# The Natural History of the Blind Goby, Typhlogobius californiensis Steindachner

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## Introduction and History

That blind fish live in caves and in the depths of the ocean is a fact well known to biologists, but few biologists know that a blind goby, *Typhlogobius californiensis,* lives in the intertidal region along the coast of Southern California and Lower California. Its present known range is Point Vincente (north) to Ceros Island (south) (Barnhart, 1936). This goby has lived so long in a burrow under the rocks with *Callianassa affinis* Holmes, a shrimp (Pl. 2, Fig. 8), that, like many other fish living in similar circumstances, it is, in the adult stages, both blind and pink, having lost eyes and pigment. Over 200 individuals of this species that I have collected ranged between 20 and 80 mm. in length. The general form of their body reminds one somewhat of catfish, as it is rather heavy and blunt, particularly in the older specimens. The fin equipment resembles that of other members of the family Gobiidae, but is somewhat reduced. The pelvic fins are arranged in such a way that they constitute a sucking pad by which the fish can hold to any smooth object.

*Typhlogobius californiensis* was first named by Dr. Franz Steindachner in 1879, and was redescribed in 1881 as *Othonops eos* by Miss Rosa Smith, who later became Mrs. C. H. Eigenmann. Jordan and Gilbert (1882) included this fish in their synopsis of the fish of North America. In 1890 C. H. Eigenmann wrote an account of the fish and its relations in which he gives considerable detail of the skeleton and other morphological characteristics. In 1893 W. E. Ritter wrote an excellent account of the eyes, the integumentary sense papillae and the integument of this fish. Other than the original descriptions and the two morphological papers just cited, little has been written about this interesting goby. It is the purpose of this paper to describe the living animal and its life activities, and to include some notes on its embryological development.

What natural history notes are included in the papers just cited are, for the most part, incorrect. One fact, however, which was emphasized by these early authors is the extreme viability of this fish under artificial conditions. It will live for long periods of time in a small quantity of sea water and without food. This fact should make it of considerable value to physiologists, particularly those who would be interested in the conditions which make it possible for this fish to stand such extremes of oxygen depletion and pollution by its own excretions.

## Habitat

*Typhlogobius californiensis*[1] lives commensally in pairs in the burrows of *Callianassa affinis*. These hosts also live in pairs and make their burrows in the sand along the beaches of Southern and Lower California where the rubble is sufficiently large to allow the deposition and holding of sand between and beneath the boulders. Pl. 1, Fig. 1 shows such a typical region. Because the shrimps feed by straining planktonic material from a current of water pumped through the burrow, it is necessary that there be more than two openings to this burrow and that the burrow be permanent. Therefore the burrows are built in those regions where the rocks of the beach are of sufficient size to prevent their being moved by tidal wash,, and sufficiently numerous to hold the sand beneath them. The beaches of Southern California are, on the whole, fairly free from heavy surf, therefore the size of the rocks of the shingle may be smaller than would be necessary in more exposed regions. Where most of the rocks of the shingle are a foot or more in diameter, the required conditions are found.

Ritter (1893) was surprised that this goby did not inhabit the burrows of the "same shrimp" in the estuaries. However, in 1900 Holmes described the *Callianassa* with which *Typhlogobius* lives as another species, thus separating it from *Callianassa californiensis,* which is the estuarine species. I have verified this separation in two earlier papers by comparing the natural histories of these two shrimps (MacGinitie, 1934, 1937). The natural history of *Callianassa californiensis,* which inhabits the estuaries, is widely different from that of *Callianassa affinis,* the one with which the blind goby lives. It would be impossible for the blind goby to live in the burrows of *Callianassa californiensis,* for the latter does not maintain permanent burrows. Since the separation of the two species was made seven years after the publication of Dr. Ritter's paper, it is not surprising that Dr. Ritter considered the two shrimps of the same species, for, though their natural histories are so greatly different, it requires close observation to distinguish between the two species by means of their structural differences. *Typhlogobius* is quite specific in its choice of a host, as it has never been found in any burrows except those of *Callianassa affinis*. The burrows of this shrimp are confined almost entirely to the intertidal region, so that some of them at least are exposed at any stage of low water. It is my belief that during spring tides practically all their burrows are exposed.

Unless it be *Lethops connectens* Hubbs (1926), no other goby is known to remain permanently within the burrows of a host as does *Typhlogobius californiensis*. There is a certain amount of evidence which may throw some light on the evolutional development of the strictly commensal condition exhib-

1. There is only one species of this genus known. Hubbs (1926) has described another genus of blind goby, *Lethops connectens*, but practically nothing is known of this fish as only three specimens have been taken. I am inclined to think that it will be found more abundantly as a commensal in some burrow in the rocky regions beginning at about the lowest tides.

