

FAUNA OF THE CHILKA LAKE
STAGES IN THE LIFE HISTORY OF *GOBIUS*, *PETROSCIRTES*
AND *HEMIRHAMPHUS*.

By D. R. BHATTACHARYA, *M.Sc., Professor, Muir Central
College, Allahabad.*

(Plates XVII—XVIII.)

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STAGES IN THE LIFE HISTORY OF *Gobius*, *Petroscirtes* AND *Hemirhamphus*.

By D. R. BHATTACHARYA.

This paper deals with early stages in the life history of *Gobius ostreicola*, Chaudhuri, *Petroscirtes bhattacharyae*, Chaudhuri, and *Hemirhamphus limbatus*, Cuv. and Val. The specimens were all collected in the Chilka Lake by members of the staff of the Indian Museum. I worked on the first two above-mentioned species in the months of May and June, 1915, in the Indian Museum at Calcutta. The specimens of the third were sent to me here at Allahabad, and I worked them out in the Biological laboratory of the Muir Central College, during the month of August, 1915. As it was too hot then for microtome work, many features of the internal anatomy have been neglected, and the paper naturally is not supposed to be exhaustive.

My sincere thanks are due to Dr. Annandale, Superintendent of the Indian Museum, and to Dr. Chaudhuri, Assistant Superintendent, Indian Museum, for kindly allowing me to work in the Museum laboratory, for placing the collections of the Chilka Lake Survey at my disposal, and for assisting me in many other ways, especially in looking up literature on the subject.

***Gobius ostreicola*, Chaudhuri.**

(Plate XVII, figs. 1—7.)

1916. *Gobius ostreicola*, Chaudhuri, *Rec. Ind. Mus.*, XII, p. 105.

The specimens were collected on the oyster-beds of Manikpatna in the outer channel of the Chilka Lake during the first week of December, 1914. The water at that place was then almost fresh owing to the floods at the close of the monsoon, though later on in the dry season the water becomes as saline as in the Bay of Bengal. The specific gravity of the water was found to be 1.01250.

The egg is elongated and oval in shape with a bunch of filaments at the distal extremity which serves as a means of attachment to foreign bodies. In this case the eggs were found attached to the concave side of a dead oyster shell measuring about $3\frac{1}{2}$ inches in length and $2\frac{1}{2}$ inches in breadth. On a rough calculation about 400 eggs were found covering a surface of one sq. cm. The method of attachment of the eggs to the shell is very characteristic. There springs from the pedicle of the egg a hyaline structure which spreads out like an umbrella and ends in viscid thread-like filaments which adhere to the shell or to the filaments of the adjacent ova. This hyaline structure is traversed by alternate rows of oval apertures which gradually become bigger in size distally. Three or four such concentric rows of apertures may be made

out under the high power of the microscope. The apertures in the last row (distally) do not keep an exactly oval shape, but are generally slightly curved or bent and much more elongated than broad.

The egg shown in pl. xvii, fig. 1 was the smallest of the lot I came across and measures .5 mm. in length. It is in one of the early stages of development. Numerous small globules, very likely oil globules, may be seen in the yolk-mass. The egg-membrane is more or less closely attached to the developing egg. The examination of the contents of the egg seems to show, however, that it is really a degenerate egg.

The egg in pl. xvii, fig. 2 measures 1.6 mm. in length. Intermediate stages between figures 1 and 2 could not be found. At this stage the embryo is fairly well developed. In a lateral view the eye, ear and heart may be seen to have begun to develop. The eye has not yet acquired pigments and is consequently colourless. The ear is a simple pit-like depression. The heart is represented by a very minute sac-like dilatation. The yolk-mass lies in a yolk-sac on the ventral surface of the body. Immediately above the yolk-mass we see the beginning of the notochord which gradually tapers towards the tail end, though it has not yet reached its extremity. On the dorsal surface of the embryo from the anterior end to about the middle of the body a thickening like that of the neural plate is observable. It marks the beginning of the development of the nervous system. A continuous fin-fold all over the body, except for a small portion of the head-end of the embryo, forms one of the most characteristic features of the embryo at this stage.

