Guidelines for the Culture of Black Bass

by
Hugh Glenewinkel, Aaron Barkoh, Todd Engeling, Lee Hall, John Paret, and Tony Owens

Management Data Series
No. 267
2011

TEXAS PARKS & WILDLIFE

INLAND FISHERIES DIVISION
4200 Smith School Road
Austin, Texas 78744

GUIDELINES FOR THE CULTURE OF BLACK BASS

by

Hugh Glenewinkel, Aaron Barkoh, Todd Engeling, Lee Hall, John Paret, and Tony Owens

Management Data Series
No. 267
2011

Texas Parks and Wildlife Department
Inland Fisheries Division
4200 Smith School Road
Austin, Texas 78744

CONTENTS

ACKNOWLEDGMENTS

This document is based largely upon earlier work published by Pat L. Hutson in 1990. Since that time, many Texas Parks and Wildlife Department fish culturists have researched and implemented new culture techniques at facilities across the state to make production techniques more efficient while increasing outputs. These new techniques are incorporated into the present version of the culture guidelines. We thank all those who contributed information for this document, especially Carl Kittel.

INTRODUCTION

Black Bass Program Overview

Black bass (*Micropterus* spp.) consist of eight species, though most bass fishermen are most familiar with largemouth bass (LMB) and smallmouth bass (SMB; *Micropterus dolomieui*). The LMB consists of the northern species (NLMB; *Micropterus salmoides*) and the Florida subspecies (FLMB; *Micropterus salmoides floridanus*). These black bass (LMB and SMB) are regarded as excellent and popular sport fish in the United States (USA; TPWD 1995). In Texas, 57% of anglers prefer to fish for LMB (TPWD 1995). Many of the species of black bass are indigenous to the eastern half of the USA and southernmost Canada and have been introduced successfully throughout North America. Texas Parks and Wildlife Department (TPWD) has produced and stocked NLMB into public waters since the late 1920s. Production of FLMB and SMB began in 1971 and 1974, respectively. To date, more than 200 million of these black bass have been stocked into Texas waters. Recently, Guadalupe bass (GLB; *Micropterus treculi*) has become a species of concern for TPWD due to hybridization with SMB in much of its native range. Thus, a stocking program has been implemented to attempt to reverse the effects of hybridization or to establish sanctuaries where the species can be preserved.

Currently, most TPWD black bass stocking programs use 38-mm total length (TL) fingerlings to establish initial year classes in new or renovated reservoirs, supplement year-class strength in waters with limited natural recruitment, or alter and improve the genetics of existing populations. For example, FLMB which has the genetic potential to grow larger than NLMB has been stocked into many Texas reservoirs to develop or enhance trophy fisheries. This manual describes current techniques for producing and distributing black bass in Texas. It provides general culture guidelines as well as specific stocking criteria and procedures used at each production hatchery. Each hatchery has unique challenges in the rearing of black bass fingerlings and should periodically evaluate and refine culture methods to improve production efficiency.

Stocking Goals

The goal for producing and stocking LMB and SMB is to enhance, restore, and maintain Texas fisheries and thereby provide quality recreational bass fishing in Texas (TPWD 1990). While this goal is the same for both species, the objectives differ.

The objectives for stocking LMB are to:

- Establish locations which maximize catch of trophy bass.
- Supplement natural recruitment.
- Maximize catch rates (number/h) of quality size (>35.6 cm or 14 in) fish.
- Maximize occurrence or genetic influence of FLMB in areas where they are best suited for survival and growth.
- Restore or maintain NLMB in systems where they have been lost or reduced in numbers due to natural or man-made causes.
- Establish locations where genetically pure populations of NLMB are maintained.

The objectives for stocking SMB are to:

- Supplement natural recruitment.

- Maximize catch rates (number/h) of quality size (>35.6 cm or 14 in) fish.
- Maximize occurrence of self-sustaining populations in areas where they are best suited for survival and growth.

The goal for producing and stocking GLB is to preserve species integrity and maximize quality recreational fishing in Texas (TPWD 1990).

The objectives for stocking GLB are to:

- Establish state sanctuaries to ensure species preservation.
- Reestablish a dominant population in their natural habitat.

Hatchery Production Goal

The goal of the hatchery black bass program is to produce quality fingerlings for stocking into selected Texas reservoirs. The annual stocking request for black bass typically exceeds the hatchery production capacity. Since 2001, the request for all fingerling black bass species has increased from 9.5 to 17.6 million in 2011, while hatchery production increased from 6.6 to 10.8 million during the same period. These requests included 805,000 SMB; 175,000 GLB; 138,000 NLMB; and 16,500,000 FLMB fingerlings in 2011.

Currently, LMB are produced at the A. E. Wood Fish Hatchery (AEW) in San Marcos, Jasper State Fish Hatchery (JFH) in Jasper, and Texas Freshwater Fisheries Center (TFFC) in Athens. Smallmouth bass are produced at the Possum Kingdom State Fish Hatchery (PKH) near Graford, whereas GLB are cultured at Heart of the Hills Fisheries Science Center (HOH) and AEW. Current black bass broodfish inventories and spawning strategies and fingerling production outputs are provided in Tables 1 and 2, respectively.

General Production Issues and Techniques

Though hatchery production of black bass of any size is possible, the cost of production dramatically increases while fish production decreases as the size of fish produced increases. The traditional culture methods for production of black bass were first described by Snow (1964), and modifications used in Texas black bass production programs were first documented by White (1981). In recent years, new technologies have led to refinements of culture methods and improvements in black bass fingerling production. Hatchery production of black bass involves three main culture methods: 1) spawn-and-rear, 2) egg or fry transfer, and 3) intensive culture.

Spawn-and-rear.—This is the oldest and simplest approach to black bass culture. Broodfish are placed into spawning ponds and allowed to pair-up and spawn freely. Stocking densities are 25-100 broodfish/ha (White 1981), and suitable spawning nests or substrates may be placed in ponds to enhance spawning. Broodfish are left in ponds until the fingerlings reach a size large enough for harvest and distribution, generally 30-45 d after broodfish are stocked into ponds (Hutson 1990). Due to cannibalism, use of this method to produce large numbers of fingerlings longer than 25 mm TL is ineffective. 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.

Egg transfer.—Ponds are prepared and stocked as described for the spawn-and-rear method. Spawning nests are checked regularly for spawns (eggs). Nests with spawns are transferred from spawning ponds into fertilized grow-out ponds where the eggs hatch and the fry are allowed to remain and grow to target size (Hutson 1983). The disadvantage of this method is that the number of fry in a pond, which may be too low or too high relative to the carrying capacity of the pond, is unknown. This makes proper management of the fish (e.g. feeding rates) almost impossible.

Fry transfer.—For this method, spawning ponds are prepared and stocked as described above for the spawn-and-rear method, but the swim-up fry are transferred from spawning ponds into prepared rearing ponds for grow-out. The free-swimming schools of fry are collected by dipnetting, seining, trapping, or pond draining (Snow 1975; White 1981; Hutson 1990). Fry stocking densities are 125,000-500,000 fry/ha for the production of 38-50-mm TL fingerlings. Grow-out ponds are fertilized according to standard fertilization practices. In well-managed ponds, growth rates of 1.0-1.5 mm/d and target length of 38 mm TL can be achieved in 30-45 d after fry stocking (Hutson 1983; 1990). This method has several advantages over the spawn-and-rear method. For example, fry stocking density can be tailored for specific culture programs or production goals, such as a target fingerling size (White 1981). Further, ponds can be stocked with fry of similar size and age to minimize cannibalism which can significantly reduce fish yield (number/ha).

Intensive culture.—The intensive culture method, as described by Snow (1973, 1975), was developed to correct the inconsistent production results associated with the spawn-and-rear, egg transfer, and fry transfer methods. Broodfish are spawned in ponds or raceways, and the eggs are collected and incubated under controlled conditions in either vertical-tray incubators (Snow 1973) or hatching jars (Sarti 1986). Broodfish stocking densities in ponds are similar to those of the other pond spawning systems, while the densities in raceways can vary by species and facility. Swim-up fry are either stocked into prepared rearing ponds for grow-out or cultured in troughs or tanks on a combination of natural and artificial foods (Snow 1969). Pond-reared fry are generally harvested at 25-50 mm TL or trained to accept artificial diet and reared to advanced sizes either in ponds (Snow 1969) or raceways (Nelson et al. 1974).

Current TPWD Production Method.—Currently, TPWD hatcheries mainly use the intensive culture method for the production of fingerling bass. Broodfish are allowed to spawn in raceways, eggs are collected and incubated in troughs, and fry are harvested and stocked into prepared rearing ponds for grow-out. Ponds are harvested when fingerlings reach 38 mm TL. Average growth rate in production ponds at AEW, TFFC, and JFH is approximately 1.1 mm/d.

CHAPTER 1

Broodfish Management

Broodfish Maintenance

An important aspect of black bass propagation is the care and maintenance of captive broodfish. Fingerling production is often limited by the number of quality fry stocked. Thus, production of sufficient quantities of quality fry is essential to program success. Broodfish in poor condition produce fewer or poor quality eggs and subsequently fewer quality fry. Therefore, the best possible conditions should be provided to maintain quality broodfish. Proactive management to control diseases, maintain optimal water quality, and provide feed of appropriate quality and quantity is necessary for successful broodfish culture (Piper et al. 1982).

Broodfish Holding Ponds

Florida largemouth bass broodfish are susceptible to rapid drops in temperature. Thus, holding ponds should be as deep as possible to prevent exposure of the fish to wide swings in temperature (Chew 1974). The ponds should be free of aquatic vegetation that can provide cover for forage (Burkhalter 1967) and limit broodfish feeding. If earthen ponds are used, bottoms should be disked, allowed to dry, and packed before filling with water. Also, pond bottoms should be sprayed with an approved herbicide to control weeds before filling with water. For plastic-lined ponds, excess feed or debris (sediments) on pond bottoms should be removed, by sweeping or spray washing, before filling with water.

