

Observations on the Unique Reproductive Behavior of *Fundulus lima* Vaillant, a Killifish from Baja California

John Brill

61 Brookside Ave., Livingston, NJ 07039, Xjg9@aol.com
Photos by the author.



As presently structured, the killifishes (oviparous cyprinodontiforms) number several hundred species with an almost world-wide distribution, being absent only from the continents of Australia and Antarctica. Such an extensive range encompasses a multiplicity of aquatic environments into which the killifishes have penetrated quite successfully. Considering the diversity of available niches that have been filled, it is only logical to expect a parallel diversity of characters, both morphological and behavioral. The diversity that exists with regard to reproductive behavior, however, is often obscured by the much oversimplified categorizing of all killifishes as “annuals” versus “non-annuals,” or “peat spawners” versus “plant spawners.” Indeed, closer scrutiny of the various killifish reproductive methodologies reveals a greater degree of variety than alluded to by such a classificatory scheme. Besides the well-known phenomenon of annualism, the exponents of which bury their eggs in the mud of their temporary pools to avoid seasonal desiccation; and the typical “plant spawners” that lay eggs rather unceremoniously in aquatic vegetation and detritus, there are other interesting, and often lesser-known, reproductive contrivances. These include the functional hermaphroditism found in *Rivulus marmoratus*; the pelagic spawning of *Lamprichthys tanganicanus*; the highly ritualized territorial behavior of various of the *Cyprinodon* species; and even egg care, as exhibited by *Jordanella floridae*. It now

appears that within the genus *Fundulus* there exists a mode of reproduction highly unusual, if not unique, within the family. Specifically, it involves a peculiar method of egg deposition in the Mexican species *Fundulus lima* (Fig. 1), a killifish about which relatively little has been written.

In a 1981 issue of *Freshwater and Marine Aquarium*, Christopher Stowell provided a detailed account of a successful undertaking to collect *F. lima* from the type locale. Aside from this paper by Stowell, what little existing literature that appears on *F. lima* deals primarily with the exaggerated condition of the contact organs on sexually active males, and the species' taxonomic relationship to the very similar *F. parvipinnis*. Literature concerning reproductive behavior in *F. lima* appears to be non-existent. To the extent that such an appraisal is accurate, the purpose of this paper is to describe for the first time reproduction in aquarium specimens of this species.

Background

The exclusively North American genus *Fundulus* contains approximately 30 species. Collectively, these range extensively over the mainland and adjacent islands in a wide variety of habitats including marine, fresh, and brackish water environments. While the fossil record indicates a more extensive western distribution (Uyeno and Miller, 1962), the genus is presently represented west of the Rocky Mountains by only two species, the typically marine *F. parvipinnis* and the freshwater *F. lima*. *F. parvipinnis* is a common inhabitant of coastal bays and lagoons from central California to Bahia



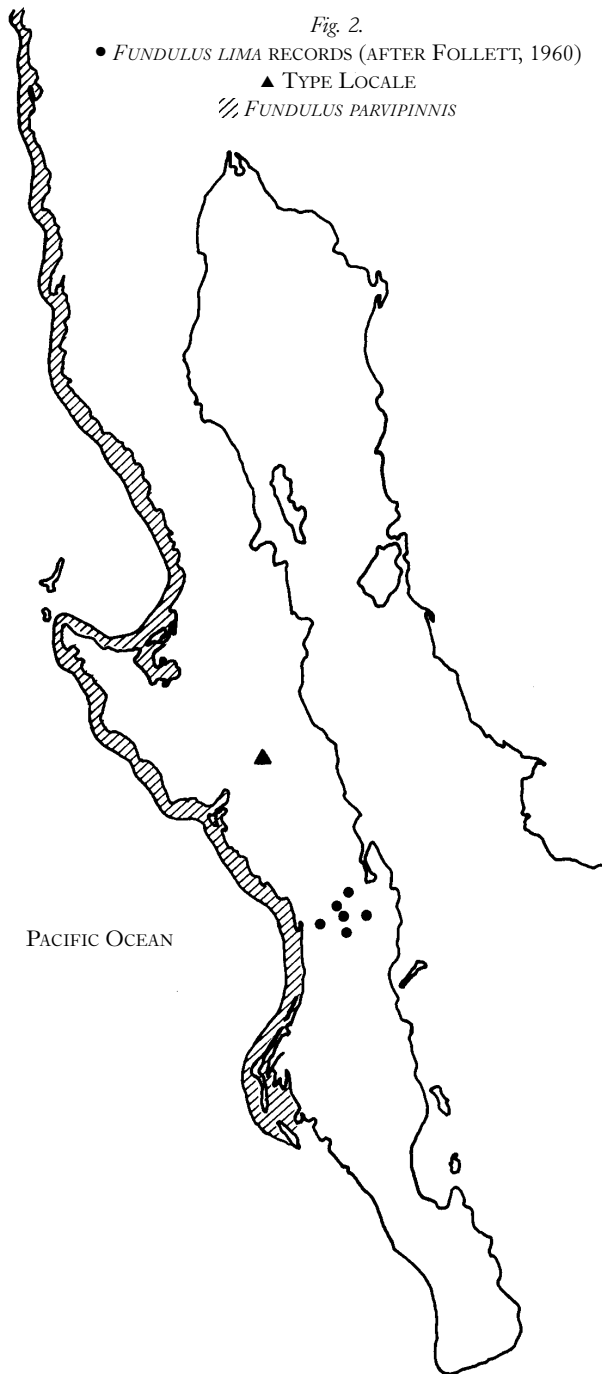
Fig. 1.
A sexually active male
of *Fundulus lima*.
Contact organs are clearly
visible on the anal fin.

