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Culture of Largemouth Bass Fingerlings

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Largemouth bass (*Micropterus salmoides*) fingerlings are produced by public and private hatcheries for recreational stocking programs and increasingly for commercial foodfish production. Because largemouth bass swim-up fry cannot be easily trained to accept prepared diets, they are usually raised in fertilized nursery ponds. There, they feed on zooplankton (tiny floating or weakly swimming organisms that drift with water currents) until they reach 1 to 2 inches (25 to 50 mm) long, when the fingerlings are feed trained to accept artificial diets. Feed-trained fingerlings are then stocked into ponds and fed pelleted feed until target sizes are reached for management objectives or until thinned out to second-year grow-out densities for foodfish production.

Although research has greatly improved production efficiencies, advances in hatchery design have in many cases dictated the intensification that largemouth bass producers have achieved:

- Spawning bass in raceways has reduced dependence on spawning ponds for fry production.
- Techniques to intensively spawn bass "out-of-season" have been developed.
- Advances in pond aeration systems, better harvest structures, and research into pond fertilization and management have improved outcome predictability for rearing fry and fingerlings.

Many of these production advances are based on large investments in capital infrastructure at publicly operated hatcheries and/or research discoveries, some of which are not economically practical for most private producers. Many private producers use techniques and practices that have remained unchanged for several decades. The economics of commercial largemouth bass fingerling production is based on site-specific factors that dictate the most appropriate production technologies for individual farms.

This factsheet will summarize some of the advances in largemouth fingerling culture and provide a "how to" description of techniques used by both large- and small-scale producers.

Genetics

Domestication in cultured species influences behavioral, genetic, morphological (relating to the species' form and structure), and physiological (relating to the ways their bodies work) traits in cultured fish. These effects may increase the performance of cultured fish in commercial aquaculture but may reduce fitness, life-skills including predator avoidance, and foraging success of cultured fish in wild settings. Domestication of cultured stocks enhances foodfish production because it improves the suitability of cultured stocks for commercial culture traits such as growth rate, meat yield, reduced size variability, and improved acceptance and use of prepared diets.

Before implementing a genetics plan, consider the desired outcome or final use of the cultured bass. If the bass will be used for conservation and native stock enhancement programs, you will need to consider genetic factors more strictly when selecting broodfish and developing culture protocols. Loss of genetic variability is a concern for conservation-minded fisheries enhancement programs trying to protect the genetic integrity of endemic (native to a specific region) populations. If the bass will be used for food production and stock enhancement programs targeting a specific outcome—such as size and growth rate—genetic considerations are less critical and should be based on production factors and market demand.

Historically, the two recognized subspecies of the largemouth bass are the northern (*Micropterus salmoides*) and the Florida (*Micropterus salmoides floridanus*). Recently, Florida largemouth bass have been elevated to individual species level (*Micropterus floridanus*), giving us the largemouth bass (northern) and the Florida largemouth bass.

Commercial producers should choose species based on market demand and suitability for the market area. Gener-

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ally, the largemouth bass is considered more suitable for foodfish production because these fish have a better growth rate during the first year, are more successful feed training, have improved resistance to disease, and better tolerate low water temperatures. The Florida species is preferred in southern climates as a sportfish because the females grow to a larger maximum size. Commercial fingerling suppliers also produce hybrids of the two species that are marketed for both foodfish production and sportfish stocking.

Broodstock selection, care, and maintenance

Male and female largemouth bass are sexually mature at 2 or 3 years old, depending on geographical location. Preferred broodfish are 2 to 8 years old—females 3 to 6 pounds (1.3 to 2.7 kg) and males 2 to 3 pounds (0.9 to 1.3 kg) (Fig. 1). Both species are fractional spawners, meaning that they spawn multiple times within a single breeding season. Male nesting behaviors provide parental care for young.

Typically, bass broodfish used for public stock enhancement programs are "wild" caught to protect the genetic integrity. They require live forage because they will not consume pelleted feeds (Table 1). Many types of live forage have been used successfully, with goldfish (*Carassius auratus*) being the most popular. Commercial largemouth fingerling producers generally use broodstock, which are feed trained due to the increased cost of providing live forage for broodstock maintenance.

If pond space allows, separate broodfish into ponds by year class and gender in the off season. This separation prevents unexpected spawning and minimizes handling during harvest and broodfish pairing. Older fish generally spawn earlier than do younger fish, which can increase disparity in fry sizes. Separating broodfish by age can reduce cannibalism of older on younger fry by ensuring that most fish spawn at about the same time.

Secondary sex characteristics are poorly defined in largemouth bass. Mature fish can be sexed with reasonable accuracy just before spawning. At other times, the morphological differences are not distinct enough for sexing.

