SOME OBSERVATIONS ON THE WACCAMAW KILLIFISH (*FUNDULUS WACCAMENSIS*) WITH NOTES ON SPAWNING IN CAPTIVITY

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In the fall of 2014, four members of the Suncoast Killifish Society, most of who are also NANFA members, journeyed from Florida to the southeast corner of North Carolina to obtain specimens of the Waccamaw Killifish (*Fundulus waccamensis*) (Figure 1). This small killifish, though quite numerous in its home range of the 9,000-acre Lake Waccamaw near Wilmington, North Carolina, is endemic only to this particular body of water. However, a second population, suspected to be introduced, occurs in Phelps Lake near Plymouth (Page and Burr 2011).

Ken Normandin, Doug Dame, Bill Shields, and myself, all share a keen interest in the group of loosely related toothed carps known as 'killifishes', especially those native to North America. Our intent was to observe this fish in its habitat, photograph them in the wild, provide subjects for captive photography, and finally, to make fish available to accomplished killifish breeders for observation and documentation. We were able to secure about 20 specimens.*

Lake Waccamaw is a large, shallow, natural body of water, averaging only 7.5 feet in depth (Figure 2). Much has been written about its origins, with speculation that it was created by geological faulting or meteorite impacts gouging out this lowland coastal lake (summarized in Stager and Cahoon 1987).The best explanation offered by geologists to date has been the unique setting of soil type and wind in this location creating the lake through wave action over a lengthy period of time. Lake Waccamaw is the largest of a series of more than 40 similarly formed bodies of water in the area, known collectively as "Bay Lakes" for the abundant Bay trees native to the area, and spread out over the nearby coastal plain. It also bears the designation of an official "National Natural Landmark". The subject of our report, however, the Waccamaw Killifish, lives only in this one, large lake and nowhere else in the world.

Appearance-wise, as well as genetically, this killifish is closely related to the Banded Killifish (*Fundulus diaphanus*) (F. C. Rohde, personal communication), which generally ranges to the north of Lake Waccamaw and up the eastern seaboard all the way to Ontario, Canada (Figure 3). There are Banded Killifish in the Waccamaw River in South Carolina (Rohde et al. 2009). It's not too difficult to see how a popula-

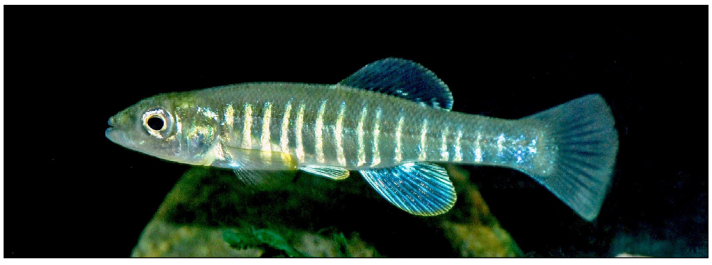

Figure 1. Male *Fundulus waccamensis*. (Photo by Joe Scanlan)

Figure 2. Lake Waccamaw, North Carolina (Spillway Area). (Photo by Doug Stuber)

*Fish were obtained under a scientific collecting/endangered species permit issued to Fred C. Rohde.

Figure 3. Male *Fundulus diaphanus,* closely related genetically to *F. waccamensis*. (Photo by Tony Terceira)

tion of the Banded Killifish found itself trapped in the lake at the southern extreme of its current range, and through time, genetically drifted from the parent stock, adapting to a large, open-lake ecosystem, while other parent *diaphanus* specimens remained in the smaller creeks and rivers favored by the Banded Killifish.

Though fed by nearby swamps and springs, drainage into the lake seems to be mostly from an enclosed watershed, so movement of new fish species in and out has been limited. A small overflow dam has prevented easy access back upstream into the lake. Due to nearby limestone deposits that offset the normally tannic, slightly tea-colored water draining into the lake, pH levels are raised, providing a higher than normal fertility factor (Stager and Cahoon 1987). In fact, it can claim more species than most similar bodies of water in the area. At least two other species—the Waccamaw Silverside (*Menidia extensa*) and the Waccamaw Darter (*Etheostoma perlongum*)—are also endemic (Shute et al. 1981).

In November 2014, our first observation of the lake showed a shallow gradient, fine sand-covered bottom with sparse emergent vegetation, mostly consisting of a 2-3 ft tall, stiff-stemmed *Panicum* grass. Water clarity was at least four feet in depth and we could readily see Waccamaw Killifish darting about at alarming rates of speed as we waded into the shallows. The stiff grass stems made seining impossible. We observed a couple of species of submerged aquatic vegetation growing in the shallows. They were identified by aquatic plant specialist Sean Murphy of the GWAPA (Greater Washington Aquatic Plant Association) as *Eriocaulon aquaticum* (Sevenangle Pipewort), a 2-3 inch tall, rooted, grass-like plant in the sandy shallows in less than one foot of water depth (Figure 4). Another rooted plant was identified as *Sclerolepis uniflora*, or the Pink Bogbutton (Figure 5). (Sean Murphy, personal communication). It was also fairly common in the shallows. Reference to these plants will become important in the discussion of the spawning habits of *F. waccamensis* later in this report. No other aquatic vegetation was observed. There are reports of *Hydrilla*, an invasive exotic plant, infestation and attempts at removal are documented (Tracy et al. 2013).