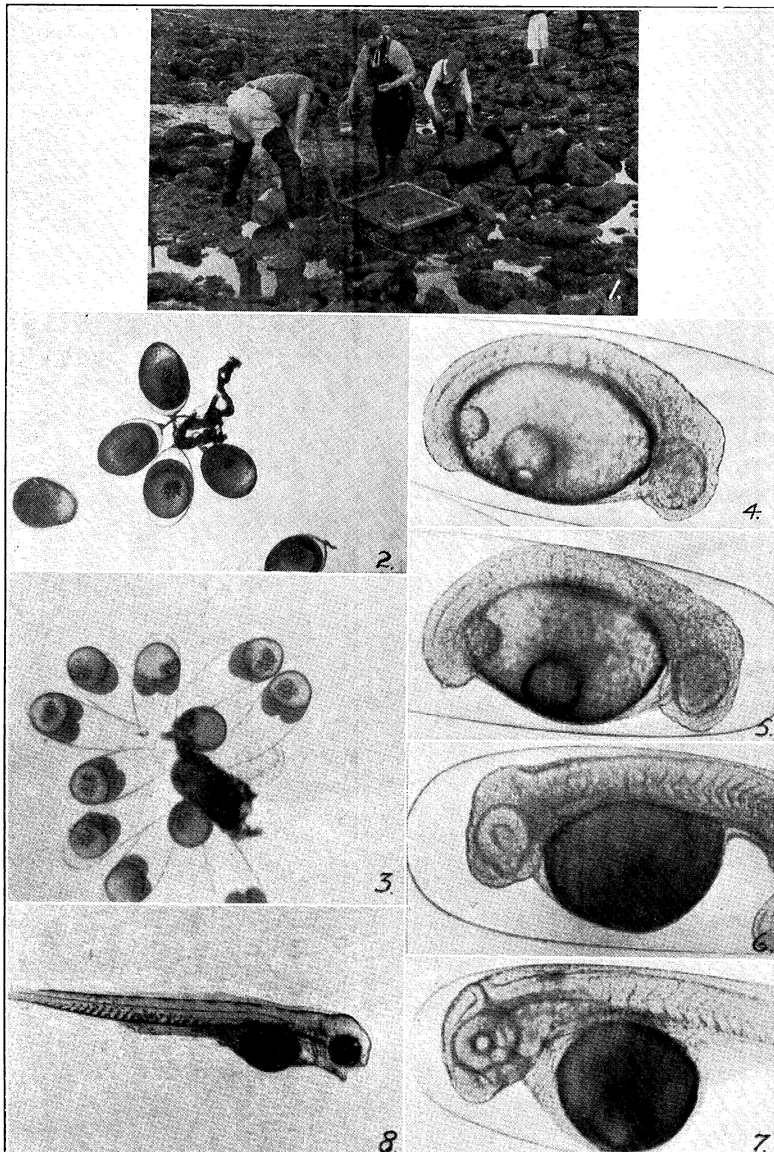


PLATE 1: Fig. 1—Collecting *Typhlogobius californiensis;* Fig. 2, Eggs taken just after being laid. Three fertilized, one not. x9; Fig. 3, First division. x6.8; Figs. 4-7, Successive stages in development. x34; Fig. 8, Newly hatched fish. x16.

ited by *Typhlogobius*. *Clevelandia ios*, the tiny goby mentioned by Ritter (1893) as living in certain burrows, has been found to use such burrows only as a place of refuge either from predators or during tidal exposure (MacGinitie, 1935). By watching the reactions of such animals as *Urechis* (Fisher and MacGinitie, 1928), *Callianassa californiensis* (MacGinitie, 1934), *Upogebia* (MacGinitie, 1930), etc. it becomes evident that the entrance of *Clevelandia* into their burrows is an invasion to which they are accustomed, for it does not disturb them, but they do become agitated when their burrows are invaded by animals other than *Clevelandia* or their typical commensals. *Gillichthys mirabilis*, another goby, may remain for a considerable period of time within the burrows of an animal such as *Upogebia*. Its eyes are somewhat reduced in comparison with those of *Clevelandia*, and it naturally seeks darker regions. It is but another step to the condition exemplified by *Typhlogobius*, where the fish remains permanently in the burrow of a particular host. Though the blind gobies may be derived, as stated by Hubbs (1927), from ancestors who lived beyond the tidal limits, I am of the opinion that the commensal habit has developed along the lines suggested above, and that either *Clevelandia* or *Gillichthys* could, in time, become commensal blind gobies. As will be explained later, I do not believe that a blind goby could persist as a species as a free-living animal, i.e., in rock crevices.

The burrows in which these gobies live are constructed entirely by the shrimps. They are rather tortuous, as they must follow to some extent the contours of the overlying rock, but they are not so extensive as those of *Upogebia*, another shrimp which also lives in pairs in a permanent burrow (MacGinitie, 1930, 1935). The pair of gobies remain in the deeper portions of the burrow, and exhibit very little activity except during periods of incubation of their eggs. It may be due to their habit of staying in the deeper portions of the burrow of the shrimps which gives them their great tolerance for stagnant conditions. *Hypsoblennius gentilis*, an estuarine blenny, will die within an hour in water in which *Typhlogobius* may live for months. *Typhlogobius* respires almost entirely through its integument, and it is mainly the rich anastomosing condition of the blood vessels near the surface which gives the fish its decided pink color. Apparently it is only during periods of vigorous activity or for a short time thereafter, that this fish makes use of its gills and operculi.