Magdalena, Baja California. Although predominantly marine, the species is tolerant of lower salinities and has been reported (albeit rarely) from fresh water (e.g., Miller, 1939 and 1943). In contrast, *F. lima* is endemic to fresh waters of Baja California, having been originally described from the springs at San Ignacio (Vaillant, 1894). It has subsequently been reported from a number of other creeks, streams, and lagoons of south-central Baja California (Follett, 1960; Fig. 2). In consideration of anatomical similarities between these two species, as well as the potential communication of *F. lima*'s type locale with the coastal waters inhabited by *F. parvipinnis*, Myers (1930) suggested *F. lima* to be a "more or less isolated geographic derivative of *F. parvipinnis*." Miller (1943) considered the euryhaline tendencies of the latter species as substantiation of Myers' thesis. One marked difference between the two species is manifest in the size and shape of the anal and dorsal fins of the adult male, those of *parvipinnis* (particularly the anal) being much higher and more pointed. Miller (1943) also stated that the contact organs of *parvipinnis* are developed to a much lesser extent than are those of *lima*.

The term "contact organ" was coined by Newman (1907 and 1909) to refer to the osseous processes ("spines") extending from the exposed margins on the scales of breeding males of many killifishes. Contact organs similar in both structure and

function may also be found on fin rays, most notably those on the anal and/or dorsal fins. Newman noted that these organs are largest and most numerous over those areas of the male's body "that come into the most intimate contact with the female during the spawning act proper or during the preliminary courtship," with species-specific differences in their distribution corresponding to differences in courting and/or spawning posture. Therefore, in species wherein males butt females during courtship, for example, the head of the male may be well endowed with such organs, in addition to the more obvious contact areas such as the posterior flanks, caudal peduncle, and the anal and dorsal fins. The purpose served by the contact organs is that of tactile stimulation and/or providing a frictional surface by which the male can more efficiently hold the female during the spawning embrace (Newman, 1909).

Myers (1930) pointed out the extreme development of the contact organs on breeding males of *F. lima* (Fig. 3). He noted that on the caudal peduncle the "central spine is enormously enlarged, equaling the exposed portion of the scale in length." Moreover, these structures were present to at least some extent on the scales covering "practically all parts of the body." This condition was noted by Vaillant (1894) in his original description and, in fact, serves as the source from which the trivial name derives ("lima" translates from the Latin as "a file," alluding to the rough texture imparted to the body surface by the enlarged spines).



Aquarium Maintenance of *F. lima*

In June 1979, a collection of *F. lima* was made in San Ignacio by members of a private collecting party (see Stowell, 1981). The habitat consisted of an approximately 200-foot stretch of spring-fed stream, the bottom of which was lined with a thick growth of brown vegetation. The water was clear and the current was moderate to swift. While water chemistry was not evaluated, water temperature was estimated at 70°-76°F

(air ca. 80°F). Syntopic with the native *F. lima* were introduced carp (*Cyprinus carpio*) and guppies (*Poecilia reticulata*). Below this section of stream the current was less swift and the water slightly turbid. *F. lima* appeared to be completely absent from this point downstream.

