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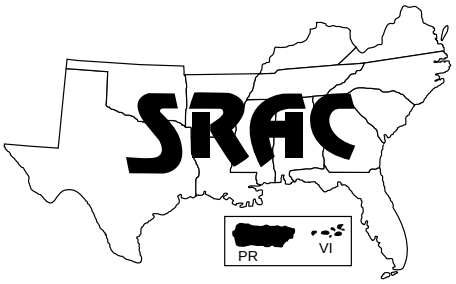

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Growing Bull Minnows for Bait

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The Gulf killifish (*Fundulus grandis*), also known as bull minnow, mud minnow, mudfish, cacahoe, chub and sometimes finger mullet, is sold as live bait to anglers throughout the Gulf of Mexico region. It is particularly prized for flounder fishing but serves well for other inshore species and also may be suitable for offshore fishing. It survives the low oxygen concentrations and high temperatures often found in bait buckets.

Bull minnows are harvested from brackish water near vegetation using minnow traps. They are usually sold directly to retailers. Seasonal fluctuations in availability and changes in environmental conditions often make the supply of wild-caught minnows inadequate to meet consumer demand.

Bull minnows readily reproduce in captivity and can be grown in ponds over a range of environmental conditions. Although not as well researched as other cultured species, enough work has been done to outline production methods and suggest marketing strategies.

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Biology

Bull minnows occur from Vera Cruz, Mexico, along the U.S. Gulf of Mexico coast to the coast of northeast Florida. The closely related mummichog (*Fundalus heteroclitus*), also sold as bait, is found northward along the U.S. east coast.

Adults and juveniles are found near shore in estuarine areas. Saltwater creeks, marsh edges, coastal ponds and the edges of intertidal oyster reefs are important habitats. As with most estuarine species, bull minnows tolerate a wide range of salinities (0 to more than 40 ppt) and temperatures 36 to 95 ºF (2 to 35 ºC), but 5 to 18 ppt salinity is thought to be the preferred range.

Spawning typically occurs during high tides in marsh vegetation. Fish kept in aquaria without external cues continue to spawn following the tidal cycle. Females deposit eggs on vegetation and the eggs are fertilized immediately by attendant males. Spawning extends over several months and the spawning period varies with geographic area. Generally, it is from spring through fall with peaks near the beginning and end of the period. A female produces only a few eggs (10 to 20) per spawn, but spawns repeatedly during the season. Eggs are yellow and average 0.08 inches (2 mm) in diameter. Eggs can tolerate exposure to air. If kept in moist containers they hatch at a high rate when returned to the water after 12 to 18 days. Embryos hatch at 9 to 28 days depending on temperature. Little is known about larval development, but salinities of 5 to 40 ppt result in better larval survival than lower or higher salinities.

Adult females are usually dull grey or green, while the male is darker with bright spotting and sometimes vertical bars on each side.

Bull minnows are omnivores and feed on whatever is available, including crustaceans (grass shrimp, various small crabs, isopods, amphipods etc.), insects and worms (annelids and polychaetes). Young fish are said to be detritivores but readily consume live foods in aquaria.

In the wild, 1-year-old fish range from 0.7 to 1.1 inches (18 to 30 mm). Two-year-old fish average 2.6 inches (68 mm). They reach sexual maturity at 1.6 to 2.0 inches (40 to 50 mm). Bull minnows may live up to 4 years but few survive to even 3. The largest adults are 5.5 inches (140 mm) long and weigh up to 1.6 ounces (45 g).

Bull minnows look much like several closely related species such as the striped killifish (*Fundulus majalis*), longnose killifish (*F. similis*) and marsh killifish (*F. confluentus*). These species usually have strong vertical bars on the sides of the body and somewhat pointed heads. Bull minnows have blunt heads, many pale spots, and bars that are usually faint.

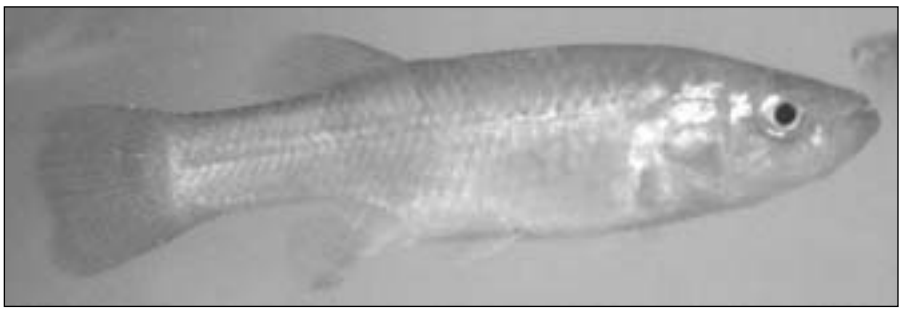

Figure 1. Female bull minnow.

Figure 2. Male bull minnow.

Culture

Bull minnows have been grown successfully in ponds in several southern coastal states. Because most of the available information comes from experimental facilities with small ponds (0.2 acres or 0.08 ha), the optimal pond size has not been established. Stocking rates and treatments are given on a per acre (ha) basis.