Broodfish are selected for spawning in the early spring when water temperatures are consistently above 59°F (15°C). In spawning condition, females are easily distinguishable from males and unripe females by examining them side by side, belly up. Ripe females exhibit a soft, distended ovarian region and a swollen, red vent (Fig. 1). Ripe males release a small amount of milt when palpated. To palpate a fish, turn it belly up and slowly but firmly apply pressure along the sides or middle of the abdominal region. For spawning, use only males that freely express milt when palpated to ensure that they are male.

Figure 1. Mature females displaying egg-swollen belly and a swollen red vent. *Photo courtesy of Prangnell and Matthews/Texas Parks and Wildlife Department.*

When handling broodfish, use a 60-second, 3 percent salt dip. Use evaporated salt (NaCl-) without the anti-caking agent that is typically found in "feed grade" salt, which can harm fish. Two sedatives are approved for bass and can be used when handling and transporting broodfish: MS-222® or Tricaine-S (Western Chemical, Ferndale WA) at 25 mg/L (ppm) for handling, or 50 mg/L for complete sedation for sex determination or tagging. A 21-day withdraw or waiting period is required before sedated fish can be stocked in public water or consumed. Aqui-S®E (AquaTactics Fish Health, Kirkland, WA) can be used to sedate fish at 10 to 100 mg/L with a zero withdraw period if the fish are sedated for less than 15 minutes and only a 3-day withdraw period for longer applications. A dose of 30 mg/L will effectively sedate bass for capture, sex determination, measurement, and relocation to spawning raceways or ponds.

Table 1. Suggested forage sizes (TL) and rates to feed LMB and FLB of increasing age ranges.

Age (years)	Typical fish weight pounds (kg)	Pounds forage/ pounds broodfish/ year (kg)	Size of forage TL inches (mm)
0–1	< 1 (0.45)	20 (9.1)	Fry–2 (50)
1–2	0.75–1.5 (0.3–0.7)	15 (6.8)	2–3 (50–75)
2–3	1.5–3 (0.7–1.3)	10 (4.5)	3–4 (75–100)
3–4	3–5 (1.3–2.3)	9 (4.1)	3–4 (75–100)
> 4	> 5 (2.3)	7 (3.2)	3–5 (75–125)

Spawning behavior

Spawning activity of largemouth bass is closely related to rising water temperatures after winter. Largemouth bass are relatively synchronous regionally in their reproductive cycle. Bass typically spawn from early spring into the summer, displaying latitude variation between northern and southern climates, with spawning times ranging from February to July in the United States. A water temperature of 64°F (17.8°C) is generally recognized as the beginning spawning temperature of this species. The spawning season usually lasts 3 to 4 weeks.

Largemouth bass are classified as fractional, batch, or "multiple" spawners. Only some of the eggs are released during a spawning event, and the females spawn more than once during the spawning season. They release the eggs at intervals, usually over several days or weeks. The intervals allow more, smaller, and immature eggs to be carried in a limited abdominal cavity space, giving the smaller eggs time to mature. The eggs mature at different times, thus avoiding complete loss of a season's spawning to predators or bad weather. Females normally release about half of their eggs during the first spawn and half of the remaining during the second spawn. A third spawn up to a month later is common. This behavior reduces the efficacy of using hormone injection for artificial spawning, as only some of the eggs respond and as a result is generally not practiced in commercial production.

The eggs of largemouth bass require a relatively long period to develop, beginning in the fall and continuing through the winter and spring. Largemouth are seasonal spawners. After spawning, no more eggs will develop until water temperatures begin to decrease during the following fall.

Largemouth bass eggs are demersal (they sink in water) and adhesive. Fertilized eggs range in diameter from 3⁄64 to 5⁄64 inch (1 to 1.5 mm). Smaller and younger fish produce smaller eggs. Egg counts of samples from ovaries of unspawned fish indicate a potential to yield 30,000 to 45,000 per pound (66,000 to 99,000/kg) of body weight.

Largemouth bass build and guard nests. The male selects and prepares the nest site and guards it against intruders. Preferred sites are protected locations in shallow water over a firm bottom or a fibrous substrate such as tree roots. Largemouth bass prefer artificial spawning substrates such as Blocksom or Spawntex™ mats (Blocksom and Company, Michigan City, IN). These substrates are generally placed 10 to 20 feet (3 to 6.1 m) apart in ponds and 6 feet (2 m) apart in raceways at water depths of 1.5 to 3 feet (0.46 to 0.91 m) and close to the pond bank to allow easy observation. The mats can then be transferred indoors or directly to other ponds for hatching.

When broodstock are initially stocked into ponds or raceways for spawning, they usually school together at first. After a couple of days, the males begin to select and guard spawning sites. Once the nest is established, the male becomes territorial, stays near the nest, and tries to entice a female to spawn. After a short courtship, the female lays eggs on the nest as the guarding male fertilizes them. Spawning can occur at any time of day, with afternoon and early evening more common in raceway spawning.