In mid-July 1979, five specimens of *F. lima* ranging in size from 2" to 2.5" standard length (SL) were obtained from Monty Lehman, a member of the collecting party. These individuals were set up in a slate-bottom 10-gallon aquarium containing established aquarium water to which kosher salt was added at the rate of two tablespoons per five gallons. pH was maintained at about 7.2. Fifty to eighty percent water changes were made no less than once a week (typically twice weekly) using aged, but otherwise untreated (except for the addition of salt), tap water. Filtration/aeration was provided by a vigorous air flow through a submersed filter containing synthetic floss, activated carbon, and crushed shells. With respect for the fish's apparently skittish nature, no direct lighting was provided although their aquarium, by virtue of its position in the fishroom, was exposed to relatively bright room lighting. Photoperiod was variable between 18 and 24 hours of light daily. Water temperature varied with ambient room temperature and ranged from a summer high of 76°F to a winter low of 58°F.

In anticipation of potential spawning activity, the fish were provided with various media commonly utilized by killifishes for egg placement in the aquarium. These included both floating and sunken synthetic spawning mops, dense free-floating vegetation (Java moss, *Vesicularia dubayana*), and a large dish containing coarse aquarium gravel.

Food items (listed here in descending order of percentage of diet) consisted of prepared flake foods, live brine shrimp, frozen beefheart, live *Tubifex* worms, and grindal worms. Feedings of vegetable matter were so infrequent as to be insignificant. Moreover, because of the low level of lighting in the aquarium, there was no growth of algae upon which the fishes could graze.

Under the above conditions, *F. lima* was maintained in very good health. An acute case of "ich" was effectively treated by the use of the commercial medication Aquarisol,[®] tripling the salt content of the water, and by performing substantial water changes. It should be here noted that the fish respond very well to water changes; these have been found to be very beneficial during both treatment and routine maintenance. As of this writing only one fish has died, this being a young specimen that jumped from the aquarium during the first week in captivity. The water level was subsequently lowered to

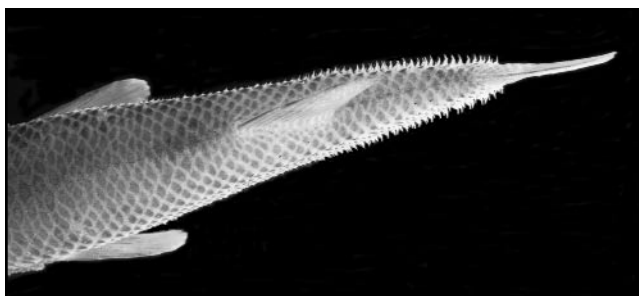


Fig. 3.

From a dorsal perspective, the highly developed contact organs of the adult male are readily observable, being most prominent on the caudal peduncle and less well-developed elsewhere. The fish pictured is a 4" (TL) specimen photographed in July, exactly one year after capture.

2" below the top of the aquarium and a tight-fitting plastic cover was provided. Unknown to me at the time, it was these two precautions which would lead ultimately to the discovery of the unusual spawning behavior of this species.

Preliminary Observations

Sexual distinctions became apparent as the dominant male exhibited a very dark and dusky overall body coloration (Fig. 1; front cover photo, top), as well as a decidedly territorial nature. The females, in addition to being more robust, were also seen to possess slightly smaller and more rounded anal and dorsal fins which contained much less pigmentation than those of the male (front cover photo, bottom). The females were known to be sexually ripe since they were observed to expel eggs spontaneously (i.e., in the absence of the male) in response to fear-invoking stimuli (e.g., the presence of my hand in the aquarium, etc.). Needless to say, these eggs never developed.

Sexual dimorphism and dichromatism will not be discussed here at length as these are well-illustrated in the accompanying photographs. It should be noted, however, that these differences are less pronounced than in sexually active adults of the great majority of killifishes, which are typically known for marked, often extreme, differences between the sexes.

Considering the fish's excellent physical condition, it was thought unusual to find no eggs in any of the spawning media during the first three months in captivity. That eggs were eventually discovered at all was serendipitous to say the least. In mid-October 1979, having removed the aquarium cover for a routine water change, I was taken completely by surprise to find 15 eggs adhering to the undersurface of the cover as well as the exposed metal rim of the aquarium almost 2" above the surface of the water. One of six eggs removed to a plastic incubation tray developed and hatched normally,

tentatively demonstrating the efficacy of such a reproductive scheme. The fish were subsequently maintained in sexual isolation for further investigation into the specifics of their reproductive behavior.

