer. For description see text. Compare figure 4, text.

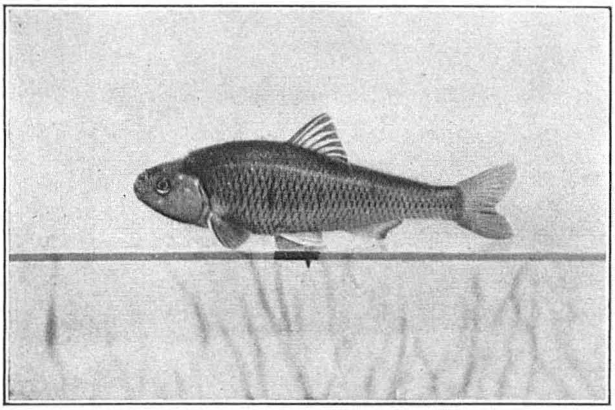

FIG. 4.—Male of the common shiner (*Notropis cornutus*), photographed in an aquarium out of doors with a reflecting camera.

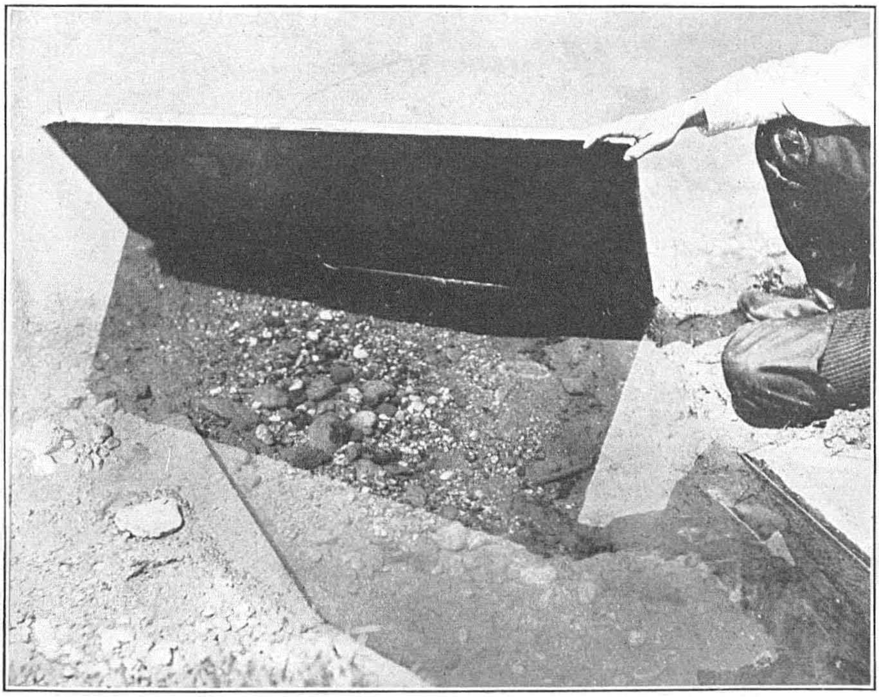

FIG. 5.—Photograph of the nest of a small-mouthed black bass (*Micropterus dolomieu*) taken with the aid of a screen, the camera above water.

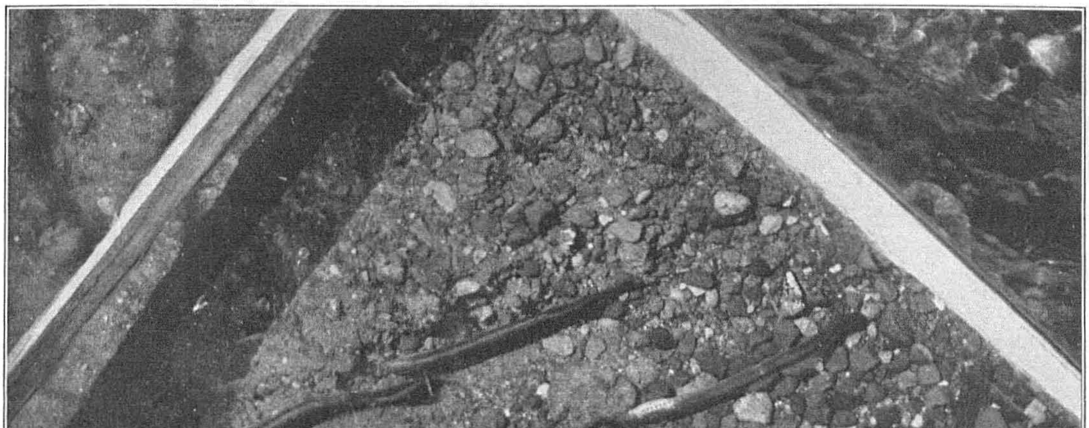

FIG. 6.—Brook lampreys (*Lampetra wilderi*) on the nest, photographed through the water glass shown in figure 2, plate CXIV, in about 8 inches of running water.