Maintaining clear water and using a flashlight can help you find spawns. If the water is stained or murky, you may need to gently lift each mat to examine it for eggs. If the guarding male does not abandon a nest being examined, a spawn is likely present.

Spawning methods

Spawning methods used for largemouth bass fry production are based on hatchery infrastructure and production goals. The scale of hatchery operations varies from small private producers with production goals of a few thousand fingerlings to large state and federal hatcheries with highly sophisticated facilities and production goals of several million. The appropriate technology is a site-based decision largely determined by resource availability. Hatchery production of largemouth bass involves three main culture methods: spawn and rear, egg or fry transfer, and intensive culture.

Generally, equal numbers of males and females are stocked as pairs. Bass spawning consistently begins at 64°F (17.8°C) and will continue to 86°F (30°C). The optimal range for egg hatching and swim-up fry production is 70 to 77°F (21.1 to 25°C) (Table 2). Hatching takes 48 hours at 70°F (21.1°C) and 30 hours at 77°F (25°C). It is not recommended to hatch bass eggs at constant temperatures above 79°F (26.1°C) because deformities have been reported.

The **spawn-and-rear method** is the oldest and simplest approach to largemouth bass culture. Broodfish stocking densities are typically 10 to 20 brood pairs per acre (25 to 50 pairs/ha). Broodfish are left in the pond until the fingerlings grow large enough for harvest and either distribution or subsequent feed training, which is generally 30 to 45 days after spawning. The spawn-and-rear method typically yields mixed-age fry that should be graded before the next rearing stage. Because the broodstock cannibalize fingerlings, this method is effective for fingerlings only up to 1 inch (25 mm). Ponds are typically fertilized to stimulate primary productivity and subsequent production of zooplankton and larval insects to provide food for the developing fry and fingerlings. Although production yields vary widely with this method, 20,000 to 40,000 fingerlings are produced per acre (49,500 to 99,000/hectare) (Table 2).

For the **egg-transfer method,** ponds are stocked with broodstock densities of generally 30 to 40 brood pairs per acre (74 to 99/ha). Ponds are managed for water clarity and are not fertilized. Spawning mats are used as a removable substrate for bass to spawn for egg collection. Spawning mats are checked daily for eggs. Nests with spawns are transferred from spawning ponds into fertilized nursery ponds, where the eggs hatch and the fry remain and grow to the target size.

The disadvantage of this method is that the number of fry to hatch successfully is unknown and may be too high or too low relative to the carrying capacity of the pond. This variable makes management difficult and production unpredictable. It could also require significantly more pond space than do other methods.

For the **fry-transfer method,** ponds are managed and stocked as described for the egg-transfer method, but the swim-up fry are transferred from spawning ponds to fertilized nursery ponds. These ponds are usually managed for water clarity because the producer must be able to observe fry and spawning activity. These ponds do not require fertilization because the fry will be removed before they begin feeding. For several days after swim-up, free-swimming schools of fry remain near the nest, where they can be collected by dip netting, seining, trapping, or pond draining. The fry-transfer method allows ponds to be more easily stocked with fry of similar size and age to minimize cannibalism. Mixed sizes of fry become more pronounced as the spawning season progresses due to the mixing of fry from subsequent spawns.

Most producers stock similar-sized fry at densities of 50,000 to 80,000 fry per acre (124,000 to 198,000/ha) into nursery ponds. Returns are wide ranging and density dependent but typically produce 40,000 to 60,000 fingerlings 1.25 to 2 inches (31.6 to 50 mm) per acre.

Table 2. Spawning, stocking, and production estimates for largemouth and Florida bass using traditional, controlled, and out-of-season spawning methods.