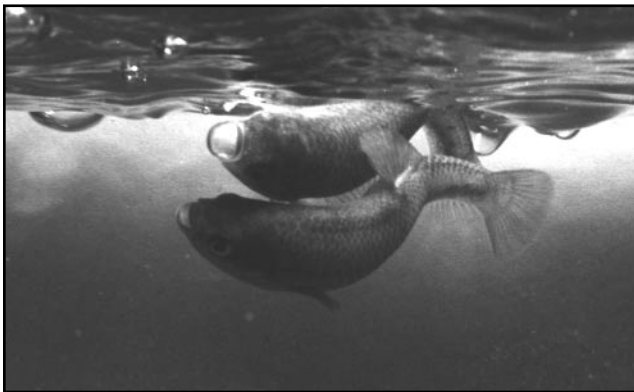
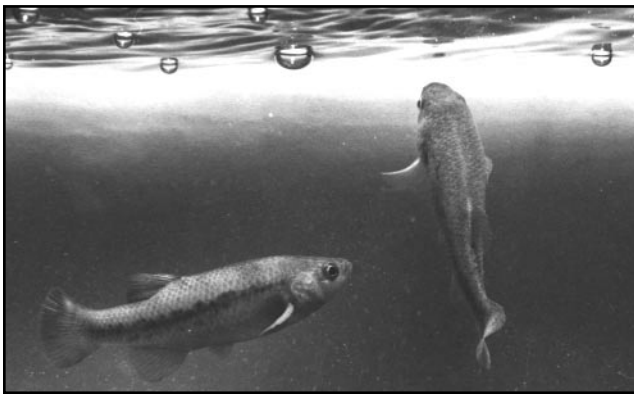
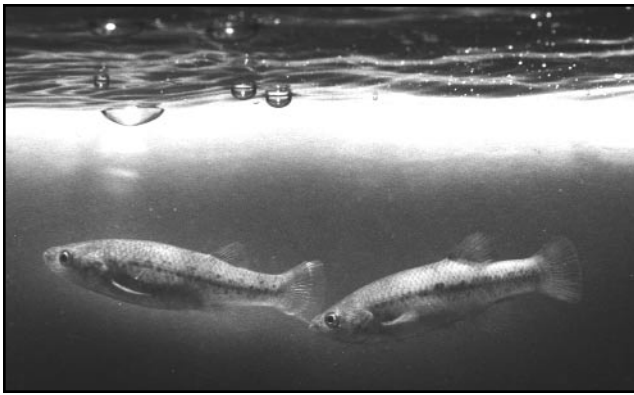
Since the actual spawning act was not observed, it was not known for certain whether the fish copulated out of the water (e.g., in the manner of the South American characin *Copeina arnoldi*), or if they simply spawned at the surface and splashed their eggs out of the water. Taking into account the fish's size and shape, the latter hypothesis seemed the more likely of the two, since it was doubted that two such stout fish could adhere to vertical, much less horizontal, extra-aquatic surfaces. (*Copeina* is a small, slender fish with a much greater surface:mass ratio.)

Subsequent observations made on 11 separate occasions and collectively comprising 16 hours of observed spawning activity unequivocally confirm this assumption: *F. lima* indeed spawns at the water's surface and splashes its eggs out of the water! Behavior throughout this period was completely consistent and varied only in minor aspects. What follows below is the procedure which I presently follow for purposes of propagating *F. lima* and an idealized conception of the resulting spawning behavior.

Spawning Behavior in *F. lima*

The sexes are conditioned separately, one fish to a 10-gallon tank, and are otherwise maintained as indicated above. After several days to a week (or longer) in sexual isolation, the sexes are united by moving the female into the male's aquarium, which is completely bare except for the presence of a filter. The distance between the water's surface and the underside of the aquarium measures between 1" and 2". Temperature during both conditioning and spawning varies with ambient room temperature. To date, spawnings have occurred at temperatures ranging from 67°F in the month of October, to 62°F in the month of February. Surprisingly, this variable appears not to be very critical. Level of illumination during spawning, however, does appear to be critical, as the species shows a strong aversion to bright lighting. Accordingly, spawning activity is observed by the light of a single 100-watt bulb at about 10' from the aquarium. Such lighting is bright enough for observational purposes, but dim enough to make the fish feel at ease. In the same regard it is essential that the observer remain completely unobtrusive throughout.

Upon uniting the sexes, the male immediately darkens in color and initiates courtship, which is comprised primarily of



Figs. 4-6.

