# North American Killifish - Part 1
# *Lucania goodei* Jordan 1880
# A Summary Review

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This article is the first in a planned series featuring killifishes of North America. Fresh, brackish and the few full-marine species that occur from the U.S. south to Mexico and the Caribbean islands will be included. Although the definition of North America encompasses Central America and the transition zone to South America at the Panama-Columbia border, the many killifishes from these regions will not be included in this series.

Some reviews, especially of little-known or studied killies, will be cursory. Others reviews, especially those that relate to more common and better studied species, will be more extensive. And because it has not yet been determined how groups of closely related species may be combined in a given review, it is uncertain how many installments will ultimately comprise this series. *Lucania goodei* (Fig. 1) is our first subject for no other reason than it is one of my favorite native fishes.

### Nomenclature

*L. goodei* has variously been known by the common names "Blue Dace" and the "Bluefin Dace," but it is a true killifish and not a dace at all. The accurate common name is the "Rainwater Killifish." It is one of only three species in the genus *Lucania*, a genus erected in 1859 by Girard. The other two include: *Lucania interioris*, which is an IUCN Red Listed species designated as critically endangered (Contreras-Balderas and Almada-Villela, 1996), and *Lucania parva*, a primarily saltwater species that has a few relict freshwater populations. These species will be the subject of a future article.

The subgenus under which *L. goodei* is placed, *Chriopeops* (Fowler, 1916) was for a time incorrectly used as the genus for this species. That is no longer the case, and the current nomenclature appears well settled. *Chriopeops* is still considered a valid subgenus. *L. goodei* is the type for the genus and its type locality is the Arlington River, a tributary of the St. Johns River which flows through a vast region of northeastern Florida.

### Distribution

*L. goodei* is found over a vast range, stretching from throughout the Florida peninsula and to the panhandle where it occupies the east coast and the regions west to the Choctawhatchee River drainage (Page and Burr, 1991). It continues north from the Florida panhandle into the extreme southeastern corner of Alabama, and the Chipola River drainage. It is also found in discontinuous ranges along Atlantic Coast as far north as central South Carolina where it is thought to have been introduced. There are also reports of introductions in Texas and California as well (Buchell, 1998). *Lucania goodei* is common throughout its natural range and appears to be very well equipped to not only survive, but to thrive in a number of different habitats.

### Literature

A beautiful and adaptable native American killifish, *L. goodei* has been the subject of many articles over the last few decades. However, a review of this body of literature reveals some startling variations in the description and experiences of the various authors. We read largely differing accounts of fin color, and to a lesser extent, variations in accounts of breeding habits, natural conditions and rearing requirements. It turns out that virtually all the reported observations are true. They are, however, incomplete because they are essentially personal observations limited to localized populations. As such, these reports represent small samplings of specific population variances and the range environments. This article attempts to present a larger view of the species by consolidating these fragmentary reports and adding the results of personal experiences with the numerous Florida populations.

## Description

Male: The dorsal fin is blue in most populations, but can exhibit combinations with other colors as well. This fin has from nine to 12 rays and is positioned in front of the anal fin insertion (Page and Burr, 1991). It is in the anal fin coloration where we see significant variations among and within populations. With some notable exceptions, these variations roughly correlate to geographic regions. The color of the anal fin varies from almost clear to a rich red, yellow, blue or green, and often in combinations of these colors.

In general terms, the *L. goodei* from the southwest coastal regions of Florida, defined for our purposes from Sarasota to Port Charlotte to Fort Myers, exhibit anal fins that are red-orange to red, with little blue coloration. These populations also show red in the posterior region of the dorsal fin (De Bruyn, 1999),(Specht, 1977). In central Florida, a region we define from Gainesville through Tampa Bay and south to Sarasota, we see *L. goodei* dorsal and anal fins in bright iridescent blue, edged in black, and with a black band at the base (Fig. 2 and color plate 5, p. 23). The central region is considered a transition zone, however, because we also see isolated populations exhibiting orange or smaller amounts of red color in the anal, replacing the blue. In areas from Gainesville to the Florida panhandle and north to Georgia, we find populations with green, yellow and greenish-yellow anal fins (Skidmore, 2000), tending to lemon yellow in the upper Florida panhandle (De Bruyn, 1999),(Specht, 1977). The coastal part of the range from Georgia to South Carolina produces specimens with clear to pale yellow or pale green anal fins with no red, orange or blue.