Factor	Largemouth bass	Florida bass
Spawning temperature, °F (°C)	65–77 (18–25)	68–77 (20–25)
Broodfish density		
Spawning/rearing pair/acre (ha)	10–20 pair (25–50)	10–20 pair (25–50)
Spawning/fry transfer	30–40 pair (74–99)	30–40 pair (74–99)
Spawning/rearing yield/acre (ha)	20,000–40,000 (49,500–99,000)	20,000–40,000 (49,500–99,000)
Fry transfer yield/acre (ha)	50,000–150,000 (124,000–371,000)	50,000–150,000 (124,000–371,000)
Indoor, 80 ft (24.4 m) raceway	20 pair or 30 females/20 males	20 pair or 30 females/20 males
Spawns/female	2	2
Fry/spawn	10,000–15,000	8,000–12,000
Fry/yield	480,000–680,000	400,000–600,000
Fry/female	10,000–30,000	10,000–24,000
Out of season, 80 ft (24.4 m) raceway	20 pair or 30 females/20 males	20 pair or 30 females/20 males
Spawns/female	3	3
Fry/spawn	7,500	5,000–7,000
Fry/yield	350,000–500,000	300,000–450,000
Fry/female	10,000–25,000	10,000–20,000
Egg incubation temperature, °F (°C)	70–77 (21–25)	70–77 (21–25)
Fry/gram (pound)	380 (172,500)	300 (136,000)
[1]Pond yield, average fingerlings/acre (size in inches, survival)		
Spawning/rearing	30,000 (1.25–2, 50)	30,000 (1.25–2, 50)
(Fingerlings/ha, size in mm)	(74,000, 32–50)	(74,000, 32–50)
Fry transfer 80,000/acre	48,000 (1.4–1.8, 60)	48,000 (1.4–1.8, 60)
(Fingerlings/ha, size in mm)	(119,000, 36–46)	(119,000, 36–46)
Fry transfer 100,000/acre	60,000 (1.5–1.7, 60)	60,000 (1.5–1.7, 60)
(Fingerlings/ha, size in mm)	(148,500, 38–43)	(148,500, 38–43)
[2]Fry transfer 125,000/acre	83,000 (1.4–1.6, 67)	83,000 (1.4–1.6, 67)
(Fingerlings/ha, size in mm)	(205,500, 36–41)	(205,500, 36–41)
[2]Fry transfer 150,000/acre	109,000 (1.4–1.6, 73)	109,000 (1.4–1.6, 73)
(Fingerlings/ha, size in mm)	(270,000, 36–41)	(270,000, 36–41)
[2]Fry transfer 200,000/acre	140,000 (1.4, 70)	140,000 (1.4, 70)
(Fingerlings/ha, size in mm)	(346,500, 36)	(346,500, 36)
Feed training success, %	70 ± 20	60 ± 30
Training density, bass fingerling weight oz/gal (g/L)	0.8–1.1 (5–8)	0.8–1.1 (5–8)
Number of fingerlings/gal, (#/L)	44–60 (11–16)	44–60 (11–16)

[1]Yields vary with reduced survival during early spring and greater survival in warmer months.
[2]These higher densities are typically used only in lined ponds.

Controlled indoor spawning

Controlled indoor spawning offers several advantages over spawning ponds for fry production:

- Broodfish can be used more intensively in a smaller culture space.
- More fry can be produced per pound of female, requiring fewer broodfish.
- Removing spawns daily and immediately replacing the mats allows the males to spawn every day.

In an 80-foot (24.4 m) raceway, 20 spawning mats can be evenly spaced along each long wall length (10 per side) (Fig. 2) and 6 feet apart to reduce male territorial aggressive behavior (Fig. 3). The number of spawning substrates should be equal to the number of males.

Spawning in raceways requires water flow rates of 50 to 75 gallons (190 to 284 L) per minute in 13,000 gallon (49,205 L) capacity raceways filled to about 10,000 gallons (37,850 L). Water levels in the raceways are lowered to reduce losses from fish jumping out and to increase the visibility of spawns without affecting spawning. Once the broodfish are acclimated to raceway conditions, water temperatures should reach a preferred minimum spawning temperature of 68°F (20°C).

Figure 2. Indoor bass spawning raceway. *Photo courtesy of Matthews/TPWD.*

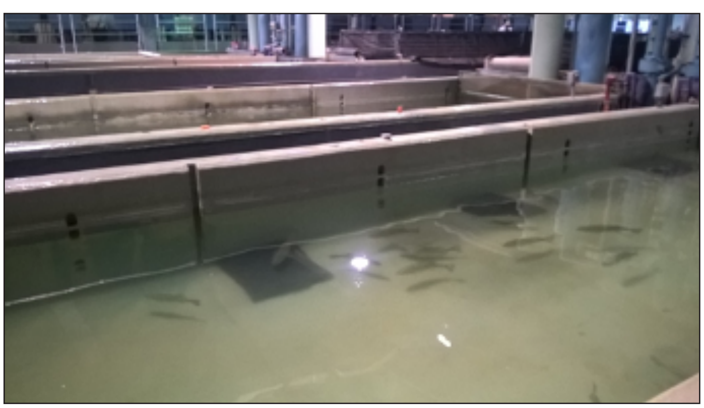

Figure 3. Spawning mats placed 6 foot (1.8 m) apart in an 80 foot (24.4 m) spawning raceway. *Photo courtesy of Matthews/TPWD.*

Wild broodstock need time to acclimate to the artificial raceway environment. This acclimation can take 3 to 8 weeks in the first year that the fish are spawned indoors. Broodfish used in concurrent years become habituated to spawning in raceways. If kept indoors indefinitely, fish can begin spawning 1 to 3 days after pairing. If kept in gender-split ponds outside, broodstock will require 1 to 2 weeks of acclimation time. To reduce bacteria and parasites harmful to eggs, do not feed broodfish in spawning raceways.