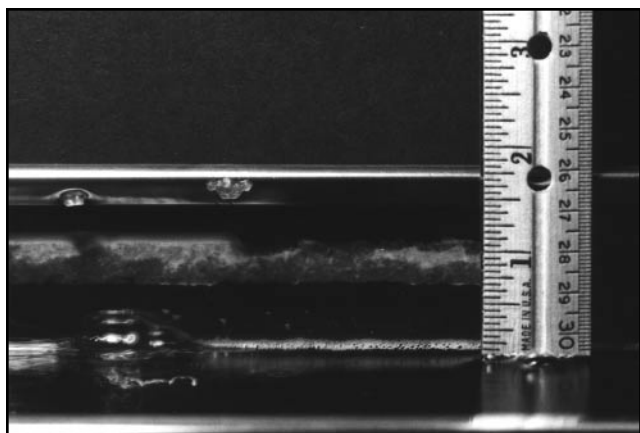
A typical spawning sequence in *F. lima*. Courtship begins with the male chasing the female, apparently attempting to coax her to the surface of the water. The female's swimming "head up" at the surface seems to signal her receptiveness to spawn. Not long thereafter, the male aligns alongside the female and the two fishes roll on their sides in a spawning embrace. It can be seen that during copulation the female's vent area actually protrudes from the water.

chasing and biting the female (Fig. 4). He will occasionally confront the female from an oblique angle and display for her, although the frequency and magnitude of such displays are not very impressive. Usually after several minutes of chasing, the male will be able to align his body parallel to that of the female, where he quivers alongside her, perhaps providing stimulation by means of his contact organs. By now a velvety

charcoal-black coloration permeates the entire body and fins of the male.

All of this courtship typically takes place in the lower reaches of the aquarium. However, a spawning embrace does not take place here. As courtship progresses, the male appears to become more intent on chasing the female to the surface of the water, the only place at which spawning will occur. As the female becomes increasingly more receptive to the actions of the male, the activity of the fish centers just below the surface of the water. The female seems to signal her receptiveness by swimming "head-up" at, or near, the surface in the presence of the male (Fig. 5). (Prior to this she signals her lack of receptiveness by fleeing from the male's advances.) The receptive female allows the male to swim alongside of her, whereby the two fish assume the typical "S-shaped" killifish spawning posture, with the male wrapping his anal and dorsal fins around the female's body. At this point, the fish quickly rotate 90 degrees or so. Instead of copulating with their bodies in a vertical plane, they are now laying on their sides, one on top of the other, with the male always assuming the bottom position. This position is without a doubt a prerequisite for copulation. Once in this position the female is driven forward a short distance, the pair now rotating slightly tail-over-head so that starting the embrace more or less parallel to the water's surface they complete the embrace with heads pointing downward and tails pointing upward. A single embrace lasts from 2-3 seconds and results in about 12-20 eggs being splashed onto exposed horizontal and/or vertical surfaces one or two inches above the water line (Fig. 7). Usually this is the underside of the aquarium cover, but occasionally includes the upper rim of the aquarium frame and/or the bead of silicone that runs along the corners of the tank. Despite the adhesive quality of the eggs, they do not invariably reach and/or adhere to these objects. Those that fall back into the water are summarily eaten by the breeders as quickly as they fall.

An embrace may, however, occur with no eggs being produced. Sometimes eggs are expelled during the first embrace; other times egg production is preceded by one or more unproductive embraces. Whether or not eggs are produced, the anal fin of the female (and possibly that of the male as well) vibrates rapidly throughout the embrace, apparently providing the propulsive force which drives the eggs from the water. Even unproductive embraces result in water being splashed onto the undersurface of the aquarium cover. Only upon close examination of my spawning photographs was it discovered that the female's vent area appears to protrude from the water at the height of the embrace (Fig. 6).

*Fig. 7.*

With the aquarium cover removed, 13 eggs in three separate clutches are visible more than 1.5" above the water line. Not shown are several eggs adhered to the undersurface of the aquarium cover.

It is also at this time that the fish's vents do not always appear to be in closest approximation, although judging from the very low percentage of bad eggs, fertilization is nevertheless highly efficient.