It might seem that the gills and operculi should show degeneration along with the eyes, but the fish use their operculi for creating food ingesting currents (that is, to suck food into the mouth), their gills for accessory respiratory organs, and their mouths and teeth for ingesting food and for fighting.

The death of both members of the pair of shrimps would result in the death of the gobies within a short time, as the fish are unable to keep the burrow in a state of usability, and, even if they were, they would starve in time, as they are unable to maintain a current through the burrow, which is necessary for bringing in food. Though, as has been stated before, the gobies will on occasion attempt to repel the invasion of other burrowing animals which may encroach upon their tunnels, they are not sufficiently aggressive to

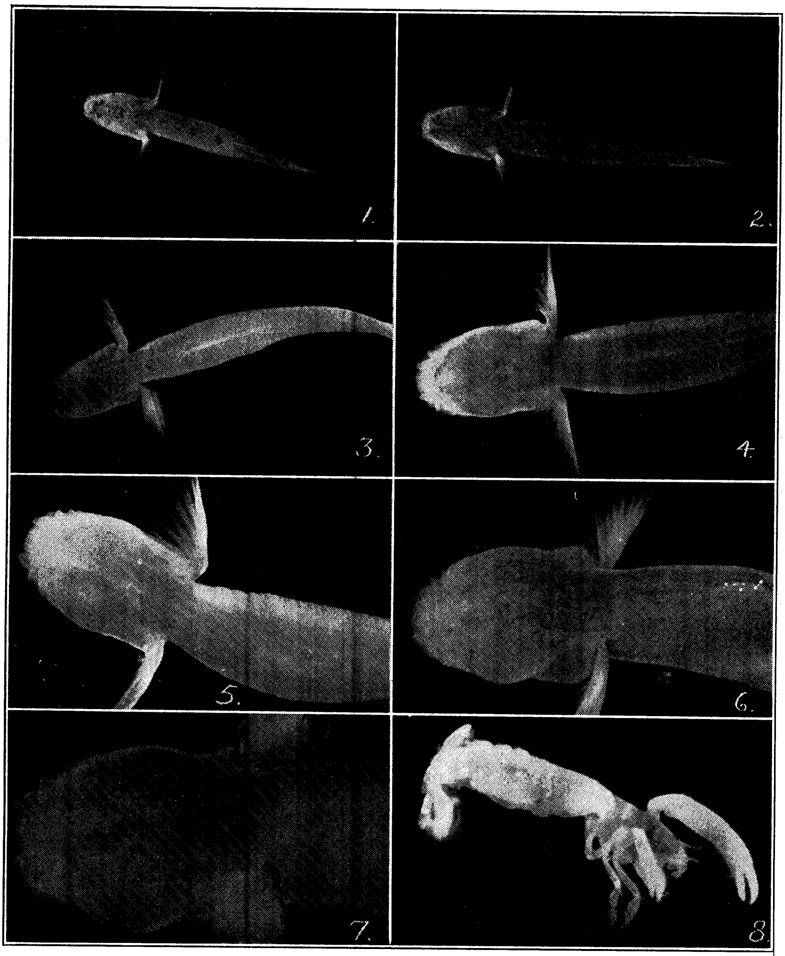


PLATE 2: Figs. 1-7, *Typhlogobius californiensis* ranging in length from 23 mm. to 85 mm. Note that in No. 6, although the fish is larger than No. 5, the eye spots are more conspicuous. In No. 7 no eye spots were visible under the binoculars. It will be seen that pigment also disappears No. 6 had been exposed to light for a considerable length of time, which causes more pigment to form than is usually present. x1.5; Fig. 8. the host, *Callianassa affinis*. x3/5.

meet with much success in keeping out other animals. It is their hosts which are ever on the alert to repel such invasions.

If it were not for the conditions found in the home of the host, a blind fish, such as *Typhlogobius californiensis*, would soon fall prey to such predators as the moray eel *Gymnothorax mordax* (MacGinitie, 1938), or the pistol shrimp *Crangon dentipes* (MacGinitie, 1937). There would be no constricted entrance to a rock crevice as there is to a burrow of *Callianassa affinis*, or, if a few such crevices could be found they would not be numerous enough to allow *Typhlogobius californiensis* to persist as a species. The fish would be devoured before they were large enough that the constriction of the rock crevice would form a protection. For these reasons I believe that the eyes of *Typhlogobius* were not lost in a darkened rock crevice, but after the goby became commensal with *Callianassa affinis*.

### Feeding

The shrimp with which *Typhlogobius* lives obtains its food by straining microscopic material from a current of water which is caused to flow through the burrow by the action of swimmerets on the under side of the body of the shrimp. These paddles can creates a fairly strong current and, since both the male and female shrimp may be feeding at the same time, it is necessary for the burrow to have a third or fourth opening. Coming in with this current of water are many small pieces of seaweed and other debris which may contain small animals or portions of animal flesh, the latter being derived mostly from the activities of predacious feeders on the surface, such as crabs when they tear their prey or carrion to pieces to enable them to eat it. This larger material is not ingested by the shrimp, but is allowed to fall to the deeper parts of the burrow where the edible portions are sorted out and eaten by the fish. Many times in the laboratory I have seen the *Callianassa* actually carry the larger material in its basket to the fishes and dump it before them.

