OBSERVATIONS ON THE BREEDING HABITS AND DEVELOPMENT OF CERTAIN BRACKISH WATER FISHES OF ADYAR, MADRAS.

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Introduction.

This work is part of a scheme proposed for the study of the brackish water fauna of the Adyar river. The Adyar backwater has an area of about 1 sq. mile lying about five miles to the south of Fort St. George. The water is shallow and practically stagnant during the greater part of the year except soon after the rains when connection is effected between the sea and the backwater, which are otherwise separated by a sand-bar. The temperature ranges from 25° C. to 33° C. and the salinity varies from 31 to 16 per mille.* This fall in salinity is really due to the influx of fresh water which the river brings after the bar is closed. The bottom is composed of loose mud with plenty of algal growth in the shallower regions. The only places where hard substrata are available for attachment of animals are near the Elphinstone Bridge and opposite the Theosophical Society Buildings where there is a stone embankment. The water here is rather deep and the place sufficiently protected for the young fishes to develop in fair safety. A comprehensive account of the Adyar backwater is given in a paper by Prof. R. Gopala Aiyar and Mr. N. Kesava Panikkar on the "Brackish Water Fauna of Madras" in course of preparation.

Very little attention has been paid so far to the study of the development of the brackish water fishes in India. The earlier works in this connection are those of Willey (1910 and 1911), Sundara Raj (1916), Bhattacharya (1916), Panikkar (1920) and Aiyar (1935) whose accounts are often incomplete.

Collections of eggs were made fairly regularly and observations were made on living material on the spot and after bringing them in clear water to the Laboratory. Care was taken to compare developmental stages obtained from the river and similar stages in the batches of eggs brought

from there and allowed to develop in the Laboratory under suitable conditions. In the case of *Boleophthalmus boddarti* eggs were artificially fertilized in the Laboratory and development followed.

The breeding habits and development of *Acentrogobius viridipunctatus*, *Petrosicirles bhattacharyae* and *Boleophthalmus boddarti* are made known for the first time though unfortunately that of the last mentioned one is still incomplete. The occurrence of external gills in *A. viridipunctatus* is very interesting and is made the subject of a separate paper. The cement organs of *Etioplus maculatus* have been studied in detail and are dealt with in another paper. In regard to *E. maculatus*, *E. suratensis*, *Aplocheilus melastigma* and *Panchax parvus* more complete developmental details are given.

*Etioplus maculatus* (Bloch).

The eggs of this form were first observed about the middle of August 1935 just after the first monsoon rains. The mother chooses the vertical edge of a stone or molluscan shell raised about a couple of inches above the bottom and lays a few eggs at a stretch allowing the male to fertilize them now and then. This is repeated, the male and female intermittently taking the responsibility of driving away other fishes which happen to come anywhere near. Panikkar (1920) has given a graphic account of the egg laying habit of *Etioplus suratensis* which tallies with my observations on *Etioplus maculatus*. Jerdon (1848)† and Sundara Raj (1916) have recorded their observations on the breeding habit of *E. maculatus* which were supplemented later by Panikkar.

No complete record exists about the development of *E. maculatus*. Sundara Raj (1916) and Panikkar (1920) have given rather an incomplete account of the larval development only. Same is the case with the account of *E. suratensis* by Panikkar who only gives a short life-history of this form.

The eggs of *E. maculatus* are peculiar in that the yolk is of a greyish brown colour, as also are the immature eggs in the ovary. This may help to serve as a sort of protective colouration as it harmonizes very much with that of the surroundings where they are generally deposited. They are oval in shape and measure 1.7 mm. in length and 1 mm. in breadth.

*Development.*—Fertilization seems to take place almost immediately after the eggs are laid and on examining a brood half an hour after oviposition most of them had reached the four-celled and eight-celled stages while

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† It appears that the form *Etioplus coruchi*, the parental care of which Jerdon gives is really *E. maculatus*. Day (Fauna of British India, Fishes—II, p. 430) quotes Jerdon's observations with reference to *E. maculatus*.
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some were in the two-celled stage and a few undivided. Evidently those that were undivided were the last to be laid or were the last to be fertilized. In these the protoplasm had collected together at the free end of the egg in the form of a blastodisc (Fig. 1) which is granular and devoid of any yolk. The undivided eggs within five minutes divided into two blastomers (Fig. 2) showing that the first division takes place about thirty-five minutes after fertilization. The yolk portion is full of small scattered oil globules which do not coalesce at this stage. (The large number of very small oil globules are not shown in the figures.)

Twenty minutes later, i.e., 55 minutes after fertilization the two blastomers divide to give rise to 4 (Fig. 3) and these, 35 minutes later, into 8 (Fig. 4). Further divisions were quite rapid and difficult to follow. Soon the whole embryonic area was converted into a cap-like cluster of small cells (Figs. 5 and 6). The blastoderm which remained like a cap at the top of the yolk gradually began to grow down towards one side (Fig. 7) and a thin layer of it began to spread over the surface of the yolk. The minute oil globules in the yolk coalesced and increased in size.