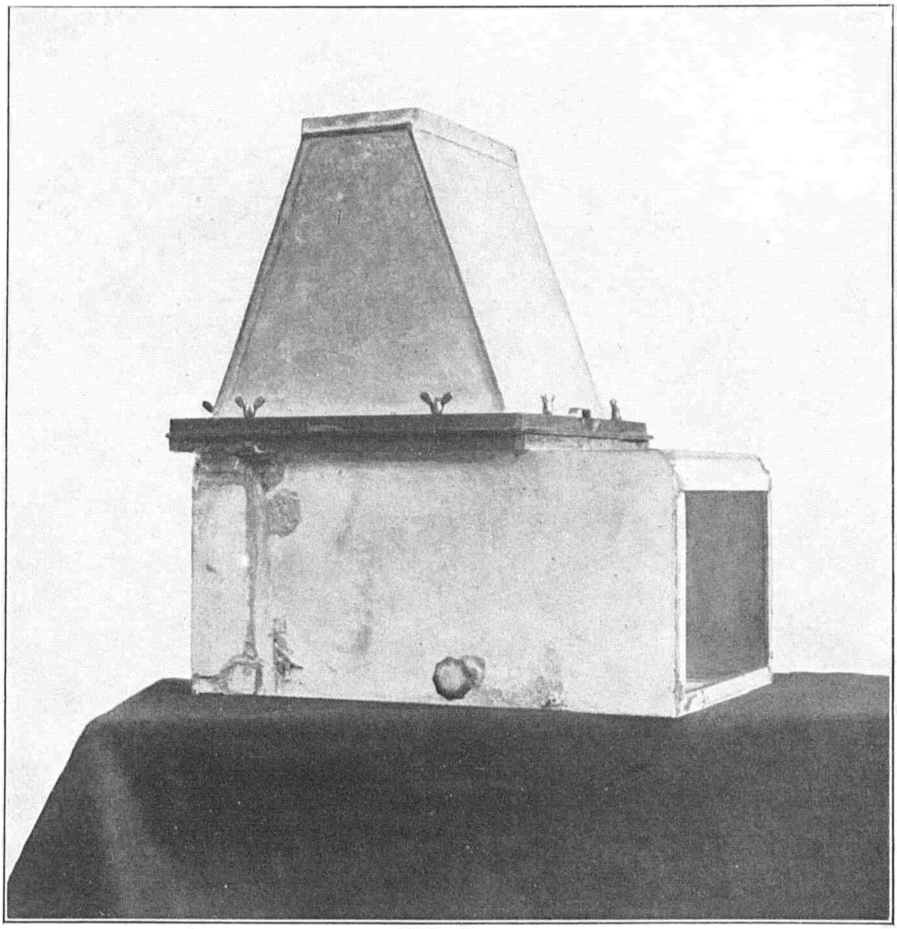

FIG. 7.—Galvanized-iron box with plate-glass front, designed by the writer to contain a 5 by 7 reflecting camera for use under water.

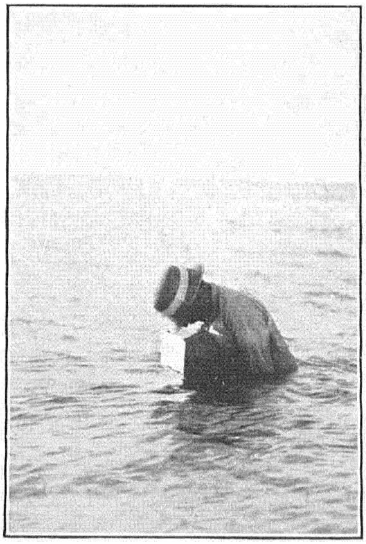

FIG. 8.—Photograph showing the method of using the reflecting camera inclosed in the water-tight box for subaquatic work. The upper part of the box covering the hood rises above the surface, while the lower part, containing the camera proper, is under water. The operator is looking into the hood through the plate glass in the top of the box. With his right hand he focuses, with his left makes the exposure.

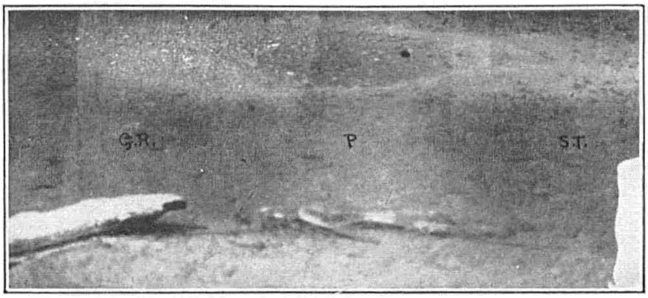

FIG. 9.—Photograph of the nest of a horned dace (*Semotilus atromaculatus*), taken with a reflecting camera and by the aid of a cloth screen used as shown in figure 6, plate CXVI. The reflected image of part of the screen is seen over the right and left parts of the nest. In the upper part of the picture at the right above *S. T.* is the sand trail; to the left of this, above *P.*, is the pit, in the bottom of which are large pebbles; farther to the left, above *G. R.*, is the gravel ridge with its top dressing of fine pebbles. The end of the ridge, its structure of coarse pebbles, is within the pit at the left.

