Guidelines for the Culture of Blue and Channel Catfish

by
Thomas Wyatt
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Management Data Series
No. 244
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TEXAS PARKS & WILDLIFE
INLAND FISHERIES DIVISION
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INTRODUCTION

The primary objective of the Texas Parks and Wildlife Department's (TPWD) Inland Fisheries catfish production program is to provide the numbers, sizes, and species of catfish needed to support the management of freshwater catfish fisheries in public waters. Both channel *Ictalurus punctatus* and blue *Ictalurus furcatus* catfish are stocked throughout the state to maximize recruitment, provide initial year-class strength in new or renovated reservoirs, replenish depleted stocks, or provide increased fishing opportunities for anglers who may be young, inexperienced, physically challenged, or unable to fish outside of urban areas. As a direct result of increased interest in the urban fishing program, stocking of catfish into community fishing lakes in or near urban areas has increased dramatically in recent years.

The Inland Fish Hatcheries branch has consistently met the annual catfish needs of the department in a timely manner. This is accomplished by maintaining and spawning channel and blue catfish brood stocks at the A. E. Wood fish hatchery and the Jasper state fish hatchery, respectively. Channel catfish brood stock is utilized to produce 2-, 9- or 12-inch fingerlings whereas blue catfish brood stock is utilized to produce 2-inch fingerlings.

Two-inch blue and channel catfish are used for "introductory" stockings into new or renovated reservoirs where they are expected to survive and environmental and habitat conditions are favorable for developing new fisheries. These fingerlings also are used for "supplemental" stockings into larger reservoirs where blue catfish or channel catfish populations are present but have limited recruitment and stocking of additional fingerlings is necessary to ensure adequate year classes are developed to maintain the fisheries.

Nine-inch channel catfish are used for "put-grow-and-take" fishery. These fish are typically stocked into smaller water bodies, usually 75 acres or less in surface area, such as community fishing lakes (CFLs) or reservoirs in state parks and wildlife management areas (WMAs) that either experience high angling pressure or limited recruitment. The reason for using 9-inch, instead of 2-inch, catfish in these situations is the survival of 2-inch catfish may be limited by predation, poor water quality, or lack of suitable habitat. Conversely, 9-inch catfish are more likely to survive and contribute to the fishery. Also, by stocking 9-inch fingerlings less time is required to grow these fish to harvestable size.

Twelve-inch channel catfish are stocked for "put-and-take" fishery. These fish are stocked into smaller water bodies in state parks and WMAs that experience high angling pressure or limited recruitment as well as in CFLs. Reasons for using 12-inch, instead of 2- or 9-inch, catfish are that growth rates may be so slow that it would take too long for the smaller fingerlings to reach legal size or that harvest rates are so high that the smaller fingerlings would not have an opportunity to grow before being removed from the water body. Research has documented that anglers tend to harvest catfish at approximately 12 inches and smaller fish are often released or considered less favorable. Another reason for stocking 12-inch catfish is to promote special events where the bigger catfish are stocked solely for the purpose of being caught within a short-time period in an effort to recruit new individuals or children into the sport of fishing.

The TPWD has five freshwater fish hatcheries and all are involved in catfish culture. Since 1941, approximately 35 million channel catfish have been stocked into Texas public waters by TPWD fish hatcheries. Approximately 18 million blue catfish also have been stocked. Currently, stocking of catfish (blue and channel) averages about 39,000 kg/year or 1.5 million fingerlings of 2-12 inches total length. The annual stocking of channel and blue catfish average 690,000 and 780,000 fingerlings and weigh approximately 37,000 and 2,700 kg, respectively.

This document should serve only as a guide. This is because fish culture techniques can be species, site, or season specific, and differences among hatcheries may exist with regards to facilities, man power, and culture conditions. However, significant changes to procedures outlined in this document must be documented so that potential improvements in culture techniques can be included in future updates. Hatcheries affected by *Prymnesium parvum* ichthyotoxicity must use this document along with their *P. parvum* management plans (Appendices A and B). Similarly, all hatcheries must use this document in conjunction with their Hazard Analysis and Critical Control Point (HACCP) program and routine hatchery maintenance plans.

CHAPTER 1

Brood Fish Management

Brood Fish Procurement and Development

Blue catfish.– Blue catfish (*I. furcatus*) brood fish are collected from the wild. This practice is the best strategy as long as suitable wild brood fish are readily available. Because of the time it takes for blue catfish to reach sexual maturity, it is an inefficient use of resources to raise brood fish from fry when other options are available. In the past, blue catfish brood fish have been collected from Lake Livingston during striped bass brood fish collection in the spring. Limited numbers also have been acquired from Sam Rayburn and Toledo Bend reservoirs and from private producers. Newly acquired brood fish, regardless of the source, should be treated with a formalin bath of 150 mg/L for 30 min and quarantined for at least 45 days (Davis 1986) or according to established guidelines to isolate them from existing stocks. Ideally, water leaving the quarantine facility should be disinfected to prevent the introduction of pathogens through hatchery effluent into the receiving water body. Because recently acquired wild brood fish are unreliable spawners and less resistant to diseases (Dorman and Torrans 1987), they should be domesticated for 2-3 years before use (B. Hall, Jasper State Fish Hatchery, Jasper, Texas, personal communication).

The Jasper State Fish Hatchery (JSFH) located near Jasper, Texas uses blue catfish brood fish that are 4-5 years old and weigh 7-18 kg each for fry production. The JSFH produces all the blue catfish for TPWD and began a monitoring program involving PIT-tagging of brood fish in April 2005. This program will enable the staff to collect spawning data on individual brood fish and cull or replace those that do not spawn consistently or get too old. This tagging program also allows documentation and management of the genetics of these fish.

Imperial strain channel catfish.–The A. E. Wood Fish Hatchery (AEW) in San Marcos, Texas maintains the Imperial strain channel catfish (ISCCF) brood stock. The strategy for obtaining new brood fish is to collect a given number of fry from each spawn to create spawning cohorts. Ideally, each pair of brood fish must contribute progeny to the next generation, but that is impractical to achieve or monitor in a production setting. The AEW strategy provides each pair of brood fish an equal chance of contributing to the resulting cohort. A broodfish year class is created by taking 500 fry from each spawn and placing them in feeding trays separate from the production fish. Once fry have begun feeding, they are enumerated and vaccinated for enteric septicemia of catfish (ESC) disease. These fry are stocked into ponds and reared the same way as production fish to 12-inch total length. Once the fish are about 1.5 years old, 400 are randomly taken from the group and reared in a pond for future brood fish, and the rest are used for 12-inch stockings.

The ISCCF are fast growing and should be managed such that they don't get too big too quickly. These brood fish can become too large for spawning containers and too expensive to feed. Two-year-old ISCCF can be sexually mature; however, fish that are at least 3 years old and weigh at least 1.3 kg (3 lb) are reliable spawners (T. D. Bates, USDA Catfish Genetics Lab, Stoneville, Mississippi, personal communication; Kelly 2004). Channel catfish 4-6 years old and weighing 1.8-3.6 kg (4-8 lb) are considered prime spawners (Kelly 2004). Through proper feeding techniques, 2- and 3-year-old fish can weigh 1.0-1.5 kg and 1.5-2.0 kg, respectively. Three to four years of maximum spawning potential and cost-effective holding in captivity can be expected after brood fish reach sexual maturity. Brood fish are culled after they reach 6 kg (6-7 years old) since they become too expensive and inefficient to keep due to increased feed requirements and pond space needs, respectively (T. D. Bates, USDA Catfish Genetics Lab, Stoneville, Mississippi, personal communication). Also these older or larger fish produce fewer eggs per kg female body weight, are more difficult to handle and may have difficulty entering spawning containers.

Based on historical spawning and hatch rate data and the current average annual catfish request, 200 pairs of channel catfish and 60-80 pairs of blue catfish of prime spawning age should be adequate for fry production each spring. It is recommended that alternative sources of brood fish be identified and evaluated for suitability based upon brood stock management practices and fish health records to be used in contingencies (e.g., when additional fry is requested or brood fish suffer massive mortality). Similarly, alternative sources of fry should be identified and used, if necessary, to supplement production fish.

Brood Fish Genetics

Genetic variation allows fish populations to adapt and survive over time, and inadvertent selection and subsequent loss of genetic variation may occur among hatchery fish as a result of domestication. Reduced genetic diversity or loss of alleles could be associated with decreased production performance either on the hatchery or in the wild. Practices designed to reduce inbreeding and the resulting selection of inappropriate traits in fish stocked in the wild are outlined in the Inland Fisheries Fish Hatchery Genetics Plan (Fries et al. 1996). Recent advances in molecular biology allow evaluation of genetic diversity at a large number of loci using minimally invasive techniques (Waldbieser and Wolters 1999). Each cohort of channel or blue catfish brood fish can be genetically profiled, and the data can be used to evaluate the efficacy of the broodfish replacement program. Whenever channel or blue catfish are acquired from sources other than TPWD fish hatcheries, their genetic and health status must be evaluated. Fish exhibiting high levels of phenotypic variation likely are inbred, and their use should be restricted to put-and-take fisheries.

Brood Fish Holding

Stocking.–Over-stocking of brood fish holding ponds can result in reduced growth and resistance to disease, poor water quality, poor egg production, poor egg quality, and poor fry quality. The latest information on the ISCCF used by TPWD recommends that, for optimum growth and condition, stocking rate in holding ponds should not exceed 1,300 kg/ha or 1160 lb/acre (T. D. Bates, USDA Catfish Genetics Lab, Stoneville, Mississippi, personal communication). Expected weight gain during holding should be considered in estimating the initial stocking rate. Also, catfish holding ponds should not be overloaded with forage or brood fish of another species. Production brood fish should be held in more than one pond to minimize the chances of catastrophic losses due to disease or water quality problems. Broodfish ponds should be checked daily for water levels, fish mortality, fish behavior, etc. Periodically, brood fish should be sampled and checked for condition, diseases, and parasites. Historically, for spawning success brood fish were managed to gain about 50% of their weight from one spawning season to the next (Jensen 1983); however, this is no longer a goal at Texas hatcheries. Currently, brood fish are fed a maintenance diet (Tables 1-3) to limit growth while providing just enough energy for optimum reproductive success.

Water Quality.–Water quality data for broodfish holding ponds should be used to determine appropriate water quality management strategies. Fresh water may be added to ponds by one of two methods to maintain or improve water quality:

- Fresh water enters ponds from the back and flows through the pond (pond flushing).
- Pond water levels are periodically lowered and refilled with fresh water (water exchanged).