About 12 hours after oviposition the embryonic ridge is visible as a median thickening in the blastodermic area (Fig. 8). By this time the cells are greatly diminished in size. The thickened median ridge, which is the embryo proper, grows downwards along one side with the thin layer of blastoderm enveloping the yolk as a film (Fig. 9). As the embryo increases in length the head portion towards the top gets larger in size and the tail end grows downwards (Fig. 10). Twenty-eight hours after fertilization the contour of the dorsal surface of the embryo gets gradually distinct (Fig. 11). Two hours later the blastoderm completely envelopes the yolk mass which becomes internal (Fig. 12). Almost simultaneously with this the rudiments of the eyes make their appearance and the somites in the anterior portion of the trunk gradually become visible (Fig. 13).

The embryo rapidly grows in size. The eyes become larger. Four hours later, i.e., about 38 hours after fertilization the auditory vesicles appear with two minute concretions and the tail end of the embryo grows broader. The first sign of movement sets in with faint and intermittent pulsation at the region of the heart (Fig. 14) when about 18 somites are formed. Forty-eight hours after fertilization the blood circulation is complete and the embryo wriggles inside the egg-membrane (Fig. 15). The tail portion of the embryo continues to grow round the yolk on which chromatophores appear (Fig. 16). The oil globules coalesce to form a large one. Eight hours later, i.e., about 58 hours after fertilization, the tail of the animal almost completely encircles the yolk mass. On the morning of the
4th day when the embryo is 72 hours old hatching takes place. The egg-case breaks open above the dorsal side of the head and the tip of the tail is thrust out (Fig. 17). By vigorous movements of the tail the opening is widened with the result the tail projects out resembling the root of a germinating pea-seed and the larva moves about very actively at the bottom with the anterior portion of the body still within the egg capsule (Fig. 25, *Etrophus suratensis*).

The larva comes suddenly out of the covering in the bent form. It remains quiescent for a couple of seconds as if taken aback by the abruptness of its exit; but loses no time to regain its activity and straightens up and moves with the head downwards at the bottom by the lashing movements of the tail.

Each larva measures 4 mm. in length. The head is attached to the yolk mass. The pigmentation of the eyes is so little that they are almost transparent. Mouth and anal openings are absent. Pectoral and pelvic fins are not developed. The median fins are all continuous and devoid of fin rays. The yolk has a single large oil globule and its surface is pigmented by closely arranged stellate chromatophores. The larva always rests at the bottom and never comes up to the surface.

A very interesting feature of this period is the presence of three pairs of cement glands on the head. Sundara Raj (1916) says that *E. maculatus* has two cement glands only and figures them as two star-shaped structures. Panikkar (1920) and Willey (1911) refer to their presence in the case of *E. suratensis*, but do not mention the number. Two pairs are dorsal, situated close together just above the eyes and the other pair is smaller and situated in front of the eyes just above the olfactory organs. Each gland is a small conical elevation with a concave depression at the top. The surface of the depression is lined with numerous mucous gland cells, the secretion from which fills the gland cavity and then oozes out continuously in the form of threads, which help to anchor the larvæ down to one place.

The larva assumes a slanting position with the head downwards and the ventral side up. It has a superficial resemblance to a tadpole. A large number of larvæ collect at one spot and the mucous threads help to hold them together (Fig. 20). When disturbed they detach themselves easily from the common mucous mass and move off; but gather in one place again.

On the second day (Fig. 21) pigmentation in the eye is greater though not complete. The rudiments of the pectoral fins appear. Sundara Raj
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(1916) has shown the heart dorsal to the yolk sac in the place of the pectoral fins. Chromatophores appear on the body above the yolk sac and on the dorsal side of the head.

On the third day the mouth and the gill slits are developed. The pectoral fins grow in size. Chromatophores increase on the dorsal side of the head and the nape. The yolk gets considerably reduced. The single oil globule persists.

On the fourth day (Fig. 22) the pectoral fins are capable of slow movement and along with this the cement glands become less active. Some of the larvae lie on their sides and the rest with their dorsal side above. The greater part of the yolk is absorbed, the oil globule being the last to be consumed.

On the fifth day most of the larvae come swimming up. The cement glands completely cease to function.

It has not been possible to see on what the young larva feeds. Fig. 23 shows a seven-day old larva. The caudal fin has become heterocercal and the anus is also formed. The caudal fin rays become visible on the tenth day.

In natural conditions, as soon as the time for hatching comes, the parents dig a small pit in the mud and transfer the eggs by their mouth into it. All the eggs are deposited in this manner and soon after hatching the larvae are removed to fresh pits. This is continued till the larvae are able to swim.

By the peculiar habits of the parents mentioned above these top heavy larvae are virtually imprisoned in the pits. This helps to keep them together making the task of protection by the parents easy as otherwise their inability for independent movement will result in their destruction. Even after the larvae are able to swim about independently and take food for themselves they are watched over by the parents for a considerably long time. During this period they do not come very near the surface. The slightest disturbance or apprehension of danger will send them shooting down to the bottom. The parents in their zeal to protect their brood will even snap at one's fingers as happened to the present writer many a time!

*Etroplus suratensis* (Bloch).

The breeding habits of *Etroplus suratensis* are similar to those of *E. maculatus*. I have seen the broods of these two forms fairly close together with continual war between their parents when one unconsciously trespasses the domain of the other. Willey (1911) was
the first to observe the nest and parental care of this form. Panikkar (1920) has given a detailed account of the breeding habits and development though he does not say anything relating to the early development within the egg-membrane. He does not figure any of the stages. The embryonic development of this form agrees so closely with that of *E. maculatus* in all details that it need not be described here.