Collect spawns daily to enable spawning activities to resume. Mats containing spawns are hung vertically in an "incubation" tank or raceway (Fig. 4). Spawns are transferred in water and should remain in the transfer tubs for less than 15 minutes before being moved into incubation tanks. Incoming water is screened through 35 mesh per inch (500 micron) screen to exclude unwanted organisms and detritus. The drain should include a saran-screen guard to prevent fry escape and aeration to keep the fry off the screens. Low-pressure air is gently bubbled along one side down the length of the trough to keep the water moving around the mats and to mix therapeutic chemicals if required. A 15-foot (4.6 m), 750-gallon (2,839 L) trough supplied with 5 to 7 gallons (19 to 26.5 L) per minute can safely handle 30 spawning mats (Fig. 4). You may need to treat spawns with approved chemicals to control fungus.

Figure 4. Bass spawns vertically hung in troughs with light aeration. *Photo courtesy of Matthews/TPWD.*

Indoor incubation of eggs was developed to improve efficiency and to make production results associated with other methods more consistent. Although maintaining consistent water temperatures during egg incubation is recommended, it is impossible in ponds. Generally, 80 to 90 percent hatch is achieved at 71 to 73°F (21.7 to 22.8°C) and 50 percent at 64 to 66°F (17.8 to 18.9°C). Fungus is the cause of mortality (Table 2).

Bass eggs incubated at 63°F (17.2°C) require 5 days to hatch; at 72°F (22.2°C), they require 2 days to hatch (Fig. 5).

Newly hatched fry swim-up in 7 to 9 days at 64 to 68°F (17.8 to 20°C) and in 5 to 7 days post-hatch at 71 to 75°F (21.7 to 23.9°C). The fry first appear as tiny golden globules along the sides of the troughs and edges of the mats (Fig. 6). The fry darken over time, turning dark gray and then black. Remove the mats from the troughs when the fry begin to swim freely in the water column. To reduce cannibalism, stock nursery ponds from spawns collected in no more than 3 consecutive days.

Controlled raceway spawning paired with indoor incubation to swim-up allows for more consistency in fry size and numbers stocked out into nursery ponds. The typical yield from stocking 80,000 fry per acre (198,000/ha) in earthen ponds is 50,000 fingerlings at 1 to 1.75 inches (25 to 45 mm) after a 25- to 35-day period. Stocking ~200,000 fry per acre (495,000/ha) in lined ponds usually yields 140,000 fingerlings at 1 to 1.5 inches (25 to 38.1 mm) after a 27- to 38-day growth period in warm climates (Table 2).

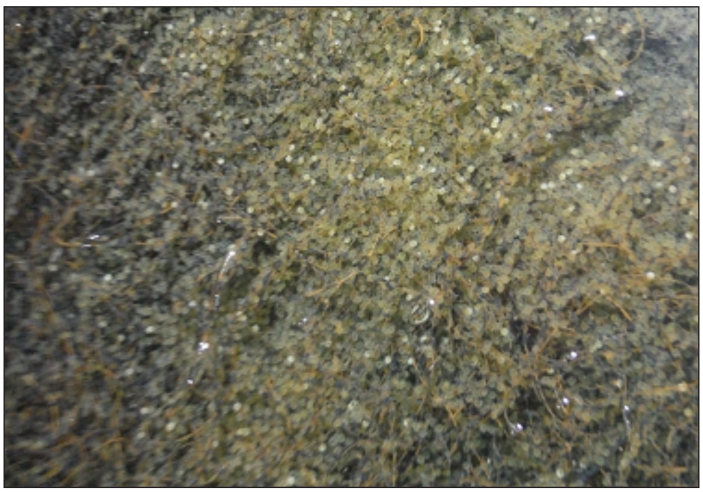

Figure 5. Bass eggs on a mat from an indoor raceway. *Photo courtesy of Matthews/TPWD.*

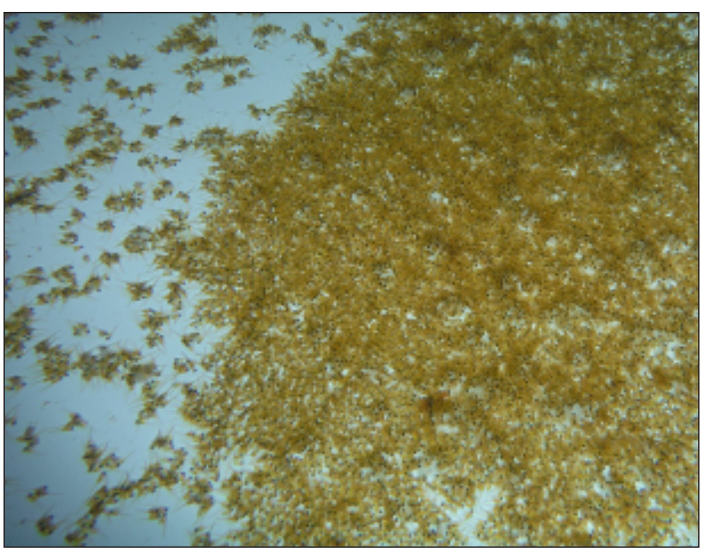

Figure 6. Bass fry 24 hour post-hatch. *Photo courtesy of Matthews/TPWD.*

Out-of-season spawning

Spawning and rearing bass in the fall allows for the production of 4-inch (100 mm) bass by March of the following spring. Protocols, stocking ratios, and stocking rates are the same as for controlled indoor spawning but require the addition of temperature and daylight manipulation to naturally induce spawning. Water temperatures are systematically lowered to 54 to 57°F (12.2 to 13.9°C) over a 4-week period, held there for 3 weeks, and then increased over a 4-week period back to ambient or 70 to 77°F (21 to 25°C).

