Construction Considerations and Design Specifications for a Flowing Water Spawning System for the Culture of River Minnows: Part 2

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Ed. note — Last issue, Barry discussed the growing need in the bait industry for an alternative to wild bait harvest. This is due in large part to new regulations concerning invasive species. Barry went on to discuss construction considerations for a moving-water culture system for river minnows. We pick up following his description of the construction of the paddle wheel mechanism.

Feeding during the spawning cycle is essential in order to limit egg predation by marauding pre-spawn females. This can occur with any of the aforementioned river minnow species. Care should be taken to avoid overfeeding, as uneaten food will settle into the spawning substrate and build up over time, thus requiring annual washing of the substrate. Under normal operation, this will be necessary every four or five years.

Some understanding of the specific minnows' physiology has led to new methods of feeding and feeds in order to match the nutrition necessary for these species. Commercial dried feed (Purina® Aquamax, for example) available in small quantities has shown to be less than adequate for nutrition, as noted by the weight loss of adults and higher mortalities. Additionally, small orders of eight to 10 bags of food are seldom cost-effective due to increased shipping costs (2008 Aquamax 300 was $40.00 per bag — an increase of 30% over 2007). Also, many feed companies require a one-ton minimum order for a mill run of food, and with the short shelf life of 90 days for Aquamax, this would not be cost effective without a much larger facility.

All of the aforementioned species (Hornyhead Chubs, Creek Chubs, and Common Shiners) readily take to dried fish food. Feeds with higher animal protein or fishmeal base may provide a more rounded diet. Some of the salmon feeds, based on fishmeal instead of soy, also have a longer shelf life. This must also be a consideration when purchasing feed. Additionally, an increase in producers would create a large enough combined order to bring more varieties of feed and drive the cost down.

Bag feeders have been used as an alternative to broadcast feeders to reduce the settling of uneaten dry food. After observing feeding behavior over the years, I created a weighted Ace nylon 1/8 in. mesh bag, cut and sewn to be 10 cm wide by 30 cm. It was weighted and filled with food, and tied at the end. This was allowed to sink in the raceway where the fish fed as needed. Additionally, this caused actively feeding fish to be drawn from spawning areas, reducing the egg predation during the spawning cycle. Hungry fish can be drawn by sense of smell and fish will quickly remove food from the bag. Wetting the bag prior to adding feed will prevent feed from falling through the mesh. Larger feeds can be used with this method but may not have the proper nutritional quality. Uneaten food should be removed from the bags and discarded into maggot feeders, though I seldom had feed left in the bags. I reduced the next day's feeding to avoid wasting food in the future.

The use of maggot feeders has been the most economical method of providing a consistent high-protein food source. Five kilograms of fish meat will yield nearly five kg of live maggots (predominantly blowfly) in Minnesota. A five gallon bucket with vents cut in the side 10 cm above the bottom, filled with fish or other meat suspended over the raceway, will provide almost continuous maggots for up to five days. Note that feeders will produce well only when temperatures exceed 16°C (60°F). Dark-colored buckets will produce even in cool weather as the bucket will warm faster and hold heat longer.