Each egg is 2 mm. long (Fig. 24) and is similar to that of *E. maculatus* in shape and colour, though slightly larger in size. When the time for hatching comes, which is on the fourth day (*i.e.*, 72 hours after fertilization as in *E. maculatus*), the egg-case above the head of the embryo splits and the tip of the tail is thrust out (*E. maculatus*, Fig. 17). The opening is widened by the vigorous lashing movement of the tail till a good length of it is outside (Fig. 25). The larva moves about in this condition for some time till with a sudden effort the portion of the body inside the capsule turns through a semicircle, as a result of which the head comes at the base of the egg capsule (Fig. 26). Now the caudal portion of the larva is outside and it moves about just as the normal one with the capsule still around it, sometimes for quite a long time, till finally the opening gets sufficiently widened for the whole animal to come out.

The larva (Fig. 27) measures 4·3 mm. in length after hatching. The secretion of the cement glands is more profuse than in *E. maculatus*. Mouth, anus and gill slits are absent. The eyes are devoid of pigment.

The larvæ crowd together at the bottom with their ventral side up as in the case of *E. maculatus* (Fig. 20) continually vibrating their tails. When disturbed they move away along the bottom and crowd together again adopting a slanting position.

On the third day after hatching (Fig. 28) scattered chromatophores appear on the dorsal side of the head and nape. Mouth and gill slits are developed. The pigmentation of the eyes which began on the second day is completed by this time. The yolk persists with the oil globule in it. The pectoral fins are incapable of independent movement. The cement glands are still active.

On the fourth day the pectoral fins are capable of movement and simultaneously with this the cement glands become inactive. By the seventh day two concentrated patches of chromatophores are formed on the dorsal side of the head. Those on the body are more diffuse. The teeth are developed and a notch appears on the caudal fin. On the eighth day (Fig. 29) the anus is formed, the caudal fin shows fin rays and the animal begins to feed voraciously on algae.
The larvae of both *E. maculatus* and *E. suratensis* are very much alike except for the slightly larger size of the latter. The difference in the nature of the chromatophores is so little that it is very difficult to distinguish one from the other. The larvae are watched over by the parents exactly as in *E. maculatus*.

When the bar opens and the sea water comes in, eggs are not laid. Developmental stages of the larvae have not been met with when the bar was open. Very probably the parents go up the river into less saline conditions. This has been the case in the Cooum† also near the bar where an examination of catches of fishermen did not show the presence of any of these fishes when the bar was open.

*Acentrogobius viridipunctatus* (Day).

The eggs of this form could be obtained from Adyar throughout the year which shows that it is a perennial breeder. They are fairly common along the southern bank of Adyar (near the Theosophical Society Buildings) where there are plenty of stones. Eggs are generally found inside oyster shells and narrow crevices between stones. In all cases the male parent remains inside the shell or crevice as the case may be, aerating the eggs and guarding them against other egg-eating fishes. One male fish that was guarding the eggs was found with wounds probably inflicted by some other fish. The mother has never been found near the eggs except at the time of oviposition. Hence this is another instance of paternal parental care commonly seen among Gobies. This habit has been noted in the case of its congener, *Acentrogobius neilli* also, the development of which has been worked out in this Laboratory by Prof. Gopala Aiyar (1935). This form lays its eggs attached to thick clusters of algal filaments inside oyster shells, in the crevices between stones and on decaying wood. The eggs are smaller than those of *A. viridipunctatus* and there is some difference in the shape of the egg-case after fertilization. The early stages in the development of both the forms are very much alike.

For the purpose of laying eggs the mother usually chooses an oyster shell, the inner surface of which is quite clean. Newly submerged cement blocks, tiles and crevices of stones without any encrusting growth are also chosen for the purpose. Oviposition in all the cases I have come across, takes place at sunrise. At this time the urinogenital papilla of the female becomes long, stout and highly vascular forming a temporary ovipositor. A few eggs are laid at a time and the male which remains outside the shell

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† A large drainage channel within the Madras City which is generally called the river Cooum.
till then goes inside and pours its milt over them and fertilizes them. These acts are repeated by the couple as a result of which immediately after oviposition one can see the eggs in varying degrees of development. After all the eggs are laid the female leaves the place and the male takes charge of them and remains inside the shell until the time of hatching. During short periods of captivity in the Laboratory aquarium the parents were seen to exhibit cannibalistic tendencies by devouring eggs and young larvae.

An unfertilized egg is round and yellow in colour and measures 0.8 mm. with a ring of transparent threads that help to anchor it to the substratum as soon as it is laid. After fertilization the zona radiata swells up and it measures 2.4 mm. in length. The adhesive threads elongate giving rise to a hollow stalk. As many as three thousand eggs are laid at a time, though the number varies considerably. The eggs are arranged fairly close together without touching one another.