Broodfish should be stocked at 200-350 kg/ha (Hutson 1990). If pond space allows, broodfish should be separated into ponds by year class and gender. This allows the allocation of forage to gender-specific ponds based on broodfish needs, prevents unexpected spawning, and minimizes handling during harvest and pairing of broodfish.

Smallmouth bass are more sensitive to warmwater conditions and can be stressed if water temperatures exceed 30°C. Pond water temperatures may be kept below this threshold level by flushing ponds with cooler fresh water during summer. All black bass broodfish are also very sensitive to golden alga (*Prymnesium parvum*) toxins. At PKH, ponds are monitored at least 3 times weekly for the presence of the alga. If detected, monitoring is intensified and ponds are treated with copper sulfate or ammonium sulfate to control the alga and prevent fish kill (Barkoh et al. 2010).

Feeding

Proper broodfish maintenance requires that these fish are offered adequate food of the right size at the appropriate time. It is suggested that a 1 kg gain in bass weight requires about 5.1 kg of forage consumption (Piper et al. 1982). The mouth gape of the different species or sizes of broodfish must be considered in the selection of the species and size of forage. Broodfish are fed koi carp (*Cyprinus carpio*), fathead minnows (*Primephales promelas*), shad (*Dorosoma* spp.), or other appropriate forage. Koi carp is preferred for adult broodfish because large quantities (numbers or weight) can be produced in an efficient manner, although fathead minnows have also been used for younger year classes of broodfish. Younger broodfish are fed at higher rates to enhance overall growth whereas older broodfish are fed to gain weight by approximately 50%

from their post-spawn weight to the next pre-spawn weight. Largemouth bass broodfish are fed at the feeding rates suggested in Table 3.

Smallmouth bass broodfish do not appear to feed as vigorously at warmwater temperatures compared to cool-water temperatures. Thus, allocation of forage should be matched with fish feeding behavior; more feed may be provided to the fish in the fall than in the summer.

The monthly quantities of feed for bass broodfish are provided in Table 4. During warm winter months, it is preferable to intermittently offer to the fish small amounts of the feed (i.e., offer some of the feed to fish and wait until most of it is consumed before offering more feed). This approach minimizes waste of feed. Ponds should be patrolled to assess forage consumption (i.e., the quantity of forage remaining) and to discourage bird predation on broodfish.

The bass feeding regimens in Tables 3 and 4 should serve as guides. Culturists should assess the feeding behavior of broodfish and provide feed as needed since feeding is related to water temperature and fish health. The broodfish feeding program should be monitored to ensure that it adequately sustains the fish to be in good condition prior to spawning. Feeding broodfish slightly in excess of the suggested amount of feed is preferable to under feeding the fish. Pelleted feeds have been used to feed SMB broodfish, but this practice is not considered a better alternative to feeding with live forage.

Fish Health

The health of captive broodfish has become an increasing concern at TPWD hatcheries. With the discovery of Largemouth Bass Virus (LMBV) and golden alga in many Texas reservoirs, implementation and enforcement of a Hazard Analysis and Critical Control Point (HACCP) plan has become a priority. Each facility has implemented a plan to reduce the possibility of spreading potential diseases and contaminants to other hatcheries or stocking sites and to reduce the possibility of receiving contaminants and disease agents from outside sources. A typical HACCP plan is provided in Appendix A. All hatcheries should monitor broodfish holding ponds daily for sick or dying fish and removed these fish from ponds immediately. If fish are in poor health, specimens should be sent to the Fish Health Lab at AEW for disease diagnosis and treatment recommendation. Appropriate management strategies should be implemented to ensure good health of broodfish since poor health often has adverse effect on fry production.

Factors that sustain good fish health include:

- Good water quality.
- Feed of adequate quality and quantity.
- No stress of fish.
- No overcrowding of fish.
- No diseases.

Water Quality

Good water quality must be maintained to ensure good fish health (Boyd 1979). Water quality variables should be monitored in each broodfish holding pond daily, preferably every morning and afternoon. Afternoon water quality monitoring is required when pond temperatures are above 15°C or if morning measurements indicate a potential water quality problem in the pond. Ponds should be flushed with fresh water to quickly correct poor water quality.

Characteristics of optimal water quality for bass broodfish holding ponds (Boyd and Lichtkoppler 1979) are:

- Total alkalinity < 300 mg/L.
- Total ammonia nitrogen < 0.3 mg/L.
- Dissolved oxygen > 4 mg/L.
- Total hardness < 300 mg/L.
- pH 6.5-8.0.
- Temperature < 32°C for LMB and < 30°C for SMB.

Handling

Broodfish handling should be kept to a minimum. If broodfish must be handled, water temperatures should be 15-26°C (Hutson 1990). Broodfish should be handled with soft-mesh nets and exposure to air, especially in windy conditions, should be minimized by quickly returning the fish into water. Nets should not be overloaded, especially with large broodfish, so that body weight does not cause injury to some fish. All broodfish should be dipped in 3% salt solution for 15-30 s after handling. If fish are to be weighed and salt-dipped, salt dipping should be performed before weighing. The salt acts as an anesthetic and may reduce fish movement to allow faster, more accurate weighing.

Suitable water quality conditions should be maintained in fish holding containers and transfer tanks. Transfer tanks should contain salt concentrations of 0.25-0.50%. Temperatures of holding-container water and the receiving water should be measured. Tempering of fish is necessary if a difference of more than 3°C exists between waters (Piper et al. 1982). Broodfish should be tempered for 20 min when moved to a different water source even if there is less than a 3°C temperature difference to allow the fish to adjust to other potential differences in water quality variables, such as pH.

Replacement and Acquisition

Replacement broodfish are reared on the hatchery or collected from the wild. The number needed each year depends on production goals. Broodfish are put in production at age 2 years old and retired at age 7-8 years old, if sufficient replacement fish are available. The need for broodfish may vary among hatcheries. Hatcheries that use raceway spawning typically need fewer broodfish than those using pond-spawning techniques. This is because the raceway spawning method results in the production of larger numbers of fry per female. Most hatcheries maintain three year-classes of broodfish and may also maintain a future-year broodfish. For raceway spawning, 100-140 pairs of fish of each year class may be maintained. This allows the use of 5-7 raceways for spawning the same year-class fish. For pond spawning, 200 pairs/year class may be maintained. Year classes may be combined or retired if sufficient replacement fish are available.

Replacement FLMB broodfish are routinely reared at AEW. The taxonomic status of each fish used to produce replacement broodfish is resolved with analyses of several microsatellite loci (Lutz-Carrillo et al. 2006). These fish should have passive integrated transponder (PIT) tags with unique numbers inserted into them for positive identification throughout their production years at a hatchery. Every few years, broodfish on hatcheries are replenished with fish from Lake Kissemmee and St. Johns River in Florida.

Replacement NLMB broodfish are usually collected by electrofishing from reservoirs never stocked with FLMB. Lakes Kickapoo, Fryer, and Scarborough have been reliable sources of pure NLMB. Lakes Cuero, Marvin, Muenster, Twin Oaks, and Alabama also have been sources of broodfish. The taxonomic status of each fish is resolved using microsatellite loci analysis and PIT-tagged for identification.

Smallmouth bass broodfish have been collected from SMB-dominated streams such as the Devil's River, reared from existing hatchery stocks, or acquired from the state of Colorado. Guadalupe bass broodfish have been collected from various water bodies and reared at HOH. The taxonomic status of each of these fish is resolved by microsatellite loci analysis.

Genetic Integrity Verification

To ensure strain integrity, a subsample of fingerlings from each year class of FLMB (or other black bass) used in production are genetically examined for quality control. Each hatchery submits 30 fingerlings from each cycle of rearing ponds to the Fish Health Lab at AEW for genetic analysis. Data submitted with these fish must identify the year class of the parents and the pond from which the fingerlings were produced so that any genetic anomalies can be traced back to the producing broodfish.

Genetics Plan.—In 1996, a breeding program was implemented to ensure adequate genetic diversity in FLMB broodfish and to prevent inbreeding (Fries et al. 1996). The breeding program requires maintaining a minimum of 180 certified broodfish (90 males and 90 females) for the production of future broodfish. New broodfish are added to the production stock every other year, if possible, depending on the needs of each hatchery.

To produce a future broodfish year class, fish of the parental year class are divided into two sets of raceways (Groups A and B). Each group of 6 raceways uses 120 pairs of broodfish (i.e., 20 pairs/raceway) for production. This should allow each group of raceways to produce an adequate number of spawns 1-3 d apart that can be incubated together in a single trough. As many spawns as possible should be collected to maximize the genetic contributions from as many parental fish as possible. Spawns from Groups A and B raceways are incubated in separate troughs, and the resulting fry are reared in separate ponds. The swim-up fry are stocked into fertilized rearing ponds at rates of up to 500,000/ha. These fish are harvested when they reach 38 mm TL. These fingerlings are restocked into rearing ponds at 12,500 fish/ha. Fingerlings are fed koi fry initially, and the size of the forage fish is increased as the bass fingerlings grow. Fathead minnows also may be used as forage. Because of their small adult size, fathead minnows can be stocked into rearing ponds several weeks before stocking bass fingerlings.

At one year of age, the fish are harvested by draining the ponds completely and dipnetting the fish. The fish are inventoried, and 600 fish from each group are retained for the program. These fish, still separated by group, are stocked into a new set of 0.4-ha rearing ponds for further growth. These fish receive 15 kg of 50-75-mm TL forage for each kilogram of bass stocked. Fathead minnows are an ideal food item for fish of this age group.

At age two, the fish are harvested, inventoried, sexed, and distributed as follows: Group A females and Group B males go to one hatchery, and Group A males and Group B females go to another hatchery. The goal is to supply each hatchery with 225 males and 225 females of future broodfish. This number should allow a 15% attrition rate each year and still leave 90 pairs of broodfish by age 8. The supply of future broodfish is rotated among hatcheries as outlined in Table 5.