However, there are significant variations even within these regions. For example, at a site in Hillsborough County east of the city of Tampa, we find individual *L. goodei* males with blue anal and dorsal fins, together in the same site with males that exhibit a great deal of orange to red in both fins (Skidmore, 2000). Obviously, the genes for both color forms exist within that same population, and at this site at least, both colorations are expressed. Likewise, in Citrus County, located in the northern part of the central region, we find isolated populations exhibiting a greenish-yellow anal fin. At Hunter's Spring on the Crystal River just south of the

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*Fig. 1.*
*Lucania goodei* blue form from Morris Bridge Wilderness Park, Tampa, Florida. See this photo as a color plate on p. 23.

Florida panhandle, *L. goodei* is reported with clear fins (Arbour, 1990). Yet north of there, in the vicinity of Tallahassee, pink anal fins are reported and this region is very far from the orange and red forms found at Port Charlotte (Ballard, 1987). The series of photos illustrate some of the color variations encountered (see color plates, p. 23).

The caudal fin is generally red-orange in all populations, but is not as intensely colored as the other unpaired fins (Webster, 1977). There is a small region of pale blue at the base, followed by a region of red or red-orange varying in intensity and the amount of red coloration. The caudal terminates with a translucent region at the margins. In those populations that exhibit a pink anal fin, there is also a pink to red region at the caudal base, virtually replacing the blue (Ballard, 1987).

The maximum male size is listed by most sources as two inches, but slightly larger males have been collected in Florida by this author and others. The body of the male *L. goodei* is fairly slender and compressed, with a small upturned mouth. There is a characteristic and rather wide zigzag patterned stripe that is a black to cocoa color, and varies in intensity dependent on both the condition of the specimen and where it is found. This stripe extends from the tip of the snout through the center of the eye, then widening on the flanks, and narrowing again as it approaches the peduncle. It terminates there to a black spot on the base of the caudal fin. There is a dark-edge to the scales that, when prominent, gives a net pattern to the flanks. The overall body color of the fish is light brown, lighter above the line, grading to an olive or dusky gray back. The area above the line sometimes exhibits a hazel sheen (De Bruyn, 1999). The body color below the zigzag pattern is darker brown grading to a cream underside. The number of lateral scales varies from 29 to 32 (Page and Burr, 1991).

Female: The females are slightly smaller than the males, getting to 1 ¾". The body of the female is light brown with a hint of the aforementioned zigzag pattern. The brown sometimes gives way below to a brilliant silver underside. Otherwise, she lacks the complex body patterns and colors of the male. All fins are clear or yellowish (Buchell, 1998)(Webster, 1977).

## Habitat

It is no surprise that such a highly variable fish would be found in a number of different natural settings. *Lucania goodei* is found in virtually every habitat available throughout its range, except perhaps in swiftly moving streams. It has been reported in cool and deep springs, with extremely clear water, and much aquatic competition (Arbour, 1990). Interestingly, clear springs are also the locale of the "clear fin" variety. This is reminiscent of the African killifish genus *Nothobranchius*, whose caudal fin color and intensity are often dependent on the clarity of their habitat. In these springs, the *L. goodei* are often found at a depth of 10 feet or more, perhaps giving rise to the reports that they are found in deep water.

Other habitats include: natural springs, rivers, lakes, small pools, and man-made retention ponds. While some people have observed that *L. goodei* remains well below the surface (Buchell, 1998; Page & Burr, 1991), others, including this author, often find them at the surface and in shallow water where they appear to prefer the protection of plants. Even in a river habitat where there is some current, *L. goodei* can be found under plants floating at the surface (De Bruyn, 1999). At Alexander Springs in central Florida, the water is often less than two feet deep, with large patches of rooted plants that are bent over by the modest flow from the spring. Each swipe of my net through these plants, and in the direction of the flow yielded a number of *L. goodei*. They were lying just below the plants, and no more than one or two feet deep.

The temperature variations among these habitats are quite large due to seasonal factors, the water source, and its depth. Many collections of *L. goodei* have been made by members of the Central Florida Region during warm summer months where standing water easily gets into the high 80s°F. Long time hobbyist Dr. Harry Specht reports that he collected them in shallow ditches in direct sunlight when the water was so hot it was uncomfortable for him to stand still and fish (Specht, 2000)! Low temperatures are equally well tolerated. This author has gotten viable eggs from *L. goodei* in water at 62°F, and has collected this species in January where the water temperatures were well below 60°F. Some members report no losses when *L. goodei* is maintained in tanks and tubs outdoors where temperatures as low as the upper 40s°F occur in the winter (Specht, 2000). There are no reports however of breeding occurring at these extremes.