The fish, unlike many North American killies, tends to be a mid-water swimmer, as opposed to a surface-hugging fish, which is usually much easier to spot and catch with a swift scoop of the net. We had to literally rush through the water with our large dip nets, starting in two feet of water and charging to the shoreline. We were able to eventually catch about 20 of the small *waccamensis*. Most appeared to be this year's spawn, about two inches long or less, but readily sexable with a vertical barring pattern most evident on the males (Figure 6).

A few specimens were provided to Tony Terciera, NANFA member and well-known fish photographer, for some good shots of this seldom photographed fish. More were supplied to Joe Scanlan MD, retired ophthalmologist, NANFA member, and well-respected breeder of North American and exotic killifish. Joe has spawned almost all of the native killies of the Southeastern US, and is the only person I'm aware of who has had success with the Stippled Studfish (*Fundulus bifax*). Six months after having collected these fish I was not too surprised to hear from Joe when he joyfully called and informed

Figure 4. *Eriocaulon aquaticum*, Sevenangle Pipewort. (Photo by Nathan Howell)

Figure 5. *Sclerolepis uniflora*, Pink Bogbutton. (Photo by Nathan Howell)

Figure 6. Lake Waccamaw Killifish: two of the breeding trio, male below. (Photo by Joe Scanlan)

us that he'd managed to pull off a spawning of these killies this spring. The following is an interview I conducted with the good Doctor in early July 2015, with an eye towards catching the particulars of how he achieved this spawning activity, what he observed, and how the ensuing fry were being raised:

INTERVIEW NOTES WITH JOE SCANLAN JULY 14, 2015

DS *Please describe your tank set up for housing these fish.*

JS I was really happy to receive these six young fish in the mail. I had prepared a 29-gallon, high aquarium with a Marineland brand system, consisting of a lid containing a filter pad, biowheel, and fluorescent light. You had clued me in by telling me that they lived in a habitat consisting of fine sand bottom and densely packed plants. So I put in a 1/2 inch-thick layer of sand, a bottom and top yarn mop, and an artificial plant. Within a week after they had settled down, I could see that I had three females and three males. You guys really did well sexing them for me. Very important, in my opinion, is the fact that this tank is also exposed to the natural temperature swings of the Montgomery, AL weather in my unheated, outdoor barn. I use primarily well water, 7.2 to 7.4 pH, with a moderate degree of hardness. I saw no need to change water in the tank until the fish had grown more.

Figure 7. Female Waccamaw Killifish. (Photo by Tony Terceira)

DS *And what were your early impressions of the behavior of these Waccamaw Killies in your tank?*

JS As usual with wild-caught fish, they were quite skittish at first, diving into vegetation and staying hidden most of the time. They eventually habituated themselves to my presence at feeding times, and soon took to regular, daily feedings of live foods. I unfortunately lost one pair of fish in the very early spring after the water had started to warm. I interpret aggression in many fishes as a good sign that breeding is about to start and sure enough this is what happened. On April 13th I collected two eggs when the water temp was in the low 60s, and there were two pair of fish in the tank. It was not until mid-June that I found one terribly battered dead male, leaving me now with a trio.

DS *Touching on your feeding practices, please tell us what you used to get the fish into spawning condition.*

JS I'm a big fan of finely chopped 'red wiggler' fish bait worms, and feel nothing is better for conditioning all of the killifish I keep here in my tanks. I also feed mosquito larvae, brine shrimp nauplii, and eventually even tiny tree frog tadpoles when available. Of course, I use frozen brine shrimp and blood worms along with flake foods as the fish grow.

DS *Whatever you feed them sure seems to work. Please tell us about your actual spawning of the fish and what you have observed in their mating behaviors.*

JS After April 13th I continued to find one or two eggs in the bottom mop, checking it every other day. I noticed the male usually hovering over the mop and the female under it. This became a sure sign that eggs were in the mop. I eventually discarded the floating mop because I never found eggs in it. One week after spawning started I found 11 eggs after a three-day spawning period. My heavy feeding of chopped earthworms was paying off. My three-month observation of this fish convinces me that the average capacity of the female is one to three eggs per day. While I never observed actual spawning, it appears to mostly occur in the early morning. I have, on occasion, observed the male vibrating and displaying in front of the female (Figure 7), both fish hovering just above the submerged mops. I've seen no evidence of eggs laid anywhere else in the tank, in the sand, etc., and no evidence of any fry ever in the tank as eggs were removed from the mops periodically. If the female is hiding under the mops, there will be at least one egg to be found there.

DS *Did you do anything to the water to trigger spawning?*

JS I have used dumps of rainwater to trigger spawning with other killies such as *F. bifax*, the Stippled Studfish, and tried this method on the *F. waccamensis*, but it did not seem to have any effect on this fish. They spawned at their

Figure 8. *F. waccamensis* eggs in the yarn mops provided for spawning. (Photo by Joe Scanlan)

low volume, but persistent rate—rainwater or not!