Genetic diversity in NLMB or SMB broodfish has not been an issue since wild fish are routinely collected from several different sites to replace broodfish in the program. If in the future these broodfish are propagated at the hatcheries, then a plan similar to the FLMB genetics plan described herein would be implemented.

CHAPTER 2

Fry Production

Broodfish Selection

Broodfish are selected for spawning in mid-March when water temperatures are consistently above 15°C. Broodfish are easily sexed in early spring prior to spawning. In spawning condition females are easily distinguishable from males or unripe females by examining them side-by-side belly up (Figure 1). Ripe females exhibit distended, soft, pendulous ovarian region, and a swollen, red, protruding vent (Figure 2). Ripe males release milt when palpated (Parker 1971). To palpate fish, turn the fish belly up and slowly but firmly apply pressure along the sides or middle of the abdominal region (Figure 3). Males in spawning condition should express milt when palpated. For spawning, use only males that freely express milt when palpated.

Fry Production Methods

Strip spawning has been used for triploid FLMB fry production in the past, but current methods for diploid black bass fry production are raceway and pond spawning. Compared to pond spawning, raceway spawning has several advantages: (1) provides control over time of spawning, (2) allows egg incubation under controlled conditions including treatment of eggs with approved chemicals to control fungus infections, and (3) allows breeding plans to be implemented to maximize broodfish participation in spawning or contribution to each progeny. In addition, the number of fry produced per kg of female is much higher for raceway than pond spawning. For example, LMB fry production averages 11,000 fry/kg of female for raceway spawning and 4,000 fry/kg of female for pond spawning. Fry produced by raceway spawning are more uniform in size which reduces cannibalism during fry rearing to produce fingerlings.

Raceway spawning of SMB has provided highly variable fry production results partly because of the quality of broodfish used in the last few years. Smallmouth bass production averages 2,200 fry/kg of female. Development of procedures for raceway spawning of GLB began at the AEW in 2009. Generally for black bass, the number of fry produced per kg of female can vary depending on the species, quality of broodfish, and success of egg incubation.

Broodfish Harvest and Acclimation for Raceway Spawning

Broodfish should undergo 2-4-week acclimation to raceway conditions prior to spawning. Fish for the first spawning cycle are transferred from holding ponds into indoor raceways in mid-February, depending on weather conditions. Pond water temperatures should be above 15°C before broodfish are harvested from holding ponds. Fish harvest from holding ponds should be scheduled for afternoons when the weather is warm. Handling of broodfish on cool windy days or when temperatures are expected to drop over the next few days can make the fish susceptible to fungal infections.

Broodfish holding ponds should be drained for fish harvest over a period of a few days. This allows harvest operations to be postponed in case of unexpected adverse weather conditions. During harvest, fish exposure to air should be minimized. Typically, 3-4 broodfish are harvested and carried in a net at a time, but this number may vary depending on the size of broodfish. Dipnets should not be overloaded with fish, especially gravid females. Water quality in pond kettles and fish transport units should be monitored throughout the harvest. Broodfish should be transported in water of 0.25-1.0% salt.

Fish are weighed as they are harvested from ponds or during transfer from a transport unit. If broodfish are moved into a raceway, weigh the fish after unloading into raceway. This reduces exposure of the fish to wind, handling stress, and the risk of fungal infections. To weigh broodfish, 2-4 fish are placed into a net, depending on fish size, and dipped in 3% salt solution for 15-30 s. The fish are then quickly weighed on a tarred balance and placed into an acclimation raceway. During the acclimation period the fish should be separated by sex. If broodfish are not separated by sex prior to overwintering in ponds, they can be sexed during harvest from ponds and placed into separate hauling units or sexed during transfer from transport unit into acclimation raceways.

In acclimation raceways water flow rates are 378-568 L/min (0.5-0.7 exchanges/h) and water levels are maintained to allow some freeboard along the raceway walls. If fish can jump out of raceways, barriers should be used to prevent fish escapement. Barriers should extend at least 60 cm above the top of the raceway. During initial acclimation, broodfish may be easily startled by sudden noises or bright lights. These fish should be monitored closely to determine how they react to normal activities around raceways. If raceway lights turn on automatically, staff should be ready to respond quickly to fish that jump out of raceways. If lights are turned on manually, this should be done slowly to prevent sudden influx of light. Two labeled tubs, each with 3% salt solution, and nets should be strategically placed in the raceway area so that fish can be picked up and quickly salt dipped and returned to the holding raceway, if necessary.

The photoperiod should be increased during the acclimation period. The natural photoperiod on February 15th is approximately 11 h from sunrise to sunset. Illumination should begin with a 12-h photoperiod and increase by 30-min weekly intervals for 4-week. This extends the photoperiod to 14 h by the time spawning begins.

Raceway Spawning Procedures

Spawning of FLMB and NLMB in raceways usually begins on March 15th. By this time the broodfish are acclimated to raceway conditions and water temperatures should reach the preferred minimum spawning temperature of 15°C. Currently, broodfish spawning ends by June 1st, but the exact date depends on the performance of the broodfish and the number of fry needed to meet the fingerling production goal. Smallmouth bass appear to initiate spawning in raceways at a minimum water temperature of about 18°C.

When acclimation of broodfish to raceway condition is complete, spawning raceways are prepared for receive broodfish for spawning. These raceways are filled with water, and water flows are maintained at about 284-322 L/min (0.25-0.35 exchanges/h). Water in each acclimation raceway is drained to about one-half of raceway volume, and the fish are gently crowded at one end of the raceway. These fish should not be overcrowded and must be watched carefully since they can jump out of raceways. After crowding, the fish are collected in dipnets and sexed as described previously. Males are placed in one weighing basket and females in another. Up to 4 fish may be placed in each basket depending on size. These fish are salt-dipped in 3% salt solution for 15-30 s, quickly weighed, and stocked into a spawning raceway. If a receiving raceway is located far from the acclimation raceway, the fish should be transported in a hauling unit to the spawning raceway. Then the fish are netted from the hauling unit, salt dipped, and stocked into the spawning raceway. Typically, 20 pairs of broodfish are placed into each raceway, although successful spawning has been achieved by using up to 30 pairs in a raceway when broodfish are smaller. When stocking is complete, spawning substrates are placed in raceways. In a 24-m long raceway, 20 Spawn-Tex® mats (~60 × 45 cm) are placed on the floor along either side of the raceway (10 mats per side) approximately equidistant apart (Figure 4). If male territorial behavior appears to disrupt spawning, spawning mats can be isolate by partitioning (J. Mathews, Texas Freshwater Fisheries Center, Athens, TX, personal communication). Fish in poor condition or that are diseased should be culled.

Broodfish stocked into spawning raceways initially school together and swim back and forth the length of the raceway. After two days of this behavior, males begin to guard spawning mats. After staking out a spawning mat, the male becomes somewhat territorial. Spawning starts 7-10 d after broodfish pairing. When a female lays eggs on a spawning mat, the guarding male fertilizes them. After spawning is completed, the male continues to guard the nest. While spawning can occur at any time of the day, raceways normally are checked for spawns at 7 a.m. each morning. Maintaining clear water and using a flashlight help to locate spawns. If water is stained or murky, it may be necessary to gently lift up each mat to examine it for eggs. Fish behavior can also indicate the presence of a spawn. If a fish does not readily abandon a nest being examined for eggs, a spawn is likely present. After spawns are located, the total number and locations are documented to facilitate their retrieval later in the day (Isaac 1998). Spawns are collected once daily in the morning to avoid cannibalism. Cannibalism has not been observed in SMB so spawns are retrieved from raceways 1 d after they are first observed.

Spawns are collected as early in the morning as possible, so subsequent spawning activities can resume quickly, using one of two methods:

1. Spawns are collected using a pitchfork, shallow tub (66 cm L × 53 cm W × 16 cm D), and utility vehicle. One person gently inserts a pitchfork under the spawning mat to slowly raise it through the water column and another person sinks the tub underneath the mat to receive it. Then both people raise the tub to the water surface. Excess water is gently poured out of the tub carefully to prevent loss of eggs along with the excess water. Adequate water remains in the tub to completely cover the eggs. The tub is placed on a utility vehicle. A fine-mesh net is used to sweep the area where the mat was to recover any loose eggs. These loose eggs are placed on the mat in the tub. Stackable tubs (Lewisystems®, Model SN 3022-6; LEWISBins+, Oconomowoc, WI) that allow several spawns to be transported at the same time to incubation troughs is recommended for efficiency.
2. Spawns are collected by lifting each mat completely out of the raceway and quickly placing it under water in a tub placed outside the raceway.

After collection of all spawns from each raceway, their locations are swept with a fine-bristled broom to remove any loose eggs or silt. Care is taken to not disturb or negatively affect adjacent spawning mats. Clean mats are deployed to replace the retrieved mats. Each replacement mat is sunk by gently pushing it down with a broom until trapped air is released.

Incubation Procedures for Raceway Spawns

Trough incubation and fry harvest:—Spawns should not remain in the tubs for more than 15 min before transfer into incubation troughs. Currently, fiberglass troughs (~ 90 cm W × 60 cm D × 450 cm L) are used for spawn incubation. Each trough is filled with water to a depth of about 50 cm. The water is screened through saran socks (500 micron) to exclude unwanted organisms. The stand pipe in each trough is provided with a saran-screen guard at the open end to prevent fry escapement and an air ring at the base to help prevent clogging of the screen guard. The trough divider screen is covered with saran to further prevent fry escapement. Low-pressure air is bubbled through an air line placed in front of the screened trough divider to help prevent clogging. All screens should be closely watched and cleaned by brushing to prevent clogging and breaking during egg incubation.

An airline is placed along the length of each trough and supplied with low-pressure air to keep the water moving gently. A wire is stretched along the length of the trough and supported with pipes placed as needed to prevent sagging. Spawning mats with eggs are suspended from the wire with hooks. Mats are suspended at an angle to allow fry to fall away from the mat after egg hatch. Each trough can hold 20-24 spawning mats without overcrowding the resulting fry. If there are not enough mats to completely fill a trough from one day's number of spawns, spawns from up to 3-d old apart can be incubated together in the same trough. Spawns can be treated with an approved chemical to control fungus infections. Efficacy of treatment must be considered and manufacturer's instructions must be followed in all disease treatments.