The earliest stage observed is an hour and a half after fertilization when four cells are formed (Fig. 30). A very large number of small oil globules are seen in the yolk which never coalesce to form a single one as in A. neilli. Twenty minutes later the next division into eight cells takes place (Fig. 31). Sixteen and thirty-two celled stages are reached two and two and a quarter of an hour respectively after fertilization (Figs. 32 and 33). Five hours after fertilization the blastomeres appear as a cluster of small cells (Fig. 34). The blastodisc is distinct when seven hours old (Fig. 35) and three hours later the embryonic ridge appears as shown in Fig. 36 as a medium thickening in the blastoderm, which spreads as a thin film round the yolk mass. When twelve hours old (Fig. 37) the head end becomes larger and the blastoderm completely envelopes the yolk mass. In the eighteen hours old embryo (Figs. 38 and 39) the neural groove is clear, the rudiments of the eyes are formed as thickenings of the ectoderm and somites appear at the posterior region. The optic and auditory vesicles are formed and the caudal end grows free, when the embryo is about twenty-four hours old (Fig. 40). In a thirty-six hours' old embryo (Fig. 41) the tail is free, the eyes are distinct and the heart can be seen as a tube between the head and the yolk mass. The heart begins to pulsate when about twenty-two somites are visible in the trunk. Meanwhile two concretions are formed in the auditory vesicles. When the embryo is about forty-eight hours old (Fig. 42) blood corpuscles are formed and shortly after, circulation begins. The animal now moves its tail gently inside the egg capsule.

When the embryo is about seventy-two hours old (Fig. 43) the important embryonic blood vessels are formed. The dorsal and anal fin folds
are formed. Pectoral fins can be seen as bud-like projections. In the eighty-four hours' old embryo the anterior end of the ventral aorta at the base of the hyoidean arch, where it divides into the two hyoidean arteries, pushes out the body surface to form the first common rudiment of the external gills.

*Four Days' Old Embryo* (Fig. 44).—The eyes turn dark and the pectoral fins become larger. The air bladder is formed. A large single chromatophore very characteristic of this form, appears ventrally at the middle of the tail portion. The external gill rudiment is longer with a notch at the tip.

*Five Days' Old Embryo* (Fig. 45).—The eyes begin to shine. The external gills reach as far as the mouth. The pectoral fins have become very large and are kept close to the body. The yolk gets considerably reduced. The notochord shows a tendency to bend upwards at the caudal end so as to give a heterocercal appearance. Peristaltic movement has begun in the intestine and the gall bladder can be seen as a pale yellowish green body.

*Six Days' Old Embryo* (Fig. 46).—The external gills grow round the snout and reach as far as the eyes and are now and then flicked by the animal. They are two, simple, non-pinnate structures partially united at the base. The very large hyoidean arteries constitute the vascular loops of the external gills. The gill slits are formed and the internal gill lamellae have begun to develop as small buds. The pectoral fins are intermittently moved. The animal occasionally wriggles inside the zona radiata.

Hatching takes place when the embryo is five to seven days old, though six days is the usual time. If a larva does not come out after the seventh day it dies as is very commonly observed in the laboratory aquarium. External gills are poorly developed and are with defective blood supply in unhealthy embryos which seldom hatch out and survive. The egg-case breaks open at the distal end and the animal comes out head first. Simultaneously with the exit of the larva the external gills become non-functional and shrink up into small structures on the ventral side (Fig. 47). The larvae can be extracted a few hours earlier without any apparent ill-effect. The force of a current of water pressed out of an ordinary pippette will bring out a fully developed larva.

The larva when it comes out is 3.3 mm. long and has a small quantity of unconsumed yolk as shown in Fig. 47, the surface of which is pigmented with stellate chromatophores. Mouth, anal opening and gill slits are present. The pectoral fins are devoid of fin rays. Between the yolk sac and the anus is a small pre-anal fin. The notochord is distinctly turned
dorsalwards (heterocercal) at the caudal end and the caudal fin is usually provided with about 10 fin rays. The auditory organ (Fig. 49) differs very much from that of \textit{A. neilli} (Fig. 50). Between the tail end and the anus is a large conspicuous stellate chromatophore with a beautiful reddish brown colour. This chromatophore is very characteristic in this form, and the others in front and behind are much smaller and inconspicuous. The larva usually moves about at the bottom and rarely comes up to the surface.

On the second day all the yolk is consumed and the liver becomes visible. The shrunken external gills either disappear or remain as minute rudiments. By the third day all traces of the external gills are lost. The notochord near the anterior end gradually gets curved. Within a week in the Laboratory aquarium the larva develops thirteen fin rays in the caudal fin (Fig. 48). The rudiments of the dorsal and anal fin rays are also formed. No other appreciable change takes place other than an increase in size. It has not been possible to observe on what the animal feeds at this stage.

The young larva or the well-developed embryo of this form can be distinguished from that of \textit{A. neilli} on account of the following characters:—The larger size, the difference in the structure of the auditory organs, the presence of external gills, the large conspicuous chromatophore on the ventral side of the trunk, the absence of any large oil globule in the yolk, the heterocercal fin and the early development of the caudal fin rays.

Before the opening of the bar at Adyar but some time after the rains start the eggs of this form could be obtained in fairly large numbers; but afterwards only very seldom, though the adult specimens were found in abundance.

\textit{Boleophthalmus boddarti} (Pallas).