The most important variables to manage in broodfish holding ponds are dissolved oxygen and un-ionized ammonia:

- The dissolved oxygen data for broodfish ponds should be collected daily as soon as possible after sunrise. Fresh water should be added to ponds immediately if dissolved oxygen levels fall below 4.0 mg/L. Dissolved Oxygen is critical during the summer months when water has the highest temperatures and therefore holds the least amount of oxygen.
- Un-ionized ammonia should be measured weekly. Ammonia can adversely affect catfish feeding, growth and resistance to disease. For optimum health un-ionized ammonia levels should not exceed 0.12 mg/L for continuous exposure (Piper et al 1982), and total ammonia levels should not exceed 2.5 mg/L for continuous exposure (Stickney 1994). Because ammonia toxicity is influenced by several water quality variables (e.g., temperature, pH, oxygen concentration, carbon dioxide concentration and salinity), each facility should establish an un-ionized ammonia threshold limit for taking remedial action to prevent brood fish from suffering exposure to high ammonia concentrations.

See Table 4 for general recommendations for water quality variables in catfish culture.

Feeding.–Good nutrition is essential to insure proper growth and condition, resistance to diseases, and successful spawning of catfish. Brood fish should be fed a complete artificial diet containing 36% protein (Jensen 1983), or a complete diet containing 30-36 % protein during warmer weather (21-29.5°C) and 25-30% protein during cooler weather (10-21°C) (Dorman and Torrans 1987). As with any species of fish, over-feeding can result in deterioration of water quality. Feeding activity slows greatly with the onset of the spawning season or under low water temperature conditions, so attention must be paid to feeding vigor. Offer all the feed the fish will consume in about 20 min during warm weather. Use the broadcast feeding method to distribute artificial feed evenly onto the pond surface. A study comparing feeding frequencies (once, thrice, or six times per week at 1.0-1.5% body weight) using ISCCF brood fish found the once per week feeding provided the best growth (D. R. Yant, Gold Kist, Inc., Inverness, Mississippi, personal communication). For spawning success, a rule of thumb is to feed brood fish 2 days per week in spring and fall, 1 day per week in winter, and 3-4 days per week in summer (Steeby and Brunson 1997). Brood fish can also be fed live forage fish to supplement the artificial diet and promote excellent health and egg development. The feeding ration should be 0.5 kg of forage per kg of brood fish (1.1 lb of forage per lb of brood fish) per year. General catfish broodfish feeding guidelines for artificial diets and forage are presented in Table 1 and Table 2, respectively. Specific feeding guidelines for ISCCF brood fish are in Table 3.

Disease Control.–Catfish suffer from a variety of diseases including viruses, bacteria, fungi, ciliates, helminthes, and parasitic copepods (Table 5), with stress as the predisposing factor. Thus, successful disease prevention depends on stress avoidance by eliminating or at least minimizing the factors (poor water quality, poor nutrition, handling, sudden water temperature changes, and overcrowding) that cause stress.

Brood fish should be periodically inspected for disease. Two common catfish diseases are columnaris and "Ich". Columnaris is caused by the bacteria *Flexibacter columnaris* that usually become active at water temperatures greater than 18°C, thus most outbreaks occur in the summer. However, there are virulent strains that attack fish in cooler waters. Columnaris is identified by gray-blue or white necrotic circles surrounded by inflamed tissues. Columnaris lesions are covered by a yellow slime and sometimes resemble a saddle in shape, hence the name saddleback disease. Columnaris attacks not only the skin but also the gills, causing extensive gill necrosis. As the name suggests, this bacteria has the unique trait of aggregating in clumps or "haystacks" and forming distinct columns (Lasee 1995). Microscopic examination of gill or dermal wet mounts will reveal long slender Gram-negative rods, usually in the characteristic "haystack" colonies. This disease may be prevented by not overcrowding fish, especially in warm temperatures.

"Ich" or "white spot disease" is causes by the ciliated protozoan *Ichthyophthirius multifilis*. Its life cycle is completed in 3-4 days at 21-24°C (69.8-75.2˚F), 2-3 weeks at 15.5°C, more than 5 weeks at 10°C, and months at lower temperatures (Lasee 1995). The infection appears as gray-white lumps, similar to grains of salt, on the skin and gills of fish. Fish infected with "Ich" tend to congregate at the water inflows and exhibit "flashing" behavior. Flashing is the fish rubbing themselves against the sides or bottom of a culture unit in an attempt to rid themselves of the disease-causing organism. This parasite has a large horseshoe-shaped nucleus, visible in live specimen under a microscope, used for positive identification. Because the organism resides under the epithelium of the skin, fin and gills, control of the disease is difficult. Success of eliminating or reducing the infection may be achieved by increasing water flow to carry away the tomites (the infecting life stage) before they locate a host.

Potential disease problems should be monitored and treated according to approved New Animal Drug Application (NADA) or Investigational New Animal Drug (INAD) methods or according to label instructions for FDA-approved drugs. Future channel catfish brood fish are vaccinated for enteric septicemia of catfish (ESC), but it is unknown how long the vaccine provides protection. Staffs do not routinely see ESC so this practice will continue until there is evidence that the vaccination is ineffective.

TPWD hatcheries should avoid brood stocks or sources of brood fish that cannot provide satisfactory disease screening records to prevent disease importation. In addition to ESC and channel catfish virus disease (CCVD), there are new and emerging diseases in both species of catfish that should be avoided. Two helpful disease identification and treatment publications are *Introduction to Fish Health Management* (Lasee 1995) and *Fish Medicine* (Stoskopf 1993).

Draining.–Draining and harvesting of broodfish holding ponds should be performed in early spring and at the time of day most likely to minimize temperature- and handling-related stress whether ambient temperatures are cold or hot. Handling of brood fish should be kept to a minimum. Transfer tanks should be equipped with compressed oxygen and contain a 0.5% salt (sodium chloride) solution. Tempering is necessary if there is a difference of more than 3°C (37.4°F) between hauling water and receiving water.

CHAPTER 2

Spawning Procedures

Pairing of Brood Fish

Sexing.–Both primary and secondary sex characteristics are useful in distinguishing males from females. Secondary sex characteristics are those not directly related to reproduction, such as body shape and coloration. Males are usually larger and have broader heads than females. As the spawning season approaches, males become lean, develop large muscular heads, and sometimes become dark. The heads of females are narrower than their bodies when viewed from above. They also develop soft, swollen bellies. Always confirm sex by examining the genitals for the primary sex characteristics. This is important with young fish and during the non-spawning season when secondary sex characteristics are less pronounced.

To examine the genitals, turn the fish belly-up. Two or three openings are present. The opening nearest to the head is the anus, while the one nearest to the tail is the genital opening. The genital opening of the male is at the end of a fleshy nipple-like structure called the genital papilla. The papilla usually becomes swollen and rigid as spawning season approaches. The genital area of the female catfish is oval and flat with two openings separated by a small flap of skin. A slit or groove is located at the head end of the genital area. A small urinary opening is located at the tail end. The female genital area often becomes red, swollen and covered with mucus as spawning time approaches. Sometimes a pulsating of the genital area can be seen (Bowling 1990). See Norton et al. (1976) for a technique for sexing channel catfish regardless of body size or state of gonadal maturation.

Size.–Broodfish pairs may be of similar size, but it is preferable for the male to be slightly larger than the female. The weights of males and females should be recorded for each pen along with the pen identification number. The JSFH uses 7-18-kg (15.4-40-lb) blue catfish for pen spawning in a pond. The ISCCF are spawned primarily in pens in raceways at the AEW. A female catfish will typically deposit 6,000-8,000 eggs/kg (2,700-3,600 eggs/lb) of body weight.

Temperature.–Blue catfish can be paired when water temperatures are consistently above 18°C (64.4°F) (Bowling 1990). However, recent production data have shown that the optimum temperature for spawning blue catfish at the JSFH appears to be 21°C (69.8°F). Channel catfish should be paired when water temperatures are consistently above 21°C (69.8°F); although, the optimum temperature for spawning appears to be 27°C (80.6°F) (Brown 1971). The ISCCF spawn when water temperatures are 21–29°C (69.8-84.2°F). At AEW, the optimum spawning temperature for ISCCF appears to be 24°C (75.2°F) in raceways or ponds.

Pen Spawning

Pen spawning has several advantages: (1) provides control over time of spawning, (2) allows selected individuals to be paired, (3) facilitates removal of spent fish to a separate pond where they can be given special care, and (4) pens protect spawning pairs from intruding fish (Huner and Dupree 1984a). Ponds for pen-spawning should be allowed to dry completely for several weeks to ensure good levels of dissolved oxygen when filled. Pen-spawning ponds or raceways should have water flowing through them to maintain good water quality. Dissolved oxygen and temperature should be recorded daily for spawning ponds or raceways, and dissolved oxygen should be maintained above 5.0 mg/L.

Preparation of raceways for spawning should include checking water flow meters and oxygen or low pressure air equipment for proper operation. The water source lines and the recirculation lines should be thoroughly flushed prior to cleaning. Raceways should be cleaned and disinfected (10 % formalin) prior to pen installation. At AEW, pens are installed at 24 per raceway (80 ft long x 8 ft wide x 3.2 ft high).

Pen size should be determined by size of brood fish or spawning container; however, a minimum pen size might be 122 cm long x 61 cm wide x 91 cm high (4 ft long x 2 ft wide x 3 ft high). At JSFH where 55-gal drums are used as spawning containers, pens average 445 cm long x 94 cm wide x 94 cm high (14.5 ft long x 3 ft wide x 3 ft high). At AEW pens for raceways are 70.5 ft long x 2.8 ft wide x 3.5 ft high. When using spawning pens, ensure the water is deep enough to cover the spawning containers but not too deep to allow the fish to escape from pens. At AEW water depths in raceways are 2-2.5 ft. Stocking rate is one male and one female per pen.

Raceways are kept as dark as possible by turning off overhead lights; however, the entire raceway area may not be in total darkness due to spawning requirements of other fish species in the building. Activities and noise around spawning raceways must be kept to a minimum after brood fish are paired, especially at night and during early morning when most of the spawning occur.

Pond Spawning

Use of the open-pond spawning method can save raceway space. Disadvantages include inability to estimate the numbers of eggs/kg female, males are more likely to eat spawns, and re-pairing is not possible as compared to pen spawning. Spawning ponds must have excellent water quality so they should be filled with fresh water just before pairing the brood fish. If these ponds are previously used (e.g., for fingerling production), they should be allowed to dry and exposed to air for several weeks before being used for spawning catfish. As with pen spawning, dissolved oxygen and temperature should be recorded daily. Stocking rates of 50-330 fish/ha (123-815 fish/acre) or 896-1,344 kg/ha (800-1200 lb/acre) are recommended (Bardach et. al. 1972; Steeby and Brunson 1997; Kelly 2004), and rates should not exceed 1,344 kg/ha (1,200 lb/acre) (Avault, 1996). Usually, the higher stocking rates are used when the eggs are removed for hatching at another location. Male-to-female ratios of 1:1 or lower are used, but the rate should not be less than 2:3 (Steeby and Brunson 1997; Kelly 2004).

