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An Indoor Hatching and Intensive Rearing Method for Fathead Minnows

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Fathead minnows are sold as bait, forage, and feeder fish. Market demand for farm-raised minnows has increased in recent years because of concerns that fish captured from natural waters might harbor serious diseases or be co-mingled with aquatic nuisance species (ANS). Fish farmers address these concerns by implementing biosecurity measures, inspecting ponds and vats for ANS, and having fish regularly tested for important diseases.

Although golden shiner and goldfish producers now operate indoor hatcheries to reduce labor costs and control stocking densities, the production techniques for fathead minnows have remained relatively unchanged for decades. Research has shown that indoor hatching prior to intensive outdoor production of fathead minnows is biologically feasible (Fig. 1). However, it is still experimental and has not been adopted commercially. The indoor hatching of fathead minnow eggs is likely to be more expensive than comparable systems for golden shiners or goldfish, and may be best suited for specific applications such as maximizing production from limited pond space, or breaking a disease cycle. Most existing fish hatcheries could be used for fathead minnow eggs. If a hatchery facility is not available, however, the capital costs of construction could preclude the adoption of this method.

Figure 1. Intensive outdoor production of rosy red fathead minnows produced from indoor hatching.

Current production method

Fathead minnows are traditionally produced using the spawning-rearing pond method, where 500 to 2,000 brood fish per acre (1,200 to 5,000/ha) are stocked into a pond. Spawning substrate is added, which can be used polyethylene irrigation pipe, boards, pallets, or cardboard. The brooders reproduce over the spawning season. If juveniles will be transferred, brooders are stocked at 20,000 to 25,000 fish per acre (49,000 to 62,000/ha). Varying numbers of young are produced, sometimes several million juveniles per acre and sometimes very few. Juvenile fish from heavily stocked ponds may be transferred to other ponds at lower densities (50,000 to 300,000 per acre or 124,000 to 741,000/ha) for grow-out to bait size. The spawning-rearing pond method requires relatively little labor and is low-cost, but it does have some disadvantages. Fish produced are a mix of sizes, and larger bait-sized fish may be few in number. Grading can be stressful on the small, feeder-size fish. Diseases are easily passed from the adults to the young. If the initial

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brood fish are contaminated by an unwanted species such as mosquitofish, this species may reproduce as well and be mixed in with the fathead minnows at harvest. Overall yields are often low, historically averaging 350 to 500 pounds per acre (392 to 560 kg/ha).

Indoor hatchery method

This publication describes the results of research on an indoor hatchery system for fathead minnows. Many producers now hatch golden shiner and goldfish eggs in tanks because it reduces the labor required for spawning mat collection and transfer and gives producers control over fish stocking densities. Stocking hatchery fry has a number of advantages. Disease transmission from adults to young is reduced, contaminating fish species can be removed, stocking density can be regulated, and the resulting fish are relatively uniform in size. A comparable system for fathead minnows would provide these same advantages. However, fathead minnow males are territorial and nests are spread out over the spawning material; thus, egg collection is a major cost. The feasibility of an indoor hatching system for fathead minnows is closely tied to the efficient harvesting of eggs. Egg collection alone was estimated to be 43 to 46 percent of the total cost of producing fathead minnow fry in a hatchery.

Egg collection

Collecting enough eggs at one time to produce sufficient fry for stocking a production pond is a key step. A female fathead minnow typically spawns every few days, but the number of eggs per spawn is relatively low. Egg production is strongly influenced by water temperature and varies with broodstock sex ratio, weight of individual females, number of days that fish have been spawning, substrate availability, and other factors.

Broodstock density

For spawning-rearing ponds with juvenile transfer, the recommended brood fish stocking rate is 20,000 to 25,000 fish per acre (49,000 to 62,000/ha). For a system of egg harvesting and indoor hatching, however, higher brood fish densities are desirable, in the range of 100,000 to 150,000 fish per acre (247,000 to 371,000 fish/ha) or 500 to 700 pounds per acre (560 to 780 kg/ha). In a study in outdoor pools, egg production increased with the number of brood fish; the highest density tested was equivalent to 144,000 fish per acre (355,800 fish/ha) or 737 pounds per acre (826 kg/ha). Broodstock densities have not been tested in commercial ponds. Logically, at some point water quality concerns will limit the brood fish stocking rate.