This interesting mud-skipper is fairly common in all cool and miry situations east of the Elphinstone Bridge, Adyar. About the breeding habits of \textit{Boleophthalmus boddarti} I could find no record of any definite observations except those by Harms.\footnote{Harms, \textit{J. W., Zeit. f. Wiss. Zool. Bd.}, 1935, 146.} According to him both \textit{Periophthalmus} and \textit{Boleophthalmus} are viviparous. Well-developed embryos, he says, were found within the ovary of the former which came out at the slightest pressure. He is not certain at what stage the young ones come out. A large number of females of \textit{B. boddarti} from Adyar was examined throughout the year, but none of them showed any developing embryos in the ovary.

A thorough search was made for their eggs which having ended in failure, an effort was made to artificially fertilize the eggs, obtained by
stripping the mature specimens. Except in a single instance the ovary was found to contain unripe ova. In the single specimen where ripe ova were present artificial fertilization was successful. Unfortunately as development proceeded the embryos began to die and though in many cases they were almost fully formed none of them hatched out. Apart from this, during the course of development many abnormalities were noted in a good number of embryos probably due to Laboratory conditions.

The ripe ovum before fertilization is 0.8 mm. in diameter. It is a round semi-transparent body with a cluster of adhesive threads sprouting from one side. The presence of anchoring threads show that as in Acentro gobius they should get attached to some surface as soon as they are extruded. It is very likely that the fertilization of the egg takes place externally. In the centre is a small group of oil globules. Soon after fertilization the zona radiata gradually swells out into an ovoid capsule and the protoplasm streams to the attached lower side of the egg to form a granular cap (Fig. 52). The attached side of the egg membrane from which the threads sprout, does not swell up in uniformity with the remaining portion with the result that the egg-case becomes almost club-shaped. The zona radiata attains a maximum length of 1.6 mm. Half an hour after fertilization the protoplasm divides into two to give rise to the two primary blastomeres (Fig. 53). This again divides into four (Fig. 54), eight (Fig. 55) and so on till three hours after fertilization they form a cap of closely packed cells (Fig. 56). Seven hours after fertilization a thin layer of blastoderm completely encircles the yolk and the embryo proper is formed in it as a median thickening (Fig. 57). When the embryo is seventeen hours old the head and the tail portions are distinct, though still attached to the yolk (Fig. 58). In a twenty-four hours' old embryo the caudal portion is free and the head comes to lie at the free end of the egg capsule (Fig. 59). Somites are formed in the trunk portion and a space is formed between the yolk and the head which locates the position of the heart. The optic vesicles are developed. The animal is incapable of any movement inside the zona radiata.

Forty-eight hours after fertilization (Fig. 60) the embryo is well developed with a considerably long tail which comes round the much diminished yolk and almost touches the head. The eyes are devoid of any pigment. The auditory vesicles have two minute concretions. The oil globules are much reduced in number. The embryonic circulation is well advanced and the animal wriggles actively inside the egg-case.

Many of the embryos were found to be living till about fifty-four hours after fertilization. When re-examined twelve hours later they were all
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found dead. This happened in spite of repeated changes of water and all efforts to keep it at the water temperature of Adyar.

Incidentally I take this opportunity to record the feeding habit of this form which is quite at variance with the observations of previous workers. *Periophthalmus* is known to be predaceous in its habits.\(^2\) On account of the close similarity in external features and habit the prevalent belief is that *Boleophthalmus* also is carnivorous.\(^3\) I have had the opportunity of making a very careful study of the feeding habits of this form in the Adyar backwater which has revealed that it entirely depends for its food on micro-organisms only. The examination of the stomach contents, throughout the year, of a very large number of specimens has definitely proved beyond any doubt that the chief food of the animal consists of microscopic unicellular algae, mostly diatoms, both littoral and planktonic. Sometimes copepods are also found among these, but they are very rare except in two instances where the stomach contained fairly large quantities of them. The non-predaceous habit of this form is corroborated by the observations made on the living specimens both in the Laboratory aquarium as well as in their natural habitat. In captivity even if the animal has to starve for weeks together it has not been noticed to feed, though a variety of food has been offered.

*Petroscirtes bhattacharya* Chaudhuri.

This form was first described by Chaudhuri\(^4\) in 1916 from Chilka Lake. Two large specimens were captured from Adyar from inside oyster shells, of which one was guarding its eggs. Bhattacharya (1917) described the larvæ of this form belonging to three different stages collected from Chilka Lake. Apart from this nothing is known about its breeding habits and development.

Eggs of *P. bhattacharya* were obtained in January 1936 when they were found inside an empty oyster shell attached to a stone at a depth of about two and a half feet of water, in front of the Theosophical Society Library, Adyar. There were about 900 eggs most of which were attached to the lower valve adhering to the rock, the upper valve containing only a very small number. The eggs were of a dull orange colour except a few towards the periphery which were beautifully pink. The whole lot was arranged in a compact manner without leaving any space between them (Fig. 61).

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Each egg has the shape of a depressed dome (Fig. 62) with the attached ventral side flat, giving it a circular outline when viewed from above. The height is 0.53 mm. and diameter 0.80 mm. Its peculiar shape should have been brought about only after oviposition. The flat ventral side and the greater part of the curved surface are covered by the adhesive substance which helps in the attachment of the egg.

An interesting feature observed was the considerable disparity in development found among the eggs of the same brood. In a few, towards the periphery of the egg mass only the embryonic ridge was just formed (Fig. 62) and these did not show more than two or at the most three days' development. These were quite healthy ones and their development was followed. Most of the remaining eggs were in a much advanced state of development, showing a difference of about six days between them. In these the embryos were fully formed with pigmented eyes, complete blood circulation, etc. (Figs. 68 and 69). Intermediate stages between these were also found.