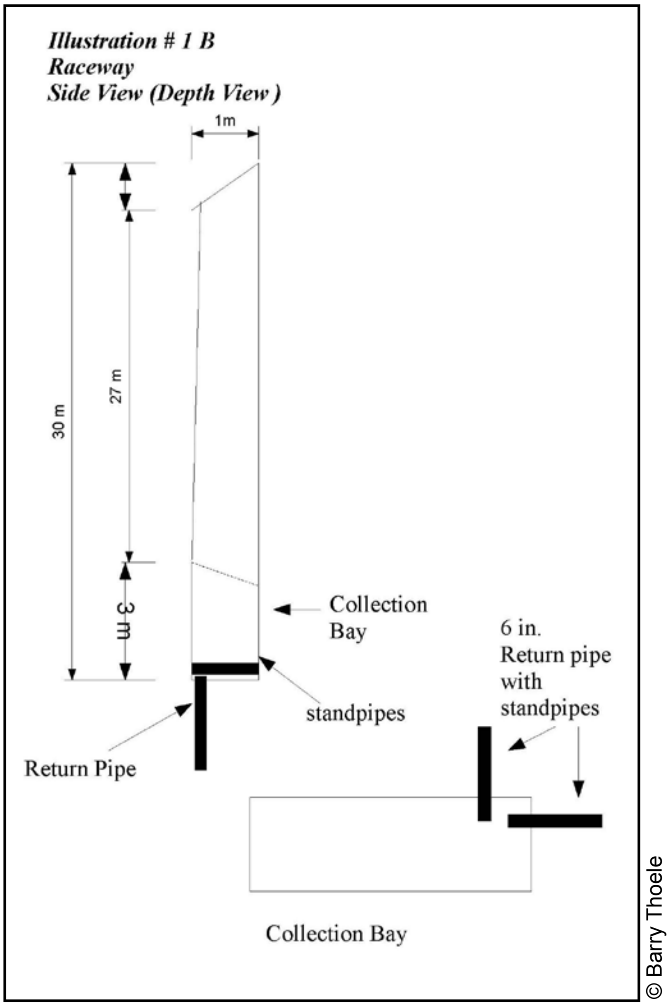

Illustration #1B.
Raceway Layout. This illustration was printed in the previous *American Currents*, but is being re-printed here due to the poor quality of the previous printing.

In Central Minnesota, rivers, lakes and wetlands provide mayflies, midges and other terrestrial insects as another source of food. The use of night-light bug feeders such as the "Bug Slugger" works well and at little cost to operate. They also have some success at controlling mosquito hatches at their peak. Most terrestrial insects can provide additional protein sources for feed for the chubs and shiners. Grasshoppers and moths have been found in the stomachs of adult minnows, as have leafhoppers and other terrestrial insects, and many are attracted to these types of feeders.

Food for fry should be ordered at least 30 days before fry are expected. The later spawning of the river minnows makes the ordering of fry feed difficult as the mills do not stock this at all times (due to the short shelf life) and it could take weeks for the mill to accumulate enough orders for the one-ton necessary for a mill run. After encountering this on more than one occasion, we constructed a small feed grinder and now place an order for feed in April and again in August. This also saves on the overall cost of feed as the fry powder and smaller sizes are considerably more expensive. With the exception of the fry powder, which is 54% protein, all have the same nutritional content as the Aquamax 300. It is hoped that cooperatives comprised of several hatcheries could order enough feed to reduce the price and reformulate to better meet the nutritional requirements of these species.

Before fry begin to appear, grow-out ponds should be inoculated with *Daphnia pulex* or *D. magna*. The use of a drift sock-type collection net was designed to collect as much as 30 to 40 kg of drained-weight *D. pulex* each week from a local pond. These were inoculated directly into the grow-out ponds. The water pump drew in live *Daphnia* and circulated them through the raceway, providing supplemental feed for fry in the raceway. This also has helped to control the inevitable algae growth common to contained outdoor systems. The combination of all these methods, along with drift seining for *Daphnia pulex* and other micro-invertebrates, have shown to provide a consistent and appropriately-sized feed that follows closely the diet consumed in the wild. Other feeding methods have been tried and discounted, as they either created a buildup of uneaten food on the bottom of the raceway and ponds, or fish did not respond well to the method. The recommended methods developed have produced good and consistent results with lowest mortalities.

The system has yet to be pushed for maximum production. Without a means of full water exchange it has been determined that it would be better to construct more systems targeted for optimum production. In my experience with culture and wild habitat, it has been shown that these species do not grow well in heavily fertilized waters. None are found in turbid or heavily polluted waters. Care needs to taken to avoid green water in the grow-out ponds.