The amount of daylight is also manipulated using a black plastic cover that blocks all light in the raceway to exaggerate dark periods. Raceways are maintained at a 10-hour photoperiod for the first 4 weeks, dropping to 8 hours during the 3 weeks spent at 54°F (12.2°C), increased to 10 hours for 2 weeks, and then increased to 14 hours for spawning.

Observations between multiple seasons of spring spawning and out-of-season spawning show no differences in Florida bass fry average size, health, or behavior. The only obvious difference is the average number of fry per spawn. Spring production typically averages 6,000 to 12,000 fry per spawn; out-of-season production is 4,000 to 7,000 fry per spawn (Table 2).

Fungus control

Fungus is a chronic but controllable concern in egg incubation. Several options for treatment depending on location and water quality are described at https://www.fws.gov/fisheries/aadap/home.htm. Effective treatments include temperature manipulation, hydrogen peroxide, and formalin.

Suitable **temperatures** for fungus growth range from 41 to 86°F (5 to 30°C). By incubating bass eggs at water temperatures above 68°F (20°C), the eggs hatch more quickly, reducing fungus-induced mortality.

Hydrogen peroxide (35 percent active) is approved for use on bass eggs at 750 to 1,000 mg/L. Concentrations of hydrogen peroxide greater than 300 mg/L can significantly increase mortality on newly hatched fry. Therefore, hydrogen peroxide concentrations of 250 mg/L or less are recommended once the fry have hatched. Monitor the mats during treatment, as tiny bubbles can form and lift the mat to the surface, possibly exposing the eggs to air.

Formalin is approved for treating bass eggs at 1,000 to 2,000 mg/L for 15 minutes with continuous water flow or at 170 mg/L for a one-hour static bath. Monitor dissolved oxygen (DO) concentrations during formalin treatments because the DO concentrations steadily decrease during treatment. Water-harden the eggs for 1 to 2 hours before applying chemical treatment.

Intensive indoor fry feeding

Largemouth bass do not accept prepared diets at first feeding and initially require live feed. The assumption is that live feeds are initially needed to inoculate the fish's gut with the digestive enzymes needed to metabolize prepared diets. In pond-based fingerling production systems, bass fry feed on naturally occurring zooplankton. Research shows that bass swim-up fry readily consume *Artemia nauplii* (brine shrimp, a saltwater invertebrate similar in size to the zooplankton found in ponds) and can be successfully transitioned to a starter diet (such as Otohime B1) after 2 weeks of feeding *Artemia*. The survival rate is more than 50 percent. Currently, intensive indoor fry feeding is not widely practiced, but it is possible and can eliminate the need for the nursery phase.

Traditional nursery phase

Nursery ponds are typically filled and fertilized when spawns are first collected from raceways or when males are observed guarding nests in ponds. This timing allows a 7- to 10-day interval for zooplankton to develop before swim-up fry are stocked into nursery ponds. The goal of fertilizing ponds is to reduce common limiting factors to produce exaggerated zooplankton populations adequate to feed the greater fry densities than typically found in natural waterbodies.

Applying fertilizer regimes can increase fish growth potential by 2 to 5 times. Fertilization produces more consistent levels of the nutrients nitrogen (N), phosphorus (P), and potassium (K). Each hatchery has different water quality characteristics that require site-specific protocols to ensure successful and efficient fish production.

Fry stocking

Swim-up fry at 0.3 inch (7 mm) should reach 1.5 inches (38 mm) in 28 to 33 days. Water quality, stocking density, and pond volume greatly influence this size-oriented production goal. For traditional bass spawning methods in earthen bottom ponds, stocking densities of 50,000 to 80,000 fry per acre (124,000 to 198,000/ha) are commonly used. Plastic-lined ponds can increase acceptable fry stocking rates to up to 200,000 fry per acre (495,000/ha) by providing greater nutrient densities and zooplankton numbers. Generally, higher stocking densities are less consistent, which increases the likelihood of harvesting smaller fingerlings because of food shortages.