First Day.—Eggs showing very early stages were chosen for following the development. These were the pink ones, situated towards the periphery. The embryonic ridge could be seen as a clear band at the top of the yolk mass (Fig. 63). A single large characteristic oil globule was present in all the eggs including those of the advanced stages.

Second Day.—As development proceeds the embryo situated on the dorsal side of the egg gradually turns to one side (Fig. 64). The process is slow as it is considerably handicapped by the peculiar shape of the egg.

Third Day.—The optical vesicles now form (Fig. 65) and the embryo sinks partially into the yolk mass.

Fourth Day.—Some of the somites in the middle of the trunk are now conspicuous (Fig. 66). The caudal end grows free from the egg mass. The heart has begun to beat and a slow circulation is visible. Scattered pigment appears on the yolk mass. The neural groove is distinct.

Fifth Day.—The embryo rolls over and the yolk mass is now on the upper side (Fig. 67). The tail gets elongated and is always kept on one side. The blood circulation is completed. The vitelline circulation is very characteristic as in the European blenny, Anarrhichas lupus. Pigmentation increases. The eyes are devoid of any pigment. The beautiful pink colour of the yolk is lost and it changes into dull orange.

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Sixth Day.—The lenses are formed. The eyes acquire a dark tinge. The auditory vesicles become visible (Figs. 68 and 69). It was in this condition that the majority of the eggs were found at the time of collection (Fig. 61).

Seventh Day.—Pigment is formed on the inner side of the abdominal wall, giving it a dark appearance, which on casual observation would appear as external. Two minute concretions are formed in the auditory vesicles. Pigment appears on the anterior end of the head above the fore-brain (Fig. 70).

Eighth to Tenth Day.—Pectoral fins are developed (Fig. 71). Gall bladder becomes visible. The yolk gets gradually reduced, as a result of which it loses its original round condition, and becomes first heart-shaped and then crescent-shaped. The oil globule becomes smaller in size. The eyes turn bright and shining.

Eleventh Day.—Yolk is considerably used up as a result of which the orange colour imparted to the embryo is lost. The oil globule still persists, though reduced in size. The pigmentation in front increases and two rows of pigment are formed on the ventral side of the tail portion (Fig. 72).

Twelfth Day.—The larva comes out, head first, by an opening made on the upper side of the shell. At the time of hatching very little yolk remains though the oil globule persists. Fig. 73 shows a larva just in the act of coming out and Fig. 74 an empty egg shell.

It was said at the beginning that the eggs contained both early as well as advanced stages of developing embryos. This difference in the development was kept up till the hatching time, when the first set hatched out seven days before the last. The time taken in the Laboratory for the eggs which showed the earliest stage of development was twelve days and these could not have been more than three days old when collected. So roughly it takes about fifteen days for the eggs to hatch out—a very long time when compared with that of most other fishes at Adyar.

Larva: First Day.—A newly hatched larva measures 3 mm. in length (Figs. 75 and 76). From the time of its coming out it begins to move about actively remaining mostly at the bottom. The mouth opening which is absent at the time of hatching is developed on the first day itself. The pectoral fins are fairly large and functional and their bases are darkly pigmented. The dorsal, caudal and anal are continuous. A pre-anal fin is absent. Ventrals are undeveloped. A characteristic feature is the presence of two rows of chromatophores on the ventral side of the body behind the anus (Fig. 77). The pigmentation formed early in front of the head of the
embryo still persists. Apart from this there are tiny scattered pigment granules on the head and body. An opercular spine becomes visible on each side as a minute cone.§

The youngest lot of larvæ of Petroscirtes bhattacharyæ described by Bhattacharya (1917) is about 3.25 mm. long. The arrangement of the chromatophores in them is as in the newly hatched one. Those described by him should be some days old as is evident by the greater length of the body and opercular spines.

Larva: Second Day.—The lower jaw grows forwards and projects beyond the upper. The opercular spines become prominent and a second pair grow in front. The pectoral fins get more pigmented. The yolk is completely absorbed (Fig. 77).

Larva: Third and Fourth Day.—The opercular spines grow longer and appear as in Fig. 78. The larvæ did not live in the Laboratory for more than four days. Bhattacharya mentions only one spine in the youngest lot of larvæ described by him. Hence, it is very likely that only one of the two spines on each side grows long as the embryo grows in size. In the two lots of older larvæ also described by him, the opercular spines are present. The characteristic chromatophores on the ventral side have disappeared and except for the presence of prominent opercular spines many of the adult features have formed. The second and the third sets of larvæ measure 13.25 and 15.9 mm. respectively.

Aplocheilus melastigma McClelland.

Aplocheilus melastigma and Panchax parvus are well known as insect larvicides. Both forms are common in the fresh and brackish waters of Madras and their eggs usually found attached to algæ, can be obtained throughout the year from the Cooum and Adyar except in times of very heavy rains. Brief accounts of their development are given below:—

The eggs of A. melastigma are generally found attached to algal filaments (Enteromorpha and Chatomorpha) at Adyar and Cooum either singly or in small clusters. Before the eggs get attached to the algæ they are carried about by the mother in large conspicuous clusters on the ventral side first noticed by Jenkins (1910). Sundara Raj (1916) has given diagrams and descriptions of the eggs and young larvæ, though in the figures of the eggs the threads are shown too stout and sparse. No detailed account of their development is given.