Spawning Containers

Spawning containers can be wooden boxes, ammunition cans, drums, large flower pots, ceramic jugs, kegs, and etc of large enough internal volume (e.g., 20 - 55 gallons) and proper dimensions to allow both male and female catfish to be inside at the same time. Ceramic (or other breakable) spawning containers must be checked for cracks that may result in breakage and injury. Containers preferably should have only one opening that is large enough for the male (e.g., 10-12-lb) or bigger fish to freely enter and exit. Most spawning containers have openings of 6-9 inches across (Kelly 2004; Steeby and Avery 2005); however, TPWD facilities have used containers with 6 -24-inch-diameter openings with success.

Spawning containers should be placed in 2-3 ft of water where conditions are conducive to spawning (Steeby and Avery 2005). Values of pH exceeding 9.5 can deter spawning activity or cause poor egg quality (Steeby and Brunson 1997), and dissolved oxygen levels below 4 mg/L appear to reduce spawning success (Steeby 1987). In ponds, the open ends of containers should face the center of the pond to prevent wave action from forcing mud or silt into containers (Davis 1986; Kelley 2004). For open-pond spawning, containers should be placed around the perimeter of the pond at 10-40 ft apart (Kelly 2004; C. Thibodeaux, A. E. Wood Fish Hatchery, San Marcos, TX, personal communication), and each provided with a float to indicate location. Placing containers in ponds about 7-10 days before spawning begins allows the males to establish their territories (Kelly 2004). In raceways spawning, containers are placed with the openings facing upstream.

In open-pond spawning, the ratio of containers to female brood fish (or spawning pairs) may vary depending on whether eggs are removed from ponds for hatching elsewhere or allowed to hatch in the pond. If eggs are transferred from ponds, a container-to-female fish ratio of 1:3, 1:4, or 1:5 is adequate (Kelly 2004; Steeby and Avery 2005). If eggs are not removed from ponds, then more containers should be provided because each container will be occupied for a longer period of time (Kelly 2004).

Hormone-Induced Spawning

Hormone-induced spawning using human chorionic growth hormone (HCG) injection has not been demonstrated to be efficacious in catfish. Studies at TPWD catfish-spawning facilities which injected 50% of the brood fish with HCG resulted in no statistically or biologically significant production difference in either channel or blue catfish. Other hormones for inducing spawning have not been investigated by TPWD staff.

Spawn Collection

Spawning containers should be checked for spawns daily or at 2-3-day intervals. Late morning is the best time to check containers because most of the spawning occurs at night or early morning. Brood fish will sometimes eat or dislodge eggs, so the eggs should be removed from the spawning containers as soon as they have turned dark yellow. Catfish eggs are adhesive and stick to spawning container surfaces. The eggs should be gently loosened from the container surfaces with a plastic spatula and placed into a bucket or McDonald jar containing spawning water. Preferably, there should be one spawn per bucket. However, should multiple spawns be carried per bucket, there should be no more than one spawn per

2 gallons of water and no more than two spawns per 5-gallon bucket (Davis 1986). These eggs should be protected from direct sunlight and taken indoors immediately to initiate artificial incubation. If eggs cannot be taken to the incubation facility immediately (i.e., in 10 min), aeration should be provided (Davis 1986) and dissolved oxygen maintained at approximately 5 mg/L. If spawning water and incubation water are of different quality, the eggs must be acclimated to the conditions of the incubation water.

Brood Fish Removal

When spawning activity ends or the need for eggs is met, brood fish should be moved from the spawning ponds or raceways to prepared winter holding ponds. Brood fish should receive a 3% salt solution dip before stocking into holding ponds. A description of pond preparation for fish stocking is presented in Chapter 4.

CHAPTER 3

Egg Incubation and Fry Production

Egg Hatching

The preferred method for incubating blue or channel catfish eggs is the use of McDonald hatching jars. This method allows better water circulation around eggs, reduces disease infections (Suppes 1972), and makes treatment of diseases easier. Jar incubation requires that the glycoprotein matrix that holds the eggs in a mass be dissolved, which is accomplished by using a pH-buffered 1.5% sodium sulfite solution (Isaac et al., 1991; Appendix C). After the matrix has been dissolved, the eggs are enumerated using the volumetric displacement method or a Jensorter to determine the number of eggs per gram. The volumetric displacement method requires a minimum of three 1-mL samples to be counted separately to determine the average number of eggs/mL. The total number of eggs is obtained by multiplying the average number of eggs/mL by the total volume of eggs or the average number of eggs/gram by the total weight (gram) of eggs.

After egg enumeration, eggs are gently placed into hatching jars containing water at rates of 10,000-40,000 eggs/jar (Dorman 1993; B. L. Hall, Jasper State Fish Hatchery, Jasper, Texas, personal communication). Water flow into each jar should be set at 2-3 L/min or enough flow to cause all eggs to gently suspend and roll to prevent suffocation and fungal infection without the eggs floating out of the jar. The time required for catfish eggs to hatch depends on water temperature. The optimum temperature range for egg incubation is 25-27°C (77.0-80.6°F), and eggs hatch in 6-10 days at these temperatures (Dorman 1993). Temperatures below 21°C (69.8°F) or above 29°C (84.2°F) should be avoided during egg incubation (Huner and Dupree 1984a). Lower temperatures are associated with a higher incidence of fungal infections and higher temperatures usually result in weaker fry (Davis 1986). Stages of channel catfish egg development at 25.5°C (78°F) are given in Table 6. For each increase of 2°F (1.1°C) above 78° F, subtract one day from the incubation time and for each 2°F (1.1°C) decrease below 78°F, add one day to the incubation time. Dissolved oxygen of at least 6 mg/L and pH of 6.5-8.0 should be maintained in egg incubation systems (http://aquanic.org/publicat/state/ga/catfish.htm).

Fry Enumeration and Rearing

When newly hatched fry (sac-fry) begin to darken in color in about 3 days after hatching, they are enumerated and moved into feeding trays (234 cm long x 55 cm wide x 29 cm high) at rates of 60,00-80,000 fry/tray. Fry should be moved before they reach the swim-up stage; otherwise, they will swim out of hatching jars into receiving aquariums, making the transfer into feeding trays more difficult. Catfish fry should be enumerated using a volumetric displacement method, or by three counts of approximately 5 gram of fry each when they are small (ready for feeding trays) or three counts of 10 gram of fry each when they are larger (ready for pond stocking) to determine the number per gram. Multiply the average number per gram by the total weight (in grams) of fry to get the total number of fry produced. Catfish fry can also be enumerated as described in Appendix D (Hall et al. 2001).

The sac-fry are held in feeding trays until they absorb their yolk sacs, develop a dark color, and swim to the water surface to seek food (3-6 days after hatching depending on water temperature). The swim-up fry are fed a finely ground starter feed (#0) of, at least, 50% protein. These fry are fed about 4-6 times daily for 7-10 days. Feed amounts may range from 20-30 gram initially to approximately 100 gram by the time fry are ready for ponds (C. Thibodeaux, A. E. Wood Fish Hatchery, San Marcos, Texas, personal communication). The feed should be spread near the schools of fish, or over the entire water surface after fry are no longer in schools. Once fry are feeding well, they are ready for rearing ponds.

Desirable water quality must be maintained in feeding trays. This is accomplished by setting the flow-through water at 18-20 L/min or at a rate sufficient to exchange the water in the trays every two hours. Additionally, trays are cleaned, at least, twice daily by siphoning uneaten feed and other debris from tray bottoms. Aeration is provided through air stones.

CHAPTER 4

Fingerling Rearing Procedures

Pond and Raceway Preparation

Earthen ponds are allowed to dry and the bottoms disked, bladed, and packed. If necessary, earthen pond bottoms are sprayed with an approved herbicide to retard growth of rooted vegetation (Fassett 1966). Sediments should be removed from plastic-lined pond bottoms and from kettles of all types of ponds. Source water should be filtered through a 500-μm-mesh sock filter to prevent undesirable organisms from contaminating the ponds. Ponds may be completely filled before fish are stocked or initially filled to a pool to further train fry on artificial feed before filling completely.

Raceway water flow meters and oxygen or low-pressure air equipment are maintained and checked for proper operation. Raceways are then cleaned and disinfected (10% formalin solution). The water source and water recirculation lines should be thoroughly flushed prior to raceway cleaning. Water flow into raceways should be turned off and recirculation lines drained prior to cleaning to prevent recirculation of debris. Raceways should be filled to the desired level and the desired water flow rate (e.g., 100-400 gal/min depending on fish size or biomass) established before fish are stocked.

If baffles (baffles promote self-cleaning of raceways) are used in raceways, the bottom edges should be no less than eight inches and no more than 10 inches from the bottoms of the raceways. The height of baffles from a raceway bottom that allows proper functioning depends on water flow rate.

If demand feeders are used ensure the feeder trigger size matches fish size and feeders are adjusted to the appropriate feed size. Also, enough feeders should be provided for the number of fish in the raceway to prevent differential feeding that results in size variation among fish.

Water Quality

Excellent water quality is essential for successful catfish production. Table 4 contains general recommendations for several water quality variables important for successful catfish culture. Stocking densities, feeding rates, water temperatures, and the weather can affect water quality, especially dissolved oxygen and ammonia levels. Water quality data must be used to determine water quality management needs and strategies.

Water quality management is critical to catfish production in ponds, so water quality should be monitored regularly. To maintain or improve water quality, fresh water may be added to ponds by two methods: fresh water enters the pond from the back and flows through the pond (pond flushed), or pond water levels are lowered and fresh water added to refill ponds (water exchange). These remedial actions require a reliable source of quality water.

Dissolved oxygen data for fingerling production ponds should be collected just after sunrise and late afternoon, especially during the summer months when water temperatures are highest and the oxygen-holding capacity of water is minimal. Remedial action (pond flushing or water exchange) should be taken immediately if dissolved oxygen levels fall below 4.0 mg/L, and emergency aeration (done without disturbing pond bottoms) is recommended for dissolved oxygen levels less than 3 mg/L. While minimum dissolved oxygen levels in catfish fingerling rearing ponds should not fall below 4.0 mg/L for extended periods, lower levels may be tolerated by the fish for short periods. When low dissolved oxygen concentrations are predicted (Boyd 1990), remedial action should be taken immediately to prevent fish mortality. It is recommended that fresh water be continuously flowed (approximately 75-100 gal/min) through advanced catfish fingerling production ponds when feeding rates are high to prevent water quality deterioration. When a continuous flow of fresh water is impossible, and as water quality dictates, ponds should be drained to about half the volume and refilled with fresh water.