Cooperation of this type among marine animals is not uncommon. Where animals are closely associated for great periods of time it is quite logical to expect that instictive reactions to each other have evolved just as they have to other factors of their environment. Many fishes will carry portions of food too large to swallow to a crab or shrimp to be torn apart, and then they will dart in to take small pieces during the process. I have seen *Clevelandia ios* and *Leptocottus armatus* do this many times, and have also seen it happen in tide pools when some cottoids carried to a nearby crab a piece of mussel that I had fed them. The cooperation between commensal and host and between paired animals is but the manifestation of instincts developed in response to environmental factors.

The clearing from the burrow of many of the larger particles of food is, so far as I have been able to determine, the only possible benefit that *Callianassa* may derive from the presence of the blind gobies, that is, the fish by their omnivorous habits clean up most of the material which enters the burrow and is not used as food by the shrimp. Although this factor is more important than one would at first assume, it is, however, of relatively small significance in that these materials could be carried to an entrance and forced outside just as is done with other foreign material which is rejected by the fish as food. But, even as it is, the shrimps spend a great deal of their time in activities which have to do with cleaning out the burrow, keeping it in shape, smoothing the sides and turn-arounds, and making repairs.

Because the blind fish live on finely divided seaweed and what suitable animal matter may enter the burrow, one of the best sources of food for specimens kept in the laboratory is the fore-gut of the sea urchin freshly taken from under water where it has been feeding. The sea urchin lives mainly on bits of seaweed which it chops into small particles by its teeth, and these particles are just the right size for feeding the fish, and, together with pieces of intestine, form a balanced diet for *Typhlogobius*. In the laboratory, however, I have made use of many sources of food, such as finely chopped dried abalone, gonads of many marine animals, crustacean larvae, bits of clam and fish, chopped seaweed, etc.

### Sensory Responses

The data which furnishes the conclusions stated under this heading were gathered almost entirely during five years of observation in the laboratory. I establish a "family group" in the laboratory in the following manner:

A pair of shrimps are allowed to make a burrow, and when this is sufficiently extensive a pair of blind fish are placed on top of the mud. They wriggle their way down through one of the openings and make their way into the burrow with the shrimps. These burrows are made within a container which I have often referred to as a "limorium" (MacGinitie, 1935). A limorium consists of a frame in the sides of which are placed two glass plates, separated from each other at varying distances, depending upon the animals to be kept in it. The space between is filled with a combination of sand and mud, the consistency of which must be such that the burrows will not cave. For the *Callianassa* and its commensal blind goby, the sides of the limorium are separated about three-fourths of an inch from each other. Thus the burrow can be confined within a rather narrow space, and, though the burrow is not visible throughout all of its length, there are sufficient portions of it which come in contact with the glass on one side or the other that, after a period of several years of observations, one becomes quite certain that the activities of both the host and commensal are known.

The blind fish may also be kept in pairs in compartments of an aquarium without their hosts and without any possible contact except with the glass sides of the aquarium and its contained sea water. I have kept many pairs of fish in this manner for several years. They will, however, make use of a glass tube under such conditions, particularly during periods of inactivity, but they leave and enter such tubes at will.

There seems to be no sensory relationship between the goby and its host except one of passive tolerance. The callianassas get along just as well without the fish in the burrow. As before mentioned, the callianassas will carry food to the fish if the latter are present, or the shrimps will also push one or both of the fish out of the way as they pass along the burrow, or will even sometimes pinch them with the large claw to make them move. These reactions to the presence of the fish are the only ones I have ever seen exhibited by the shrimps. On the other hand, except when they are brooding their eggs, the fish are entirely indifferent to the callianassas.

The fish meet their environment almost entirely through chemotropic and thigmotropic responses. The keenest sense which they possess is chemotropic. In comparison with most free-living marine animals, the remainder of their senses are exceedingly dull, and, in comparison, even their senses of smell and of touch are considerably reduced. They can sense the presence of food in the runway or in the burrow, and will wriggle along in the direction from which the current is bringing them the scent, and then will locate the food by the tactile papillae situated around the mouth. They sort out the food material from the other debris by touching it with one or more of these sensory papillae. Of course, they can, and sometimes do, reject particles after they have been taken into the mouth. Though these tactile papillae (see Ritter, 1893) are undoubtedly developed to perform a tactile function, they are not nearly so sensitive as, for example, the tips of the arms of an octopus or the hairs on the dactyls of most crabs and shrimps. However, under the conditions in which the fish live, particularly because of the lack of competition, the papillae are suffiicently sensitive for their needs.