General requirements include:

- Ready access to a dependable supply of brackish water with salinity of 5 to 30 ppt.
- Adequate land and appropriate soil to construct shallow (3-foot or 1-m) ponds that have properly sloped bottoms so they can be completely drained. Ponds also must have harvest basins. Pond construction may require permits from the Corps of Engineers or other agencies.
- Holding facilities (tanks, air supply, etc.) for grading and maintaining minnows before sale.

Published information focuses on developing culture systems that address the small number of eggs produced by females. This low production is unlike many other cultured species where a few females can produce enough eggs to supply the needs of the culture operation.

The most cited system is one that uses three phases to produce bait-size bull minnows. Other strategies are possible and perhaps preferable, but the three-phase system is a documented plan and a starting point that can be modified based on experience and resources.

The three-phase system

The first phase is a spawning pond devoted to egg production. The pond should be free of wild fish and vegetation. Adults about 0.35 ounces (10 g) or larger are stocked at 10,000 per acre (24,710 / ha), with two females for every male. Stocking is done in January or early February. Fish are fed small floating feed pellets twice daily at 3 percent of their body weight per day. Pellets are $^{3}/_{32}$-inch (1.6-mm) and contain 28 to 40 percent protein.

As water temperature rises (above 68 ºF or 20 ºC in the northern Gulf), spawning mats are placed around the edge of the pond. Spawning mats are generally 3 feet by 2 feet by 3 inches (91 by 61 by 7.6 cm) and made of vinyl-coated welded wire with a mesh of 2 inches by 4 inches (5.1 by 10.2 cm) to hold spawning media (coarse, fibrous material such as treated Spanish moss or coconut fibers), which are available from aquaculture supply stores.

Mats are placed just below the water surface. They work better if elevated off the bottom so that spawning can also occur under the mat. Spawning mats may not do as well on the downwind side of ponds where debris and other materials pile up and foul the mats. Mats should be checked periodically for egg production and all mats moved to the phase-two pond within a week to avoid a wide range of hatching dates. This helps prevent predation of recently hatched fish by fish that have hatched earlier.

The second phase is a hatching pond or ponds devoted to hatching eggs and growing fry. The ponds must be properly prepared before the spawning mats and eggs are placed in them. All wild fish should be removed, the ponds refilled with water filtered through fine mesh (285-micron or 0.01-inch) material, and the ponds treated for aquatic insects.

Removing wild fish and filtering the water are extremely important in all three phases. Wild fish left in ponds or fish eggs and larvae that enter from the water source can become major predators of and competitors with bull minnows. This makes fish sorting extremely time consuming. Sheepshead minnows (*Cyprinodon variegates*) are particularly adept at invading ponds and becoming a serious problem.

Predacious air-breathing insects should be controlled by applying a mixture of 1 part oil and 8 parts diesel fuel at a rate of 2 gallons per

acre (18.7 l/ha). Some states do not allow the use of petroleum products for controlling pond insects. In these places, ponds must be filled just before egg stocking.

If aquatic insects can be controlled, hatching ponds should be fertilized a week before stocking and periodically thereafter. Forty pounds per acre (45 kg/ha) of 12-12-12 fertilizer has been used successfully, as has 250 pounds per acre (280 kg/ha) of dried chicken manure. Some research on fertilizing saltwater ponds indicates that the amount of phosphorus can be reduced or eliminated. Fertilizer is applied as needed to maintain about 12 inches (30 cm) of Secchi disk transparency in the pond water.

Approximately 1.5 million eggs can be stocked per acre (0.40 ha), with the expectation of obtaining about 1 million fry. The number of eggs transferred can be estimated by counting the number of eggs in several squares of the wire mesh and multiplying by the total number of squares. This is more difficult than it sounds, as it is hard to see the eggs in the mats and it can be quite tedious to separate eggs from the spawning material.

As fry begin to appear in the pond they are fed finely ground minnow meal (28 to 32 percent crude protein) at 5 pounds per acre per day (5.6 kg/ha). The role of feed in bull minnow production is unclear. At lower fish densities, bull minnows have grown just as well in fertilized ponds with and without feed. Feed may act as additional fertilizer for natural food production or, for fish that learn to eat it, feed may be an additional source of nutrients.

In phase three, young fish are transferred into ponds (prepared as in phase two) for grow out to harvestable size minnows. When young fish reach about 900 to 1,500 per pound (0.3 to 0.5/g), they are harvested from phase-two ponds during the cool part of the day using a small-mesh seine. Ideally, fish are kept in an adequate holding facility for a day and graded through a $^{16}/_{64}$-inch (6.3-mm) minnow grader. Fish that pass though the grader are then restocked into separate ponds from the retained fish to get a more uniform size per pond.

With the three-phase system there are several options for stocking, depending on what size fish the market needs and when they are needed. The time needed to produce a certain size fish is largely dependent on the density of stocking. For example, stocking at 50,000 per acre (123,500/ha) can produce 2.5-inch (64-mm) minnows in about 5 weeks. If the stocking rate were 100,000 per acre, grow-out would take a little more than 6 weeks. At a stocking rate of 200,000 per acre fish would grow very little. This rate could be used to hold fish over the winter. Many other combinations of size and time to harvest are possible depending on the size of fish stocked and the density.