Attention should be paid to events or conditions that may be associated with oxygen depletion in ponds:

- after a heavy rain
- during periods of calm, cloudy days
- during periods of strong winds
- during the fall when air temperatures are rapidly cooling
- after chemical treatment of aquatic weeds
- if the water color changes suddenly

When any of these conditions exists, ponds should be monitored several times daily for signs of oxygen depletion which include:

- Large numbers of fish swim to the top to gulp air at night or early morning. If disturbed, they dive but quickly return to the surface.
- If oxygen depletion has not reached a lethal level, fish are at the surface in the early morning but return to deeper water as the oxygen level increases during the day. This may continue for several days, and remedial action should be taken immediately.
- Feeding habits suddenly change.

If a pond shows signs of oxygen depletion or the dissolved oxygen level in the top 3 ft of water is less than 3 mg/L, immediate action must be taken to reduce stress or prevent fish losses.

Ammonia adversely affects catfish growth and resistance to disease. For optimum catfish health, un-ionized ammonia levels should not exceed 0.12 mg/L for continuous exposure (Piper et al 1982), and total ammonia levels should not exceed 2.5 mg/L for continuous exposure (Stickney 1994). Water samples should be taken once weekly from production ponds for un-ionized ammonia and total ammonia measurements. Due to water chemistry differences, each facility should establish ammonia threshold limits for taking remedial action.

Flow-through raceways should have minimal water quality problems if adequate flow rates (e.g., 100-400 gal/min) are maintained. Raceways with re-circulating water or low flow may have increasing ammonia levels over time that can interfere with fish production, so ammonia levels should be monitored at least weekly. Adequate water exchanges and cleaning to remove uneaten feed are essential to maintaining good water quality in raceways.

Pond Stocking

Desired harvest density is an important consideration when determining stocking density. The maximum harvest weight for ponds with 6,117-L kettles and water-flow-through rate of 100 gal/min is approximately 2,532 kg or 5,582 lb (Table 7). Beyond this biomass, low dissolved oxygen levels become an issue. Additionally, potential poor feeding resulting from poor water quality should be considered when determining fish stocking density.

Stocking density also depends on the size of fingerlings desired at harvest. For example, swim-up fry stocked at approximately 500,000/ha (200,000/acre) produce 51-mm (2-in) fingerlings in approximately 60 days and at 37,500/ha (15,000/acre) produce 152-203-mm (6-8-in) fingerlings in 120 days (Bowling 1990). Under ideal conditions and a linear growth rate of 1.3 mm/day (0.05 in/day), 235 optimum growing days are required for channel catfish to grow from fry to 305 mm (12 in) total length. However, channel catfish may take up to 10-14 months to grow from fry to 305 mm (12 in) total length at Texas state hatcheries. Fry should be tempered to reduce stress before stocking into ponds.

To produce 51-mm (2-in) catfish, fry are stocked at approximately 370,600/ha (150,000/acre) to achieve the target size in about 25-40 days. These fry may initially be stocked into a pool or the pond kettle for about a week to train them to take artificial feed before filling the pond completely. The kettle is usually provided with cover (e.g., tarp) to protect the fry from direct sunlight, excessive heat, and predators.

For advanced channel catfish production, 51-75-mm fingerlings are stocked at approximately 24,700-37,050/ha (10,000-15,000/ac) to produce 229-mm (9-in) fish in about 80 days. Sparrow (1996) suggested that stocking catfish at these rates should provide good growth without the pond reaching its carrying capacity (Appendix E). An average growth rate of 1.7 mm/day and feed conversion ratio of 1.2 have been achieved at these rates. To achieve uniform growth in advanced catfish ($\geq$229 mm), rearing ponds should be stocked with quality, uniform-size fish.

Production of 305-mm (12-in) channel catfish involves stocking 229-mm (9-in) fingerlings at 12,350-14,820/ha (5,000-6,000/acre) for 80-110 production days.

Raceway Stocking

The TPWD has three hatcheries with capabilities to produce channel catfish fingerlings in raceways. At AEW, raceways used for catfish culture are approximately 80 x 8 x 3.2 ft in dimensions. Fry are stocked at 150,000-200,000 per raceway to produce 51-mm fingerlings whereas 51-mm fingerlings are stocked at approximately 6,000 per raceway for 229-mm (9-in) fingerling production. Water flow rates are maintained at 100-160 gal/min for fry culture to produce 51-mm fingerlings and 350-400 gal/min for 51-mm fingerlings culture to produce 229-mm fish. Light intensity is kept at a minimum, especially when source water lacks turbidity. Low-pressure airlines are often used to create air bubble curtains throughout the raceways to reduce noise and vibrations associated with an indoor culture facility. Staff continues to work to improve catfish production success in raceways. Appendix F contains an abstract of work done by Lyon and Engelhardt (2001) on raceway culture of channel catfish at the AEW facility. The study suggested late afternoon feeding, routine cleaning, and low light intensity are important factors for successful culture of catfish in raceways.

Feeding Catfish in Ponds

Feed consumption by catfish is directly related to water temperature, fish size, fish density, water quality, stress, and feed type. Feeding should be discontinued if dissolved oxygen levels fall below 4.0 mg/L at dawn, low dissolved oxygen is predicted for the next day (Boyd 1990), or signs of oxygen depletion are evident. Feeding regimes should be guided by these facts:

- Feed requirements for fish increase with increasing water temperature and decrease with increasing fish size (Foltz 1982).
- Feed requirement relative to fish body weight decreases with increasing size of fish.
- Food intake and not utilization is the growth limiting factor (Andrew and Page 1975).

General recommendations for feeding catfish are:

- Feed the fish and not the pond (i.e., avoid waste).
- Minimize size variability in fingerlings by achieving satiation in all fish.
- Avoid overfeeding fish.
- Use maintenance diets for over-wintering brood fish or 12-inch fish that require no additional growth.

Suggested best times to feed catfish are between mid-morning and mid-afternoon (Piper et al 1982). However, when channel catfish are fed to satiation daily, time of feeding does not seem to make any difference in water quality, feed consumption, feed conversion, or weight gain (Robinson et al 1995). Night feeding is strongly discouraged because of potentially poor water quality concerns, and feeding late in the day is discouraged because of increased metabolic oxygen demand during feeding and digestion.

Winter feeding may be beneficial to catfish but feeding at temperatures below 15°C (59˚F) appears to have little effect on growth. Feeding at 1% body weight in winter at temperatures above 12°C (53.6˚F) as often as fish will eat may promote good health (Tucker 1985). Three winter feeding regimes (no-feeding, 1% body weight feeding on warm days only, and 1% body weight feeding on alternate days) revealed no-feeding was detrimental whereas feeding improved fish condition and length. However, there was little difference between warm days verses alternate days feeding because they resulted in the same amount feed offered to the fish (Lovell and Sirikul 1974). Catfish should not be fed at temperatures of 10ºC or less (Dorman and Torrans 1987; Steeby and Drunson 1997).

Fry.–Feeding of fry in ponds should begin on the day of stocking. A 36% or greater protein catfish feed is recommended for fry. Target feed conversion ratios of no greater than 1:1.5 and continuous growth of 7.0 mm (0.25 in) per week should be maintained through proper feeding and water quality management.

Fry are fed at 0.5-1.0 kg per feeding, 3-4 times daily during the first week when they are in pools or kettles and 3 times daily during the second week when they are in open pond. After the second week, feeding regime is based on tables (e.g., Table 8). The feed should be broadcast along the perimeter of the pond.

Fingerlings.–When catfish fry reach the fingerling stage (≥ 0.5 in), TPWD hatcheries may use any of these three feeding methods in ponds:

- Feeding by percent of total body weight: This method is based on size of fish, water temperature, and fish biomass. Table 8 can be used to calculate daily feeding rates; however, the behavior of the fish during feeding should be used as an indicator of how much to feed and avoid waste.
- Feeding to meet established criteria: This approach involves determining a desired harvest length and feed conversion rate for the growing period, estimating growth rate for the growing period, and offering a pre-determined amount of feed daily (or according to a regime) in order to meet the criteria.
- Feeding to satiation: This method involves feeding fish whatever they will consume during morning hours after dissolved oxygen has begun to increase, by scattering the feed widely over the pond surface. A rule of thumb for feeding duration is when 90% of the feed is eaten within 15 min or less (Piper et al 1982). Pond-raised channel catfish fed to satiation daily had higher condition factor than those fed to half-satiation daily or fed to satiation every third day (Robinson and Rushing 1994).

The decision of which method to use is based on program assignment, fish density, overall feed consumption or feeding activity, and water quality. However, fingerlings in production ponds should be fed 1-2 times daily. Conversely, 12-inch fish on maintenance diet may be fed to satiation once weekly rather that feeding by percent body weight three times per week.

The feed may be delivered to the fish by hand, mechanical blowers, or demand feeders. When demand feeders are used, adequate units must be provided to prevent aggressive fish from dominating the feeding sites, which can results in significant size variation among fingerlings. The required number of demand feeders depends on the number and size of fish as well as the size and quantity of feed to be offered to the fish. Use of demand feeders on ponds may not be biologically beneficial. Fish using demand feeders may consume more feed but weight gain may not be different from that of hand-fed fish (Robinson et al 1995). In windy areas, feeding rings may be used along with any of the feed delivery methods to minimize loss of feed to the fish.

Feeding Catfish in Raceways

To train catfish fry to take artificial feed and to feed them more efficiently, the fry initially are crowded into one-half of the length of the raceway for 10-16 days, before they are released to occupy the whole raceway. Fry are hand-fed 3-4 times daily at 15% body weight initially. As the fish grows, the feeding rate declines to a minimum of 6% of body weight. Fish body weight is estimated from an established growth rate of 1.5 mm/day and the stocking rate.

Fingerlings may be fed by hand, demand feeders, or automatic feeders. Care must be taken when hand feeding to ensure fish have ample time to consume the feed as it floats through the raceway. The methods and most of the related issues discussed under "feeding catfish in ponds" also apply to feeding fish in raceways. Appendix G presents the abstract of a study on the effects of hand feeding verses demand feeding on water quality and production of channel catfish in indoor raceways (Wyatt and Barkoh 2002).

Raceway Maintenance

Baffles may be installed to provide self-cleaning of raceways. If baffles are not used, raceways must be swept clean daily with long standpipes removed or replaced with shorter standpipes. Frequency of raceway cleaning depends on rate of accumulation of sediments, waste, and feed. Sweep slowly to minimize disturbance and stress of fish, and sweep from "upstream" toward "downstream" end of raceway. A shorter standpipe also may be used to "fast-flush" raceway. Fast-flushing allows incoming water flow rate to remain the same while total water exchange occurs more often because the volume or capacity of the raceway is less due to the shorter standpipe.

Pond and Raceway Fish Harvest

When the target length of catfish is attained, fish in ponds or raceways should be harvested as soon as possible. Catfish can be harvested any time of the year but very hot or very cold temperatures should be avoided. If water temperatures are low, fish can be harvested any time of the day. However, when water temperatures are high, as in summer months, fish should be harvested as early in the morning as possible when water temperatures are minimal to avoid stress of fish due to hotter water late in the day. Dissolved oxygen levels should be monitored and maintained above 4.0 mg/L during water draw-down and fish harvest by allowing inflow of fresh water into ponds.