Diet

Brood fish should be fed daily to satiation to maintain egg production. A commercial 28 to 32 percent protein catfish feed is suitable for fathead minnow brooders, and for fish with access to natural foods, there is no advantage to diets with fish meal or fish oil as compared to diets with vegetable proteins and poultry fat. Typical sizes of catfish pellets (5/32- to 3/16-inch diameter or 0.4- to 0.5-cm diameter) can be used even though they are too big to fit into the mouth of a fathead minnow. Minnows surround and work on the pellets as they soften. Fish take at least 30 minutes to reach satiation.

Spawning

Fathead minnows generally start spawning at 60 to 65 °F (16 to 18 °C) and cease at about 85 °F (29 °C). Males establish and defend nests on the undersides (or sides) of substrates. Female fathead minnows lay adhesive eggs that must “stick to the ceiling” to stay within the nest. Males will mate with a series of females, and nests have eggs in varying stages of development. Daily egg production per pound of brooders is highly variable despite the fact that fathead minnows spawn over a prolonged season and individual females may spawn every 4 days or so. In various studies, daily egg production has ranged from 736 to 4,872 eggs per pound (1,623 to 10,741 eggs/kg) of brood fish. Grading brooders to remove some males (typically larger fish) has been recommended as a way to skew the sex ratio and increase egg production. For spawning-rearing ponds, a five female to one male ratio has been recommended. However, the effect of broodstock sex ratio on egg production where eggs are removed for indoor hatching has not been tested.

Water depth by itself apparently does not influence nest location, and nests have been found up to 5 feet (1.5 m) deep. Favored nest depth may vary with water temperature. At the beginning of the season, more nests were found near the surface where water was warmer. Fathead minnows also appear to favor nest sites at the ends and edges of substrates. Literature suggests that fathead minnows prefer nesting near each other. The size of the territory claimed by each male is variable; some nests are adjacent, while others are widely spaced.

For an indoor hatchery system, maximizing the number of eggs on supplied substrate is important. Nests that are on other materials in the pond, such as aerators, vegetation, or sticks, cannot be easily collected. Thus, it is important to remove as much alternative substrate as possible to increase the attractiveness of supplied substrate.

Figure 2. Eggs lining the edges of 6-inch-wide (15-cm-wide) conveyor belt material.

Substrates

Male fathead minnows will establish nests on the underside of just about any horizontal surface, even narrow strips such as aerator cords, and sometimes nests are even found on vertical surfaces. Larger substrates are preferred as nest sites, in the range of 24 to 40 square inches (155 to 258 cm^2), although territories can be compressed.

Substrate should be durable, easily cleaned between spawns, and easy to manipulate during the egg removal process. A textured or rough substrate is essential for good egg retention. Research has shown that less than half the eggs laid will stick on smooth substrates, while rough or textured substrates retain the majority of eggs. In tests, 6-inch-wide (15-cm-wide) conveyor belt material worked well for egg collection, as the belts were easily coiled for transport and egg removal (Fig. 2). Plastic geoweb material (used for slope stabilization) has also worked well as spawning substrate. The geoweb tested consisted of 3-inch-wide (7.6-cm-wide), textured, high-density plastic strips welded together to form a series of cells (EnviroGrid EGA 203T-29, textured, not perforated; available from vendors such as Geo Products and U.S. Fabrics). This material was selected because the textured surface retains eggs and because the narrow width and cellular form suit fathead minnow biology—fatheads appear to prefer to nest near the edges of substrates and also near each other, in colonies. Each cell provides 39 square inches (252 cm^2) of overhead substrate. A single geoweb panel opens up to 8.4 feet (2.56 m) deep and 21.4 feet (6.52 m) long and costs about $200, including delivery (2012). In tests, a panel was cut into short strips, each zip-tied to a plastic pipe float at the top and a weighted pipe at the bottom (small diameter pipe filled with sand and capped) (Figs. 3 and 4).

Figure 3. Sections of plastic geoweb used as spawning substrate. Plastic pipe was used as a float, and a small diameter pipe filled with sand served as a weight.

Figure 4. Up to three nests were found within a cell of the geoweb material.

Amount of substrate

Supplying sufficient substrate for all males is simply not practical or necessary. Only about one-third of males are actively spawning at any one time. For tanks or pools, providing 8 square inches (52 cm^2) of substrate for one-third of the male brood fish might be feasible. In a pond, adding substrate at this rate would require a substantial amount of material. Fortunately, when substrate is limiting, nests tend to be closer together, facilitating egg harvest.