As is also the case with their hosts, the gobies become quite concerned about the presence of other animals within the burrow, even of annelid worms over two inches in length. Worms smaller than this they will eat, but, though the fish have a fairly capacious mouth, it seems impossible for them to swallow objects much larger than an eighth of an inch in diameter. Since the entrances of the burrows are constricted to a considerable extent, being usually no larger than from 2 to 5 mm. in diameter, few invaders ever enter the burrow, and if they do the Callianassas usually eject them, though the fish will sometimes fight such invaders. More will be said about the tactile and olfactory senses of these fish under Mating or Pairing, and Reproductive Activities.

The eyes of the newly hatched *Typhlogobius* are perfectly normal, but after the fish take up their abode in the burrow of a pair of shrimps, the retina withdraws to some extent, usually becomes twisted out of shape, and covered with body layers until in most adults the eyes are indiscernible (see Ritter, 1893). There is, however, some variation in the visibility to the observer of the eyes in fishes of the same size. But, so far as I have been able to determine, any goby of whatever age or size is able to distinguish between strong light and darkness, though this reaction becomes less marked as the fish grows older and the eyes become more deeply covered by the body layers. At all times the fish exhibit a tendency to remain deep within the burrows, that is, they seek that portion of the burrow which is deep and level. Since this reaction is carried out in total darkness, it is impossible to say whether the presence of a strong light also causes them to make this reaction. But in any case, it is evident that a strong light will agitate a blind goby of whatever size or age.

The blind gobies are more concerned about their tactile adjustments than they are about being in the dark. They are, of course, also sensitive to vibrations in the water. As is the case with most fishes, *Typhlogobius* will head into a current of water, though not with the determination that many fish exhibit. The Callianassas with which the blind gobies live will soon die if not kept in a tube or burrow where they can come in contact with its walls. This is not true, however, of the fish, though they do exhibit some tendency to remain in the angle of the sides of an aquarium, or, as has been mentioned before, will spend more time within a glass tube if one is present than would be true if they were making only a hit or miss adjustment.

No stimulus other than forcible ejection will cause a blind goby to leave its burrow, but, like Urechis (Fisher and MacGinitie, 1928), if a chemical sufficiently strong be introduced, it will die in the burrow instead of leaving. However, I have never tried poisoning tidepools. Since they are so securely hidden in the burrows of the shrimps, these fish, when once established, are practically free from the attacks of enemies. I have never seen any indication of the burrows of the shrimp host having been dug out by any predacious feeder. In the first place, the burrows are too extensive for a predator to obtain sufficient returns for his efforts. The predator would have to be small, as the burrows often penetrate crevices between the rocks which are no larger than the burrow of the shrimp. Considering these things, I know of no predator of the right size which is equipped for such activity. Enemies are shown to be practically non-existent by the fact that both the fish and their hosts have a relatively long life span. This conclusion is the result of the following data: 1. Careful screening shows few juvenile shrimps and fiish in comparison with the number of adults. 2. Fish which have been kept in the laboratory for as long as four years, and well supplied with food, grow slowly. One pair which I had had in the laboratory for four years has grown from about 75 mm. to 82 mm. in this length of time. This pair is now the largest of this species of fish that I have seen. From the amount of growth shown by other smaller blind gobies that I have had in the laboratory, I suspect that these were at least six or eight years old when they were brought in, so that a conservative estimate would place their age now at not less than ten or eleven years.

These fish are extremely hardy and are able to undergo adverse conditions which would be fatal to any other tidepool fish with which I am acquainted. As long as their skin is kept moist with ocean water they will continue to live for a period of a week or more. Also, if put in a jar of sea water they may be kept there at least two or three weeks without any change. They may be handled a great deal without any apparent ill effect, and, though their skin seems to be soft and tender, it is exceedingly tough.

In summing up the tropisms of the blind goby it can be said that all senses are somewhat degenerate, and that this fish would be unable to live even underground in a burrow without the ministrations of its host. The advantage, therefore, is all on the part of the blind goby. It is not necessary for a state of commensalism to begin as a symbiotic relationship. In a case such as the one herein being described the relationship was commensal from the beginning.

**Mating or Pairing**

*Typhlogobius* mates early and remains paired throughout life. Pairs of *Typhlogobius* with an over-all length of less than 20 mm. have been taken from burrows on the beach. Since the newly hatched fish is 3.25 mm. in length, and the egg-laying season is during the two months from the middle of May to the middle of July (mainly in June), and since these paired fish were taken in December, it means that pairing takes place sometime within the first six months of the life of the fish. The fish become sexually mature the first summer after hatching, that is, in one year. Pairing, therefore, occurs before sexual maturity, i.e., the first spawning. The life span is not known, but, from all indications, it can easily be 10 or 15 years, and apparently parallels that of the host.