During harvest, ponds are drained and the fish are allowed to congregate, but not overcrowded, in the kettles (Table 7). Water in each kettle is continuously exchanged by flowing fresh water through it throughout the harvest to maintain water quality. Catfish are harvested by dip-netting and carrying them quickly into transfer tanks or hauling units. If fish are to be carried far from the ponds, they should be carried in buckets containing pond water. No more than 10 lb of 2-inch fish or 15 lb of advanced fingerlings should be carried in a hand net at one time, and no more than 15 lb of fish be carried in a 5-gallon bucket of water (Davis 1986).

To harvest fish in raceways, the water levels are drawn-down to crowd the fish by replacing long standpipes with shorter standpipes. The amount of water remaining in a raceway should depend on the biomass of the fish (watch fish behavior). Water flow through the raceway is increased to avoid water quality deterioration or stressing of fish by having a lot of fish in a relatively small volume of water. The fish are crowded to one end of the raceway and harvested by dip-netting them into transfer tanks or hauling units as described for ponds.

Transfer tanks and hauling units should be equipped with compressed oxygen and contain a 0.5% salt solution. Water in these tanks should be well aerated, with dissolved oxygen at or near saturation before they receive fish. Fish should not be exposed to sudden changes in temperature when being moved from pond to transfer tank or hauling unit. Loading densities and dissolved oxygen concentrations of transfer tanks and hauling units should be monitored to ensure fish are not stressed.

Fingerling Enumeration

Proper sampling is important to achieving the best estimate of numbers of fingerling catfish. When sampling a fish population, all fish in the population must have an equal chance to be taken in the sample. Thus, taking fish samples while a pond is still draining is inappropriate since the samples may be unrepresentative of the population. For most ponds (i.e., without well-designed harvest kettles) the best approach is to harvest all the fish into a hauling or holding unit and taking the samples from the unit. If the fish are held in well-designed harvest kettles, troughs, or raceways, they must first be crowded before sampling. The degree of crowding depends on the condition, species, and size of the fish as well as quantity of fresh inflow water. After crowding, a deep and fast dip is taken through the entire water column, alternating taking the samples from the upper and lower ends of the holding unit. All the fish taken in the net sample must be used for the enumeration. If the fish are to be transported that day, the samples can be taken directly from the hauling compartments. Take at least two samples from each compartment and determine the average number and size (length and weight) of fish for each compartment. Sampling calculations (average length and number of fish/kg or number of fish/lb) can be checked against a standard length-weight relation table (Piper et al, 1982) to see if the estimates are good.

CHAPTER 5

Fish Transportation

Preparation and Loading

Fish should be taken off feed for approximately 48 hours before transport. Loading factors to consider are water temperature, hauling time, condition and size of fish, transport equipment, and fish species (McCraren 1978). All equipment should be checked for proper operation on the day before a trip. Transport tanks should be equipped with compressed oxygen with a back-up system of agitators. Ideally, the transport tank should be filled with the same water as that holding the fish; otherwise, the fish should be acclimated to the conditions of the transport water before loading. The transport water should contain 0.5% salt, an anti-foaming agent, and dissolved oxygen concentration of 6.0 mg/L and below saturation. Table 9 presents estimated weights of channel catfish hauled per gallon of water at 18.3° C (65° F) (McCraren 1978; Piper et al 1982). Loading rates may be increased by 25% for each 5.5°C (10°F) decrease and decreased by 25% for each 5.5°C (10°F) increase in temperature. Ice can be used to reduce transport water temperature. One-half pound (0.22 kg) of ice per gallon (60 g/L) of water will reduce water temperature by about 5.5°C (10°F). Each hatchery should use Table 9 as guide to develop loading criteria for transporting the different species and sizes catfish. Table 10 shows hauling volumes, densities, and durations that have been successful for TPWD hatcheries.

Transportation

Drivers should take the most direct and safe route from the hatchery to the stocking site. The oxygen delivery system, the dissolved oxygen and temperature of the hauling water, and the condition of the fish should be checked every hour during transport. The dissolved oxygen should be maintained at 6 mg/L and below saturation by proper adjustment of the oxygen delivery system, and the temperature (20-30°C) maintained with ice, if necessary. For high hauling densities or long hauling distances cooler temperatures are recommended.

Stocking

At the stocking site, catfish should be gradually acclimated from the transport water conditions to that of the receiving water before stocking. Tempering of the fish may be achieved by gradual or intermittent exchange of the transport water with the receiving water. A portable water pump may be used to pump water into the transport tank during the water exchange process. Proper tempering requires 20 min for every 12°C (21.6°F) change in water temperature. If there is any question about the water chemistry differences (pH, salinity, etc.) between the transport water and the receiving water, fish should be tempered for a minimum of 15 min. After tempering, the fish should be carefully released with the transport water into the receiving water body.

All stockings should be coordinated with the appropriate district management office. District biologists should be informed of a pending stocking a week before the stocking and on the day of stocking, preferably before the driver leaves the hatchery.

CHAPTER 6

CHAPTER 6: Data Reporting

Water quality, spawning, fingerling production, and trip sheet data should be entered into the Fish Hatchery Data System (FHDS) according to procedures in the Data Management Plan on the "N" drive (N:\IF Hatcheries\Data Management) of the TPWD server. Catfish held in over-wintering ponds are to be designated cycle 7. Appendix H contains the Data Management Plan, current at the time of preparing this manual. The "N" drive should be checked periodically for changes and updates to the plan and for program deadlines.

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Table 1.–Artificial diet feeding regimes for catfish brood fish at different water temperatures (After Warren 2002).

Water temperature	Percent of body weight to feed	Feeding frequency
21°C and above	3	Daily
21 – 12 °C	1	Three times weekly
11-12°C	1	Once weekly or on warm days
10°C or less	-	No feeding

Table 2.–Catfish brood fish forage feeding rates, May through November (After Warren 2002).

Feeding period	Percent of yearly need
May - June	30
July	20
August	10
September	20
October - November	20

Table 3.–Imperial strain channel catfish brood fish feeding regime.

Month	Activities
July	Stock broodfish ponds at 11,115 kg per ha. Begin feeding a 32% protein floating feed once a week at 1% of body weight. Provide supplemental forage at 1% body weight.
August – September	Continue above feeding program.
October	Begin feeding fish twice a week at 2% of body weight. Continue providing forage at 1% body weight.
November	When water temperatures fall below 15°C, resume feeding once a week at 1% body weight.
April	When water temperatures rise above 15°C, resume feeding twice a week at 2% body weight until fish are harvested for spawning.
May – June	Spawning

Table 4.–Optimal and tolerated levels of selected water quality variables for growth of channel catfish (Tucker et al. 1990).

Variable	Optimal level	Tolerated level
Salinity (ppt)	0.5 – 3.0	< 0.1 – 8.0
Temperature (°F)	80 - 85	32 - 104
Dissolved oxygen	5 - 15 ppm	2 ppm - 300 percent saturation
Total alkalinity	20 - 400 ppm as $CaCO_3$	< 1 to >400 ppm as $CaCO_3$
Total hardness	20 - 400 ppm as $CaCO_3$	< 1 to >400 ppm as $CaCO_3$
Carbon dioxide	0 ppm	Depends on dissolved oxygen concentration
pH	6 - 9	5 - 10
Un-ionized ammonia	0	< 0.2 ppm as N
Nitrite	0	Depends on chloride concentration
Hydrogen sulfide	0	< 0.01 ppm as S

Table 5.–Catfish diseases and control measures.

Disease	Agent	Type	Symptoms	Measures
Channel catfish virus disease		Virus	Reduced feeding activity; erratic swimming behavior; sometimes spiral; alternating hyperactivity and lethargy; swollen abdomen; distended vent area; bulging eyes; hemorrhaging	No treatment; good management practices
Enteric septicaemia	*Edwardsiella ictaluri*	Bacterium	External hemorrhages on underside and around mouth; white focal lesions on fish back and sides; occasionally grey lesion on top of head that can erupt to an open lesion	Oxytetracycline; Sulfamethoxine; Ormetoprin
Columnaris disease	*Flavobacterium columnare*	Bacterium	White spots on mouth, edges of scales and fins; cottony growth around mouth; fins disintegrate at edges; 'saddleback' lesion near dorsal fin; fungal invasion of gills and skin	Oxytetracycline; Sulfamethoxine; Ormetoprin
Aeromonas septicaemia	*Aeromonas hydrophila; A. sobria*	Bacteria	Fraying and reddening of fins; depigmentation; ulcers	Oxytetracycline; Sulfamethoxine; Ormetoprin
Water mould	*Saprolegnia* spp	Fungi	Gray/white patches on skin or gills resembling cotton-wool, later becoming brown or green; normally small, focal infection spreading rapidly over body or gills	Formalin
Gill and/or external parasites	*Trichodina* sp; *Trichophora* sp; *Ambiphrya* sp; *Ichthyobodo* sp; *Ichthyophthirius multifiliis*	Protozoans	Small white spots on skin or gills; irritation, flashing, weakness, loss of appetite, and decreased activity; gills pale and very swollen	Formalin

Table 5.–Catfish diseases and control measures (*Continued*).

Disease	Agent	Type	Symptoms	Measures
Proliferative gill disease	*Aurantiactinomyxon* sp; *Deo digitata*	Myxozoans	Swelling and red and white mottling of gills gives raw minced meat appearance	Formalin
Copepod parasites	*Ergasilus* sp; *Argulus* sp; *Lernaea cyprinacae*	Copepods	Visible parasites on gills	Formalin
Other parasites		Helminths; cestodes; trematodes		Formalin

Table 6.–Stages of channel catfish egg development at 25.5°C (78°F). For each increase of 2°F (1.1°C) above 78°F, subtract one day from incubation time; for each 2°F (1.1°C) decrease below 78°F, add one day to incubation time (After Warren 2002).

Distinctive features	Age (days)
No internal pulsation	1
Pulsation visible	2
Bloody streak visible	3
Entire egg bloody	4
Eyes visible	5
Embryo moves in egg shell; eyes prominent	6
Embryo development complete; no bloody streak	7
Embryo begins to break from shell	8

Table 7.–Quantities of advanced channel catfish successfully held in different sizes of harvest kettles at the A. E. Wood and Dundee fish hatcheries (Source: TPWD hatchery database).

Pond size (acre)	Kettle volume (L)	Number of fish	Length of fish (mm)	Total weight (kg)
1	6,117	7,454	351.7	2,803
1	6,117	8,595	276.2	2,693
1/2	4,653	1,500	408.1	897
1/2	4,653	3,100	357.0	1,188
1/2	4,653	2,477	323.0	964
1/4	3,830	1,726	356.1	637
1/4	3,830	1,807	356.0	822

Table 8.–Amounts (% body weight) of different feed sizes to feed to different sizes of fingerling catfish at various water temperatures (After Warren 2002).