§ The opercular spine, which is only a juvenile feature, is absent in the adult.
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Eggs are round and 1.1 mm. in diameter, covered all over with short filamentous threads which are too short to be of an adhesive nature (Fig. 79). From one region alone a thick cluster of long slender threads is given off which helps in the attachment of the egg to the algae. The yolk is of a clear transparent nature with a large oil globule.
The earliest stage of development that I have observed in the eggs attached to the ventral side of the mother is that in which the blastoderm has formed and has begun to spread round the yolk (Fig. 79). The embryonic region becomes clear on the second day (Fig. 80). The embryo lies sunk in the yolk. The rudiments of the eyes and the neural groove are visible.

On the third day (Fig. 81) the neural groove is large and conspicuous. The embryo becomes larger in size. Auditory vesicles are formed. The eyes begin to get pigmented and the lenses become visible. Circulation has begun, though not very vigorous. The somites are very clear throughout the trunk. The tail gets elongated and freed from the yolk. The embryo is incapable of making any movement.

On the fourth day the eyes are strongly pigmented. The yolk sac circulation is complete. The tail grows much longer and comes round the yolk. Pigment is formed in the body including the yolk sac. The animal wriggles inside the egg membrane.

On the sixth day (Fig. 82) the eyes become bright and shining. The chromatophores get definitely arranged in the body. No appreciable change except in the reduction of the yolk is noticed till it hatches out.

The minimum time for hatching is eight days and by this time practically all the yolk is absorbed. The larva moves about actively as soon as it comes out and measures 4·5 mm. in length on the first day. It always swims along the surface of the water. The dorsal fin which is continuous with the caudal is very small and starts far behind. The caudal fin is heterocercal and provided with fin rays (Fig. 83). The arrangement of the chromatophores in five rows on the trunk, one dorsal, two lateral and two ventral, is very characteristic. The young larva and the changes that take place are described and figured by Sundara Raj (1916).

Incidentally it may be stated that though the majority of eggs hatch out in a fortnight's time, in exceptional cases some eggs had their hatching period unduly prolonged.

*Panchax parvus* Sundara Raj.

This form was first described by Sundara Raj (1916) from Madras. The animal breeds most intensively about February though the eggs have been collected in other parts of the year also.

Eggs are round and each measures 1·3 mm. in diameter. One to three long threads, sometimes as long as 15 mm. or more are given off from the surface of the egg which help it to get attached to algae as soon as it is
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extruded. The figure of the egg of Panchax parvus given by Sundara Raj is not however accurate. The threads from the egg are neither so numerous nor so short as shown by him.

The earliest stage examined is one in which the embryonic ridge has formed and the blastoderm has begun to spread downwards (Fig. 84). The yolk is clear and transparent with a small group of oil globules which persists till the animal hatches out.

By the second day the blastoderm completely envelopes the yolk mass (the neural groove is visible) and rudiments of the eye are formed (Fig. 85). The oil globules coalesce and become larger and fewer in number. The circulation which begins on the third day is complete by the fourth (Fig. 86). The embryo grows in size. The neural groove becomes large and pectoral fins appear. A Kupffer's vesicle becomes visible at the place where the tail end gets free from the yolk mass. Gradually the yolk gets reduced. Pigment is formed in the body, first of a dull brown colour which later turns dark. They get definitely arranged by the seventh day (Fig. 87). The Kupffer's vesicle becomes large and has a beautiful pink colour (Fig. 87 Kf.). This is absent in A. melastigma. The eyes are black and shining and the head at this time appears proportionately large. Active respiratory movements can be observed and the fluid inside the egg-case is kept in constant motion by the rapid movement of the pectoral fins.

The hatching takes place usually on the eighth day. The larva is 6 mm. long and is extremely agile in its movements from the time of hatching. The arrangement of chromatophores in six rows on the trunk, two dorsal, two lateral and two ventral, is very characteristic of the larva (Figs. 88 and 89). The lower lip is pigmented and projects somewhat beyond the upper. The Kupffer's vesicle disappears on hatching. The dorsal, the caudal and the anal fins are all continuous and the caudal, which is heterocercal, alone is provided with fin rays. The abdominal portion of the animal is considerably longer than that of A. melastigma, on account of which the anus is situated far behind. The larva mostly keeps to the surface of the water.

General Observations.

Among the fishes whose breeding habits and development were studied parental care has been noticed in Etroplus suratensis, E. maculatus, Acentrogobius neilli, A. viridipunctatus and Petrocirtes bhattacharyae, whereas parental care as such is found to be absent in Panchax parvus and Aplocheilus melastigma. The fact that in the last-mentioned one eggs are found

6 Sundara Raj, 1916, attributes to P. Parvus the breeding habit given by Thomas for Haplochilus panchax in his book Tank Angling in India, Madras, 1887.
attached to the ventral side of the mother may be interpreted as a sort of parental care though it is clear that the action is not an intentional one on the part of the parent, but brought about by the presence of adhesive threads in the eggs.