Operation: Creek Chubs

Creek Chubs (Fig. 1) spawn in early May to June in this location, at a water temperature of 12.8°C (55°F). They are generally finished when water temperatures reach 17°C (65°F) (Reighard, 1910). This happens earlier in the raceway system than in the natural environment. Early spawning can take place in April, if the raceway is used to warm the water.

The high ground systems' ponds must be filled in late March or early in April to allow water to warm before filling

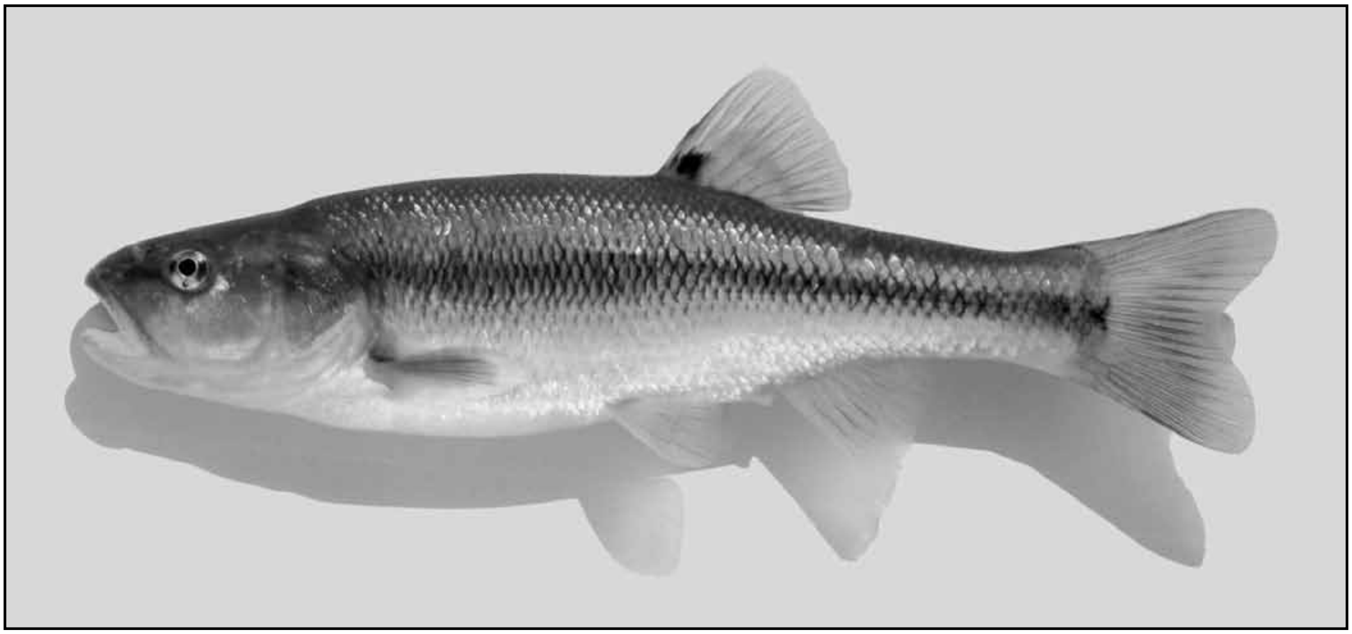

Fig. 1.
Creek Chub (*Semotilus atromaculatus*).

the raceway. The stand pipes should be put in place and the standpipe to pond number two should be capped to prevent Creek Chub fry from entering both ponds. Pond water temperatures can be raised by as much as two degrees Celsius in a week by circulating water through the raceway during the daytime hours. Solar radiation absorbed by the gravel in the raceway can raise water temperatures early enough to allow the first spawn as much as 30 days before conditions in the wild. During warmer years this has beat wild spawn by as much as 45 days. This can allow several successive spawns. If the first species to be spawned is Creek Chub, barriers should be placed in wing dam formations around the raceway creating resting areas for pre- and post-spawn fish (see Illustration #3). As water temperatures reach 10°C (50°F), the raceway is filled to the level of the standpipe and the paddle wheel should be started. It will take as much as an hour for full current flow to be established.