Typically, the eggs hatch in 2-4 d after spawning, and the fry are ready for harvest in 7-10 d after spawns are placed into incubation troughs, depending on water temperature. The progression of fry development can be observed in incubation troughs if the water is clear. At hatching, the fry appear as small golden globules along the sides of the troughs and edges of the mats. The color of the fry darkens over time. Mats are removed from troughs when the fry begin to swim freely. Mats should be examined to remove trapped fry during removal; this is especially important when different aged spawns are incubated together. Mats are gently rinsed several times to free trapped fry by dipping the mat in incubation water and allowing it to drain by lifting it above the water surface. This may be repeated several times to free all trapped fry. Avoid vigorous rinsing of mats to prevent injury to fry and avoid displacing diseased (fungus-infected) eggs and dirt trapped in the mats into incubation water. Accumulation of dead eggs and dirt in incubation water may cause water quality to deteriorate or hamper fry harvesting efforts. Mats are removed from each trough 1 d before fry harvest.

Prepare to harvest the fry by turning on the lights above the trough, turning off the low-pressure air supply, and removing the air delivery line along the length of the trough. The lights attract the fry to the surface of the water, and the reduced water turbulence allows the fry to swim easily. Fry that have not swum up may be very hard to see since they blend in with the fine silt on the bottom of the trough. Look for fry that may still be at the bottom of the trough. Allow all healthy fry to swim up before commencing harvest. When the fry have swum up, slowly and gently sweep the silt and trash from the front to the back of the trough bottom. This must be done very slowly with a fine-bristled broom as wide as the trough so that no sediment is kicked up into the water column or left behind. After sweeping the trough bottom, slowly drained down the water to about one-half the volume. A saran-crowding net is used to slowly crowd the fry from the back to the front of the trough. Once the fry are crowded, the harvest operation must begin immediately. Maintain the screens to make sure they do not clog up and break.

A scale that is accurate to one-tenth of a gram is recommended for weighing the fry at harvest. A small plastic container is partially filled with water and tarred on the scale. The fry are collected using a fine-mesh fry aquarium net (25 × 18 cm), excess water is allowed to drain from the net, and the fry are placed into the tarred container and weighed. Repeat this activity until all fry are weighed.

Fry are enumerated by using a standard weight index of 275 fry/g for FLMB or NLMB. Recent work with GLB and SMB indicates that this standard index may not be appropriate for these species. Using on-site data from a 3-year period, PKFH currently uses a SMB standard index of 100 fry/g. Alternatively, sub-samples of fry are weighed and counted to determine the average number of fry per gram for each group of SMB and GLB fry harvested. Then the total weight of fry is multiplied by the average number of fry per gram to obtain the total number of fry harvested.

Pond Spawning

Pond spawning of black bass is used at AEW when surplus broodfish are available and raceway space is limited. Pond spawning is routinely used at JFH and periodically at the other facilities. Recommended broodfish stocking rate is 140 kg females/ha. Males are stocked at the same number as females regardless of weight (Hutson 1990). The spawn-and-rear (advanced fry) or egg transfer method, described above, may be used.

Pond preparation and management:—Earthen ponds are allowed to dry and the bottoms are disked and packed. Bottoms and sides of ponds are sprayed with an approved herbicide to control unwanted vegetation. Plastic-lined ponds are cleaned of bottom sediments including removal of sediments from all drain boxes or kettles. Pond filling begins 1-7 d before broodfish are stocked. Incoming water is filtered through a saran-sock filter to prevent unwanted organisms from entering the pond. Ponds are fertilized to promote phytoplankton and zooplankton population growth while reducing the establishment of filamentous algae and rooted macrophytes. Initial fertilization rate targets are 0.5 mg N/L and 1.0 mg P/L. Follow-up applications of fertilizers may also be performed but usually at reduced rates compared to rates for fingerling production ponds. The main goal of fertilization is to keep ponds productive and zooplankton populations adequate for fish, without compromising water quality. In parts of east Texas where the waters are soft (e.g., total hardness < 20 mg/L), lime may be used to increase alkalinity and hardness of the water. If hydrated lime is used, it should be added when pond filling with water begins so that any spike in pH will return to a normal level before broodfish are stocked. Water quality variables should be maintained at levels suitable for broodfish holding ponds. Water temperature, pH, and DO should be measured twice a day (morning and afternoon).

Advanced fry production:—Advanced fry (15-20 mm TL) are produced in plastic-lined or earthen ponds. In plastic-lined ponds spawning substrate is provided. Shallow plastic pans filled with gravel or weighted artificial turf mats are used as substrate. Substrates are placed approximately 3 m apart at 1.0- to 1.5-m depths of water. The number of pans or mats placed in each pond equals the number of males.

Beginning 14 d after broodfish are stocked into ponds, pond edges are checked daily for schools of fry. Ponds are usually drained 30 d after broodfish stocking. Extreme care should be taken when draining ponds to ensure that fry do not become trapped in puddles as a pond drains or trapped against the drain screen. At facilities without modified Kansas kettles, broodfish are removed from the ponds by seining as the ponds drain. The fry can then either be seined as well or freshwater is added to the pond as it drains. Addition of fresh water attracts the fry into the kettle from where they can be dip-netted. At facilities with modified Kansas kettles, broodfish and fry are allowed to collect in the kettles. While in the kettle, a refuge is established for the fry by placing a fine-mesh screen to block the force of the incoming water. Some of the fry at or near the water surface may be harvested before crowding the rest. Normally, the broodfish stay in deeper water while the fry are in shallow water, allowing most of the fry to be harvested without exciting the broodfish. As the fry are harvested, they are weighed in a tarred bucket containing water and placed into a holding tank. When the majority of fry has been harvested, a sample is taken and 30 are randomly measured for TL. Fry may be enumerated by using a standard length-weight table (Piper et al. 1982). Usually, these fry are stocked into rearing ponds for additional growth.

Spawn removal:—This method provides more control over spawning and fry production than the advanced fry production method. However, it requires an additional incubation facility and rearing space. Spawning ponds are not fertilized because zooplankton production is not needed as the fry are not reared in these ponds. In addition, the increased turbidity resulting from increased phytoplankton biomass adversely affects the ability to locate and remove spawns quickly. Procedure steps are as follows:

- Place artificial spawning substrates (e.g., Astroturf or Spawn-Tex® mats), each provided with a float marker for location identification, approximately 3 m apart along the perimeter of each pond, preferably before pond filling. Substrates should be at 1.0-1.5-m depths of water when ponds are full. The number of mats should equal the number of males.
- Females are paired at 140 kg/ha. Males are stocked at the same number as females regardless of weight.
- Check spawning mats daily for spawns beginning 5-7 d after stocking broodfish.
- Retrieve mats with spawns, place (submerge) them in a tub of pond water, and deploy replacement (fresh) mats into ponds.
- Transport spawns to the incubation room ensuring all spawns are under water.
- Incubate spawns as described for raceway spawning.
- Spawning continues until the desired numbers of fry are produced.

Strip Spawning of Largemouth Bass

Strip spawning has been used in the production of triploid FLMB (Fries et al. 2002) and found to be extremely stressful to the fish. It is not recommended for routine fish propagation but for special circumstances such as research projects. It is more feasible at hatcheries that use raceways for spawning. Procedure steps are as follows:

- Spawning raceways are prepared as describe earlier.
- Broodfish are tagged with T-bar type tags with unique color combinations and paired into

raceways.

- Broodfish are watched from a vantage point.
- Broodfish pair in courtship or performing pre-spawning activities are identified by their color codes then captured by dipnetting.
- Broodfish pair is anesthetized in a solution of MS-222 before spawning.
- The female is strip-spawned by exerting firm pressure along the abdomen (from head end towards tail end) to allow the eggs to flow from the vent into a shallow pan containing about 1 L of water. Concurrently, milt from the male is stripped onto the eggs using a similar technique. Milt from each male is usually small and a pipette may be used to collect the milt from the vent and transferred into the eggs. The pipette should be rinsed in Hanks Balanced Salt Solution to delay the onset of sperm motility until the milt is mixed with the eggs. Thorough mixing of the gametes is accomplished by gentle stirring of the milt and eggs using a turkey feather for at least 2 min to effect fertilization.
- Fertilized eggs are transferred into McDonald hatching jars for incubation. Spent fish are salt-dipped in 3% salt solution, held in a recovery tank with 0.25% salt solution for several days, and then stocked into holding ponds.

ShareLunker Bass Spawning Procedures

The ShareLunker program is a special breeding program that uses fish that weigh more than 6 kg caught by anglers from the wild and donated to the program. In exchange for donating the fish, the angler receives a complimentary replica of the fish and special recognition and award from the TPWD. The program runs from October 1st to April 30th. These fish are held in holding tanks at TFFC until they are ready to spawn. Prior to spawning, the tank lighting is adjusted so that the fish become accustomed to a 12-h photoperiod. In late February or early March, the females are genetically checked to determine if any is an intergrade and if so to what degree. Generally, only fish that have 95% or greater of the FLMB genes are used in the program.

For spawning, raceways are divided into six compartments with screens to isolate the males and thereby reduce aggressive territorial behavior. Each compartment is provided with one spawning substrate and one female. When spawns are observed, the mats are retrieved from the raceways and transported to an incubation room as described above. Eggs are removed from mats by using sodium sulfite solution (15 g/L) and rinsed a few times to remove sodium sulfite residues and debris. The eggs are enumerated using an egg counter and placed in McDonald jars for incubation. Eggs from different spawns are kept separate. After hatching, fry from an individual spawn are stocked into the same pond or group of ponds for grow-out.