Plate xvii, fig. 3 shows an empty egg-membrane from which the embryo has been extruded. The wavy line at the upper end marks the point of rupture during extrusion.

The specimen in pl. xvii, fig. 4 measures 2 mm. At this stage we find the nervous system fairly well developed. The notochord reaches the extremity of the tail and is slightly curved upwards (heterocercal), and the caudal fin-fold acquires a corresponding shape. The epichordal lobe becomes reduced in size and the hypochordal lobe becomes comparatively enlarged. The continuity of the fin-fold is more or less broken near the middle of the body by its extreme narrowness, and we get anteriorly a dorsal fin-fold, posteriorly a caudal fin-fold, and ventrally a pre-anal fin-fold. The transition from fig. 2 to fig. 5 is rather abrupt. A truly heterocercal stage is not visible and we apparently get a homocercal (fig. 7) from a diphyrcercal (fig. 2) type. Fig. 5, however, approaches the heterocercal stage to some extent. Black stellate chromatophores lie in streaks both above and below the notochord, but do not reach the caudal extremity. The anus lies near the middle of the body, but the anterior portion of the alimentary canal is either undeveloped or indistinct. The heart acquires a coiled shape.

Plate xvii, fig. 6 shows a slightly more advanced stage. It has a curved tail, which is of course not a characteristic feature of this stage, for many specimens of earlier stages possess coiled or curved tails. This stage marks the development of pectoral fins and of another structure—probably the gas-bladder which lies just in front of the yolk-mass.

Plate xvii, fig. 7 is the most developed of the specimens which I have seen. It is not yet hatched, but in all likelihood is just ready to be hatched. Of course, hatched specimens leave the colony and lead independent lives and that is why I have not come across them. At this stage the eyes become quite prominent and acquire pigments. The pupil looks yellowish-grey with a brownish spot in the middle, and the bulk of the eye looks brownish-black under the high power of the microscope. The yolk-mass gradually decreases in size. Two streaks of black (in places brownish) resembling stellate chromatophores may be seen lying dorso-laterally, one on either side of the notochord. A big chromatophore lies just in front of the yolk-mass. Embryonic fin-rays may be seen under the high power in the homocercal (not yet true homocercy) caudal fin. The embryonic dorsal fin also becomes well developed. No pigments have been found to occur in the embryonic fins. The pelvic fin has not as yet made its appearance. The pectoral fins are well developed and become fan-shaped. The transparency of the body is lost and every preparation to reach the adult form is more or less begun.

Petroscirtes bhattacharyae, Chaudhuri.

(Plate XVII, figs. 8—11.)

1916. *Petroscirtes bhattacharyae*, Chaudhuri, *Rec. Ind. Mus.*, XII, p. 107.

This species is believed to be a new one and no description of its larval stages seems to exist. Some specimens were obtained off Balugaon on 6-iii-1914, and others near Barkuda I. on 19-xi-1914. The specific gravity of the water (corrected to a standard temperature of 15°C) was about 1.007 on the former occasion and about 1.006 on the latter, showing a low salinity on both.

Only three distinct stages are available. The smallest specimen found measured 3.25 mm. in length and the largest specimen 15.9 mm. (including the middle caudal fin-rays). The following table gives the measurements in mm. of (1) the smallest, (2) the next higher stage—I shall call it medium for the sake of convenience, and (3) the largest specimens available.

Stage.	Total length.	Depth of body.	Length of caudal fin.	Length of pectoral fin	Length of spine.	Length of head.	Length of pelvic fin.
I. Smallest	3.25	.6	No distinct caudal fin.	.5	.3	.8	Not yet developed.
II. Medium	13.25	2.25	1.8	2.5	1.25	2.5	1.75
III. Largest	15.9	2.7	2.1	3.25	1.8	3	2.25

The specimen shown in pl. xvii, fig. 8 measures 3.25 mm. in length (stage I). The muscle segments are fairly well developed and are about 34 in number, out of which about 24 can be distinctly made out, the myocommas of the most anterior and the most posterior segments being rather indistinct. The myotomes have not yet quite acquired the shape of the adult and are slightly wavy in character.