Phase-three fish are fed floating feed twice daily at 10 percent of the stocked weight per day. After about 10 days, fish are sampled to determine their average weight and then fed 5 percent of the total weight. Further adjustments are made every 10 to 14 days. If the total weight of fish exceeds 500 pounds per acre the rate should be reduced to 3 percent per day. Feed should not exceed 25 pounds per acre (11.3 kg/ha) per day. At higher feeding rates pond aeration may be needed to keep dissolved oxygen within acceptable levels.

When fish reach market size they are harvested by seining, trapping or pond draining. Because this is one of the most critical activities in commercial production, considerable thought and planning should go into the process ahead of time. This planning begins when ponds are constructed. Pond bottoms must be smoothly graded with no stumps or other obstructions. Water must drain properly so that fish can be concentrated in one area or in a catch basin. Improperly graded ponds cause minnows to be stranded in the mud and lost. Even ponds in which fish will be trapped should be drainable for pond maintenance.

Harvesting strategies depend on the amount of fish needed and the labor available. Trapping can be effective as long as fish density is high. Although relatively few fish are caught per trap, a good number can be caught over several days. Partial harvests can be done by seining. Fish not needed can be returned to the pond or transferred to another pond. Draining should result in a total harvest.

Regardless of the harvesting method, plans should be made for holding and grading the harvested fish. The trapping method takes longer, so fish must be held until enough are accumulated for a sale. With the other harvesting methods there are enough fish for immediate transportation. However, they should be graded and held for a day for a top quality product. Holding fish for a day allows them to recover from handling stress. It also allows the producer to remove dead or dying fish. Fish retained on a $^{24}/_{64}$-inch (9.5-mm) grader are large enough for market.

Other production systems

The three-phase system gives managers more control but also requires more labor than a one- or two-phase system. A one-phase system would combine the spawning pond, hatching/fry pond, and grow-out pond. A two-phase system might combine the hatching/fry pond and grow-out pond or the spawning pond and hatching/fry pond. Disadvantages of these combinations are less certainty about the amount of production and greater risk of predation by adults on juveniles.

Bull minnows have also been grown in recirculating systems with mixed results. Good growth was difficult to achieve when artificial diets were the sole source of food. On the other hand, recirculating systems provide maximum management control and ease of harvest.

Disease, salinity and water quality

Bull minnows, like any other fish, are subject to parasites and infections when under stress. Research shows that cultured bull minnows remain relatively free of these problems, or at least do not seem

much affected. More intense culture conditions may lead to infections not yet encountered. Bacterial infections have occurred when fish were exposed to freshwater in ponds for a period of time.

The minimum salinity recommended for bull minnow culture is 3 ppt. Lower salinities may affect spawning success and disease resistance. However, bull minnows will live in freshwater and there is at least one report of production in freshwater. Not all freshwater is equal in ionic content and it is generally assumed that most brackish water fish will do better in freshwater with a high ionic content. Precise guidelines have not been established for bull minnows, but waters with a high total hardness and a high calcium hardness are more likely to support production.

The stocking and feeding rates discussed here should not cause the water quality problems found in more intensive culture systems. However, it would be prudent to monitor water quality for salinity, dissolved oxygen, ammonia and nitrite to better understand how these factors relate to management decisions and production. With higher stocking and feeding rates ponds should be monitored closely and aerated if necessary.

Financial considerations

Accounting for all possible costs is one of the most important steps in planning an aquaculture business. A number of general aquaculture enterprise budgets are available from the Regional Aquaculture Centers or from your state Cooperative Extension Service. A budget more specific for bull minnows ("Economic Considerations for the Prospective Mudminnow Culturist in Florida") provides information on costs relative to anticipated income and is listed below.

In addition to understanding costs, it is essential to understand potential markets. The prices paid for bull minnows sound quite lucrative, particularly when compared on a dollars-per-pound (kg) basis to traditional aquaculture products such as catfish. However, before investing any money, it will be important to know how many bait dealers in your area are potential buyers, how often do they need product, how much product they need, what price they pay, and what they are willing to pay. Most bait dealers already have relationships with suppliers and may be reluctant to change to an unknown supplier. Unlike food fish production, where fish are sold to the local processor, there are lots of smaller buyers in the bait business and considerable effort may be needed to market and sell your product.

Significance

Several studies have indicated a strong demand for live bait by saltwater anglers. At times, the demand cannot be met from the existing supply, which comes mainly from wild-caught fish. One way to meet the demand is to culture live bait. Bull minnows are a good candidate for culture and are an important bait throughout the southeast.

Additional reading

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SRAC fact sheets are reviewed annually by the Publications, Videos and Computer Software Steering Committee. Fact sheets are revised as new knowledge becomes available. Fact sheets that have not been revised are considered to reflect the current state of knowledge.

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