Broodstock should be sorted and added to raceway, and maggot feeders filled and placed. Due to their larger size, Creek Chubs have been fed the larger size and less expensive floating feeds. They seem to grow well on these feeds. Once feeding rates are established, drop- or broadcast-feeders could be employed to maintain adequate feeding for this species. Creek Chubs train to feed quickly and prefer floating food. Aquamax 400 was used in the past for feeding Creek Chubs but proved too large for Hornyhead Chubs or shiners.

Broodstock numbers for river minnows are different with each species. The nest building and spawning behavior of the Creek Chub has been well documented first by Reighard (1910), whose observations were summarized by Miller (1964:326) and again by Ross (1977). To summarize:

"...*male Creek Chubs tend the nest while gravid females remain in resting areas until ready to spawn. A single male Creek Chub will spawn with several females on the same nest.*"

Stocking rates will vary, depending on the sizes of males and females. Larger males will spawn over larger areas and spawn with more females. A ratio of 10 females to one male is what has been used, but should be adjusted based on the size of the male.

Creek Chub broodstock are considerably larger than the Hornyhead Chub, and have different requirements for spawning. Some adjustment of conditions, such as the addition of larger gravel (1-2.5 cm diameter) may be required. Additional obstructions could be added to the raceway maximize spawning area. A one-course high row of six by eight by 16 concrete blocks arranged in a wing dam pattern (see illustration #3), provides enough obstruction to provide resting areas for broodstock and fry, yet allow continuous current flow.

Spawning should, under normal conditions, be complete within 10 days to two weeks. Cool weather could extend the spawn by several days to weeks. It may be beneficial to place a cold frame dome over the raceway to eliminate the weather factors that can affect the time and duration of the spawn. Spawning activity needs to be monitored daily for Creek

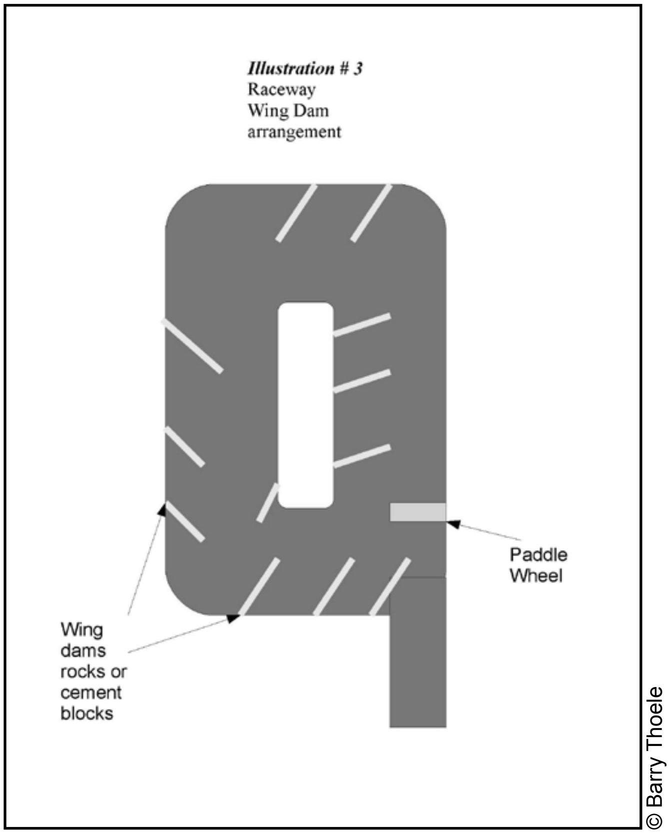

Illustration #3.
Raceway wing dam arrangement.