The "concentration" of the body segments has not yet taken place except at the anterior end.

The dorsal, caudal, and anal fin-folds are continuous (a primitive character). Furthermore, the skeletal supports of the fin-folds are either not yet developed or if developed (there are faint indications of the development of the fin-rays towards the caudal end) are not visible even under the high power of the microscope. The pelvic or ventral fins are not yet developed. The pectorals are short and contain 9 fin-rays.

The pigments are a characteristic feature of the larva. There are eleven fairly big black stellate chromatophores in the anal fin-fold from about the middle of the body to the base of the caudal fin-fold. There are also scattered but rare small brown (or in places blue black) pigment spots both in the dorsal and anal fin-folds. The caudal fin-fold is practically free from pigments. At the distal extremity of the pectoral fin beginning from about the middle, pigments of a deep blue black colour are very densely situated.

The posterior region of the alimentary canal and anus are visible. A short opercular spine and a frontal protuberance are developed. The notochord is well developed and extends to the tip of the tail end.

Slightly older stages than these are available. They show a slightly heterocercal tail fin. The caudal fin-rays in these have just begun to develop, but are not yet segmented. In the anal fin-fold the number of chromatophores varies from 12-15 in number.

Plate xvii, fig. 9 (stage II) measures 13.25 mm. in length (including the middle caudal fin-rays). This is a much more advanced stage than fig. 8. The myotomes are well developed, and the myocommas are quite distinct. The longitudinal horizontal septum separates the epiaxial from the hypaxial portion of muscle segments.

The fin-folds have become discontinuous and we get a long dorsal, a caudal, and a long anal fin. The diphyrcercal and heterocercal stages have been passed through, and we get the homocercal type of fin characteristic of the adult. The caudal fin consists of 22 jointed fin-rays and is practically free from pigments. The ventral fin is short and slender and lies anterior to the pectorals on the ventral side of the body. It consists of 2 fin-rays only. The pectorals are composed of 13 fin-rays, and are deeply pigmented (blue black) towards the distal end. The dorsal and anal fins are composed of spinous rays which will be described in detail in the next stage. On each side of the dorsal and anal fins, and closely attached to them is a membranous fin-fold in which lie a row of pigments or chromatophores (fig. 9 *i*). The stellate chromatophores of fig. 8 are lost at this stage.

The frontal prominence and narial tentacles are developed. The eyes are well developed and acquire deep pigments. Two (only) opercular spines, one on each side of the body, are developed, their extremities having a curiously bent shape. Whether this is their natural condition or is due to injury (which seems more likely), I cannot say, but all the available medium-sized and large specimens (6 only in number) showed this bent condition. The pigments of the brain are visible dorsally through the cartilaginous cranium and the various elements which compose the adult skull are as

yet imperfectly developed. The operculum is fairly well developed and the gills may be easily made out under the microscope. The mouth is armed with sharp pointed teeth.

Plate xvii, fig. 10 (stage III) measures 15.9 mm. in total length (inclusive of the middle caudal rays). The myotomes are well developed. As far as could be made out under the microscope there are about 42 myotomes on each side of the body. The "concentration" of muscle segments must have taken place in the region of the paired fins, and in the most anterior and posterior regions of the body, but throughout its greater length the correspondence between muscle segments, radial muscles, unjointed fins or spines, and the superficially segmented dorso-lateral and ventro-lateral dorsal and anal fin-folds respectively—as I propose to call them—is very remarkable. A reference to figures 9, 10 and 11 will show that on each side of the dorsal and anal fins there is a membranous superficially segmented fin-fold containing towards the distal end a number of black pigment spots or chromatophores. These membranous fin-folds are devoid of spines (fig. 11c), and their segmented portions or processes are very short, flat and blunt. The dorsal fin consists of the conical muscle processes at the base, from the apex of which (I could not see any close connection between the two) arise unjointed rays or spines (fig. 11). A muscle segment or myotome corresponds with a radial muscle process, a spine, and a segment of the dorso-lateral membranous fin-fold on each side. This correspondence even in the post-larval stage lends support to the theory of segmentation in vertebrates. Certainly later on during development this arrangement undergoes a great deal of modification so essential to keep up the rigidity of the body in order to keep pace with the growingly active movements of the animal. The conical muscle prominences, which in all probability are radial fin muscles, seem to hide from view the corresponding radialia or somactidia, for they are not visible anywhere even under the high power of the microscope. These conical prominences are not yet separated from the myotomes from which they are developed.