Fish length (inches)	Feed size	Average daily water temperature °F (°C)								
		65 (18.3)	67 (19.4)	69 (20.5)	71 (21.7)	73 (22.8)	75 (23.9)	77 (25)	79 (26.1)	81 (27.2)
0.5-1.0	1	3	4	4.3	4.5	5	5.3	5.5	5.7	5.9
1.0-2.0	2	2.5	3.5	3.8	4.2	4.4	4.6	4.8	5	5.2
2.0-4.0	1/16 in	1.2	2.4	3.6	4.8	6	7.2	8.4	9.6	10.8
4.0-6.0	1/8 in	0.7	1.4	2.2	2.9	3.6	4.3	5	5.8	6.5
6.0-8.0	3/16 in	0.5	1	1.5	2.1	2.6	3.1	3.6	4.1	4.6

Table 9.–Estimated catfish weights (lb) per gallon of water that can be transported for three time durations at 18.3ºC (After Warren 2002).

Weight of fish (no. per lb)	Transport time 8 h	Transport time 12 h	Transport time 16 h
1	6.30	5.50	4.80
2	5.90	4.80	3.45
4	5.00	4.10	2.95
50	3.45	2.50	2.05
125	2.95	2.20	1.80
250	2.20	1.75	1.50
500	1.75	1.65	1.25
1,000	1.25	1.00	0.70
10,000	0.20	0.20	0.20

Table 10.–Hauling durations for selected quantities of advanced catfish (Source: TPWD hatchery database).

Trailer volume (L)	Number of fish	Total weight (kg)	Length of fish (mm)	Hauling time (h)
2,450	4,477	533	242.7	9.0
2,427	4,057	483	242.7	9.0
2,607	4,956	590	242.7	9.0
2,343	4,418	526	242.7	9.0
2,450	997	380	344.0	6.5
2,427	994	361	334.5	5.5
2,343	815	474	362.0	4.5
2,692	995	411	362.0	5.0

Figure 1.–Fish harvest data form

CULTURE WORKSHEET

DATE:____________________ CULTURIST'S INITIALS:_________________

ACTION: INITIAL STOCKING | SECONDARY STOCKING | SAMPLING | MORTALITY | PARTIAL HARVEST | FINAL HARVEST | ABORTED

USAGE: HOLDING | SPAWNING | FRY REARING | FINGERLING REARING | SPECIAL REARING | DISPLAY

POND TROUGH JAR CIRC-TANK # ________ SPECIES: ____________

TOTAL NUMBER: __________ TOTAL WEIGHT OR VOLUME: ____________ kg g ml

MEAN LENGTH: ___________ mm (-) AVERAGE WEIGHT: ____________

SOURCE _________________ CYCLE __________ DESTINATION _____________________

NOTES: ____

____

1.	21.
2.	22.
3.	23.
4.	24.
5.	25.
6.	26.
7.	27.
8.	28.
9.	29.
10.	30.
11.	31.
12.	32.
13.	33.
14.	34.
15.	35.
16.	36.
17.	37.
18.	38.
19.	39.
20.	40.

Figure 2.–Fish length data form

FISH LENGTH DATA
Hatchery:____________________ Date of Collection: _____________

Pond #	**Sample number (T.L. in mm)**										**Ave.**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	

APPENDIX A

Dundee State Fish Hatchery *Prymnesium parvum* Management Plan

DENNIS G. SMITH

Abstract

This management plan was prepared as a guide to control the toxic alga *Prymnesium parvum* and its ichthyotoxin and eliminate, or at least minimized, its adverse impact on fish production. The plan includes monitoring presence and abundance of *P. parvum* and concentration of un-ionized ammonia nitrogen, and application of effective chemical treatments. Ammonium sulfate is applied at concentrations to raise the un-ionized ammonia nitrogen concentrations to 0.2-0.4 mg/L when water temperatures are 15°C or higher, and copper sulfate (or Cutrine-Plus) is applied at 0.2-0.4 mg Cu^{2+}/L when water temperatures are up to 15°C. The selected target concentrations of un-ionized ammonia nitrogen and copper depend on the tolerance of the fish that would be exposed to the treatments.

Introduction

The Dundee State Fish Hatchery is located in Archer County, Texas below Lake Diversion which supplies water to the hatchery. The hatchery has 97 ponds: 73 are plastic-lined totaling 24 ha (59.5 acres) and 24 are earthen ponds totaling 9.3 ha (23 acres) of surface water. Other culture units include four outdoor raceways and indoor 12, 1.8-m fiberglass round tanks, 90-jar egg incubation system and 4-trough (970-L) rearing system. All indoor culture systems can be operated as flow-through or closed systems. The spawning and rearing building which houses the indoor culture units also is equipped with an ozone generator and UV system for treating lake water containing *Prymnesium parvum* cells or toxins.

Fish species cultured at this facility include striped bass *Morone saxatilis*, palmetto bass (female striped bass × male *M. chrysops*), channel catfish *Ictalurus punctatus*, black basses *Micropterus* spp., koi carp *Cyprinus carpio*, rainbow trout *Oncorhynchus mykiss*, walleye *Stizostedion vitreum* and saugeye (female walleye × male *S. canadense*).

In 2001 fishes on the hatchery suffered substantial mortality from *P. parvum* ichthyotoxicity. Losses included 5.1 million striped bass and palmetto bass, 1,500 black basses, and thousands of channel catfish, rainbow trout and koi carp. Through the efforts of hatchery staff and the Hatcheries Golden Alga Task Force, strategies have been developed to control *P. parvum*. These strategies form the basis of the *P. parvum* management plan described herein. This plan continues to evolve and modifications are made to it as more effective or efficient solutions to the *P. parvum* toxicity problem are discovered.

Prymnesium parvum Management Plan

Pond Management

- Fill ponds well in advance of fish stockings to allow water temperatures to rise so treatment with ammonium sulfate, if needed, can be effective.
- Avoid flushing ponds too rapidly and decreasing temperature if ponds must be flushed. If possible avoid pond flushing.
- Treat ponds at least two days prior to anticipated stockings to allow treatments to work and toxins to decompose.
- Perform bioassays and check for cells any time *P. parvum* toxicity is suspected and on the days before fish stockings.
- Maintain a minimum of 0.18 mg/L un-ionized ammonia nitrogen (UIA-N) or 2 mg Cu^{2+}/L in ponds depending on treatment option.

Prophylactic Treatments of P. parvum in Ponds

- Measure pond water temperature and pH.
- If pond water temperatures are consistently above 28°C
  - *P. parvum* may be absent or present in very low numbers and ichthyotoxicity is unlikely. Treatment should be unnecessary.
  - Monitor ponds for presence of the alga and signs of toxicity at least once per week.
- If pond water temperature is 28°C
  - Check for presence of *P. parvum* cells twice per week.
  - If cells are present measure ammonia, temperature, and pH.
  - Calculate concentration of UIA-N.
  - Apply ammonium sulfate to raise UIA-N to 0.3 mg/L if UIA-N is less than 0.18 mg/L.
- If pond temperatures are below 28°C, consult an ammonia ionization table (Piper et al. 1992) or hatchery ammonia spreadsheet to determine proportion of total ammonia in the un-ionized form.
  - If the proportion of total ammonia in the un-ionized form is less than 5%
    - Apply Cutrine-Plus® or copper sulfate to raise copper concentration to 0.25 mg/L.
    - Measure copper concentration once per week.
    - Maintain copper concentration above 0.2 mg/L.
    - Check for presence of *P. parvum* cells once per week for monitoring purposes.
  - If the proportion of total ammonia in the un-ionized form exceeds 5%
    - Measure ammonia, temperature, and pH once per week (twice per week for sensitive species such as striped or palmetto bass).
    - Calculate concentration of UIA-N.
    - Apply ammonium sulfate to raise UIA-N to 0.3 mg/L if UIA-N is less than 0.18 mg/L.
    - Check for presence of *P. parvum* cells once per week for monitoring purposes.

- If the proportion of total ammonia in the un-ionized form is low (5-15%) and pH is expected to increase above 8.5
    - Reduce target ammonium sulfate treatment to achieve UIA-N of 0.25 mg/L. This treatment level is high enough to control *P. parvum* but requires less ammonium sulfate and lower total ammonia. Thus, should pH rise the UIA-N generated may not be toxic to the fish. Treatments at this lower UIA-N rate may require more frequent applications.

Indoor Culture Units

- Use UV- and ozone-treated lake water (treated water) for all culture activities in the spawning and rearing building if lake water contains *P. parvum* or its toxin. High dosage UV (180 to 200 mJ/cm^2) and ozone treatment is required to eliminate *P. parvum* toxicity if toxins are present in the supply water.
    - Check treated water for presence of *P. parvum* or toxin to be sure the system is working.

Treatment of Ichthyotoxicity

- Treat ponds or other culture units with potassium permanganate at 2 mg/L above the demand rate for temporary relief if fish show signs of ichthyotoxicity.

Fish Harvest

- Check incoming lake water for toxicity and presence of *P. parvum* one day before fish harvest.
- If *P. parvum* or toxin is absent in lake water
    - Harvest fish using routine hatchery procedures.
- If *P. parvum* or toxin is present in lake water but water not toxic.
    - Do partial pond draining the day before harvest.
    - Harvest fish as scheduled within 2 hours using lake water.
    - Treat pond water with potassium permanganate if fish exhibit signs of ichthyotoxicity.
- If lake water is toxic
    - Suspend fish harvest until the condition improves.
    - If fish must be harvested, use non-toxic water from adjacent ponds or treated water and potassium permanganate treatment if fish show signs of ichthyotoxicity.

Fish Hauling Units

- Fill fish hauling units with treated water.
- Rinse fish to be transported from the hatchery with treated water before loading to avoid introducing *P. parvum* into hauling tanks and ultimately into stocked lakes.
- After fish loading, check hauling unit water for *P. parvum*.
    - If *P. parvum* is absent deliver fish according to hatchery guidelines.
    - If *P. parvum* is present drain out some water, refill with treated water, and recheck for *P. parvum*. Repeat until no *P. parvum* is found.

- Upon return to the hatchery, disinfect hauling units with 10% chlorine bleach.
- Use lake water free of *P. parvum* cells or toxins, or treated water to transfer fish between hatchery culture units.