Chubs as they lack the prolonged spawning period of the Hornyhead Chub.

Adult Creek Chubs should be removed immediately after the cessation of spawning activity to prevent the adults' predation on the fry. This is an ongoing problem with this species if not fed to satiation, and the principal reason for segregating the Creek Chub from other species in the grow-out ponds.

After spawning activity is complete, adult chubs can be easily trapped from the raceway with a "B"-trap or a double-throat river trap. Most river minnow species, in my experience, have a defined sense of smell and can be baited with chopped fish or pelleted fish food in a 1/8" nylon mesh bag. This bag should be placed directly upstream of the throat of the trap, and the throat placed so as to be facing directly downstream. The current should flow directly through the throat. A piece of black polyethylene rope, tied to the top of the trap and centered on the opening, will guarantee proper alignment. Over 10 gallons of minnows have been trapped from the raceway within 30 minutes with either type baited trap, if they are watched and emptied as they fill. Larger broodstock should be sold to the bait market as up to 30% of adults will have reached the end of their life cycle at age I. The remainder can be moved to a holding pond for the next year's spawning. Natural ponds work well for holding broodstock as do small man-made ponds. Fry handling of Creek Chub has been documented in the publication *Raising Bait Fishes* (Circular 35 USFWS 1956), including stocking rates and feeding practices.

Current flow should be maintained after the broodstock have been removed in order to maintain aeration for the eggs until hatched. Fry can be seen collecting in eddies behind the obstructions and in the collection basin in the flow. Fry can be fed in the raceway with live *Daphnia magna* or *pulex* for several days to ensure the entire hatch has been completed. The feeding of dry food for fry within the raceway should be minimized to avoid a buildup of uneaten food, leading to water quality problems and algae growth.

Algae growth can be controlled with bundles of barley straw placed at intervals throughout the raceway. Placement in flowing water maximizes the algicide effect and a single application each year will carry throughout the entire spawning season.

Draining and Fry Handling

Draining the raceway and washing fry out to grow-out ponds should not be done sooner than 14 days after broodstock have been removed. The water pump should be allowed to continue to operate until the fry have been washed into the collection basin. The paddle wheel should be shut down and current allowed to stop. Begin dropping water level by angling the standpipe. The water level should be lowered slowly to avoid stranding fry in the gravel. It has been helpful to rake a narrow channel through the middle of the raceway as the water level lowers. This will help avoid the stranding of fry in pockets and pools created by the movement of substrate by broodstock. When the water level has been lowered to the collection basin, the standpipe has been lowered to 15 cm, and fry have been cleared from all but the collection basin, the inlet pump can be shut down. The standpipe can then be removed and the remainder of the fry can be herded to the return pipe and into pond.

Setup for Second Spawn

After completely draining the raceway and moving fry into Pond #1, transfer the ¾ hp water pump into Pond #2 and the supply line into the raceway. Uncap the standpipe for Pond #2. Substrate should be leveled and cement block