A comparison with the *Petroscirtes* species juv. described by Max Weber in *Die Fische der Siboga Expedition*, published in Leiden, 1913, will show certain striking differences. Max Weber describes in his specimens the dorso-lateral folds as being provided with elongated spine-like processes, but in my specimens the processes are very short, flat and blunt. Again he shows only one pigment spot (which is comparatively bigger) in each segment of the anal fin close to the base of the spine, but in my specimens a number of comparatively smaller pigment spots lie more or less in a row not at the base of the anal fin, but at the apex of each dorso-lateral and ventro-lateral fin-fold segment. Again he shows the pigments only in the anal fin, but in my specimens they occur both in the dorso-lateral and ventro-lateral fin-folds in the same positions. He also shows a number of smaller spines in the operculum, which are absent from my specimens. These differences provide ample evidence to prove that my specimens belong to a different species to that described by Max Weber.

The caudal fin is composed of 24 jointed fin-rays. The pectoral and ventral fins are fairly well developed, the former being deeply pigmented towards the distal end. The opercular spine, eyes, and mouth are well developed. A short, blunt and flat

protuberance lies in front of the head above the mouth which I have called the frontal prominence. The mouth is provided with fairly well developed pointed teeth. Later post-larval stages would have shown interesting developments but unfortunately we have not got them.

Hemirhamphus limbatus, Cuv. and Val.

(Plate XVIII, figs. 1—6.)

Young stages of this species were taken in all parts of the Chilka Lake in fresh as well as in brackish water.

Some of the specimens in this collection do not seem to have been well preserved. However, a fairly gradual series of larval stages have been found, and the collection therefore is interesting. I have sorted out the specimens and divided them into 13 distinct stages. Some of the specimens were stained with Borax Carmine, and others with methylene blue. The latter brings certain structures, *e.g.*, cartilaginous skeleton and chromatophores, prominently into view and allows them to be traced for greater distances than the former does. But, on the whole, I found specimens stained with Borax Carmine more suitable for descriptive purposes. The accompanying table shows the length in mm. of body, snout and gas-bladder of the 13 larval stages I am going to describe.

Stage.	Length of body including snout and tail fin.	Length of snout.	Length of gas-bladder.	REMARKS.
I	2.5	.0841	?	Specimen not well preserved.
II	2.75	.1069	.1662	
III	3	.1187	.2375	
IV	3.75	.1306	.5770	Fin-fold still continuous, but slightly constricted towards tail.
V	6	.1425	3	More or less distinct tail fin: fin-fold still slightly continuous.
VI	6.75	.1544	3.125	
VII	7.5	.1781	3.5	
VIII	8	.1900	3.75	
IX	8.5	.2109	4	
X	10	.2375	4.5	
XI	10.5	.2612	5	
XII	11	.2850	5.25	
XIII	12	.3444	5.75	A young fish.

STAGE I. This is the smallest specimen I have come across. It measures 2.5 mm. in length. I have not sketched it, as the poor fixation of this specimen makes it difficult to determine the details of internal anatomy with any degree of accuracy. The eye and the gas-bladder is already formed. The lower jaw is prolonged into a slender beak. On the ventral surface a big chromatophore is present (see pl. xviii, fig. 1). The dorsal surface of the gas-bladder is pigmented. The tail is protocercal.

STAGE II. This specimen measures 2.75 mm. in length. The beak or snout becomes slightly more elongated and distinctly pronounced at this stage. The same chromatophore is present on the ventral surface. The tail begins to assume the heterocercal type, and the notochord and myotomes become fairly distinct. The cartilaginous development of the skull and visceral arch has begun. The cartilage cells are quite distinct.