CHAPTER 3

Fingerling Production

Pond Preparation

Production ponds must be properly prepared for success in fingerling bass production. Earthen ponds are allowed to thoroughly dry and then disked, bladed, and packed. Bottoms of these ponds are sprayed with an approved herbicide just before filling with water to prevent growth of unwanted vegetation. Plastic-lined pond bottoms and harvest basins are cleaned of sediments. Each pond is provided with an insect-mesh screen which is packed with an expandable foam rubber seal, such as Denver Foam (Backer Rod Mfg. Inc., Denver, CO), to prevent fish escapement through the drain pipe. For ponds with screens that fit loosely into slots, the screens should first be set, packed, and then secured with wooden wedges to create the tightest seal possible.

Ponds are filled with water 7-14 d before the anticipated date of fry stocking. If ponds have recently been used and not sufficiently dry then any standing water is sprayed with 100% bleach to kill unwanted fish or other aquatic organisms. All incoming water is filtered through 500-micron-mesh screen socks to prevent introduction of undesirable fish into ponds.

The size of the fry to be stocked is an important factor in determining the lead time to begin filling ponds with water before fish stocking (i.e., pre-stocking time interval). The pre-stocking time interval should be well managed to allow stocking of fry when their preferred prey item(s) are dominant in the pond. Parmley (1986) found that LMB fry begin feeding at 6.7 mm TL with a preference for copepod nauplii initially and then shifting to copepod adults. At 11 mm TL the fish consume mainly copepod adults and cladocerans. Conversely, rotifers are not an important food items for LMB fry. Based on Parmley's (1986) findings, raceway-spawned fry which are approximately 7 mm TL at time of stocking should be stocked into ponds dominated by copepod nauplii. Normally, copepod nauplii dominate zooplankton communities in ponds 7-10 d after filling, depending on the fertilization and inoculation strategies used in pond management. Pond-spawned fry may range from 14-25 mm TL at harvest depending on their growth rates in spawning ponds. These advanced fry prefer larger prey items such as cladocerans, adult copepods, and insect larvae. These fish should be stocked when the populations of their preferred prey items are peaking in rearing ponds, which is usually 10-14 d after filling ponds with water.

Water Quality Management

Maintaining proper water quality in ponds is essential for successful fish culture. Water quality should be monitored twice daily (morning and afternoon) for DO, temperature, and pH. Ideally, these measurements should represent the highest and lowest expected readings of the day. Thus, monitoring should be done at or just after dawn and late in the afternoon. Pond water quality management should follow these guidelines:

- Salinity < 2 ppt.
- Dissolved oxygen > 4 mg/L.
- Total ammonia nitrogen < 0.3 mg/L.
- Total hardness = 100-300 mg/L.

- pH = 6-10.
- Temperature < 32° C.

Pond Fertilization

Fertilization provides the needed nutrients to stimulate growth and reproduction of micro-algae to support zooplankton production, the primary prey items of black bass fry (Parmley et al. 1986). Fertilization regimes must offer adequate levels of nutrients (nitrogen and phosphorus) at the appropriate time. Organic, inorganic, or various combinations of both can be used to successfully produce black bass fingerlings (White 1981; Hutson 1990; Kurten et al. 1995). Each hatchery has different water quality characteristics which determine the fertilizer applications needed to ensure successful fish production. Different water quality and facility conditions necessitate that each hatchery monitors and applies fertilizers to best meet its production needs. Further, hatcheries should periodically review their fertilization regimes to ensure that the nutrients needed for good primary production are maintained in-between fertilizer applications.

An important aspect of fertilization is its relationship with pond pH. The addition of fertilizers, especially inorganic types, can over-stimulate pond productivity to a point where high afternoon pH levels can negatively affect growth and survival of LMB fingerlings. Staffs should be familiar with the pH tolerances of LMB life stages and implement strategies to prevent or minimize incidences of elevated pH levels.

Table 6 shows the fertilization regime used at AEW. The goal of this fertilization regime is to achieve nutrient levels of 0.5 mg N/L and 1.0 mg P/L. Cottonseed meal is used as an organic fertilizer because of its high carbon-to-nitrogen ratio content. Uran (32-0-0) and phosphoric acid (54% P_2O_5) are used as sources of inorganic nitrogen and phosphorus, respectively. Uran (3 parts), phosphoric acid (1 part), and pond water (9 parts) are mixed to form a solution which is then applied to ponds. Because of the addition of water, the Uran and phosphoric acid are kept in solution. The similarity of the plastic-lined ponds at AEW allows staff to apply the same quantity of fertilizer mixture (e.g. 13 L of solution) to each pond to achieve the target nitrogen and phosphorus rates. Nutrient levels should be monitored periodically to ensure that target levels are achieved or maintained in production ponds.

The AEW has a pond filling strategy designed to maximize pond fertility during the early stages of filling and to control pH after the fry are stocked. Ponds are filled until they are about 45 cm from being full, then the incoming water is turned off. The ponds are maintained at this level until the day before fry stocking when freshwater is again added to ponds. Fry are stocked into this "refuge of freshwater." Freshwater continues to flow into ponds until they are full. The justification for this strategy is to concentrate nutrients to enhance primary and secondary productivity during early pond filling stages, protect newly stocked fry from pH swings by providing a freshwater refuge, stimulate additional productivity by increasing pond volume, and reduce pH swings by adding freshwater.

The TFFC has adopted a fertilization program that relies heavily on organic fertilization and less on inorganic fertilizers (Table 7). This is because Lake Athens, the source of water for the hatchery, has high phosphorus content during the spring season. Consequently, there is usually no need for additional inorganic fertilization. The fertilization regime consists of a single application of inorganic fertilizers and several applications of cottonseed meal per pond. By relying mainly on cottonseed meal, usually elevated pH levels are avoided during the production cycle (Kurten et al. 1999).

The JFH ponds are fertilized with ammonium nitrate (33-35% N) and phosphoric acid (54% P_2O_5) to achieve initial nutrient levels of 0.5 mg/L for both phosphorus and nitrogen. Cottonseed meal is applied at 225 kg/ha. Follow-up applications of 0.25 mg/L of nitrogen and lighter rates of cottonseed meal are applied every Monday, Wednesday, and Friday unless filamentous algae blooms begin to appear in ponds.

The PKH monitors water quality and fertilization regimes very carefully due to the presence of golden alga in Possum Kingdom Lake, the source of water for the hatchery. Ponds are filled 7-14 d in advance of fry stocking, depending on whether water is from the shallow or deep source of water. The decision of which source of water to use is based on whether or not golden alga is present in the incoming water. Ponds receive a prophylactic treatment of ammonium sulfate (32-0-0) at 7-10 mg/L to control golden alga. When golden alga is present, additional treatments with ammonia sulfate are made to maintain un-ionized ammonia levels of 0.16-0.25 mg/L (Barkoh et al. 2010) during the production cycle. Total ammonia nitrogen is maintained below 2.1 mg/L. Cottonseed meal is applied as outlined in Table 6.

The DFH also has golden alga in its water supply reservoir and has to carefully manage ponds to control the alga and improve pond productivity by fertilization to successfully raise fish. Currently, DFH is not culturing black bass species, but may do so in the future. Fertilization regimes for this facility are based on work done to ensure that golden alga is controlled to successfully produce striped bass (*Morone saxatilis*) and Palmetto bass fingerlings.

Zooplankton Management

Zooplankton of appropriate quantity and quality is essential for successful production of black bass fingerlings. Parmley (1986) reported that LMB fry begin feeding at 6.7 mm TL with preference for copepod nauplii initially and then shifting to copepod adults and cladocerans by 11 mm TL. The density of preferred organisms should be at least 100 organisms/L at time of fry stocking. Rotifers are not important food items for LMB fry (Parmley 1986). During the production cycle, a shift from a rotifer-dominated zooplankton community to one dominated by copepods-cladocerans mix occurs; then rotifers repopulate as a result of the bass fry grazing on the larger zooplankters. Pond management goal should match zooplankton of appropriate quality and quantity with size or age of fish.

Production ponds should be sampled periodically throughout the culture period to evaluate zooplankton quantity and quality. Zooplankton samples are usually taken in the mornings, preferably before sunrise. Initial samples should be taken when ponds are full enough to effectively sample the water column. Thereafter, samples should be taken at least once weekly, and on the day prior to fry stocking. Most facilities sample ponds using an oblique 4-m tow of 5.75-cm diameter 80-micron mesh Wisconsin plankton net. The samples are concentrated to a volume of 90 mL, and densities of the major zooplankton groups (cladocerans, copepod nauplii, copepod adults, and rotifers) are determined microscopically.

It is a good strategy to maintain at least one zooplankton inoculation pond (ZIP) for the purpose of inoculating newly filled ponds or supplementing production ponds that have low zooplankton densities of the appropriate taxa. Zooplankton is collected from these ponds in two ways:

- A tempering pump is used to fill a hauling unit with water from the ZIP which is then transferred into a production pond. This method adds both phytoplankton and zooplankton to production ponds.
- An electric water (or airlift) pump is used to pump water from the ZIP into a large 500-micron-mesh collection net (harvester). This method concentrates the zooplankton in the net. Providing a sport light to the pump intake area attracts zooplankton and enhances collection. The zooplankton concentrate is transferred from the net into production ponds using buckets.

Fingerling Growth and Harvest

Pond stocking rates vary among hatcheries due to differences in pond productivity, fish target size, and local experience. However, fry stocking rate should be selected based on the carrying capacity of the pond and the target size of fingerlings. Currently, the requested size for most black bass species is 38 mm. These fish must be produced in good health and condition within established time frames. Based on previous production data, growth rates for black bass fingerlings are 1.0-1.5 mm/d when survival rate is about 50%. Stocking rates that achieve the 38-mm TL fish are summarized in Table 8.