Natural water characteristics are quite varied, especially between the coastal and inland regions, both of which are greatly influenced by periodic heavy rains that are characteristic of southeastern U.S. summers. The water found in inland Florida for example, tends to be slightly acid and soft, with low conductivity. The water at Florida's coastal regions is quite hard, has high conductivity, and pH values are often in excess of 7.5. The composition of natural springs and their extensive outflows tend to be much more stable because of the constant replenishment from the deep aquifer. Therefore, these habitats are not as much affected by rainfall or external temperature. They tend to be somewhat acid, yet moderately hard, and temperatures hover around 72°F throughout the year.

Since *Lucania goodei* thrives in all these environments, it is obviously quite tolerant of water chemistry and temperature extremes, confirming its ability to adapt not only to highly variable natural environments, but the unnatural environment of the aquarium as well. It should be noted that some older literature implies that salt or brackish water is tolerated or even recommended. I believe that these references confused the requirements of the closely related marine form, *Lucania parva*, and inadvertently applied them to *L. goodei*. This species may be able to withstand such water conditions for periods of time, but their natural habitat is fresh, not brackish water.

## Collecting

Henri DeBruyn's excellent article (De Bruyn, 1999) provides a practical and general tutorial on collecting Florida natives. Because of its common distribution and its propensity to take shelter under overhanging or floating plants, *Lucania goodei* is one of the more easily collected killies. A dip net, quickly thrust under the plants or around submerged objects and quickly lifted or dragged to the bank will produce a few *L. goodei* with each try. Partially submerged logs and stemmed plants in a few feet of water are ideal habitat, and *L. goodei* can sometimes be found in large numbers in such micro-habitats (Fig. 3). Some will also be taken in seines especially if worked through plant beds. It is often found with *Poecilia latipinna*, *Heterandria formosa*, *Gambusia affinis holbrooki*, and *Fundulus chrysotus*.

Generally, the sexes are quite even and pairs will inevitably be caught. Although *L. goodei* sometimes appears to shoal, it is not truly a schooling fish, and once a group is scattered fewer individuals are picked up with each pass. The group will not reassemble until the interlopers have left, and the water is once again calm.

## Aquarium Environment

*L. goodei* is not a gregarious species or one that displays readily. It is skittish, will lose color and crowd around any


*Fig. 2.*
*L. goodei* from the transition zone between Tampa and Sarasota Florida, captured in Myakka State Park. The anal and dorsal are primarily blue but show the intrusion of some red coloration. Please see the color copy of this photo on p. 23.


*Fig. 3.*
Rum Island Park, Swanee River drainage system. Many *L. goodei* were taken around the partially sunken log, along with several madtom catfish.

object in bare aquariums or those with little cover. To observe any kind of natural behavior, and to appreciate the wonderful colors, one must provide a heavily planted tank with plenty of overhanging or floating vegetation, or artificial spawning mops that provide the same kind of cover. For those who are unfamiliar with the construction of a spawning mop, a sketch and step by step instructions are given at the end of this article. Any activity around the tank will send this species hiding. A quiet environment will be rewarded with observations of colorful males actively courting females, driving them into the spawning mops or strands of vegetation to deposit their eggs. In the presence of a group of compatible species such as the *Pteronotropis* types, some individual *L. goodei* will swim and feed with the group, and abandon their normal shyness.

Males are not aggressive and although occasionally driven, females are not harassed or damaged by the spawning process. Large groups can be maintained in a 20-gallon aquarium, and one pair or trio do well in a 2.5-gallon tank. Overcrowding however will result in loss of color. The fact that this killie is highly tolerant of water variations does not imply that poor aquarium management is tolerated without a corresponding decline in vitality. This is a tough little fish and not prone to disease, so if they appear uncomfortable or lose color, water quality should be immediately examined.