STAGE III (pl. xviii, figs. 1 and 2). The eye is well developed and looks like an opaque black mass. Dorso-ventrally it is longer than laterally. The beak is curiously shaped, being bent in front like that of some birds. The visceral arches are well developed. Under the high power of the microscope, the visceral arches are seen to be lined by more or less parallel rows of cartilage cells. The heart lies just below and behind the basibranchial cartilage, and is in a fairly advanced stage of development. The various chambers are however just formed, and their connections and the various blood vessels which they give rise to are quite indistinct. The gas-bladder has an oval shape and is invested dorsally with pigment bodies. It is continued anteriorly into a hollow tube-like structure which seems to open just at the junction of the pharynx with the oesophagus. The notochord is well developed, and bends sharply upwards at the caudal end to form the beginning of the heterocercal type of tail fin. The myotomes and myocommas are developed, but the body is still more or less transparent. The alimentary canal is formed, but its different regions are rather indistinct. It lies close beneath the gas-bladder. Posteriorly it opens by the anal aperture. The glandular epithelium lining the internal cavity of the stomach is visible under the high power of the microscope, but the cavity of the stomach is very narrow. The spinal cord lies just above the notochord. The brain is also formed, but its various regions are indistinct. The liver is also formed and lies beneath the oesophagus and the anterior region of the stomach. It becomes more distinct in the next stage. The big stellate chromatophore still persists on the ventral side of the body. Except for this one, and those in the gas-bladder, no other chromatophores are to be seen in the body. The dorsal, ventral, and caudal fin-folds are still continuous and quite distinct.

STAGE IV (pl. xviii, fig. 3). The specimen has been sketched exactly as it was found with the mouth wide open. It gives a good idea of the relation of the upper and lower jaws. The cartilage cells are very numerous and prominent at this stage. The mandibular, hyoid, and branchial arches are all well developed. The last branchial arch is rather indistinct. Rows of papilla-like outgrowths appear on the first 4 branchial arches, those of the first 3 being quite prominent. These seem to be the rudiments of the branchiae. The opercular membrane also makes its appearance.

The hyoid arch has a curved shape, and the arches of both sides meet ventrally. At their point of junction is to be seen a small cartilaginous piece (probably basihyal) projected forwards,—its hinder portion meeting the anterior prolongation of the basibranchial. The various divisions of the arches are not yet differentiated. The cartilaginous cranium is formed and is still more or less transparent. The heart may be faintly made out, as before, beneath and behind the basibranchial cartilage. The gas-bladder takes an elongated shape, and its dorsal surface is deeply pigmented black. Its anterior prolongation becomes indistinct, but its posterior prolongation is quite distinct, and it seems to open just behind the anus by a distinct slit. The notochord is well developed, and is constricted off into a number of pieces, to form the beginning of the future vertebral column. The skeletogenous layer has started its work, and the skeletogenous cells may be seen in large numbers just at the base and above the notochord. In the latter place they are quite abundant, and may be seen to enclose the spinal cord. The heterocercal tail is fairly well developed, but the fin-rays have not yet made their appearance. The myotomes are well developed, and the transparency of the body is still to a large extent retained. The alimentary canal seems in some places to consist of a solid cord of cells, and the cavity is obliterated, but this may be due to external causes.

The liver may be seen as a thick mass of cells, in front of the stomach. The big stellate chromatophore still persists, though it is now much reduced in size. In addition to it, a number of small chromatophores (about 16) make their appearance on the ventral side of the body. The fin-folds are still continuous, though much narrowed towards the caudal end.

STAGE V (pl. xviii, fig. 4). This stage is much more advanced than stage IV. The intermediate stages which would have been very interesting are missing. The snout or beak does not seem to have kept pace with the enormous increase in the length of the body. In fact, I tried to establish a ratio between the length of increase of the body, the gas-bladder and the beak, but failed hopelessly. The above table (p. 388) will show that the increase in the length of the beak has no relation whatsoever with the development of the body.