As for water quality, I have not even been very regular with water changes as I would have to if I wanted *F. bifax* to spawn. In fact, these fish seem to be very tolerant of a variety of water conditions at all levels of their life cycle—as adults, eggs, and even the fry.

DS *Speaking of eggs and fry, please describe what you observed.*

JS The eggs are quite large by killifish standards; 2+ millimeters in diameter and perfectly clear. In fact, I've often thought they'd make wonderfully easy-to-use subjects for embryology studies based on these characteristics.

After mid-June when the dominant male had killed the other male, I began operating with a trio, but saw no big change in egg production. I assume a single male had taken over the harem. After the first spawning week I had seen no eggs in the top mop so I removed it, which turned out to be a mistake. After early July I reintroduced a floating mop and began to see more eggs in that upper mop (Figure 8). I think the female just seemed to prefer something new. But this only lasted for a few days.

DS *As an experienced killie breeder, and with many different species from around the world, what did you think of the eggs and fry, in comparison to your experiences with other fishes?*

JS The gestation period time runs from 10 to 14 days on these eggs, depending on water temperatures, which started running from the low 60s and now is in the low 80s F. Furthermore, I want to again point out these eggs are extremely resilient. As an experiment, I exposed an egg-laden yarn mop, placed in only a couple of inches of water and in full sunlight for two days, with daytime temps running 97 degrees and nighttime temps of 75 degrees. The eggs hatched a week later. Fry are relatively large when hatched, able to take brine shrimp nauplii quickly, and micro-worms as well. I've even left some *Daphnia magna* adults in the fry tanks, with their tiny offspring providing a good food source for the very young fish.

Figure 9. Male *Fundulus waccamensis*. Note blue coloration in anal fin. (Photo by Joe Scanlan)

DS *So tell us how fry production has been going for you. Any problems getting them up to size?*

JS I must now have well over 100 fry, spread over several tanks, with the oldest cohort now being 1.5 inches in length. Based on this rapid growth I'm quite convinced these fish mature and spawn in one year, unlike some of the other *Xenisma*, a subgenus of *Fundulus*, such as *F. bifax*, that require a second year to reach sexual maturity. I will soon be placing the largest of these Waccamaw Killifish spawns in my small, outdoor fish ponds to see if they will successfully over-winter and reproduce for me. At three months of age, they are already even sexable! I've had much luck with many other native killies in these outdoor settings; such as Golden Topminnow (*Fundulus chrysotus*), Bluefin Killifish (*Lucania goodei*), and surprisingly this far north, even the Flagfish (*Jordanella floridae*), a native endemic to the Florida peninsula.

DS *One last request, please describe the fry-rearing tanks and set up you have found successful.*

JS Fry rearing was done first in a Petri dish to hatch out, then a shoebox or a two-gallon tank with daphnia and a snail for uneaten food along with some floating plants, until large enough to move on, as a cohort, to a 10-gallon tank. The newly hatched fry live mostly on baby brine shrimp and "Ken's Golden Pearls" (a superfine, commercially produced, egg-based food for fry) until big enough for mosquito larvae, and eventually chopped earth worms. Again, I'd like to finish with my impression that this is a fast growing fish with a great reproductive potential in the first year of its life cycle.

DESCRIPTION OF *FUNDULUS WACCAMENSIS*

Overall appearance is of a very narrow, sleek body, with both sexes reaching a maximum of 2.5 to 3 inches in length. The female is uniformly silver gray in color with 12-13 narrow, vertical black bars. Breeding males have an overall "chrome yellow" cast to the sides of their bodies, with dark gray/brown dorsum, extending down into 15 vertical stripes (Figure 9). Body color-

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(**Waccamaw Killifish,** continued from page 22)

ing in between these stripes fades from a light, golden color to a light blue over the posterior half of the body. Iridescent bright blue coloration is evident in the fins, particularly on the anal fin, and blue also noted at the base of the caudal.

Congratulations to Dr. Scanlan for successfully spawning another fascinating native killie and in the process increasing our understanding of this highly localized species.

References

Page, L.M., and B.M. Burr. 2011. *Peterson field guide to freshwater fishes of North America north of Mexico*. Boston: Houghton Mifflin Harcourt.

Rohde, F.C., R.G. Arndt, J.W. Foltz, and J.M. Quattro. 2009. *Freshwater fishes of South Carolina*. University of South Carolina Press, Columbia.

Shute, J.R., P.W. Shute, and D.G. Lindquist. 1981. Fishes of the Waccamaw River drainage. Brimleyana No: 6:1-24.

Stager, J.C., and L.B. Cahoon. 1987. The age and trophic history of Lake Waccamaw, North Carolina. The Journal of the Elisha Mitchell Scientific Society 103(1):1-13.

Tracy, B.H., W.C. Starnes, F.C. Rohde, and R. Heise. 2013. North Carolina's Imperiled Fish Fauna, Part XII. http://nc.fisheries.org/wp-content/uploads/2014/10/Fall2013Newsletter.