There is a difference of opinion regarding the impact of large water changes. To be sure, *L. goodei* is subject to rapid and extreme changes in water conditions in their natural habitats where large rainfalls inundate and cleanse watercourses in a matter of minutes to hours. Nonetheless, some authors have indicated that large water changes will require a recovery period before *L. goodei* will resume normal activity (Buchell, 1998), while others hold that frequent water changes induce spawning (Terceira, 1972). I normally change 30% of the water each week without noticeable changes in behavior. However, the new water is quite close chemically to the old, minimizing any shock potential. As in all things, moderation is recommended, and if the new water matches the water it is replacing, large water changes should not be a problem. At a minimum, moderate weekly water changes are highly recommended to keep pollutants at their lowest practical level.

As in nature, temperature extremes in aquaria are well tolerated. My fishroom is an air-conditioned and insulated, but unheated garage. The *L. goodei* tank is on a lower shelf and remains in the high 70°F range throughout the hot summer, and in the mid to low 60°F range in the coldest part of the winter. I have not observed any change in behavior or seasonality under these conditions except that spawning ceases when the temperature is less than 60°F. The age of the fish and nutrition seem to be more important than temperature regarding the health and propagation of this species.

### Feeding

*L. goodei* have large appetites as do most North American killifish, and they can consume surprising amounts of food given their size. They tend to dash from their hiding places to feed, then quickly retreat. They will feed at leisure only when there is no nearby activity, or when they are associated with a group of compatible species. Some earlier articles indicated that only live foods are taken, but this is simply not so. All manner of food is taken and generally taken eagerly. Of course, all live foods are relished as are most freeze dried and frozen foods. Dry food is also reported to be taken without problems (Specht, 1977).

The technique of keeping native fishes in outdoor ponds and aquariums is not uncommon in the southern states, and in the case of *L. goodei*, is quite successful within the temperature range from the upper 40s°F to the low 80s°F. Experienced hobbyists have had success in outdoor aquariums that have an abundance of green water, and are planted with *Elodea*, Hornwort, and Java Moss clumped on the bottom (Specht, 2000). Occasional feedings are necessary because it is unlikely that enough insect food sources in the typical urban area will find their way into a backyard pond or aquarium.

### Pre-Breeding Conditioning

Quite simply, pre-conditioning is a two-week process that includes increasing the quantity and nutritional value of the foods offered, more frequent water changes and separating the males and females. Please note that pre-conditioning is not necessary to propagate this species. However, as with most killifish, *L. goodei* will respond to a pre-breeding conditioning regime with more eggs than if such a process is not employed.

### Breeding and Fry

Although fry are sexable at three months, *Lucania goodei* will not produce viable eggs until it is eight to 10 months of age. It is a obligate plant spawner that will deposit eggs in nylon spawning mops, standing plants, or peat fiber and Java Moss in clumps on the substrate. Most breeders use floating nylon mops that are longer than the tank is high so that some portion of it spills over the bottom (De Bruyn, 1999). *L. goodei* employs a breeding routine that is common for top-spawning killifish. The male approaches from below, behind or aside the female, and when she pauses at the spawning media, they assume the expected "S" shape followed by rapid gyrations and the simultaneous release and fertilization of the egg.

Although some authors report that many eggs are laid by well-conditioned females, others indicate that eggs are sparingly laid each day. This author has not seen an extraordinary number of eggs at one time, generally picking less than 15 after a few days. However, this may be due to the recorded propensity for *L. goodei* adults to eat eggs, a practice sure to hold down apparent egg production.

Many hobbyists, this author included, consider the mid 70s°F the best spawning temperature, and do not prepare water with any special qualities. Clean non-polluted water at nominal pH conditions and temperatures in the 70s°F will keep this species in top form, and will bring good breeding results.

### Artificial Egg Incubation

The egg size is fairly small at about 1 mm (0.04"), and they are not particularly delicate to handle. In fact, all killifish eggs are firm and are easily handled without damage, and a healthy fertilized egg is quite difficult to crush between the fingers. The eggs are picked from the spawning mops and placed in a shallow container with a small amount of aged tap water. The eggs are exceptionally clear and the development of the embryos is very easy to observe with even a modest microscope.

The eggs are examined every few days, dead eggs removed, and the incubation water is periodically changed to eliminate contamination. As the accompanying graph illustrates (Fig. 4), the rate of egg development is highly correlated to and almost linear with storage temperature. These data were generated from several incubation lots stored at various times of the year, and hence at different temperatures in my uncontrolled garage. As expected, visual examination did not produce evidence of resting or diapause stages, or periods within the maturation cycle where the rate of development varied. In essence, development proceeded continuously and more or less consistently as it does with most non-annual killifish.