Egg mimics

Egg mimics increase the attractiveness of spawning substrate. Female fathead minnows prefer to mate with males that already have eggs in the nest. Male fathead minnows will attempt to take over the nests of other males, even if there is other substrate available. Substrates with "nests" of about 1-mm diameter glass bead egg mimics were strongly preferred as nest sites over plain substrates, and substrates with greater numbers of egg mimics collected more real fathead minnow eggs. However, egg mimics represent an additional cost and are likely not practical for commercial egg collection systems. The exception might be ponds with plentiful alternative nesting sites, where egg mimics could make supplied substrate relatively more attractive.

Frequency of collection

Collect eggs at least every 2 days during warmer weather (above 70 to 75 °F or 21 to 24 °C), or remove substrate altogether. Three days between collections is too long in warm water (eggs hatch in 3 to 5 days).

Egg removal

Eggs can be removed from substrate using a bath of 1.5 percent sodium sulfite solution. Soaking eggs in the solution for a minute or so is helpful. Unlike golden shiner eggs, which fall off almost immediately, fathead minnow eggs require more time and gentle agitation of the substrate to loosen them. Some eggs will remain attached, but can be washed off with a gentle stream of the solution. The sodium sulfite solution has no oxygen, so eggs should not be left in the solution any longer than necessary. One study found that eggs could be left in the solution for up to 30 minutes without apparent harm. Loose eggs fall to the tank bottom. Using a conical tank for washing substrates eases egg collection; the solution can be drained periodically through a screen filter into a container for re-use (Fig. 5). Eggs collect on the filter and are transferred to a hatching jar for incubation.

Figure 5. Eggs are removed with 1.5 percent sodium sulfite solution and collected in a screened funnel.

Egg incubation

Fathead minnow eggs can be incubated in hatching jars (e.g., McDonald jars) in the same manner as other fish eggs (Fig. 6). Egg numbers may be estimated volumetrically by using a graduated cylinder to determine total egg volume and then counting several small sub-samples. Egg counts per milliliter (mL) are generally in the range of 470 to 580; assuming 500 eggs per mL provides a conservative estimate for planning purposes. The water flow should be adjusted so that the eggs roll freely (e.g., 0.6 to 0.7 gpm or 2.3 to 2.6 Lpm), but vigorous movement should be avoided as it can reduce hatch. Conceivably, eggs could be left attached to substrate for indoor incubation. However, this would require relatively large tanks to hold the substrates, and fungus treatment would be more complex and

Figure 6. Fathead minnow eggs are incubated in McDonald jars. At hatching, fry move with the water flow into circular tanks. The plastic bag (upper left) was used to drip in a chemical solution for fungus treatments over time.

expensive. Disinfecting eggs before they are placed into hatching jars is desirable, but appropriate doses of disinfectants such as iodophor have not been determined for fathead minnow eggs. Some fish species are very sensitive to this disinfectant.

Fungus treatment

Fathead minnow eggs are very susceptible to fungal infections and must be treated. Daily treatments with hydrogen peroxide (500 mg/L) or formalin (500 mg/L) for 15 minutes worked well to reduce fungus in research trials. If using hydrogen peroxide, insert a fine mesh (e.g., 600-micron or less) screen to retain eggs within the jar, as bubbles attach to eggs and float them upwards.

Hatching

Time to hatching varies with water temperature and egg age at the time of collection. Eggs hatch quickly at 68 °F (20 °C), within 2 to 4 days. Hatching rates of 75 to 80 percent have been obtained when eggs are treated to control fungus. Fry leaving the hatching jar are collected in a holding tank (Fig. 7). The tank drain is covered with a fine-mesh screen to retain fry. Aeration is provided through a flexible air stone or perforated hose wrapped around the drain screen; this also helps reduce clogging and fry impingement.

Figure 7. Newly hatched fry held in circular tanks.

Counting fry

Fry numbers can be estimated with the same techniques used for other species that have tiny fry. Fry are too small and delicate to be collected in a dip net and weighed. The volumetric method is simple but time-consuming. Fry are retained in a tank with a known water volume, the water is gently stirred to evenly distribute the fry, and three or more subsamples are collected from the tank (Fig. 8). Fry in each subsample are counted, and the counts averaged to obtain an estimated number of fry per unit volume. This estimate is then multiplied by the tank water volume to estimate total fry numbers. It is useful to use several sizes of sampling cups to avoid counting too many or too few fry. With experience, hatchery personnel will be able to visually estimate fry numbers, as is true in commercial golden shiner hatcheries.