Production ponds should be managed so that the fry grow 1.0-1.5 mm/d. At these growth rates, a 7-mm raceway-spawned fry should reach the 38-mm target size in about 31 d. Pond-spawned fry stocked at 15 mm TL should be ready for harvest in 23 d after stocking. Fish growth should be monitored weekly to estimate growth rate and when to harvest the fish. To estimate fish size and growth, a sample of 30-40 fish is taken from each pond by dip-netting or seining. The fish are measured for TL. The average TL is calculated for each pond and used to estimated growth rate (mm/day) as follows: (average sample length – average stocking length)/production days. Growth rate data are used to estimate when ponds may be ready for harvest. Fish growth rate data should be examined weekly to determine if fish are growing as expected. If fish are not growing as expected, zooplankton and water quality data should be examined to determine the cause and implement solutions.

At most hatcheries fish samples are taken near the kettle or harvest basin since this is the most accessible area. However, fish size estimates from such samples may be biased because the larger fish usually occupy these areas of the pond. Fish size estimate should not be used as the sole criterion to determine if a pond is ready for harvest. Additional factors to consider are days in production, availability of food resources, and growth rates over the production period.

Preparation for harvest.—When the fish reach the target size, the following protocol should be used for efficient harvest and delivery of the fish:

- Estimate the number of fingerlings expected from each pond and the harvest date.
- Notify fisheries managers of the receiving lakes of the impending fish deliveries.

- Drain fingerling rearing ponds over a 2-d period relative to the lake stocking schedule. Slowly draining ponds over weekends allows harvest and delivery of fish to be completed early in the week.
- Before pond draining begins, inspect pond drain screen for rips or tears and proper seating in the channels to prevent fish escape.
- Inspect ponds, especially the harvest area, for excessive debris and filamentous algae that may cause the screen to clog or break. If air supply is available to the ponds, place a bubbler in front of each screen to reduce clogging of the drain screen and to keep fingerlings from getting trapped against the drain screen.
- Monitor the pond during draining to ensure dissolved oxygen levels are adequate for the fish and the drain screens are not clogging up.
- If ponds are draining over several days, freshwater should flow into ponds overnight to maintain water quality.
- If ponds have bottom kettle valves in the drain basins, such as the Kansas kettles, the bottom valves should be opened about halfway during pond draining for about 15 min to flush out accumulated sediments from kettles. This helps maintain good water quality and is important if fingerlings are held in the kettle for extended periods of time.
- Plan to harvest fingerlings as early in the morning as possible, especially for ponds not equipped with Kansas kettles. Air and water temperatures are cooler in the mornings and less stressful on the fish. Also, cooler water holds more oxygen than warm water.
- Before fish are harvested, the work area must be prepared. All harvest equipment must be in proper working condition. Concrete surfaces that have been under water for several weeks can be extremely slippery due to presence of algae and mud. These surfaces must be thoroughly cleaned and extreme care must be taken while working on them to prevent slip-and-fall accidents.

Harvesting ponds with kettles.—Harvest methods vary depending on the type of pond harvest basin. Ponds with Kansas kettles are drained completely to allow all the fish to collect in the holding kettles. For these ponds, each bottom kettle valve should be opened about 30 min before the pond drains completely into the kettle. This helps maintain good water quality and allows the fish to acclimate from pond water temperature to supply water temperature. Harvesting of fish should begin at least 30 min after all the pond water has drained into the kettle. This allows sediments to be flushed out of the kettle and improve water quality to reduce stress on the fingerlings. Once the water quality in the kettle has improved (e.g., less turbidity), harvest of fingerlings begins as follows:

- First, the fingerlings are crowded away from the incoming water and a screen is placed to restrict their movement toward and protect them from the turbulent incoming water.
- Next, the fingerlings are crowded toward the incoming water and another screen is put in place to confine the fish in a section of the kettle. Because overcrowding can lead to stress and mortality in fish, the size of the confinement area should be adequate for the number of fish in the kettle.
- A large sample is taken with a large dipnet, and then 3-4 subsamples (approximately 100 fish each) are taken from the sample using a smaller dipnet. For each subsample, the water is allowed to drain before the fish is transferred into a tarred bucket with water and weighed on a digital platform scale.
- The weight of the fish is recorded and the fish are hand counted to determine the number of

fish/kg.

- A random sample of at least 30 fish is taken and all fish are individually measured to determine average TL.
- The fish are harvested by dip-netting from the kettle and placed into a tarred bucket with water for weighing. The bucket and fish are weighed, weight of the fish recorded, and the fish placed into a hauling unit.
- The number of fish harvested is estimated by multiplying the estimated fish/kg by the total weight of fish harvested from each pond.
- Weighing buckets should never be overloaded with fish to prevent injury to fish.

Accurate data collection requires use of accurate and reliable scales, fish sampling that is representative of the population, and a sample size that is statistically adequate. If a pond has multiple partial harvests, sampling each batch of fish is necessary to have an average sample that is representative of the population.

Harvesting ponds without kettles.—Ponds without kettles are drained slowly, and the fish are harvested as the pond drains:

- Fingerlings are either seined from these ponds or dip-netted from the drain box.
- Fish captured are placed in a tarred bucket containing water and weighed on a scale. The weight is recorded, and the fish are transferred into a hauling unit.
- To expedite harvest of the fish, draining of the pond water can be slowed down by closing the drain valve about halfway and allowing freshwater to flow into the pond. The fingerlings are attracted to the incoming freshwater in the drain box where they can be dip-netted. The drain can then be re-opened, and the process repeated.
- Because the fish usually are not of the same size or evenly distributed in the pond, fish sampling for length measurements and enumeration are best performed after all, or at least most, of the fish are harvested into a hauling unit. Fish samples are taken from the hauling unit but the procedures for length measurements and fish quantification are the same as described above.
- Generally, the most accurate information for trips is fish lengths (TL) estimated from fish on hauling units rather than fish in ponds.

CHAPTER 4

Fish Distribution

Equipment and Loading Factors

Routinely, fish are harvested from ponds and transported directly to the receiving water body. Standard TPWD hauling units are trailer-mounted hauling boxes, each divided into three compartments. Each compartment can contain 790-960 L of water and is equipped with an oxygen-diffusion stone supplied with compressed oxygen, and also an agitator. All agitators should be wrapped in mesh coverings that prevent fingerlings from entering the agitator baskets during operation. Hauling units should be inspected for any problems (e.g., cracks) prior to filling with water. Salt should be added to the water in the hauling unit to achieve a 0.2-0.3% solution. The air stones should be inspected for proper diffusion, and the flow meters and associated piping system should be inspected for leaks. Fish should be loaded after the oxygen level of the water in the compartments is supersaturated (≥20 mg/L). Loading densities depend on the following factors (McCraren 1978):

- Water temperature.
- Hauling time.
- Condition of fish.
- Size of fish.
- Aeration system.
- Fish species.

Before harvesting fingerlings, estimate how many are needed for each destination and can be safely transported on each hauling unit. If environmental conditions in the hauling tank are constant, hauling unit carrying capacity depends on fish size. Fewer kg of small fish can be transported per liter of water than larger fish. For example, one-half as many kg of 50-mm fish can be hauled as 100-mm fish (Hutson 1990) for a given hauling time. Hutson (1990) used the formula in Appendix B to determine fish loading density. There are programs available for calculating fish loading rates, and these should be used along with past trip sheets data to determine safe loading densities for hauling units. As rule of thumb, AEW loads approximately 50 kg of 38-mm fingerlings per 960-L compartment.

Transportation

The transportation truck must have a working cell phone along with phone numbers of the relevant management biologists, hatchery manager, and hatchery program director. After the fish have been loaded on the hauling unit, the driver should take the most direct and safe route from the hatchery to the stocking site. The condition of the fish must be checked 30 min after loading and at least every hour thereafter. The oxygen delivery system, dissolved oxygen concentration, and water temperature should be checked every hour. Dissolved oxygen should be maintained above 6 mg/L by proper adjustment of the oxygen delivery system. Water temperature (< 28^{o}C) should be maintained with ice as needed.

- 60 g/L (0.5 lb/gal) of ice reduces water temperature by about 5.5^{o}C (10^{o}F).

Stocking

Upon arrival at the stocking site, fish should be acclimated to the receiving water chemistry. Fingerlings always should be tempered for at least 30 min before release into receiving waters, even when temperatures of hauling and receiving waters are similar. Proper tempering requires 20 min for every 4°C change in water temperature (McCraren 1978). However, tempering is done not only for temperature but for other water quality factors as well. Tempering is accomplished by pumping lake water into the hauling unit. After tempering, the fish should be stocked in the best available habitat. Management crews may take fingerlings in boats for distribution in suitable habitats at several locations. This process can take time, and the driver needs to be aware of the condition of the fish in the hauling unit and after the tempering process.

Coordination

Fish stocking must be coordinated with the appropriate district management office. District biologists should be informed of the pending stocking a week before and on the day of the stocking, preferably before the trip begins.

CHAPTER 5

Data Reporting

Trip Sheets

Trip sheets are required for every stocking event. Trip sheets have been standardized and can be printed with pre-trip information from the Fish Hatchery Database (FHD) (http://gofish.tpwd.state.tx.us/Stocking/TripSheets/TripForm.aspx). All relevant trip sheet information, including the pre- and post-trip check lists should be completed by the driver within 24 h after fish delivery. The trip sheet should be given to the individual responsible for data entry into the FHD, and the information should be entered into the database within 48 h of receipt. Another individual should verify the data entered into the database no later than 7 d after the information has been added to the database.

Harvest Data

Harvest data should include, at least, all routine production statistics for each production unit (e.g., pond). The data may include: number of fish harvested, average TL of fish, number of fish/kg, and weight (kg) of fish harvested. This information is used to evaluate production methods and outputs (i.e., pond management success). Therefore, adequate and accurate data are essential. If a pond has multiple partial harvests, sampling each partial harvest is necessary, and the weighted mean values for the production variables reported. Further, whenever multiple ponds or multiple harvests (i.e. multiple datasets) are involved in the estimation of production statistics, weighted mean values must be reported. In these cases, avoid reporting "pond averages" which may obscure deficiencies in production.