At least one author observed that eggs incubated at higher temperatures result in fry weaker than those incubated at lower temperatures (Buchell, 1998). My observations did not support this contention, and since the robustness of

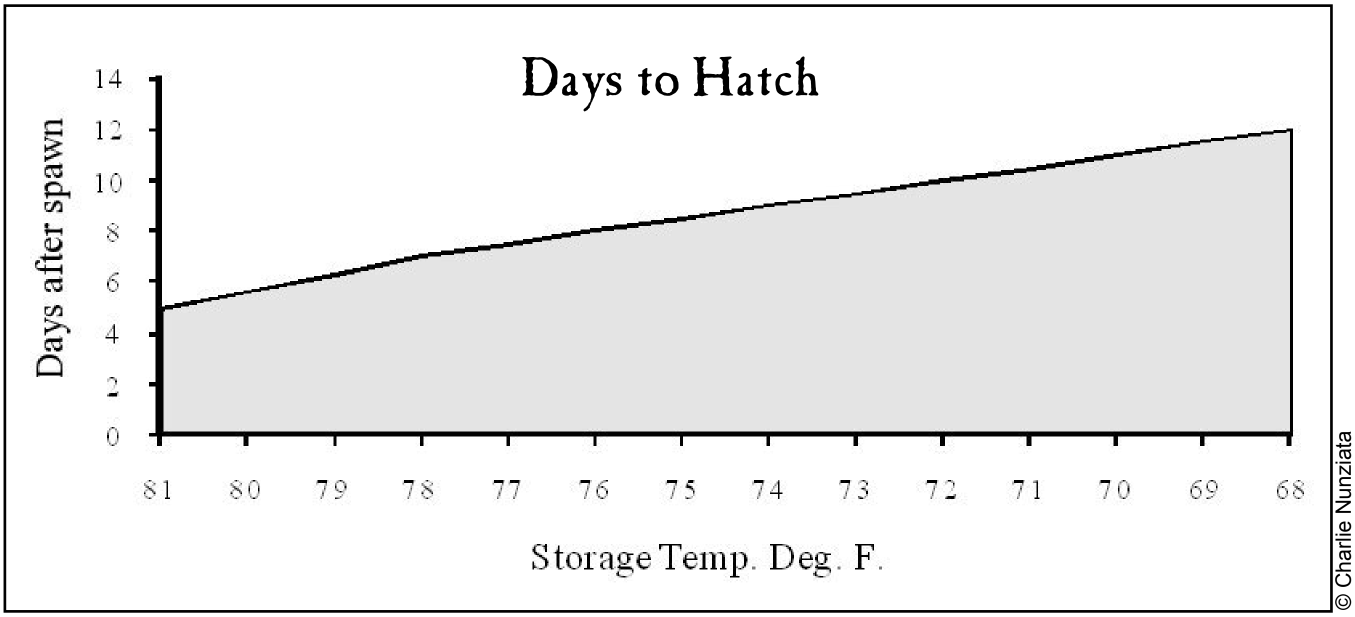


*Fig. 4.*
Correlation of egg development and egg storage temperature.

the fry can be affected by many factors, additional evidence would be required to support this idea. Nonetheless, there is an obvious rationale for weaker fry when incubation is at elevated temperatures. To simplify a very complex process, at some point in the embryo's development, nutrients are stored in a structure often referred to as the yolk sack. This nutritional source is thereafter consumed as the embryo develops and, in killifish, is essentially exhausted at the point of hatching. Killifish fry do not normally hatch with a significant yolk structure.

Incubation at elevated temperatures increases the animal's metabolism, accelerating the consumption of the yolk resource. The graph illustrates this effect through the greatly reduced incubation time as the storage temperature increases. Obviously, the embryo consumes the nutrition in the yolk more quickly at elevated temperatures to support this accelerated development. If the hatching is delayed by even a few days beyond the optimum hatching point, the yolk may be completely consumed, and energy is thereafter drawn from body elements, weakening the fry.

## Natural Egg Incubation

If eggs are allowed to hatch in the tank, the parents will consume most of the fry (Specht, 1977). However, many fry will survive in aquariums and outside ponds that are heavily planted and provide good cover (Specht, 1977). The term "natural aquarium" is applied to the husbandry of killifish in this manner. From a practical standpoint, it is an aquarium with enough natural or artificial plants to act as spawning media and to provide sufficient cover to allow fry to hatch and safely feed in the presence of their larger tankmates.