More often than not, the entire spawn is delivered in only a single copulatory act, although it is not uncommon for eggs to be produced in several separate embraces. After the female is spent, she becomes unreceptive to the (sometimes aggressive) advances of the male, and she may be abused by him if the two are left together for an extended period of time. As the eggs most often appear within 20-40 minutes of the sexes being united, it is usually unnecessary to keep them together for more than about an hour, unless of course their spawning endeavors are disrupted by activity outside the aquarium or by too high a level of illumination, etc. I should point out that, because these fish are quite important to me, I am being somewhat overprotective; they could very well be left together for longer periods of time with no adverse effects. However, utilization of this episodic spawning regimen entirely precludes the female's being battered by a potentially intolerant male. The promiscuous male, on the other hand, is only too eager to spawn with a fresh, ripe female that is introduced as the spent female is removed.

It cannot be overemphasized that, throughout the course of 16 hours of observed spawning activity, copulation was never observed to take place anywhere but at the water's surface; nor did the fish ever spawn against any substrate. Moreover, the uniformity of behavior throughout the entire series of spawnings is very impressive. There was little or no variation in the fish's specific actions, nor in the sequence in which they occurred. Although the courting male would align

*Fig. 8.*

At times the pair will spawn near (or even in) the vigorous filter outflow.

alongside the female anywhere in the aquarium, a spawning embrace (as defined above) would occur only at the surface. While the fish seemed to show a slight preference for spawning along the sides of the aquarium (particularly along the rear glass), they have been observed to spawn at virtually all surface locations, including any of the four corners, the center of the tank, and even in the violent filter outflow (Fig. 8). It was found that if the aquarium cover was removed and narrow cardboard "target" strips were placed above the water, the fish did not actively seek these targets under which to spawn; they would spawn under an open area just as readily as under a target (although these "experiments" have been few and may not accurately indicate the fish's true propensities).

Treatment of the Eggs

The large (ca. 3 mm diameter) eggs are profusely covered with a white, fuzzy substance that probably serves an adhesive function. This "fuzz" is extremely fine and only appears as such at about 100 times magnification. To the unaided eye it appears almost gelatinous in consistency. It extends a distance of 1-2 mm off the surface of the eggs and is so prominent that the eggs appear at a glance to be covered with fungus.

Should the eggs be left where they land, they are invariably gone within 24-28 hours. It is not known whether they fall back into the water spontaneously or if the parent fish (typically just the male) actively splash them down in order to eat them. While their mode of detachment is uncertain, their fate is not, as the eggs are most certainly eaten as they enter the water. (In this regard it will be interesting to see what becomes of eggs left out of the water when both breeders have been removed from the aquarium.)

Table 1. Incubation times of *Fundulus lima* as related to temperature. Mean temperatures rounded to nearest 1°. Note: Eggs were generally spawned and incubated at ambient temperatures. However, in at least one instance eggs were incubated at controlled higher temperatures for the sake of experimentation.

| Range | Temperature/°F | | Incubation Time/Days | Number of Eggs |
|-------|----------------|------|----------------------|----------------|
| | Mean | Mode | | |
| 62-65 | 64 | 64 | 28-35 | 13 |
| 62-67 | 64 | 64 | 30-31 | 2 |
| 64-69 | 66 | 65 | 21 | 1 |
| 62-72 | 69 | 70 | 25-35 | 10 |
| 74-82 | 79 | 79 | 14-18 | 5 |

If the eggs are to be saved, they are removed from their place of attachment and incubated in typical killifish fashion. Specifically, they are placed in a plastic shoebox, Petri dish, etc., containing any clean water (preferably from an established aquarium) to which is imparted a very light coloring with acriflavine. The eggs may be left to incubate at either ambient or controlled temperatures which, as far as can be told from present (limited) experience, may be anywhere from 62°-82°F. (This range will likely be enlarged with further experimentation.) Recorded incubation times as related to temperature are given in Table 1.

As can be seen, there is considerable variability between eggs from the same spawn even when incubated together. Were larger samples used in these experiments, it is probable that the degree of variability would be even larger.

At a temperature of about 78°F ($\pm 4^\circ\text{F}$) the heart begins beating in about three days. By five days the eyes are becoming pigmented, and by eight days they are dark and well-formed. So large are the eggs that the heart may be seen beating using nothing but the unaided eye. Just prior to hatching at about 14 days, the iris of the eye is seen to be very prominent and the rays of the caudal fin (which is folded over the embryo's right eye) are easily discernible.