Fry are more sensitive to cooler water than are fingerlings and adults, and Florida bass are less cold tolerant than are largemouth bass. Slowly acclimate the fry to pond water temperatures before stocking. Avoid rapid temperature changes of more than 5°F (2.8°C) per day and rates above 2°F (1°C) per hour. The minimum acclimation time for fry should be 30 minutes. Stock fry as early in the morning as possible to minimize heat stress and exposure to high pH. Dissolved oxygen levels should be between 6 and 15 mg/L and below 200 percent saturation to avoid hyperoxia-induced fry mortality (Table 3).

Table 3. Recommended water quality ranges for optimum growth of largemouth bass fry in ponds.

Parameter	Recommended range
Alkalinity, total (mg/L as $CaCO_3$)	80–200
Ammonia (mg/L NH_3)	0.0 (< 0.1, 96-h LC50 0.72–1.20)
Current velocity (cm/s)	< 4 (optimum)
Hardness, total (mg/L as $CaCO_3$)	100–300
Hydrogen sulfide (mg/L)	< 0.001
Nitrite (mg/L NO_2-N)	< 80 (recommend < 19)
Nitrate (mg/L NO_3-N)	< 126
Oxygen, dissolved (mg/L)	6–15
pH	6.5–8.5
Salinity (g/L)	< 2
Solids, suspended (mg/L)	5–25 (optimum)
Solids, total dissolved (mg/L)	100–350
Temperature °F (°C)	73–86 (22.8–30) (optimum for fry growth)

Zooplankton management

Bass fry begin feeding at 0.3 inch (7 mm) TL with a preference for small cladocerans (water fleas) and copepod nauplii (crustacean larvae) initially and then shifting to larger copepod adults, cladocerans, and insect larvae by 0.5 to 0.75 inches (13 to 19 mm). Rotifers are not directly important food items for largemouth bass fry but are necessary for producing and maintaining copepod and cladoceran populations. Zooplankton populations of more than 380 zooplankton per gallon (100/L) of suitable size are optimal.

Sample the production ponds periodically throughout the culture period to evaluate zooplankton quantity. Take zooplankton samples in the mornings, preferably before or at sunrise. Collect initial samples 1 to 2 days before stocking. Then sample at least once weekly. Standardize the zooplankton samples so that volume can be estimated to calculate density after counting. Concentrate the samples and determine the densities of the major zooplankton groups (cladocerans, copepod nauplii, copepod adults, and rotifers) microscopically.

Feed training

Training success can be related to many variables, including initial fish size and condition, the acceptability of the training diet, the suitability of the training system, and the genetic potential of the strain. The most important factor in successful feed training is the size of the fingerlings. Most producers feed train largemouth bass fingerlings at 1 to 2 inches (25 to 50 mm), with 1.5 to 2 inches (38 to 50 mm) being consistently more successful.

Bass generally strike at pellets on the surface or as they slowly sink and do not readily eat pellets off the tank bottom. Initially, bass ingest and reject pellets many times before they consume them. Floating or slow-sinking pellets that remain accessible for an extended period may increase the success of feed training.

Largemouth bass do not tolerate high levels of carbohydrate in their diet, which produce "pale liver syndrome" and have been implicated in poor resistance to stress and disease, resulting in increased mortality. Diets recommended for largemouth bass are high in protein (45 to 62 percent) and fat (15 to 18 percent) and low in carbohydrate (less than 20 percent). The appropriate feed size for feed training largemouth bass fingerlings is 3⁄64 to 1⁄16 inch (1.2 to 1.5 mm).

Some producers use a training diet (such as Otohime EP2) initially and gradually replace the training diet with a commercial diet. To increase success, wet the commercial diet for a few minutes before feeding to soften the pellets. When feed training, feed largemouth bass by hand every 2 hours throughout the day. The feed-training process generally takes 6 to 10 days.

Successful feed training starts with the correct stocking density. Stocking training tanks at high densities elevates competition, which ultimately stimulates the bass to take the prepared diet. Stock fingerling bass in tanks at densities of 0.8 to 1.1 ounce per gallon (5 to 8 g/L). Initial stocking densities for various size tanks are listed in Table 4. Water temperature also affects feed-training success. Optimal temperatures are 72 to 78°F (22 to 26°C).

Table 4. Initial stocking densities recommended to maximize feed training success in various tank volumes. Values assume bass size = 1,000 fingerlings per pound (2,200/kg).