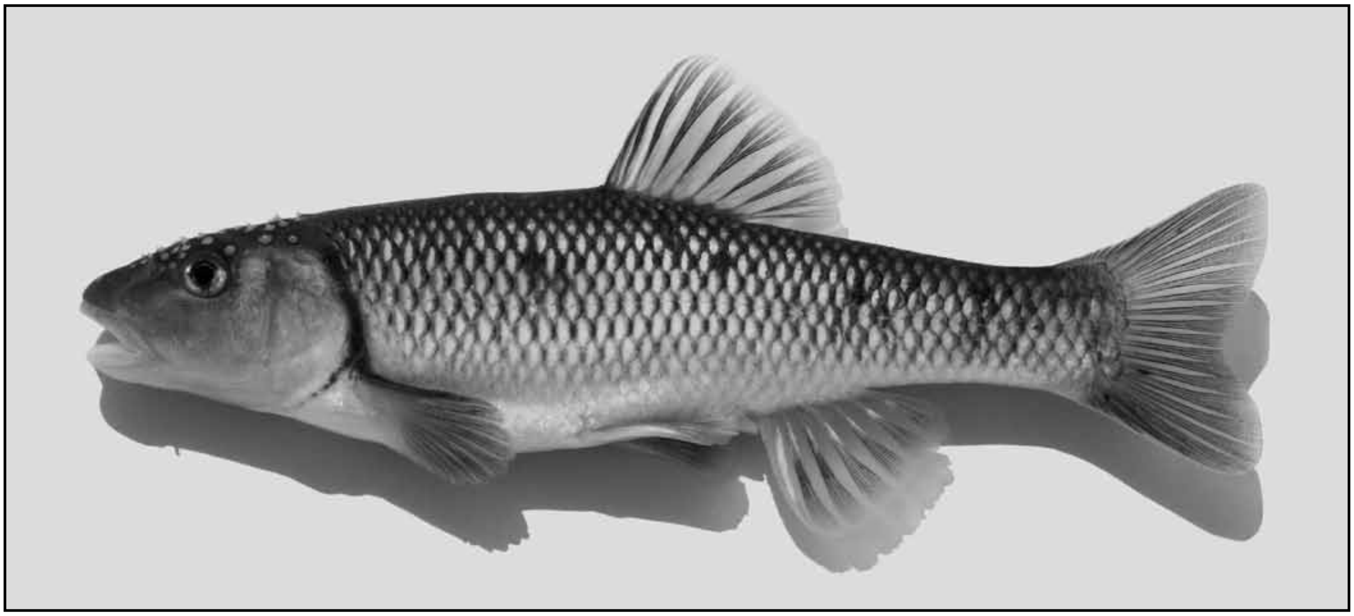

Fig. 2.
Breeding male Hornyhead Chub (*Nocomis biguttatus*).

obstruction pattern changed to accommodate the Hornyhead Chub (see illustration #4). When the water level reaches the overflow level of the standpipe, the paddle wheel should be started to allow water flow to stabilize.

Broodstock Hornyhead Chubs (Fig. 2) should be sorted and counted with a ratio of one male to 20 females. This is a common number found in healthy streams with adults age III and VI. Smaller broodstock would require adjusting the amount of females down as the smaller males hold fewer females in the harem. With healthy populations, no fewer than 10 females have been present with a single nesting male.

With the amount of available spawning material and obstruction pattern within the raceway, it is possible to increase spawning activity and decrease the area needed to forage for appropriate size gravel for the nest. This also stops some of the egg predation that takes place when the male leaves the nest for more gravel.

The addition of male Common Shiners during the spawn will further decrease egg predation. With the addition of the Common Shiner, however, it becomes necessary to closely monitor feeding and spawning activity. The adult Common Shiner is known to feed on fry from all species. At the cessation of spawning activity, all broodstock must be removed as post-spawning feeding activity increases could result in adult Common Shiners preying on fry. The method used for trapping Creek Chub from the raceway will work well with these