Since hatching may be delayed for days after development appears to have ceased, the eggs may be "force hatched" when, under microscopic examination, the embryos appear fully developed. Various forced-hatching techniques include making a simple water change, increasing the CO₂ content of the water, and/or subjecting the eggs to a change in temperature. All three variables may be combined by transferring the eggs to a small vial, exhaling into the vial while capping it tightly, and placing it in a slightly cooler location. Some hobbyists prefer to place the vial in their pant's pocket as they go about their fishroom chores, assuming the resulting increase in water temperature, possibly in conjunction with the physical agitation of the eggs, facilitates hatching. While I have found forced-hatching to be effective with fully developed *F. lima* eggs, there seems to be no difference in fry mortality between eggs

that are force hatched and those that hatch much later without such artificial intervention.

Regardless of the circumstances under which the fry emerge, they are quite strong at birth. Although they are fairly mobile, they are unable to maintain their buoyancy when at rest. This condition is ephemeral, as the fry are seen hovering at all water levels by the time they are one day old. Since they possess little or no yolk upon hatching, they are offered their first foods at this time. These include brine shrimp nauplii, microworms, and finely powdered prepared foods. As feeding commences, a few snails added to the shoebox and twice-weekly water changes help prevent the water from fouling.

Measuring about 9 mm (3/8") TL at birth, the fry are very slender and elongate, a form they retain throughout their first few months of life, notwithstanding their hearty appetites. Growth has been fairly slow in my aquaria, most probably attributable to the relatively low temperatures (60°-65°F) at which they're maintained. As of this writing, the oldest F1 fish measures only 20 mm (3/4") TL at four months of age. I would obviously anticipate a higher rate of growth as the summer months bring warmer temperatures to my fishroom.

Discussion

While the discovery of such an idiosyncratic reproductive methodology has, for me, been very exciting and extremely interesting, I am bothered by one rather large shortcoming, namely my inability to offer an acceptable theoretical rationale for such behavior. It would be very nice if the habitat from which my fishes were collected was shrouded in overhanging vegetation or some other such analog to my aquarium cover but, unfortunately, this is not the case. Also disconcerting is the disinterest shown by my specimens for targets placed above the water (although as mentioned above, these trials were few and the results are not necessarily representative). It is also possible that the fish spawn along the periphery of their open-water habitat and splash their eggs onto the stream's banks and/or emergent vegetation where they drop into the

water at a later time. This hypothesis would gain much support should a tendency to spawn along the sides of the aquarium be shown to be significantly greater than a tendency to spawn in the center of the tank. Although such a trend seems to exist, there are not enough data to call it significant.

A further possibility is that the spawning behavior of *F. lima* is not designed to deposit eggs on terrestrial surfaces. Commenting on a similar observation by Mayer (1932) in the European species *Valencia hispanica*, Breder and Rosen (1966) claim that such aquarium behavior may simply mean that, in nature, the eggs are widely scattered and not necessarily directed toward extra-aquatic objects.

However, while I am admittedly at a loss to explain why *F. lima* spawns like it does, I have no doubt whatsoever that the reproductive behavior outlined in this paper is, in fact, representative of the species, i.e., that it is not an aberration brought about by the highly artificial conditions of life in the aquarium. My reasons for this belief are severalfold. Foremost is the fact that the fish are simply too good at what they do for it not to be an inherent trait. It is highly unlikely that the degree of precision required to carry out such a highly ordered and strictly defined behavioral sequence could be happened upon randomly by fish not possessing the requisite genetic "pre-wiring." Moreover, the consistency with which this behavior was observed is compelling. As mentioned previously, never were the fish observed to spawn in any manner but that as described herein. Nor would they even embrace anywhere but at the water's surface. While certain other killifishes (particularly several of the genus *Rivulus*) have been reported periodically to deposit eggs above the water line (i.e., on top of floating spawning mops), this is an occasional phenomenon in fishes that normally accept other media in which to deposit their eggs. The same may be said in regard to Mayer's (1932) observations on *Valencia hispanica*, since *V. hispanica* spawns readily in both floating and sunken mops. These occurrences are quite different from the highly specialized and uncompromisingly consistent behavior found in *F. lima*.

Also, the total indifference shown by *F. lima* for seemingly more "conventional" spawning media (plants, gravel, etc.) is evidence against its utilizing such media in the wild. Most, if not all, killifishes will readily accept media which is, to some extent, similar to that encountered in the wild. Thusly, the South American annuals will accept peat moss as a substitute for the mud in which they would normally spawn. The so-called "plant spawners" deposit their eggs readily in synthetic spawning mops, etc. However, while these fishes may compromise a bit

in accepting artificial conditions, the major aspects of their reproductive behavior do not vary much, and if they do they are likely awkward and inefficient. Almost without exception, there is a close correspondence between captive spawning behavior and that which occurs in nature. Should *F. lima* spawn differently in the wild, it is hard to imagine why, upon entering the aquarium, it decided to turn upside-down and splash its eggs out of the water. It is even harder to imagine how it could do so with such proficiency were the behavior not genetically conditioned.