Water Quality Data

Water quality data are used to make pond (or culture unit) management decisions or to refine management strategies. Thus, accurate recording and timely reporting of water quality data are important. Water quality data should be reported to production managers in a timely manner so that water quality management decisions can be timely made. If water quality data are collected using a multi-parameter data logger, the data should be downloaded daily into the FHD. Data entry into the FHD is required weekly. Meters must be calibrated daily or according to manufacturer's instructions to ensure proper performance.

Spawning and Incubation Data

Spawning and incubation data are necessary for proper allocation of pond space for fingerling production and therefore must be comprehensive. Information recorded on spawning and incubation data sheets should include: fish weight and number, number of spawns produced, number of fry produced, fry produced per kg of female, and the destination of the fry.

Pond Production Data

Pond production data including, but not limited to, filling dates, water quality data, zooplankton data, feeding and fertilization records, stocking records, sampling records, and harvest data, must be entered into the FHD in a timely manner. Production data should be entered into the database within 7 d of the occurrence.

Status Reports

Data for monthly status reports are entered into tables in the Hatchery Production Status Report by the 10th of each month. This report is located at N:\IFHatcheries\Hatchery Status Reports. Annual reports for spring production are due by September 1. These reports are prepared by hatchery biologists.

Program Summary Report

Program summaries are prepared by the respective program directors and disseminated to staff before the annual programs evaluation meeting. This meeting normally convenes in January.

LITERATURE CITED

Barkoh, A., D. G. Smith, and G. M. Southard. 2010. *Prymnesium parvum* control treatments for fish hatcheries. Journal of the American Water Resources Association 46(1):161-169.

Boyd, C. E. 1979. Water quality in warmwater fish ponds. Agricultural Experiment Station, Auburn University, Alabama.

Boyd, C. E., and F. Lichtkoppler. 1979. Water quality management in pond fish culture. Research and Development Series 22, Agricultural Extension Service, Auburn University, Alabama.

Burkhalter, A. P. 1967. Aquatic weed identification and control manual. Bureau of Aquatic Plant Research and Control, Florida Department of Natural Resources, Tallahassee.

Chew, R. L. 1974. Early life history of the Florida largemouth bass. Florida Game and Freshwater Fish Commission, Fishery Bulletin 7, Tallahassee.

Fries, L. T., P. L. Hutson, and H. J. Warren. 1996. Fish hatchery genetics and genetics plan. Management Data Series 130, Texas Parks and Wildlife Department, Austin.

Fries, L. T., G. L. Kurten, J. Isaac, Jr., T. Engelhardt, D. Lyon, and D. G. Smith. 2002. Mass production of polyploid Florida largemouth bass for stocking public waters in Texas. Pages 393-399 *in* D. P. Philipp and M. S. Ridgeway, editors. Black bass: ecology, conservation, and management. American Fisheries Society Symposium 31, Bethesda, Maryland.

Hutson, P. L. 1983. Smallmouth bass culture in Texas. Progressive Fish-Culturist 45:169-171.

Hutson, P. L. 1990. Florida largemouth bass culture in Texas. Texas Parks and Wildlife Department, Management Data Series 35, Austin.

Isaac, J. Jr., T. M. Kimmel, R. W. Bagley, V. H. Staats, and A. Barkoh. 1998. Spawning behavior of Florida largemouth bass in an indoor raceway. Progressive Fish-Culturist 60:59-62.

Kurten G., L. Hall and N. Thompson. 1995. Comparison of Cottonseed meal and alfalfa meal for fertilizing earthen Florida largemouth bass spawning and rearing ponds. Texas Parks and Wildlife Department, Management Data Series 113, Austin.

Kurten G., L. Hall and N. Thompson. 1999. Evaluation of cottonseed meal supplementation of inorganically fertilized Florida largemouth bass spawning ponds. North American Journal of Aquaculture. 61:115-125

Lutz-Carrillo, D. J., C. C. Nice, T. H. Bonner, M. R. J. Forstner, and L. T. Fries. 2006. Admixture analysis of Florida largemouth bass and northern largemouth bass using microsatellite loci. Transactions of the American Fisheries Society 135:779-791.

McCraren, J. P. 1978. Manual of fish culture: fish transportation. U.S. Fish and Wildlife Service, Washington, D.C.

Nelson, J. T., R. G. Bowker, and J. D. Robinson. 1974. Rearing pellet-fed largemouth bass in a raceway. , Progressive Fish-Culturist 36(2):108-110.

Parker, W. D. 1971. Preliminary studies on sexing adult largemouth bass by means of an external characteristic. Progressive Fish-Culturist 33:55-56.

Parmley, D., G. Alvarado, and M. Cortez. 1986. Food habits of small hatchery-reared Florida largemouth bass. Progressive Fish-Culturist 48:264-267.

Piper, R. G., I. B. McElwain, L. E. Orme, J. P. McCraren, L. G. Fowler, and J. R. Leonard. 1982. Fish hatchery management. U.S. Fish and Wildlife Service, Washington, D.C.

Sarti, M. J. 1986. Largemouth raceway spawning at Jake Wolf Memorial Fish Hatchery. Pages 35-36 *in* Robert Sweet, editor. Midwest black bass culture. Missouri Department of Conservation, Kansas City, Missouri.

Snow, J. R. 1964. Training manual for warm-water fish culture. U.S. Fish and Wildlife Service, Marion, Alabama.

Snow, J. R. 1968. Production of six to eight inch largemouth bass for special purposes. Progressive Fish-Culturist 30:144-152.

Snow, J. R. 1974. Controlled culture of largemouth bass fry. Southern Division of the American Fisheries Society 26:22-25.

Snow, J. R. 1975. Hatchery propagation of the black basses. Pages 344-356 *in* H. E. Clepper and R. H. Stroud, eds. Black Bass Biology and Management. Sport Fish. Inst.,Washington, D.C.

TPWD (Texas Parks and Wildlife Department). 1990. Fish stocking philosophy. Inland Fisheries Division, PWD RP 3000-336 (11/90), Austin.

TPWD (Texas Parks and Wildlife Department). 1995. Texas largemouth bass management. Committee Report, Inland Fisheries Division, Austin.

White, B. L. 1981. Culture of Florida largemouth bass. Pages 146-159 *in* P. L. Hutson and J. Lillie, editors. Midwest Black Bass Culture. Texas Parks and Wildlife Department Austin.

TABLE 1.—Florida largemouth bass broodfish inventory and spawning strategy for Texas Parks and Wildlife Department freshwater hatcheries.

Hatchery	Spawning strategy	Year classes	Production pairs
A.E. Wood	Raceway	3	250-300
TFFC*	Raceway	3 or more Lunker Program	250-300 or more ShareLunkers
Jasper**	Pond	3	400-450
East Texas Fish Hatchery (ETFH)***	Raceway	3	250-300

*TFFC is Texas Freshwater Fisheries Center.
**Jasper's broodfish need should decrease when the ETFH starts operation.
***ETFH to acquire Jasper's broodfish when it starts operation.

TABLE 2.—Current black bass fingerling production capabilities of Texas Parks and Wildlife Department freshwater hatcheries.

Hatchery[Z]	Hectares used for bass rearing*	Fingerlings/ha**	Production capability
A.E. Wood	17	250,000	4,250,000
Jasper	14	123,000	1,700,000
PK	3	197,000	985,000
TFFC	16	123,000	2,000,000
Total	52		8,935,000

* Hectares used over two rearing cycles.
** Five-year average for each hatchery.
[Z]PK is Possum Kingdom State Fish Hatchery; TFFC is Texas Freshwater Fisheries Center

TABLE 3.—Suggested forage sizes and rates fed to black bass of different ages (C. Kittel, A. E. Wood Fish Hatchery, San Marcos, Texas, personal communication).

Age (years)	kg forage/kg brooder/year	Size of forage (mm)
0-1	20	Fry-50
1-2	15	50 -75
2-3	10	75 - 100
3-4	9	75 - 100
>4	7	75 -125

TABLE 4.—Suggested yearly feeding schedule for black bass broodfish (C. Kittel, A. E. Wood Fish Hatchery, San Marcos, Texas, personal communication).

Month	Percent of total to feed
January-March	5
April-June	20
July	20
August	10
September	25
October-December	20

TABLE 5.—A schedule of black bass broodfish rotation among Texas Parks and Wildlife Department freshwater hatcheries.

Year class	Group A females[Z] Group B males	Group B females Group A males
2008	AEW	Jasper
2011	TFFC	AEW
2013	ETFH	TFFC
2015	AEW	ETFH
2018	AEW	TFFC
2019	AEW (from Florida)	AEW (from Florida)
2020	ETFH	TFFC
2022	AEW	ETFH
2024	TFFC	AEW
2026	ETFH	TFFC

[Z]AEW is A. E. Wood Fish Hatchery; TFFC is Texas Freshwater Fisheries Center; PK is Possum Kingdom State Fish Hatchery; ETFH is East Texas Fish Hatchery; Jasper is Jasper State Fish Hatchery.

TABLE 6.—A. E. Wood Fish Hatchery management schedule for 0.4-ha ponds stocked with raceway-produced fry to produce 38-mm total length fingerlings.

Day	Action	Cottonseed meal (kg)	Uran (L)	Phosphoric acid (L)
Day 1	Filling and fertilization	22.7	3	1
Day 3	Zooplankton inoculation			
Day 4	Fertilization	91	6	2
Day 6	Zooplankton inoculation			
Day 7	Fry stocking			
Day 8	Fertilization	22.7	3	1
Day 10	Fertilization	22.7	3	1
Day 12	Fertilization	22.7	3	1
Day 15	Fertilization	22.7	3	1
Day 18	Fertilization	22.7	3	1
Day 21	Fertilization	22.7	3	1
Day 24	Fertilization	22.7	3	1
Day 27	Fertilization	22.7	3	1
Day 35	Fingerling harvest			
Total		295.3	33	11

TABLE 7.—Texas Freshwater Fisheries Center management schedule for 0.4-ha ponds stocked with raceway-produced fry to produce 38-mm total length fingerlings.