Figure 8. Fathead minnow fry concentrated prior to stocking.

Fry culture

Pond preparation

Ponds for fry should be drained and dried if at all possible. Well water is added several days before fry are stocked (e.g., starting the day that eggs are brought into the hatchery). If fry are stocked into ponds with established plankton blooms, fry survival will likely be variable and low. Old water often has predaceous copepods and varying amounts of natural food. Fertilization protocols vary with location and experience. At the University of Arkansas at Pine Bluff, good results have been obtained by fertilizing the first day of pond filling with 50 to 100 pounds per acre (56 to 112 kg/ha) of rice bran, followed by twice weekly applications of 25 pounds per acre (28 kg/ha) of rice bran for several weeks. Inorganic fertilizer is applied only if the pond does not develop a plankton bloom within 10 days. See SRAC Publication No 469, *Fertilization of Fish Fry Ponds,* for additional information.

Fry stocking

Fry are best stocked early in the morning or late in the day, when temperatures are cooler. Fry may be transported from the hatchery to ponds in plastic bags with oxygen or in a tank equipped with a fine-bubble oxygen diffuser system. Fry should be acclimated to pond water temperature before stocking.

Fry stocking rates

There is limited information on appropriate stocking rates for fry. Previous work on the stocking of golden shiner fry from hatcheries found that survival rates in commercial ponds were similar to those in experimental ponds. If this holds true for fathead minnows as well, fry for the feeder market can be stocked at 1 to 2 million per acre (2.5 to 5 million/ha) with good survival and high yields. To produce bait minnows, lower fry densities are indicated, about 300,000 to 500,000 per acre (740,000 to 1.2 million/ha). However, if the density is too low, fish will mature and might begin to spawn at 3 to 4 months of age.

Figure 9. One-month-old rosy red fathead minnows feeding at the surface (about 1.4 million fish per acre or 3.5 million per hectare).

Feeding and aeration

Commercial catfish feeds can be used for fathead minnows. Newly stocked fry are fed daily with finely ground (meal) catfish feed for 3 to 4 weeks (Fig. 9), then switched to crumbles (crumbled extruded pellets) for several weeks before being fed extruded pellets. Fathead minnows are well adapted to intensive production. In experimental ponds, maximum feeding rates have exceeded 100 pounds per acre (112 kg/ha) per day. Fathead minnows take longer to satiate than catfish, and it is important to distribute feed over the entire pond. During feeding, shoals of minnows actively swim around at the surface, but fish appear to have trouble finding feed unless it is dropped in front of them.

Ponds in which fish are fed at high rates require aeration. In experimental trials in 0.1-acre (0.04-ha) ponds, nightly aeration started 3 weeks after fry stocking. While one aerator was sufficient for these small ponds, commercial ponds would require multiple aerators spaced around ponds. It is unlikely that all the small fathead minnows in a large pond would congregate behind one or two large aerators. Purchasing additional aerators and installing additional electrical service would obviously increase costs. Alternatively, fish could be confined to a portion of the pond (e.g., split-pond system).

Production trials

Production trials were conducted for two growing seasons in 0.1-acre (0.04-hectare) ponds inside a fenced and netted enclosure. Fish were stocked at varying densities (100,000 to 3.2 million per acre; 250,000 to 7.9 million/ha) over time as fry became available and harvested after 132 to 169 days. Yields ranged from 400 to 5,000 pounds per acre (450 to 5,600 kg/ha) (Fig. 10), varying with the number of fish harvested. Feed conversion ratios (FCR) ranged from 1.62 to 1.83 for ponds with high fish densities at harvest (1.3 to 2.0 million fish per acre or 3.2 to 4.9 million/ha). In the experimental trials, feed was provided at a fixed rate across all ponds regardless of fry stocking density, and FCRs of 2.1