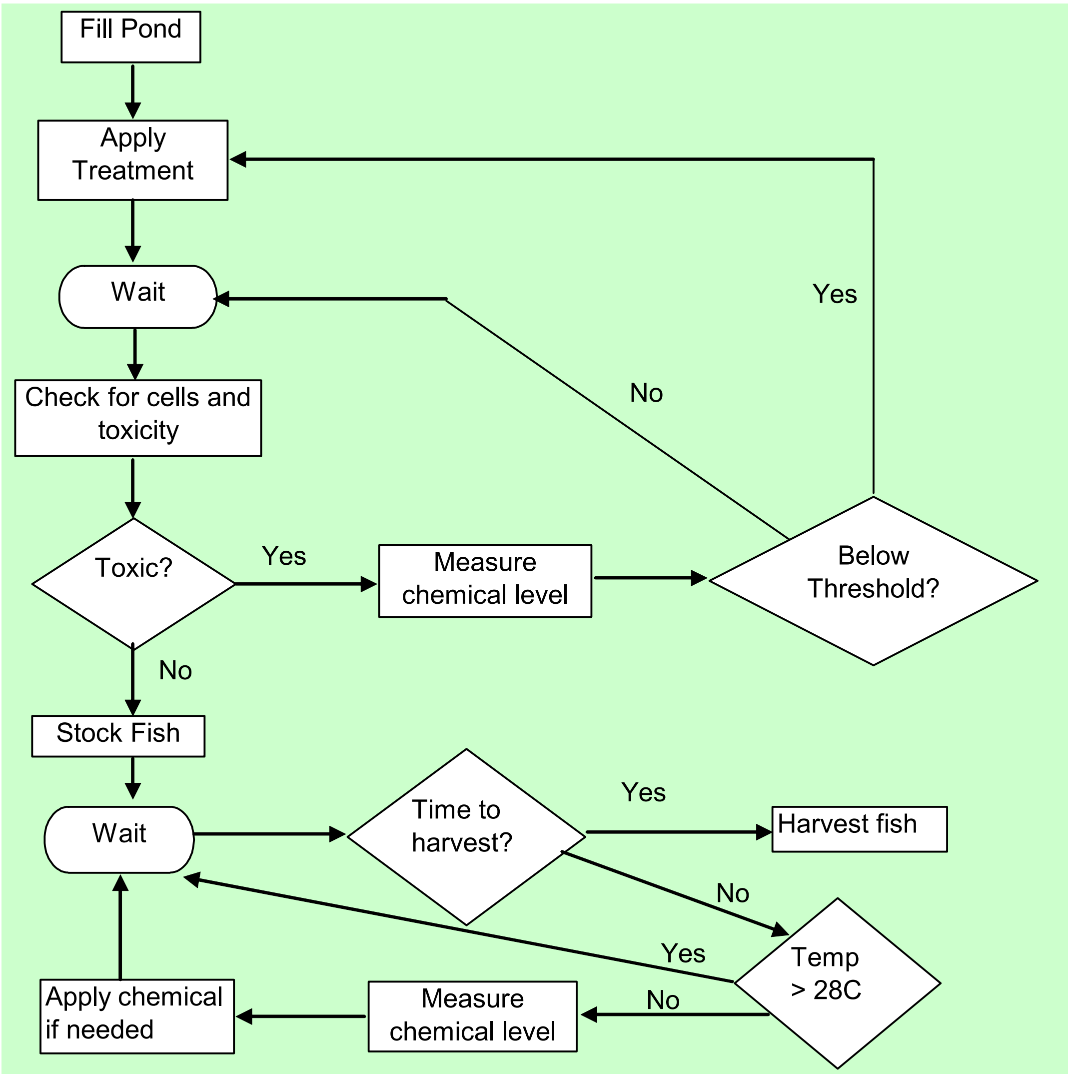

FIGURE 1.—A schematic diagram of the Dundee State Fish Hatchery pond management plan.

APPENDIX B

Possum Kingdom State Fish Hatchery *Prymnesium parvum* Management Plan

DALE D. LYON AND JOHN PARET

Abstract

The Possum Kingdom State Fish Hatchery *Prymnesium parvum* management plan was prepared to provide a systematic approach to controlling this toxin-producing alga to make fish production possible. The essential facets of the plan are monitoring presence and density of *P. parvum* and levels of un-ionized ammonia nitrogen and Cu^{2+}, and application of chemical treatments. Ammonium sulfate is applied at 10 mg/L or at amounts to raise the un-ionized ammonia nitrogen concentrations to 0.25-0.40 mg/L when water temperatures are 15°C or higher. Cutrine-Plus® is applied to achieve a copper concentration of 0.20 mg Cu^{2+}/L when water temperatures are up to 15°C. The target concentration of un-ionized ammonia nitrogen or Cu^{2+} depends on the fish species being cultured. Potassium permanganate is applied to neutralize the toxin to provide temporally relief to the fish during toxicity or an impending toxicity event.

Introduction

The Possum Kingdom State Fish Hatchery (PK) is located in Palo Pinto County, Texas below Possum Kingdom Lake, the main source of water for the hatchery. The lake water comes to the hatchery through a 4.5-m (14.8 ft) deep intake valve (shallow water) or an 18-m (59-ft) deep intake valve (deep water). Additional water for the hatchery is provided by a well. Effluent water from ponds and indoor culture units can be reused in ponds after filtration by a re-circulation system. Culture units include 42 plastic-lined ponds (9.4 ha or 23.2 acres), four indoor raceways, a 48-McDonald jar egg incubation system and 12 holding troughs. The incubation system can be operated as flow-through or closed system with filtration, heating, and cooling capabilities. All holding troughs have flow-through capabilities but only four have re-circulation capabilities.

Fish species cultured at this hatchery include striped bass *Morone saxatilis*, palmetto bass (female striped bass × male *M. chrysops*), channel catfish *Ictalurus punctatus*, smallmouth bass *Micropterus dolomieu*, koi carp *Cyprinus carpio*, bluegill *Lepomis macrochirus,* crappie *Pomoxis* spp., rainbow trout *Oncorhynchus mykiss*, and walleye *Stizostedion vitreum*.

P. parvum was first confirmed in Possum Kingdom Lake in 2001 following extensive toxin-related fish kills in the reservoir. This alga was found in our hatchery ponds in 2002 when ponds were filled with lake water following a renovation in 2001. This alga consistently appears to bloom during colder months (January-March), and blooms often result in massive and extensive fish kills. During summer months, when temperatures exceed 28°C, the alga usually disappears or occurs in very low densities and toxin-related fish kills are rare. Spring and fall appear to be transitional periods when *P. parvum* densities fluctuate, and fish kills are sporadic.

Since 2001 staffs at PK and Dundee hatcheries, in cooperation with the Hatcheries Golden Alga Task Force, have been developing strategies for controlling the alga. The strategies that seem to work best for PK constitute the management plan described below. As more effective or efficient strategies are developed this management plan will be updated.

P. parvum **Management Plan**

The PK hatchery has adopted a prophylactic approach to managing *P. parvum* with the goal of elimination the alga from culture systems or keeping densities low to prevent toxicity. The strategy is to treat a pond when *P. parvum* is present (i.e., even if a single cell is detected in a water sample (i.e., 2,000 cells/mL)). Because the ammonium sulfate used to control *P. parvum* is a fertilizer and the hatchery water is less buffered, this strategy minimizes the potential for higher pH levels or wide pH swings that are detrimental to sensitive fish such as striped bass. Similarly, the strategy allows minimal use of other chemicals (e.g., copper compounds). However, this strategy necessitates year-round monitoring of *P. parvum*. Presence of *P. parvum* is monitored twice weekly in summer ($\geq$ 28 ˚C) and thrice weekly when temperatures are $<$ 28 ˚C and *P. Parvum* toxicity is more likely.

Before a treatment, the un-ionized ammonia nitrogen (UIA-N) or Copper (Cu^{2+}) concentration in a pond is determined and the difference needed to achieve the target treatment level is provided by applying ammonium sulfate or Cutrine-Plus®. Because non-target substances, such as debris and other organic matter, can absorb some of the active ingredients of the treatment chemicals, this 'demand' must be considered when calculating treatment rates. For example, when ponds are turbid Cultrine-Plus® and potassium permanganate are applied at 0.3 mg/L to achieve the target concentration of 0.2 mg/L (active ingredient).

Currently, three chemicals are used in controlling *P. parvum* and its toxicity. Ammonium sulfate (AS) is a common fertilizer that consists of 21% N. Because it is the un-ionized ammonia nitrogen (UIA-N) portion of total ammonia from AS that lyses the alga, the effectiveness of AS is contingent on pH and temperature. Therefore, AS is not used when water temperatures are less than 15°C.

Cutrine-Plus® is a liquid copper compound and an algaecide that quickly and easily disperses in cold water. It is used at water temperatures <15°C because the cheaper AS is not effective. However, copper is effective algaecide at any temperature. Cutrine-Plus® may be considered in broodfish holding ponds if pH does not allow effective use of AS. Trout are sensitive to copper so they are no longer cultured in ponds at this facility.

Potassium permanganate ($KMNO_4$) is an oxidizer that appears to neutralize the *P. parvum* ichthyotoxin. It is used to provide a quick but temporally relief to fish exhibiting stress due to *P. parvum* toxicity.

Brood Fish Holding (striped bass or white bass)

- Fill indoor holding troughs with well water and operate as closed system
  - Check for the presence of *P. parvum* to be sure the system is free of the alga.
  - If no cells are present there should be no need for further monitoring.

Jar Rack Egg Incubation

- Fill egg incubation system with well water and operate as a closed system.
- Check system water for *P. parvum* cells.
  - If no cells are present there should be no need for further monitoring.

Spring Fry Rearing (striped bass, smallmouth bass, koi carp, etc)

- Clean all pond bottom sediments.
- Begin filling ponds 14 days before fry stocking with shallow or deep lake water.
- Treat ponds with 10 mg/L of AS at time of filling.
- Check ponds for presence of *P. parvum* 4 days and 1 day before fry stocking.
- Ensure that all ponds have UIA-N and pH within tolerable limits for fry.
- For striped bass conduct 24-hour survival tests on all ponds before stocking.
- Check all ponds with fish for *P. parvum* three times per week.
  - Treat ponds containing *P. parvum* with ammonium sulfate to achieve UIA-N level of 0.25 mg/L for fry or 0.35 mg/L for fingerlings.
  - Monitor pH and UIA-N daily in each pond.

Summer-Fall Fingerling Rearing (channel catfish and koi carp)

- Begin to fill ponds with lake water 14 days before stocking.
- Initial application of 10 mg/L AS is recommended
- Check ponds for *P. parvum* twice daily before stocking
  - If *P. parvum* is absent continue to fill ponds according to culture guidelines.
  - If *P. parvum* is present treat to raise UIA-N to 0.4 mg/L if temperature is 15 °C or higher, or treat to raise Cu^{2+} to 0.20 mg/L if temperature is below 15 °C.
- After stocking fish monitor pond temperatures and pH daily and *P. parvum* two – three times per week.
  - If pond temperatures are consistently above 28°C.
    - No treatment should be necessary but monitor *P. parvum* twice per week.
  - If pond temperatures are 15-28°C.
    - Monitor UIA-N and treat to raise UIA-N to 0.4 mg/L if *P. parvum* present.
  - If pond temperatures are below 15°C.
    - Monitor copper levels and toxicity, and treat with Cutrine-Plus to raise Cu^{2+} to 0.20 mg/L if *P. parvum* is present. If toxicity is present (determined via bio-assay or stressed fish) treat with KMNO4 at 0.3 mg/L for a target concentration of 0.20 mg/L (i.e., demand is 1 mg/L).