Day	Action	Cottonseed meal (kg)	Uran (L)	Phosphoric Acid (L)
Day 1	Filling			
Day 2	Fertilization	22.7		
Day 3	Zooplankton inoculation			
Day 5	Fertilization	91	2.8	0.465
Day 6	Fertilization	22.7		
Day 8	Fertilization	22.7		
Day 10	Fry stocking/Fertilization	22.7		
Day 12	Fertilization	22.7		
Day 15	Fertilization	22.7		
Day 18	Fertilization	22.7		
Day 21	Fertilization	22.7		
Day 24	Fertilization	22.7		
Day 27	Fertilization	22.7		
Day 35	Fingerling harvest			
Total		181.6	2.8	0.465

TABLE 8.—Fry stocking rates and expected growth and survival rates for Texas Parks and Wildlife Department black bass producing hatcheries.

Hatchery	Fry/ha stocked	Expected growth rate (mm/day)	Expected survival (%)
A.E. Wood	500,000	1	65
TFFC[Z]	250,000-312,500	1	65
Jasper	150,000-200,000	1	50
Possum Kingdom	250,000-312,500	1	65
Dundee	250,000-312,500	1	65

[Z]TFFC is Texas Freshwater Fisheries Center.

FIGURE 1.—Comparison of male and female largemouth bass secondary sexual characteristics - male on the top.

FIGURE 2.—Female largemouth bass ready for spawning.

FIGURE 3.—Male largemouth bass ready for spawning.

FIGURE 4.—A. E. Wood Fish Hatchery raceways set up for bass spawning.

Appendix A

Texas Parks and Wildlife Department Inland Hatcheries HACCP Plan for Fish Distribution (Hazard Analysis and Critical Control Point)

Fish Distribution

1. Product Description

Name	TPWD Inland Hatcheries
Locations	A.E. Wood Fish Hatchery, Dundee Fish Hatchery, Jasper Fish Hatchery, Possum Kingdom Fish Hatchery, Texas Freshwater Fisheries Center, Heart of the Hills Fisheries Science Center
Species of fish	Largemouth bass, Smallmouth bass, Striped bass, Hybrid striped bass, Bluegill sunfish, Channel catfish, Blue catfish, Saugeye, Walleye, Rainbow trout, and other species as required
Cultured, wild harvested or both	Both
Method of distribution	Truck and trailer
Intended use	Public water stocking to support recreational fishing

2. Action

Step 1	Fill distribution unit with water
Step 2	Collect fish from pond, raceway, or culture tank
Step 3	Transfer fish into distribution unit
Step 4	Transport to stocking site
Step 5	Acclimate hauling water quality to ambient conditions
Step 6	Release fish into receiving water
Step 7	Disinfect and rinse distribution unit and equipment upon return to hatchery

3. Potential Hazards

Aquatic Nuisance Species (ANS) - Species found in the hatchery water supply that could potentially cause ecological harm if released into other water bodies, or species found in the receiving water body that could potentially cause harm if transported and introduced into the hatchery culture system.

Fish	
Other vertebrates	
Invertebrates	Mud crab (*Rhithropanopeus harrisii*), exotic trematode, (*Centrocestus formosanus),*Red rim melina (*Melanoides turberulatus*), Quilted melania (*Tarebia granifera*), Giant rams-horn snail (*Marisa cornuarietis*), Asian clam (*Corbicula fluminea*),
Pathogens	Largemouth bass virus
Plants and algae	Golden algae *(Prymnesium parvum),* Giant salvina, (*Salvinia molesta)*, Hydrilla (*Hydrilla verticulata*)

4. Hazard Analysis Worksheet

Step	Identify potential ANS hazards introduced or controlled	Significant ANS hazard (Yes / No)	Justification	Applied preventive measures	Critical control point (Yes / No)
1. Fill distribution unit with water	Fish	No	No ANS identified in water supplies		No
	Other vertebrates	No	No ANS identified in water supplies		No
	Invertebrates	Yes	Exotic trematode present in water supply at AEW		No
			Exotic mud crab present in water supply at PK	Fill with treated (disinfected or filtered) or well water	Yes
	Pathogens	Yes	LMBV present in water supply at TFFC and Jasper		No
	Plants and algae	Yes	Golden algae present in water supply at Dundee and PK	Fill with treated (disinfected or filtered) or well water	Yes

Step	Identify potential ANS hazards introduced or controlled	Significant ANS hazard (Yes / No)	Justification	Applied preventive measures	Critical control point (Yes / No)
2. Collect fish from pond, raceway or culture tank	Fish	No	No ANS identified in water supplies		No
	Other vertebrates	No	No ANS identified in water supplies		No
	Invertebrates	Yes	Exotic trematode present in water supply at AEW		No
			Exotic mud crab present in water supply at PK		No
	Pathogens	Yes	LMBV present in water supply at TFFC and Jasper		No
	Plants and algae	Yes	Golden algae present in water supply at Dundee and PK		No

Step	Identify potential ANS hazards introduced or controlled	Significant ANS hazard (Yes / No)	Justification	Applied preventive measures	Critical control point (Yes / No)
3. Transfer fish into distribution unit	Fish	No	No ANS identified in water supplies		No
	Other vertebrates	No	No ANS identified in water supplies		No
	Invertebrates	Yes	Exotic trematode present in water supply at AEW		No
			Exotic mud crab present in water supply at PK	Use treated or well water from distribution unit to transfer fish	Yes
	Pathogens	Yes	LMBV present in water supply at TFFC and Jasper		No
	Plants and algae	Yes	Golden algae present in water supply at Dundee and PK	Use treated or well water from distribution unit to transfer fish	Yes

Step	Identify potential ANS hazards introduced or controlled	Significant ANS hazard (Yes / No)	Justification	Applied preventive measures	Critical control point (Yes / No)
4. Transport to stocking site	Fish	No	No ANS identified in water supplies		No
	Other vertebrates	No	No ANS identified in water supplies		No
	Invertebrates	Yes	Exotic trematode present in water supply at AEW		No
			Exotic mud crab present in water supply at PK		No
	Pathogens	Yes	LMBV present in water supply at TFFC and Jasper		No
	Plants and algae	Yes	Golden algae present in water supply at Dundee and PK		No

Step	Identify potential ANS hazards introduced or controlled	Significant ANS hazard (Yes / No)	Justification	Applied preventive measures	Critical control point (Yes / No)
5. Acclimate hauling water quality to ambient conditions	Fish	Yes	ANS may be present in receiving waters	Disinfect and rinse distribution unit on return to hatchery	Yes
	Other vertebrates	No	ANS may be present in receiving waters	Disinfect and rinse distribution unit on return to hatchery	Yes
	Invertebrates	Yes	Exotic trematode present in water supply at AEW		No
			Exotic mud crab present in water supply at PK		No
			ANS may be present in receiving waters	Disinfect and rinse distribution unit on return to hatchery	Yes
	Pathogens	Yes	LMBV present in water supply at TFFC and Jasper		No
	Plants and algae	Yes	Golden algae present in water supply at Dundee and PK		No

Step	Identify potential ANS hazards introduced or controlled	Significant ANS hazard (Yes / No)	Justification	Applied preventive measures	Critical control point (Yes / No)
6. Release fish into receiving water	Fish	No	No ANS identified in water supplies		No
	Other vertebrates	No	No ANS identified in water supplies		No
	Invertebrates	Yes	Exotic trematode present in water supply at AEW	Do not stock into sub tropical, spring fed systems	Yes
			Exotic mud crab present in water supply at PK		No
	Pathogens	Yes	LMBV present in water supply at TFFC and Jasper	Stock fish known to carry LMBV (LMB, BLG, STB) in waters known to be infected or directly influenced by water system infected with LMBV	Yes
	Plants and algae	Yes	Golden algae present in water supply at Dundee and PK		No

5. HACCP Plan Form

Critical control point	Significant hazard	Control measures	Monitoring				Corrective action(s)	Records	Verification
			What	How	Frequency	Who			
1. Fill distribution unit with water	Golden algae	Fill with treated water (disinfected or filtered) or well water	Golden algae in water source	Cell counts	Weekly	Hatchery staff		Record golden algae cell counts in log	Hatchery manager to review log and ensure that water source is monitored
	mud crab	Fill with treated water (disinfected or filtered) or well water	Crab larvae in water source	Zooplankton counts	Weekly	Hatchery staff		Record mud crab larvae counts in log	
3.Transfer fish to distribution unit	Golden algae	Use treated or well water from distribution unit to transfer fish	Golden algae in distribution water	Cell counts	Each load	Hatchery staff	Flush with treated water (disinfected or filtered) or well water	Record golden algae cell counts in log	Hatchery manager to review log and ensure that distribution water is monitored
	Mud crab	Use treated or well water from distribution unit to transfer fish							
5. Acclimate water quality to ambient conditions	ANS may be present in receiving waters	Disinfect and rinse distribution unit on return to hatchery						Complete post trip checklist	Hatchery manager to review post trip checklist

Critical control point	Significant hazard	Control measures	Monitoring				Corrective action(s)	Records	Verification
			What	How	Frequency	Who			
6. Release fish into receiving water	LMBV present in water supply at TFFC and Jasper	Stock fish known to carry LMBV (LMB, BLG, STB) in waters known to be infected or directly influenced by water systems infected with LMBV	LMBV in stocked fingerlings	Represen tative samples from each facility	Annually	Fish Health Lab		Maintain database of LMBV prevalence in each hatchery	Fish Health Lab Director to maintain records of LMBV prevalence in stocked fingerlings
	Exotic trematode present in water supply at AEW	Do not stock fish from AEW into sub tropical, spring fed systems	Trematod es in stocked fish from AEW	Represen tative samples from AEW	Annually	Fish Health Lab			Fish Health Lab Director to maintain records of trematode prevalence in stocked fingerlings

Appendix B

Formula for Calculation of Fish Loading Density

$$L = \frac{K}{C - D}$$

Where:

L - Loading density (kg/L)

K - Kilograms of fish

C - Tank capacity (L)

D - Water displaced by fish (L)

Texas Parks and Wildlife Department
4200 Smith School Road, Austin, Texas 78744