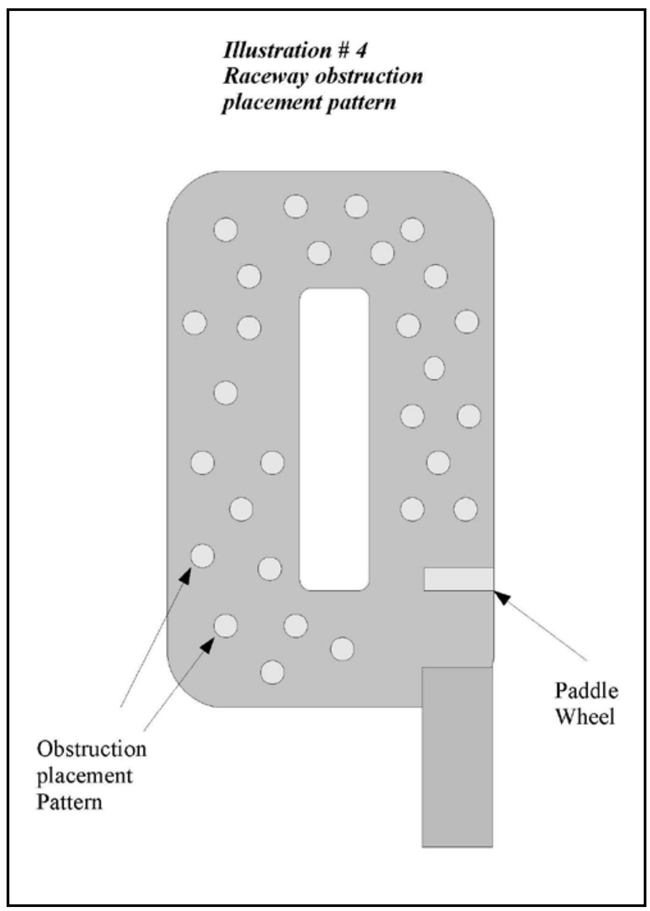

Illustration #4.
Raceway obstruction placement pattern.

Fry Handling

While fry handling of other freshwater fish species has been standardized, it becomes much more difficult as the water warms. With the many attempts at handling fry after water temperatures reach 17°C (62°F), high mortalities have proven the benefit of the standpipe return method for moving fry into the grow-out ponds, requiring minimal handling during the warm water period. Fry can be easily moved after they have reached Young-of-the-Year (YOY) or juvenile size when the water has cooled in fall below 10°C (50°F). They can be collected by trap or seine and moved to larger grow-out ponds or into an indoor recirculating system for over-wintering. The use of an indoor recirculating system may prove the fastest means to grow fry to market size, but further research needs to be done on correct nutrition and feed conversions before this could become a viable method.

species as well.

During 2006, three cycles of 10 gallons of broodstock were spawned consecutively. The first spawn began in late April, the second 10 gallons in June, and the third was attempted in July. This last spawn was of limited success with few fry produced. The author believes three and even more spawnings could be accomplished if broodstock were held in cold water indoors. The overwintering of broodstock is also necessary in order to compensate for natural conditions that make early harvest difficult if not impossible to predict.

Acknowledgments

I appreciate the opportunity to be able to publish this system for posterity. I have devoted much of my life to the study and understanding of these species and their place in the ecosystem. I believe for the bait industry to survive the changes we all face, it is essential to share knowledge, not hoard it. With invasive species on the doorstep, the future of wild harvest is uncertain. In my opinion, the future of the bait industry is in culture. My hope is that this system will prove useful for generations to come — for bait culture and for scientific study.

I want to thank Jeff Gunderson and the University of Minnesota, Sea Grant, for the technical assistance and the access to papers and information, and for the encouragement and patience to see this completed.

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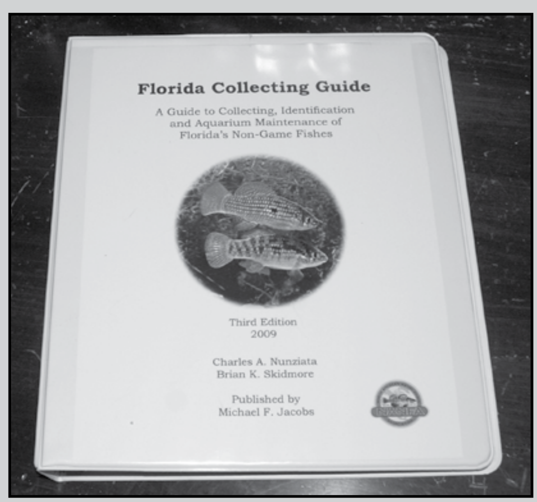

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