Killie-keepers that employ this method will simply harvest the surviving fry periodically. For some species whose eggs are very small, this is the only practical breeding method, but many hobbyists prefer to use this method for other species as well simply because it eliminates the labor associated with the artificial method noted above. And although the number of fry that result from this method is substantially less than the artificial method, it is often productive enough to fulfill the goals of the breeder.

## Fry Care

If there is a difficulty propagating *L. goodei*, most authors agree that the problem is the loss of fry in the first few days after hatching. Such losses mostly result from contaminated water and to be sure, deterioration of water quality will almost certainly kill the fry. Once past the critical first few weeks, however, the fry are easy to raise with few if any losses.

Although not supported with hard evidence, most hobbyists believe that many fry are not able to take newly hatched brine shrimp immediately after hatching, but rather require microscopic foods such as infusoria, rotifers and the like. For those that do not culture microscopic foods, thread-like plants that harbor incredibly large colonies of microscopic life —

hair and string algae particularly — can be used to provide these food sources. Clumps of these plants added to the fry container will provide an ample food supply until the fry grow enough to take larger foods.

Microworms and newly hatched brine shrimp can be added after a few days while infusoria or a like food is continued for the slower growing fry (De Bruyn, 1999). Cyclop-eeze® and other small non-living foods can be added to the diet three or four weeks after hatching. A feeding regime like this will result in maximum fry growth. Overfeeding is difficult to control, so it is recommended that some snails be added to the fry tank immediately after the first feeding to mop-up the uneaten food.

Water changes must be made, but there have been some concerns regarding the volume of water that can be safely changed. Some authors warn that large or frequent water changes can shock the fry and result in losses (Buchell, 1998). This author finds that losses from water changes can be eliminated if the new water and the fry tank water are chemically similar. Every attempt should be made to match the hardness of the replacement water to that of the fry tank water. In the first few weeks, fry water changes should be made slowly, over the course of a few hours. Thereafter, a weekly 30% water change in fry tanks can be done at once along with the adult tanks. A very small amount of rock salt, the equivalent of ¼ teaspoon per gallon, should be added to the fry tank after the water change is complete. This will substantially reduce the bacterial load.

## Conclusion

I've been keeping and raising killifish since the mid-1960s and it was not until I moved to Florida in 1993 that I became familiar with and developed an appreciation for this wonderful little fish. Try a pair or two of *Lucania goodei*, and if you do, you will come to treasure them as I have. Once they are in your fishroom, they are there to stay for a very long time!