Along these lines, it is suggested that the field observations by Stowell (1981) merit reinterpretation. What was considered "an unmistakable attempt to spawn, in the typical killifish fashion," namely the attempt by one fish to push another against a clump of vegetation, was more likely the aspect of courtship referred to as "aligning" in my spawning description. It is not unlikely that superimposed upon this observation was the observer's expectation of what killifish reproduction is supposed to look like and where it typically takes place.

Additionally, there are components of the spawning act which are most certainly adaptations corresponding to this particular method of reproduction. For example, if as suggested by Newman (1909), the contact organs function in part to create a frictional surface with which the male holds the female in spawning, it is immediately evident that the competency of the male *F. lima* in such an intricate spawning act may very well be contingent upon the development of these organs. There would, thusly, be positive selective pressure for the enlargement and extensive distribution of these organs, both of which are found in *F. lima*.

Further, that 20 or more eggs may be released in a single embrace is a marked digression from the typical killifish method of egg expulsion. Were the eggs to be released singly or several at a time, as is characteristic of killifishes, spawning for *F. lima* would be an exhausting and/or highly inefficient endeavor. Also noteworthy is the complete absence of a substrate against which the fish spawn. Foster (1967) recognized the almost universal tendency (among killifishes) for the breeders to clasp (i.e., embrace) against a substrate. He regarded the typically "pelagic type of spawning, with a large number of eggs being expelled all at once in open water" to be an essentially uncharacteristic mode of killifish reproduction, having been absent in more than 40 species studied by him as well as all of those discussed in the literature.

By far the most intriguing discovery is the uncanny similarity between the behavior I observed in *F. lima* and that described by Foster in the Oryziidae, a group formerly

considered among the killifishes but subsequently recognized as a separate family by Rosen (1964).^{*} Foster writes:

Most of the courtship behavior consists simply of the male pursuing the female, swimming along a short distance below and behind her. If the female is receptive to the courtship activities of the male she performs a peculiar "head-up" behavior which has been described and figured by Ono & Uematsu (1957). The male stays ventral to the female throughout the preliminaries of the courtship behavior. The spawning act or clasp is similar to that observed in other species of killifishes in that the dorsal and anal fins of the male are inclined toward and closely appressed against the female, while the bodies of both fish are bent into parallel sigmoid curves.

However, I wish to point out that the spawning of the medakas differs in two significant ways from that of most of the other killifishes which have been studied by me or described in the literature: (1) the spawning clasp of the medaka is "pelagic," i.e., consistently performed in open water, not in contact with any substrate; and (2) all of the eggs are extruded by the female and fertilized by the male at the culmination of a single clasp, which may last 30 seconds or more.

With the exception of the longer duration of the spawning embrace and the fact that the eggs are not splashed from the water, there is little to separate Foster's account of *Ozyriasis* reproduction from mine of *F. lima*. Of particular interest is the same "head-up" behavior by which the female signals her receptiveness to spawn. Considering the taxonomic distance between *Oryziias* and *Fundulus*, however, these similarities can at best be considered the result of evolutionary convergence, if not simple coincidence.

Subsequent to Foster's article, Berkenkamp (1974) reported on the spawning of the African species *Lamprichthys tanganicus*, stating that this species spawns "not on plants but without a substrate in the open water." He does not detail the actions of the breeders during spawning, nor does he specify the number of eggs released per spawning embrace, although his reference to an "enormously large spawning" obtained by Ladiges would imply that this number is fairly large. Again, the similarities to *F. lima* are interesting, if only coincidental.

Conclusion

It is obvious that the reproductive behavior of *F. lima* deserves further study. Far from being a definitive statement on *F. lima*, these observations could serve no better purpose than simply to stimulate the interest of those more qualified than myself to evaluate this phenomenon. The establishing of

^{*}Editor's note: A more recent classification places the former family Oryziidae (medakas or ricefishes) as a subfamily (Oryziinae) of Adrianichthyidae within the Order Belontiiformes.

an aquarium strain of *F. lima* would do much to facilitate such study. To this end, the task at hand would seem to be that of insuring the continued existence of *F. lima* in the hobby so that others might also have the opportunity to observe the unusual and enigmatic reproductive behavior of this species.

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