Winter Holding Ponds

- Monitor ponds for *P. parvum* three times per week.
  - If water temperatures are <15°C treat with Cutrine-Plus to raise Cu^{2+} to 0.2 mg/L if *P. parvum* is present. If pH values are very low and water temperatures are

slightly greater than 15°C, Cutrine-Plus is still recommended because AS is ineffective at low pH levels even if temperatures are near 15°C.

Raceway or Trough Culture (rainbow trout and channel catfish)

- All flow-through water in raceways and troughs should be tested for toxicity prior to use.
- Source water for raceways and troughs should be monitored for *P. parvum* cells three times per week.
    - If *P. parvum* is present perform bioassay to test for toxicity.
        - If lake water is not toxic stock fish and operate raceway/trough as flow-through.
        - If lake water is toxic do not use raceway/trough (Go to Trout Pond Production).

Trout Production in ponds

Use ponds for trout production or holding, instead of indoor raceway or troughs, when lake water is toxic. PK always has an emergency trout pond filled as back-up; however raceways have been used since 2006.

- Before trout arrival, fill pond with lake water.
    - Treat with Cutrine-Plus to raise Cu^{2+} level to 0.2 mg/L if temperatures are less that 15°C. This pond should be *P. parvum*-free and should also have $\leq$ 0.12 mg/L residual Cu^{2+} to receive trout.
    - Treat with 10 mg/L AS if temperatures are 15°C and higher. This pond should be checked for ammonia before receiving any fish and should have a UIA-N of no greater than 0.4 mg/L.
    - Monitor the emergency pond three times weekly.

Fish Harvest

- At harvest check incoming lake water for *P. parvum*
    - If *P. parvum* is absent harvest fish using lake water
    - If *P. parvum* is present perform bioassay: if negative harvest fish using lake water; if positive use recirculation water.
    - Fish leaving the hatchery must be rinsed in well water before loading into hauling unit.
    - Fish to be transferred between hatchery culture units need not be rinsed with well water.

Fish Transportation

- Fill hauling unit with well water and check all compartments for *P. parvum* after loading fish (Note: all fish leaving the hatchery must be rinsed in well water before loading).
    - If *P. parvum* is absent deliver fish according to hatchery guidelines.
    - If *P. parvum* is present drain out some water, refill and re-check for *P. parvum*. Repeat until no *P. parvum* is found.
    - Upon return to the hatchery, disinfect hauling unit with 10% chlorine bleach.
- Use *P. parvum*-free lake water or well water to transfer fish between culture units on the hatchery.

Monitoring Sites

- Monitor *P. parvum* in lake water at the dam, hatchery intake water, and ponds and indoor culture units in use.

Appendix C

Procedures for Dissolving the Glycoprotein Matrix of Catfish Eggs Using Sodium Sulfite (After Dorman 1993)

Preparation of Solution

Make a10X concentrated stock solution: Dissolve 150 grams of sodium sulfite Na_2SO_3 per liter of distilled water. Store the solution in a plastic container.

Make a 1.5% sodium sulfite solution: Mix 100 mL of the stock solution with 900 mL of hatchery water.

Adjust pH of the 1.5% sodium sulfite solution to the pH of hatchery water: Gradually add approximately 10% hydrochloric acid (HCL) to the 1.5% sodium sulfite solution until the pHs of the solution and hatchery water (incubation water) are the same.

Dissolving the Matrix

Place the egg mass (spawn) in a container (McDonald jar, plastic container or stainless bowl) and cover it with the sodium sulfite solution (1 L per 500 gram egg mass).

Gently stir with a glass rod until the matrix completely dissolves and eggs are separated (1-3 min).

Remove the dissolved matrix from the eggs by placing the McDonald jar on a jar rack and flowing water through it for several minutes. For bowls or similar containers, decant the solution from the eggs, rinse the eggs with fresh hatchery water, and decant the solution. Repeat the rinsing process until all matrix tissue is eliminated from eggs.

APPENDIX D

Sample Sizes for Quantification of Blue Catfish Fry at a Desired Power and Precision[1]

Belva L. Hall, Aaron Barkoh, J. Warren Schlechte, and Neil Thompson

Abstract.--Sample sizes required for estimation of mean number of fry/g, with variance of no more than 10% of the mean and 80-90% power, for enumeration of blue catfish *Ictalurus furcatus* fry were determined with a two-stage sampling design. The power analysis suggested that, for the desired power and precision, a sample size of between six and nine or a design with 3 samples and 2-3 sub-samples should be adequate in providing reliable estimates of blue catfish fry numbers.

[1] Source: Texas Parks and Wildlife Department, Inland Fisheries Division, Management Data Series Number 193, Austin

APPENDIX E

Comparison of Two Stocking Densities for Production of Advanced Channel Catfish *Ictalurus Punctatus* in Plastic-Lined Ponds[2]

Reese Sparrow

Abstract.--Two stocking densities were compared in order to evaluate survival and growth of advanced channel catfish *Ictalurus punctatus* in plastic-lined ponds. Channel catfish were stocked, at rates of 24,700 fish/ha and 37,050 fish/ha, into six 0.4-ha ponds. Total ammonia-nitrogen, un-ionized ammonia, pH, temperature, dissolved oxygen, yield, production, percent survival and feed conversion between the two densities were evaluated and no significant differences were found ($P > 0.05$). These findings would lead to the conclusion that the carrying capacity of ponds has not been reached at this facility.

[2] Source: Texas Parks and Wildlife Department, Inland Fisheries Division, Management Data Series Number 132, Austin.

APPENDIX F

Raceway Culture of Channel Catfish[3]

Dale D. Lyon and Ted Engelhardt

Abstract.--Texas Parks and Wildlife inland fish hatcheries produce over 236,000 advanced channel catfish *Ictalurus punctatus* fingerlings annually for stocking into small urban impoundments. These fingerlings are produced at all five hatchery locations. Three of these sites have the ability to utilize raceway systems for catfish culture. With the installation of water re-use systems at the A. E. Wood and Possum Kingdom hatcheries and filtration systems at the Texas Freshwater Fisheries Center, water usage concerns associated with raceway culture can be mitigated. Described in this addendum is a set of general culture guidelines for the production of 229-mm channel catfish fingerlings. The techniques described herein are based on two successful years of raceway production of this species at the A. E. Wood Hatchery.

[3] Source: Texas Parks and Wildlife Department, Inland Fisheries Division, Management Data Series Number 202, Austin.

APPENDIX G

Effects of Hand Feeding and Demand Feeding on Water Quality and Production of Channel Catfish in Indoor Raceways[4]

Thomas Wyatt and Aaron Barkoh

Abstract.--Channel catfish *Ictalurus punctatus* were reared in indoor raceways from about 8.5 cm to 19.0 cm total length to compare the effects of hand feeding (Treatment 1) verses demand feeding (Treatment 2) on water quality and selected fish production variables (harvest weight, daily weight gain, daily growth, total length, survival, feed conversion and cost/kg of fish produced). Fish under demand feeders fed to satiation mainly during evening and night hours, while hand-fed fish received the daily rations in morning and evening feedings at rates based on body weight. Statistically, differences in water quality and fish production variables between treatments were not significant. However, feed conversion ratio was significantly lower for Treatment 2 than for Treatment 1. For the majority of the production variables, the differences could be of practical significance to fish culturists. The mean harvest length for Treatment 2 was 12 mm longer than that of Treatment 1. The mean harvest weight (658.2 kg) and mean daily weight gain (0.9 g/d) for Treatment 2 were about twice those of Treatment 1. For the hand-fed fish, production cost was about 375% higher, while feed conversion efficiency was 40% less. Thus, demand feeding improved production of advanced fingerling channel catfish in indoor raceways.

[4] Source: Texas Parks and Wildlife Department, Inland Fisheries Division, Management Data Series Number 203, Austin.

APPENDIX H

Data Management Plan

Trip sheet data

Data entry deadline

- Within 7 days of fish delivery.

Data audit process and deadline

- Hatcheries will certify that data is accurate and complete for the previous year by November 15th. An email with the total number of records and total fish stocked by species will be sent to regional offices. Database stocking totals should match numbers provided in annual fish hatchery production reports.

- Regional offices will certify that data is accurate and complete for the previous year by December 15th. The number of records and total fish stocked by species will be compared between offices.

- Fred Janssen will certify that regional office databases are consistent with the Austin Master copy by January 15th. A report of the total number of records and total fish stocked by species for the previous year will be emailed to all Inland Fisheries offices by February 1.

- The previous year is defined as all stocking records between November to 1 October 31.

Common Trip Sheet Errors

- The miles and man-hours should only be entered once on split loads.

- Catchable rainbow trout (RBT) should be entered as Adults in the stage field.

Fish Production data

Data entry deadline

- Within 14 days of fish culture activity.

Data audit process and deadline

- Annual hatchery production reports will be accompanied by a statement of database record verification, accuracy, and completeness. Auditing will be conducted at the same time as annual production report writing. Auditing and statement deadline will be the same as production reports:

    a. Rainbow trout – June 1
    b. All black bass – September 1
    c. Striped and hybrid bass – September 1
    d. Blue Catfish– September 1
    e. Other species (Walleye, Saugeye, etc.) – September 1
    f. Forage – December 1
    g. Sunfish – December 1
    h. Channel Catfish – December 1

- Regional Directors may adjust deadlines annually as required by annual production activities.

- Regional Directors will audit records while preparing annual production summaries.

Fish Hatchery Database System (FHDS) Guidelines

Rearing Code

- Fry rearing – length at stocking is $<$25 mm (all LMB and SMB).

- Fingerling rearing – length at stocking is ≥25 mm (second production cycles of Koi, CCF, RBT).

- Special rearing – Lunkers, Triploid Florida largemouth bass (FLB) and any other ponds that need to be separated from main production data.

- Egg incubation – eggs placed into jars or spawning mats placed in incubation troughs.

Cycle #:

- The first group of ponds stocked each spring should be annotated as cycle 1. The second group of ponds should be annotated as cycle 2 and so on.

- Try to group ponds in logical blocks.
- RBT cycle should correspond to each shipment of trout.

- Individual pond stocking and harvest rearing codes and cycles should match.

- Each fry rearing stocking record should include a stock date, number stocked, and mean length.

  Standard fry lengths:

LMB	7 mm
SMB	7 mm
Koi	6 mm
STB	5 mm
HSTB	5 mm
CCF	15 mm

- Each fingerling rearing stocking record should include a stock date, number stocked, weight stocked, and mean length.

- Each fry or fingerling rearing harvest record should include a harvest date, number harvested, weight harvested, and mean length.

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