Small gobies are nearly always found with small callianassas, though this does not always hold strictly true. However, never have I found a very small pair of fish with large callianassas, and, from what has been said, it is evident that the opposite would be impossible. Usually the callianassas and the blind fish are of about the same size. The life history of the goby after hatching and up to the time pairing takes place, that is, the first four months of its life, is still unknown. It is hoped that within the next two or three years this portion of the life cycle will be solved. The gonads begin to develop when the fish is about six months of age, and constantly enlarge until the following summer. From this time on the fish show a very strong fighting instinct toward others of their own sex, and this accounts for the fact that never are more than a pair of blind gobies found in any one burrow. For instance, if a male goby invades the burrow of an established pair, the two males will at once enter into combat and continue until one or the other is killed or driven from the burrow. During this time the female is indifferent to what is going on, unless, as will be shown later, it is during the period of the incubation of the eggs. The same thing is true if another female enters the burrow, for then the two females will fight until one or the other is destroyed or driven out. The fish are equipped with a good set of small, sharp, needle-like teeth. In fighting, one fish will bite the other and hang on, sometime for two or three hours. If the attacked fish is able it will twist its body and also take a good hold on its adversary. At intervals after this, one or both fish perform shaking movements which apparently serve only to set the teeth deeper in the wound. Fighting of this type, in which the fish maintain their biting hold for such long periods of time, could be engaged in only by fish which respire mainly through the integument, as it is impossible for any water to pass over the gills while the fish has its mouth full of its adversary. If one fish bites the other near the head in such a manner that the fish which is bitten cannot at the same time obtain a hold on its adversary, it in turn takes the next bite, for evidently the jaws of the first attacker eventually tire sufficiently that the fish which is held can finally wriggle loose. I once saw two of these fish remain attached to each other for several hours, one having hold of the lower jaw of the other, while its own upper jaw was in turn firmly held in the mouth of the other. Upon the release of one fish by the other a crescentric set of bloodshot punctures will be left where the teeth of the biter have punctured the skin of the victim. This sort of fighting will continue for two or three days or until, as has been said before, one or the other is killed or forced out of the burrow—usually the former.

That these fish pair and that they engage in combat only with members of the same sex is sufficient evidence that they can distinguish sex by a chemotropic sense. However, certain other reactions of this fish verify this conclusion. If a blind goby inclosed in a thin cellophane tube closed at both ends is placed in a burrow with an established pair of blind gobies, no particular attention is paid the object by either member of the pair. If, however, a small opening is made in the cellophane, then the member of the pair which is of the same sex as the fish in the cellophane wrapper will become quite active and will begin searching for the invader. Too, if one handles a goby and then puts one's hand in an aquarium with an established pair of blind gobies, that individual of the pair which is of the same sex as the fish which was handled will often exhibit the fighting instinct, but for only a few minutes, as there is undoubtedly a complication of the human scent with that of the fish scent on the hand, the latter losing its strength very rapidly. That these gobies recognize the opposite sex by a chemotropic sense emphasizes the important biological principle of variation, for Breder (1935) found that with his guppies "sex recognition is feeble if present at all," and Noble (1934) found that sex recognition in the sunfish *Eupomotis gibbosus* depends mainly on form and movement, and (1938) that the females of the jewel fish *Hemichromis bimaculatus* "will select the most highly colored of several possible mates," while with the males "sex identification is a matter of learning." In fact, by comparing the guppy with the blind goby we have shown two extremes, one in which there is practically no sex recognition and the other in which sex recognition is not only very acute, but in which the fish pair permanently.

Though pairing takes place early, and, without disturbance, lasts through life, if an invader enters the burrow and kills its rival, the other member of the pair accepts its new mate without even any indication that the change has been made. These blind fish may be moved around and pairs broken up and exchanges made, but so long as only one male and one female remain together, there will be no fight. When, as is often the case, only single members of a pair are obtained from the tidepools when one is collecting, they can be paired in the laboratory by allowing eliminative combat, or by using an established pair in which one knows the sex of the individuals. In time one becomes able to distinguish between the sexes of the medium sized or larger individuals, particularly at the time the gonads become filled, as the ovaries and testes may be seen through the body wall, the former being yellow, and the latter cream colored. Too, at such times the female is considerably more robust than the male, and, in the larger, older fish, the female is always somewhat broader in the head and body than is the male.

By using an established pair in which the sex of the individuals is known the collected material may be separated into male and female by placing the gobies one at a time with the known pair and leaving them there only long enough to determine whether it is the male or the female that becomes concerned. In using this method it is well to allow 10 or 15 minutes to elapse between the introduction of each fish to be tested. For example, if a male has just been placed with the established pair and taken out and another fish, say a female, is immediately introduced, the male may attack it, because of the fighting instinct having been stimulated by the male which had just previously been introduced. By careful collecting, however, one is usually able to obtain both members of a pair in the field and to keep them together for establishment in the laboratory.

### Egg Laying Activities

The sex products develop in the gonads of *Typhlogobius* for several months before egg laying takes place. The amount of sex products developed depends upon both the size of the gobies and the amount of food available. Along the coast of Southern California it frequently happens that the plankton and debris are pretty meager during the fall and well into the winter months, so that it can be said that in general the eggs and sperm which are mature at laying time (which has its peak about June) began their development about the first of February. Through observations of the spawning seasons of many of the marine animals over a period of thirteen years I have found that the spawning times may vary a great deal, depending upon such factors as food, temperature, etc. This holds true for these blind gobies, and it may even be that more than one spawning takes place in a season, that is, if a pair of gobies spawn in early May the chances are that they will spawn again in July. In the laboratory, due to the abundance of food and somewhat higher temperatures, three and four spawnings a year may be obtained from a pair of these gobies.