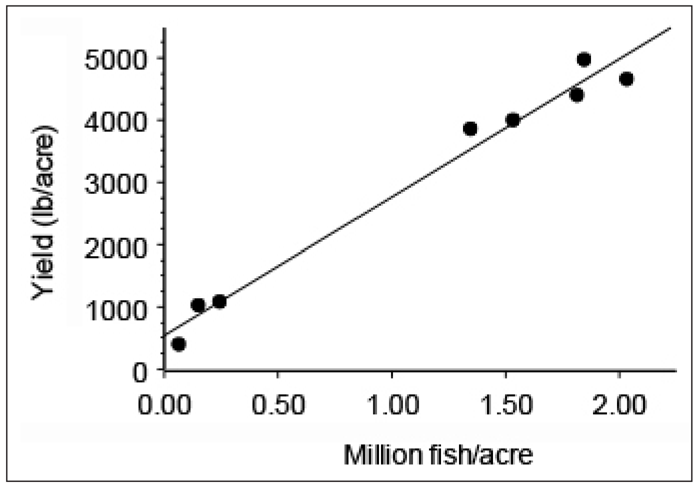

Figure 10. Yield (pounds per acre) of rosy red fathead minnows stocked as fry in 0.1-acre ponds and cultured for 132 to 169 days.

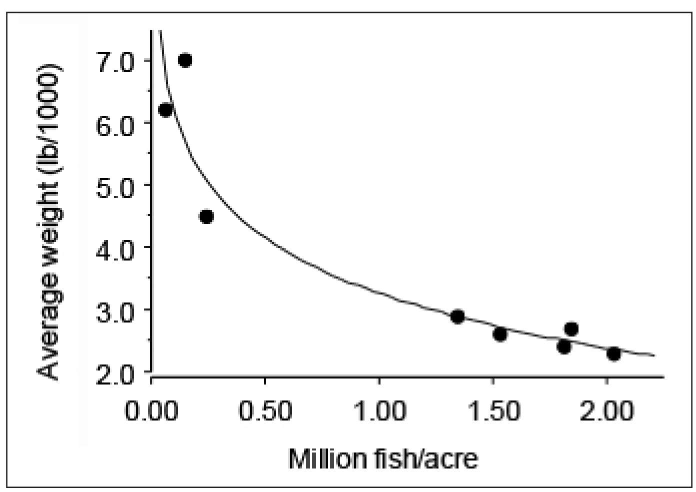

Figure 11. Average weight per fish of rosy red fathead minnows decreased with the number of fish harvested per acre, after 132 to 169 days.

to 3.2 were obtained in three low-density ponds (100,000 to 324,000 fry per acre or 250,000 to 800,000/ha). Normally, FCR is lower at low fish densities than at higher densities. It's likely that in practice, if feed is provided in proportion to stocking rate and pond fertility is maintained through fertilization, lower FCRs could be obtained. Average weight per fish declined with the number of fish harvested per acre (hectare) (Fig. 11). Fish from high-density ponds were small but relatively uniform in size. At low densities (100,000 to 140,000 fry per acre or 247,000 to 346,000 fry/ha), fish grew quickly but matured early, and reproduction occurred 3 to 4 months after stocking fry. Male fathead minnows developed tubercles by 48 days post-stocking, fish of both sexes were mature by 84 days, and reproduction was observed at sampling on day 112.

Diseases and predators

Fathead minnows are very adaptable to intensive production, but diseases are always a concern, especially at increased fish densities. Diseases were not a problem during these experimental trials, but obviously this will not always be the case. In addition, ponds used in these trials were fenced and netted to exclude birds. Fish covered pond surfaces during feeding. Without netting, bird depredation probably would have caused serious losses.

Economics

A fathead minnow hatchery could be added to an existing golden shiner or goldfish hatchery. A rough estimate of total costs suggested that a 10-million fry hatchery added to an existing hatchery would cost $514 per million fry. Given economies of scale, costs were estimated to drop to $362 per million fry for a 50-million fry hatchery. The economics of intensive production of fathead minnows has not been studied. Fixed costs of baitfish production are relatively high. Assuming that fish produced can be sold, increasing yields through feeding and aeration will distribute these costs over more product, reducing the percentage that fixed costs contribute toward break-even price.

Summary

The indoor hatching of fathead minnow eggs has a number of advantages, including reduced disease transmission from adults to young and control over stocking densities. Intensive production methods have resulted in relatively high yields in protected experimental ponds. However, because this is a new method that has not been tested commercially, producers considering indoor hatching are cautioned to start small and experiment first before investing in large-scale production.

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