The operculum is well developed and the branchial arches can only be indistinctly made out. The papilla-like outgrowths have reached a considerable size and are quite a characteristic feature of this stage. The cranium is fairly well developed, and its transparency is lost. The gas-bladder has kept pace with the increase in length of the body and the same is the case with the alimentary canal. The position of the gas-bladder in the body is now denoted only by a long series of deeply pigmented bodies close beneath the notochord. On a careful examination under the high power of the microscope a dense network of capillaries may be seen lining the walls of the gas-bladder. These capillaries probably form the "retia mirabilia" or "red bodies" of the adult. They are arranged in fan-like tufts over almost the whole extent of the inner surface of the gas-bladder. Owing to the opacity of the body the notochord is not distinctly visible, but it is being gradually enveloped by the skeletogenous cells to form the future vertebral column. The condition of the tail is midway between

the heterocercal and homocercal type—a rather nearer approach to the latter. The caudal fin-rays are quite distinct.

The gradual growth of the myotomes has increased the opacity of the body. The chromatophores of the last stage have all disappeared, except of course those of the gas-bladder. In their place we find a paired ventral row of chromatophores, which probably become attached together and form a continuous streak between the anus and the caudal fin. A middle paired row (one on either side of the body) consisting of about 24 chromatophores, occurs on the sides of the body and in a lateral view seems to lie over the notochord. A dorsal paired row lies on the dorsal surface of the body. Each row consists of 16 distinct anteriorly situated chromatophores, and a continuous streak posteriorly consisting of about 9 chromatophores. Pigment spots also make their appearance in the upper jaw. Large irregular pigment bodies are to be seen on the dorsal and lateral sides of the head. They are irregular in their distribution (not shown in the figure). Ventrally in the anterior region of the trunk close behind the head, a line of small black pigment spots make their appearance. The dorsal and ventral fin-folds still exist, though in a much more modified form. The dorsal and anal fins are developed, but their skeletal structures are not yet visible.

STAGE VI (pl. xviii, fig. 5). There is not much difference between this stage and the previous one. The snout in particular shows very little increase, while the general increase in length is .75 mm. The bony framework of the skull is developing fast and the head region has become quite opaque except on the ventro-lateral edge, where the branchiae are just visible through the operculum. The gas-bladder becomes more densely pigmented. All the 3 paired rows of pigments described in the previous stage are present. The pigments in the head region are repeated again as in the previous stage, except that now the beak also acquires pigments.

The tail acquires true homocercy. The caudal fin-rays are well developed, and faint traces of segmentation are visible in it. The myotomes have considerably grown in thickness and nearly completely hide the notochord from view. There are about 45 myotomes of which 40 are quite distinct. The dorsal and anal fins are fairly well developed and their skeletal structures are also visible. Very faint traces of them were really found in the previous stage. A careful examination under the high power of the microscope reveals the presence of pterygiophores (Parker) or radial elements (Bridge). Corresponding to each fin-ray there is a baseost and an axonost (Cope), the former lying between the heads of two adjacent axonosts as a small round body. The ventral fin-fold still persists, though the dorsal fin-fold disappears. Another striking feature is the appearance of the pectoral fin close behind the operculum.

STAGE VII. The general pigmentation of the body is the same as in the previous stage. The pigments in both the upper and lower jaws and the head are better developed than in stage VI. The fins are pigmented.

STAGES VIII, IX, X, XI, and XII. These stages are marked by the gradual growth of the body beak, and gas-bladder. The pigmentation is practically the same as in stage VII. A gradual growth of the gills, the bones of the skull, and the

skeletal structures of the pectoral, caudal, dorsal, and ventral fins takes place. The ventral fin-fold persists, and the pelvic fin has not yet made its appearance.

STAGE XIII (pl. xviii, fig. 6). The specimen measures 12 mm. in length. The myotomes are fully developed, and more or less completely hide from view the organs inside the body. The prolongation of the lower jaw as snout or beak becomes quite a prominent feature, being just over $\frac{1}{3}$ of a mm. in length. The pelvic fin makes its appearance for the first time. The dorsal and anal fin-rays are well developed. The dorsal fin contains 11 distinct and 2 or 3 indistinct fin-rays. The anal fin contains 14 distinct fin-rays. The ventral fin-fold still persists though faintly, but seems to be interrupted or folded up in the region of the pelvic or ventral fin. The animal is now really a young fish in nearly all respects, and thus marks the termination of the larval stage.