It is also possible to produce spawning in both sexes by injecting the fish with the hypophysis from another fish. For this purpose I use members of the genus *Paralabrax*, or, as they are commonly called, kelp bass or sand bass, because they can be caught from the front porch of the laboratory. However, I suppose that the hypophysis of any other common fish would work as well. The hypophysis is mascerated with a pestle in a mortar with a little seawater, and is then injected under the skin of the blind goby with a hypodermic needle, 1/4 cc. of a fairly concentrated solution being sufficient. One may expect the injected fish to spawn within less than a month. It is, of course, necessary that the fish be well supplied with food during this time. By this means I have obtained as many as 6 or 8 spawnings in a year from one pair of fish.

One group of blind gobies that I collected and did not separate into pairs seemed to get along very well together for several days, as is usual. This group was then injected with hypophysis and still left together. Fighting began during the third night after the injection, and the following morning several of the fish were dead and others were still engaged in a battle to the finish. Under such conditions any male or female will take a biting hold on any other fish of the same sex, and thus there may be three or four in a group which are attached to each other by their jaws. Of course, since there was no control group, it is impossible to say whether or not the injection of hypophysis caused the fishes to begin fighting sooner than they otherwise would. However, blind gobies which are allowed to remain in a group after being collected do not usually begin fighting until they become more accustomed to their new surroundings, which requires more time than in the above instance.

By actual count the eggs laid and fertilized in one spawning by a pair of blind gobies somewhat above average size totaled 11,000 $\pm$ 50, all of which hatched. By fairly close estimates the spawnings of others have ranged between 2500 and 15,000 eggs, depending upon the size of the pair.

Egg-laying is always preceded by certain definite activities on the part of gobies. The first indication of the approaching spawning is a tendency of the two fish to remain more of the time in bodily contact, and often as they are thus in contact shivering or shimmying movements pass along the body of first one and then the other of the fish. This may continue for several days or a week, and then the two fish will begin to clean a space on the glass of the aquarium or the side of the burrow where a rock or shell affords a smooth surface. The pelvic fins are well forward just beneath and posterior to the pectoral fins and are fused together to form a sucker-like cup of the type found on the common tidepool (cling) fish *Caularchus maeandricus,* though the sucker on the under side of the goby is not nearly so large, fleshy and strong as it is on *Caularchus*. During the cleaning process the gobies, first one and then the other of the pair, attach themselves here and there by means of this cup, and, by wriggling their body, clean the surface by rubbing it with the ventral side of the body, the pectoral fins and the anal fin. During this cleaning operation the fish may remove projections or sessile objects by means of their mouths. Under natural conditions, in the burrow with its sandy walls, some excavating may be done. I have seen only the male engaged in this latter activity, but it is possible that the female may help also. It is impossible, of course, to see within a burrow, but on two occasions the egg laying was done so that it could be seen through the opening of the burrow in a limorium. In one case the eggs were laid on the glass of the limorium, and in the other upon a shell. In these two cases the male made available a larger surface for the attachment of the eggs by removing some of the sand. The sand is moved by fanning it loose with the pectoral fins, by carrying it in the mouth or by a combination of both methods. The goby deposits the sand in the runway, from where the shrimps either carry it to another portion of the burrow and smooth it out, or carry it to the entrance and push it outside.

Occasionally during periods of rest from their cleaning activities, shimmying movement are indulged in. At the end of about two days of cleaning preparation, egg laying begins. The female extrudes an almost transparent ovipositor about 1/4 inch long and begins to deposit eggs at the rate of 1.4 eggs per second. The deposition of each egg is accompanied by a movement of the posterior portion of the body of the female to one side and downward, she at the same time clinging to the surface of the rock or glass by the sucker already described. As each egg is laid a little forward movement takes place so that the eggs finally come to be scattered about over the surface prepared. After depositing eggs for a period of two or three minutes (average), which means somewhere between one and two hundred eggs, the female moves away and the male moves over the eggs and at the same time gives off sperm to fertilize them. The time that the female spends in laying before moving away and allowing the male to fertilize the eggs varies a great deal. Occasional turns have been as long as 5 or 6 minutes for the female, though the time spent by the male over the eggs is much more uniform, and, I think, never more than two minutes. The first eggs laid are deposited singly, but later eggs are placed both adjacent to and attached to the stalks of the first ones laid until the whole becomes a plate, the eggs of which are segregated in bunches somewhat resembling grapes.