	Recommended stocking density based on oz (g) fish/gal rearing volume		Recommended stocking based on number of fish/tank	
Tank size, gallons (L)	Total weight in pounds (kg) at 0.8 oz (22.7 g) fish/gal	Total weight in pounds (kg) at 1.1 oz (31.2 g) fish/gal	No. fish @ 0.8 oz/gal and (kg/gal)	No. fish @ 1.1 oz/gal and (kg/gal)
1,300 (4,921)	65 (29.6)	89.4 (40.6)	65,000	89,375
1,100 (4,164)	55 (25.0)	75.6 (34.3)	55,000	75,625
975 (3,690)	48.75 (22.1)	67.1 (30.4)	48,750	67,063
650 (2,460)	32.5 (14.8)	44.7 (20.3)	32,500	44,688
502 (1,900)	25.13 (11.4)	34.5 (15.7)	25,125	34,563
325 (1,230)	16.25 (7.4)	22.4 (10.2)	16,250	22,375

Bass not transitioning to artificial feed will weaken and aggregate to the surface and sides of the tank, eventually clogging the outlet screens. Manually remove these fish, as they can spread bacterial diseases such as *Flavobacterium columnare.*

Feed training Florida bass

A modified approach has been developed for large-scale feed-training programs for Florida bass, which are more difficult to feed train. *Artemia* are often used to help bass feeding on microscopic invertebrates transition to artificial diets. Feed Florida bass 24 hours a day and remove uneaten feed regularly to ensure that the water quality remains adequate.

Fingerlings are fed a starter feed such as Otohime C-1, 1⁄64 inch (0.4 mm), for the first 48 hours. By the third or fourth day, mix a 3⁄64 inch (1.2 mm) commercial diet with the starter feed. Start with a mixture of 75 percent starter diet and 25 percent commercial diet, slowly decreasing the amount of starter and increasing the amount of commercial diet until the feed is 100 percent commercial diet.

The ratio of feeds and duration used depends on the initial fish size and, to a lesser degree, water temperature. Larger fish (less than 1,000 per pound (2,200/kg)) need 4 to 6 days to feed train; smaller bass (more than 1,000 per pound (2,200/kg)) need to stay on the starter feed for 7 to 10 days. Water temperatures below 68°F (20°C) will extend these intervals. Hand-feed the fingerlings every 30 minutes around the clock for the first 2 days or until all fish are actively feeding.

First-year growth

After the fingerlings are trained to accept a prepared diet, size-grade them and separate the feeders from the cannibals and non-feeders. Traditionally, uniformly sized bass are then stocked back into ponds at first-year grow-out densities of 8,000 to 20,000 fingerlings per acre (19,800 to 49,500/ha), depending on the intended use and desired size at harvest.

Another option is to stock trained fish at 100,000 to 150,000 fingerlings per 13,000 gallon (49,205 L) raceway for pellet rearing to 4 to 5 inches (100 to 127 mm). Concentrating feed-trained fingerlings indoors in raceways ensures that the fingerlings remain on feed and provides the producer with better disease-control options, such as treatments of hydrogen peroxide (50 mg/L), formalin (25 mg/L), and/or salt (5 ppt). Raising bass in raceways requires a large supply of water to maintain suitable water quality by flow-through.

A third approach is to raise bass fingerlings indoors in recirculating aquaculture systems (RAS), which remove waste biologically and mechanically. Although pond-based production of advanced fingerlings is the most common method of production, a small number of commercial producers have been successful in raising advanced fingerling largemouth bass to 6 to 8 inches (150 to 203 mm) in RAS at production densities of up to ¾ pound per gallon (340 g/L).

Fish spawned in the spring, feed trained in tanks, and then cultured in ponds should reach 6 to 10 inches (150 to 254 mm) by the fall of the first year. Fish that do not reach a minimum size of 8 inches (203 mm) should be marketed for sportfish stocking at this stage, as they likely will not reach the minimum foodfish size (1.25 pounds (0.57 kg) or more) after the second growing season.

Lower stocking densities produce more predictable outcomes with less incidence of water-quality problems and disease outbreaks. Foodfish producers typically stock first-year ponds at 8,000 to 12,000 fish per acre (19,800 to 29,700/ha) to maximize individual weight gain.

Summary

Meeting the challenges of intensifying largemouth bass culture will require further research into all facets of existing culture techniques for the species. Much can be learned by reviewing the techniques highlighted in this article; however, incorporating and applying these methods will depend largely on the level of hatchery design and infrastructure development. Aquaculture facilities with good water supplies, large raceways, many troughs and tanks, and control over environmental conditions have distinct advantages to intensify production.

Managing natural food production and pond fertility will always be a significant aspect and challenge of production, because fry do not readily take to artificial diets. Currently, the highest level of intensification consists of spawning broodfish in raceways, harvesting eggs and hatching them in troughs, stocking ponds with fry for fingerling production into lined ponds, and then transitioning fingerlings to commercial diets for grow-out to market or stocking size. Aquaculturists should realize that each of these steps poses challenges and opportunities for optimization. Timing and understanding the environmental conditions and variability unique to each hatchery are crucial to developing a successful program.

Suggested readings

Matthews, M.D., and R.B. Stout. 2013. Out-of-season spawning method for Florida largemouth bass to produce advanced-sized fingerling by early spring. North American Journal of Aquaculture 75:524-531.

Tidwell, J.H., S.D. Coyle, and L.A. Bright. 2019. Largemouth Bass Aquaculture. Sheffield, UK: 5m publishing.

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