The Adyar bar opens at the end of October or by the beginning of November and the river remains connected to the sea till about March-April, though after the end of January the connection is intermittently cut off due to the accumulation of sand. A period of intensive breeding is noted within the brackish water area among fishes during the early pre-monsoon rains at which time the river is not sufficiently flooded to find an outlet into the sea. After the opening of the bar sudden changes in salinity occur in the brackish water zone and breeding is found to be less intensive. Some forms like *Etroplus* go up the river into less saline regions and come back only when the variation in salinity is not sudden. It has been definitely found that *Acentrogobius viridipunctatus*, *A. neilli*, *Panchax parvus* and *Aplocheilus melastigma* are perennial breeders in the brackish water area. Recently (1936) a large number of very young larvæ of *Hemiramphus limbatus* was found at the end of July and beginning of August after a few showers. Evidently this form breeds about this time.

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REFERENCES.

(Only such references on the breeding habits or development of Indian Fishes as are directly referred to in the text are given below.)

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EXPLANATION OF FIGURES.

LIST OF ABBREVIATIONS.

1, 2 & 3 Cement Organs ; eg.-External Gill ; gb.-Gall bladder ; Kf.-Kupffer's vesicle ;
og.-Oil globule ; pf.-Pectoral fin ; sp.-Opercular spine.

Figs. 1-23. Developmental Stages of Etroplus maculatus.

Fig. 1. One celled stage 30 minutes after fertilization × 40
2. Two " " 35 " " 40
3. Four " " 55 " " 40
4. Eight " " 1 hour and 30 min. " 40
5. 2 Hours and 30 minutes old × 40
6. 5 " " 30 " 40
7. 9 " old " 40
8. 12 " " × 40
9. 20 " " × 40
10. 24 " " × 40
11. 28 " " × 40
12. 30 " " × 40
13. 32 " " × 40
14. 38 " " × 40
15. 48 " " × 40
16. 54 " " × 40
17. 72 " " × 40

(Larva in the act of coming out).
18. Empty shell × 40
19. Newly hatched larva × 27
20. A group of young larvae resting at the bottom attached by their mucus threads. × 8
21. Larva Second Day × 27
22. Fourth " × 40
23. Sixth " × 27

Figs. 24-29. Developmental Stages of Etroplus suratensis.

24. A well-developed embryo about 60 Hours old × 27
25. A larva coming out of the shell × 27
26. A larva with the egg capsule around. Semi diagrammatic.
27. Newly hatched larva × 27
28. Larva Third Day × 27
29. Eighth Day × 20

Figs. 30-49. Developmental Stages of Acentrogobius viridipunctatus.

30. Four celled stage 1 Hour and 30 minutes old × 54
31. Eight " " 1 " " 50 " " × 54
32. Sixteen " " 2 Hours old × 54
33. Thirty-two " " 2 " " 15 " " × 54
34. 5 Hours old × 54
35. 7 " " × 54
36. 10 " " × 54
37. 12 " " × 54
38. 18 " " × 54 (Side View).
39. 24 " " × 54 (Dorsal View).
40. 24 " " × 54
41. 36 " " × 54
42. 48 " " × 54
43. 72 " " × 54
44. 96 " " × 54
45. 120 " " × 54
46. 144 " " × 54
47. Newly hatched larva with the shrunken external gills behind the lower jaw. × 40
48. Larva Seven Days old. × 40
49. Auditory Organ of a newly hatched larva. × 170
50. " " " " " " Acentrogobius neilli × 570

Figs. 51-60. Developmental Stages of Boleophthalmus boddarti.

51. Egg immediately before fertilization. × 40
52. One celled stage 10 minutes after fertilization. × 40
53. Two " " 30 " " × 40
54. Four " " × 40
55. Eight " " × 40
56. Three Hours old × 40
57. Seven " " × 40
58. Seventeen Hours old × 40
59. Twenty-four " " × 40
60. Forty-eight " " × 40

Figs. 61-78. Developmental Stages of Petroscirtes bhattacharyae.

61. Cluster of eggs showing the compact arrangement. × 40
62. Side view of an egg. × 70
63. Earliest stage observed with the embryonic ridge. × 70
64. Embryo Second Day × 70
65. " Third " × 70
66. " Fourth " × 70
67. " Fifth " × 70
68. " Sixth " × 120 (Extracted)
69. " " " × 70
70. " Seventh " × 70
71. " Eighth " × 120 (Extracted)
72. " Tenth " × 70
73. Larva coming out, Twelfth Day × 70
74. Empty Shell × 70
75. Newly hatched larva (Dorsal View) × 40
76. " " (Ventral View) × 40
77. Larva Second Day (Side View) × 40
78. Head of the larva on the Fourth Day showing the opercular spines. × 170
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Figs. 79–83. Developmental Stages of *Aplocheilus melastigma*.

79. First Day (Earliest stage observed)  × 54
80. Second Day  × 54
81. Third Day  × 54
82. Sixth Day  × 54
83. Caudal fin of a newly hatched larva.  × 70

Figs. 84–89. Developmental Stages of *Panchax parvus*.

84. First Day (Earliest stage observed)  × 54
85. Second „  × 54
86. Fourth „  × 54
87. Seventh „  × 54
88. Newly hatched larva (Dorsal View)  × 20
89. „ „ (Side View)  × 20

All figures have been reduced to ¾ the magnifications given.