When the eggs are first laid the case ranges from 675 to 720 microns wide and 780 to 870 microns long, and the egg practically fills the case (Pl. 1, Fig. 2). Immediately after the egg is fertilized the case or membrane begins to elongate, and attains a length of from 2700 to 2850 microns. The shape of the case to some extent anticipates the shape of the future embryo (Pl. 1, Fig. 3). One laying of 5,040 eggs was laid between 2:25 p.m. and 4:45 p.m., making a total of 2 hours and 20 minutes for the entire laying. The first division occurs about 2 hours, or a little more, after fertilization. In the case of the laying just cited, the first division took place 2 hours and 15 minutes after fertilization. The second division, which is at right angles to the first, occurred at 5:50 p.m., or 1 hour and 10 minutes after the first. To develop from the 2-cell to the 4-cell stage requires about 40 minutes, from the 4-cell to the 8-cell stage about 40 minutes, and from the 8-cell to the 16-cell stage about 35 minutes.

The embryo fish surrounds the yolk at about 17 to 18 hours, and at about the beginning of the fifth day it extends beyond the yolk and reaches the end of the capsule. From this time on the tail must be turned back along the side of the body, and after this occurs the tail is reversed from side to side occasionally. Pigment in the eyes and along the head and back begins to form about the end of the fifth day. Fins are formed about the seventh day. (See Pl. 1, Figs. 4-7.)

The incubation period is between 10 and 12 days, and during this time both the male and the female are very attentive to the care of the eggs. At intervals one or the other, or sometimes both together, will pass over the eggs and fan them with their pectoral fins, thus keeping the eggs clean. On the day that the fish hatch both gobies are busy, constantly working at the eggs, and the movements of the bodies of the parents over the eggs seem to facilitate the escape of the embryoes from the egg cases. As soon as the last eggs hatch the parent fish lose all interest in the empty egg cases.

This cleaning of the eggs is not uncommon among those marine animals which have a fairly long incubation period and which attach their eggs in some way. In addition to certain fishes, octopi and many crustacea display this cleaning activity to a high degree (MacGinitie, 1934). When this cleaning activity is not kept up the eggs of some fishes, crustacea and octopi will become so overgrown with detritus and fungus growth that the embryos will die before hatching.

As stated above the eggs of the blind goby hatch in about 10 to 12 days at temperatures ranging from 17 to 20° C. At the time of hatching the eyes of the fish are perfectly normal and they have a considerable amount of pigment scattered over the dorsal side (Pl. 2, Fig. 8). Those hatching in the light show considerably more pigment than those which hatch in the dark. The larval fish wriggle out from the large end of the capsule, and, at the time of hatching they still carry a considerable amount of yolk, which disappears about three days later. Colored blood cells make their appearance 4 days after the fish have hatched, or shortly after the yolk has been absorbed. The larvae are positively phototropic from the time they hatch, and continue thus for a week after hatching. I have never carried the fish to the stage where they become negatively phototropic and seek underground burrows.

During the time that the embryos are developing within the egg capsule the parent fish not only clean and care for the eggs, but will unitedly attempt to defend them against any intruders. During this time the male and female will engage in combat with fish of either sex. They also prevent the callianasses from coming in contact with the eggs, and will often bite at one's fingers or a glass tube. In other words, they resent the movement of any object near the eggs, particularly of any living animals other than their hosts, and, as has just been said, cannot be moved from their protective position even by the callianassas.

Blind fish will not eat their own young, at least not for many days after hatching, but blind gobies other than the parents will readily eat the newly hatched larvae.

## Summary

1. The blind goby *Typhlogobius californiensis* lives commensally in the burrows of the shrimp *Callianassa affinis*. These burrows are intertidal along the coast of California and Lower California, and there are one pair of shrimps and one pair of blind fish in each burrow. The burrows are found only where the boulders of the rocky region are sufficiently large to allow the deposition and holding of sand between and beneath them.

2. A probable evolutional sequence resulting in the lack of pigment and eyes of *Typhlogobius* is given.

3. The blind gobies are entirely dependent upon the activities of the shrimps for their persistence as a species.

4. The food of the gobies consists of either animal or plant detritus which find their way into the burrows with the currents created by the hosts. An excellent source of food in the laboratory is the gut of the sea urchin.

5. Chemotropic and thigmotropic senses are fairly well developed; the others are decidedly degenerate.

6. The eyes and pigmentation are normal in the newly hatched *Typhlogobius,* but both begin to disappear after the fish take up their abode in the burrow of a pair of shrimps.

7. When once established underground the fish have no enemies. The fish and their hosts have a life span of at least 10 or 12 years.

8. These blind fish pair early and remain paired throughout life. Their spawning season is from May until July, mainly during June.

9. The gobies are very sensitive to the invasion of other blind gobies of their own sex, i.e., a male will at once engage in mortal combat with an invading male, and a female will do likewise with an invading female. One of a pair will accept a new mate at any time.

10. The recognition of the sex of the invader is entirely chemotropic.

11. The spawning activities consist of cleaning a space for the deposition of the eggs, the laying of the eggs by the female and their fertilization by the male. This is followed by the concerted efforts of the pair to guard the eggs and to keep them clean until they hatch about 10 days later.

12. It seems fairly certain that the injection of a pair of blind gobies with the hypophysis from a marine bony fish induces spawning out of season. The estimated number of eggs in spawning in the laboratory ranged between 2500 and 15,000.

13. Embryological development follows the normal course exhibited by other members of the family.

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