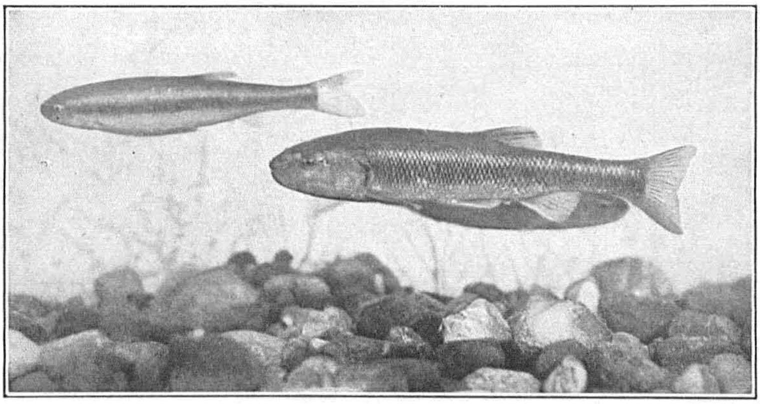

FIG. 10.—Male and two females of the horned dace (*Semotilus atromaculatus*). One female is above at the left, the other behind the male. The head of the male bears four pearl organs. Photographed with a reflecting camera, the fish in an aquarium out of doors.

FIG. 11.—Male horned dace picking up a stone. His lips are grasping it.

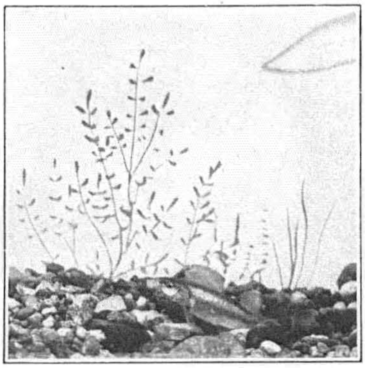

FIG. 12.—Male horned dace about to drop a stone which he carries in his mouth.

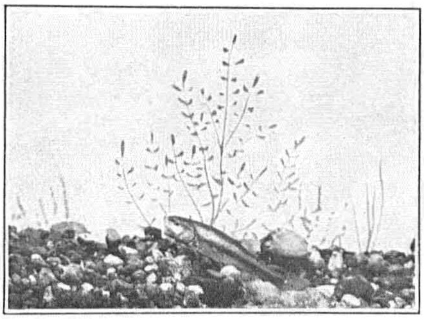

FIG. 13.—Male horned dace which has just dropped a stone, but has his mouth still open.

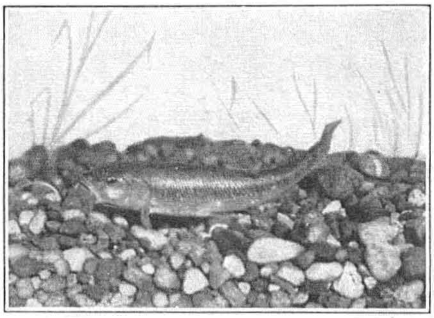

FIG. 14.—Male horned dace pushing along the bottom a stone too big to carry.

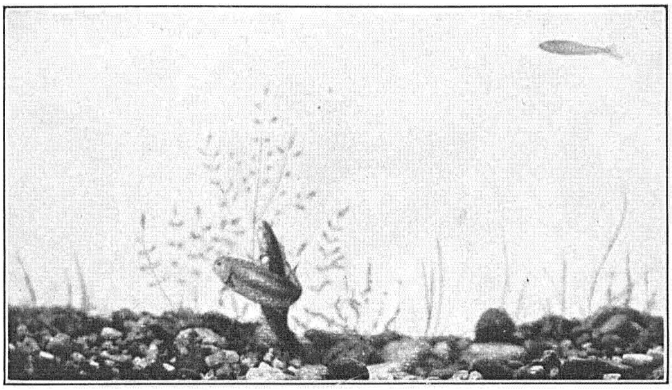

FIG. 15.—Photograph of dace in the act of spawning. The female is in the upright position. The male has either not completed his embrace of the female or has just relaxed it. Photograph made with a reflecting camera, the fish in an aquarium out of doors.

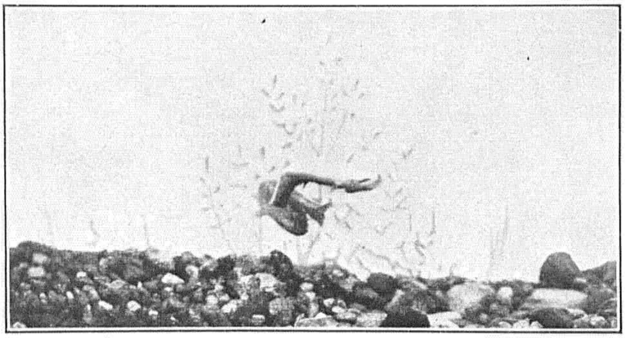

FIG. 16.—Male and female of the horned dace just after completion of the spawning act. The female floats belly up as though dead. The male appears to examine the falling eggs, which are in front of his head and in front of the stones beneath him as well as in the intervening clear water. Photograph made with a reflecting camera, fish in an aquarium out of doors. The vegetation shown in this and the other figures was painted on the back of the aquarium.