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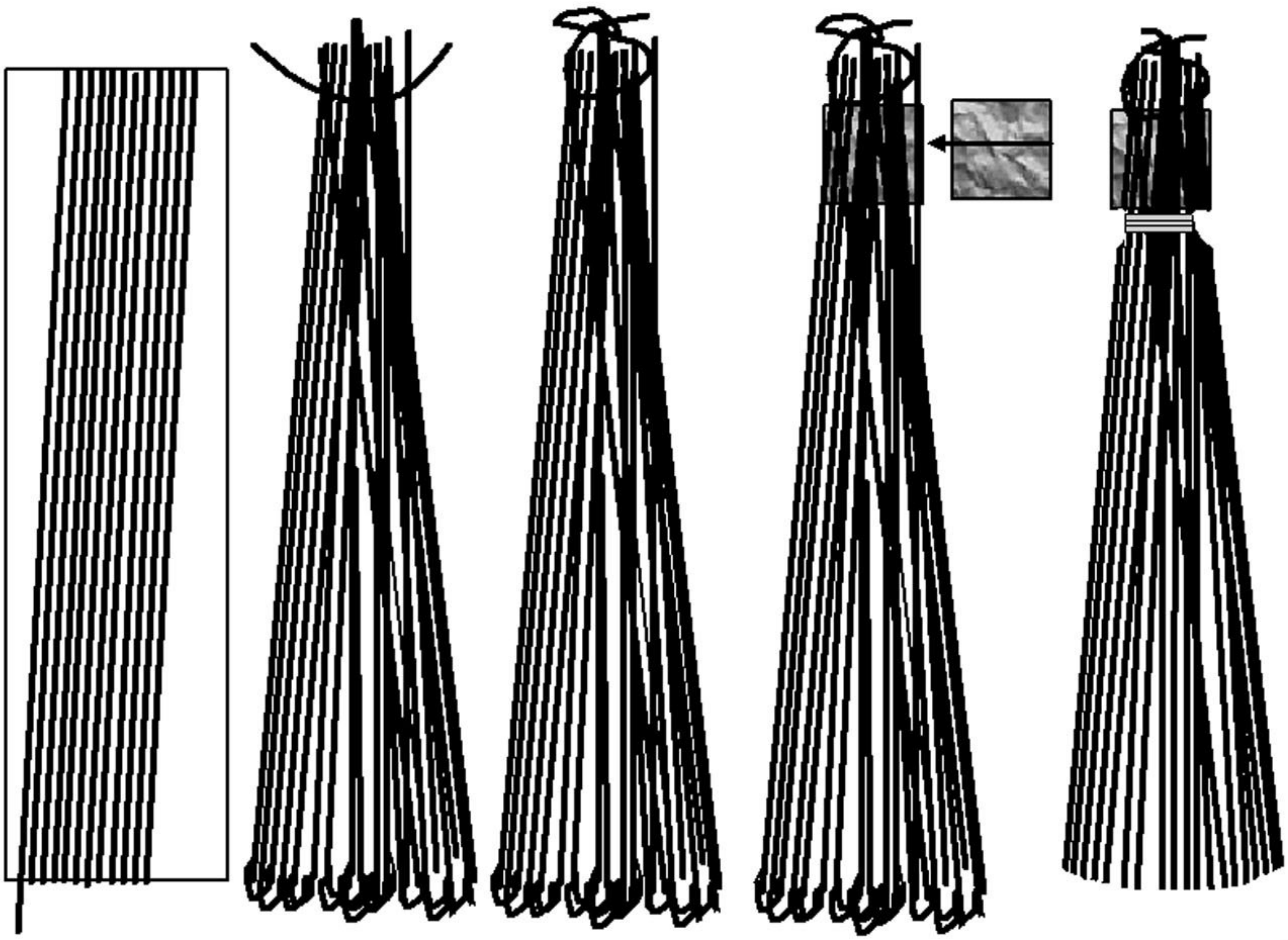
**Please see the spawning mop info on the following page and the color plates related to this article on p. 23!**

# Addendum: Making a Killifish Spawning Mop



Step 1: Wind yarn* threads around a flat stiff object such as a hardcover book. 100 to 150 turns is ideal. Make sure the length is appropriate for the tank depth.

Step 2: Gather and slide the yarn bundle off book.

Step 3. Hold the loops on one end together.

Step 4. Hold and thread length of yarn through and under the loops of the pinched end.

Step 5: Tie knot to secure upper end of bundle.

Step 6: Insert float. Any material that will not leach into the water is acceptable. Foam cubes or balls are ideal.

Step 7: Tie a length of thread or rubber band below float, securing it against knot.

Step 8. Cut open other end of bundle with scissors, and trim irregular ends.

*Any colorfast, non-shrinking nylon yarn can be used. A dark color will show the eggs more clearly, and the color of the breeding fish will not fade. I personally use a dark green usually noted as "green sage".


The most commonly used yarn is a medium weight, designated as #4. The symbol shown will be on the packaging. Yarn with a smaller diameter will take a lot more turns to produce a mop, and it will be dense. Too large in diameter will make the mop bulky, and smaller eggs tend to get buried within the individual strands rather than sit on top of it. But many killifish breeders will use all these sizes with success.


4. *Lucania goodei* blue form. Morris Bridge Wilderness Park, Tampa, Florida.


5. *Lucania goodei* from the transition zone between Tampa and Sarasota Florida, captured in Myakka State Park. The anal and dorsal are primarily blue but show the intrusion of some red coloration. This illustrates the transition from the full blue anal fin specimens from Tampa and north, to full red anal fin specimens found south of Sarasota.


6. Green anal form. Anal is green with a black border, darker blue-black along rays at base. Dorsal green with dark blue along rays at base.


7. Red anal form. Anal is red with a narrow blue submargin and black border, lighter blue at base. Dorsal is intense blue, with a red distal region.


8. Yellow anal form. Anal pale orange distally, greenish at base. Dorsal is blue, with a orange distal region.