Guidelines for the Culture of Bluegill Sunfish *Lepomis Macrochirus*

by
Thomas Wyatt
Dale Lyon
and
Aaron Barkoh

Management Data Series
No. 251
2008

TEXAS PARKS & WILDLIFE

INLAND FISHERIES DIVISION
4200 Smith School Road
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INTRODUCTION

Bluegill sunfish *Lepomis macrochirus* are produced by Texas Parks and Wildlife Department (TPWD) freshwater fish hatcheries for stocking into impoundments that are new or have been adversely impacted by drought or golden alga *Prymnesium parvum* toxicity. Bluegills are used to establish healthy forage base in these impoundments to support game fishes. Historically, bluegill fingerlings have also been produced to provide forage for captive largemouth bass *Micropterus salmoides* broodstock held on hatcheries. This practice has, for the most part, been phased out for two reasons: preference by Inland Hatcheries staff to utilize koi carp, a strain of the common carp *Cyprinus carpio*, as forage for bass and the increased request by Inland Fisheries Management staff for bluegill fingerlings for use in fisheries enhancement projects. The stocking request for 50-mm bluegill fingerlings was over 805,000 in 2007. To meet the increasing request for bluegill fingerlings, all TPWD freshwater hatcheries participate in the culture of bluegills.

Although bluegills are widely cultured for stocking recreational ponds (Dupree and Huner 1984) and reservoirs to establish forage base for sport fish, comprehensive culture guidelines appear to be unavailable in the mainstream literature. This document was prepared to provide guidelines for the culture of bluegills with emphasis on the production of 50-mm fingerlings in ponds.

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 *P. 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

Broodfish Management

Broodfish Procurement and Replacement

Bluegill broodfish are collected with frame nets or hook-and-line in areas sunfishes are known to occur in abundance. Because several species of "sunfish" readily hybridize, care must be taken to minimize the chances of collecting hybrids. Reference sources such as "Freshwater Fishes of Texas" and field guides (McGowan and Kemp 1971; Chilton 1998; TPWD 2002; Thomas et al. 2007) may help ensure collection accuracy. Also management biologists are a good source of help in fish identification. Broodfish should be collected just prior to being ready to spawn and may be held in a temporary holding pond or paired directly into spawning-rearing ponds.

During collection, handling of broodfish should be kept to an absolute minimum. Broodfish should be placed in holding tanks with a 0.5% salt solution and an anti-foaming agent for transport to the hatchery. Back at the hatchery, all fish should be dipped in a 3% salt solution for approximately 1 min before stocking into ponds.

Annual mortality and culling of broodfish necessitate broodfish replacements to maintain an adequate broodstock for the program (Engelhardt and McCarty 1990). This is accomplished by collecting adults from the wild or developing a broodstock from offspring of the broodfish on the hatchery. With the latter strategy, a small number of fingerlings from pond spawning is retained and reared as future broodstock. Staff at the A. E. Wood Fish Hatchery Genetics Laboratory in San Marcos recommends that fingerlings from 100 or more spawning pairs be integrated to ensure genetic diversity in each future broodstock.

Broodfish Holding

Stocking.—Ponds for holding broodfish should be allowed to dry completely, if possible, before refilling and restocking. These ponds should be free of vegetation that would provide cover for forage (Burkhalter 1967) or interfere with fish harvest. Broodfish should be stocked into holding ponds at 224–336 kg/ha (200–300 lb/acre) (Huner and Dupree 1984). In general, as many as 600 adult fish (averaging 227 g/fish or 0.5 lb/fish) can be over-wintered in a 0.4-ha (1-acre) pond.

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 ponds (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 (UIA):

- The dissolved oxygen data for broodfish ponds should be collected daily, just before or at sunrise. Dissolved oxygen levels will be at their lowest at this time. 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 can be measured weekly and more frequently when inorganic fertilizers are used in ponds. Ammonia can adversely affect bluegill feeding, growth, and resistance to disease. For optimum health, UIA levels should not exceed 0.12 mg/L for continuous exposure (Piper et al. 1989) 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 UIA threshold limit for taking remedial action to prevent broodfish from suffering exposure to high ammonia concentrations.

The health and development of broodfish are as important as those of fingerlings; therefore, proper water quality management is very important. Some water quality variables, especially at hatcheries that have to control *P. parvum,* can be challenging to manage successfully. Addition of ammonium sulfate to control *P. parvum* can result in high pH, UIA, and excessive blooms of green algae.

Ranges of water quality variables for successful culture of warmwater fishes, including bluegills are listed below (Piper et al. 1989; Engelhardt and McCarty 1990):

- Dissolved oxygen levels ≥5.0 mg/L.
- Tolerable temperatures 0.6–32.2ºC
- Optimum temperatures 12.8–26.7ºC
- Spawning temperatures 18.3–26.7ºC
- pH 6.5–9.0
- Total hardness 50–400 mg/L as $CaCO_3$
- Ammonia <0.3 mg/L

Feeding.—Proper broodfish maintenance requires that the proper amounts and sizes of feed be provided on an appropriate feeding schedule. The quantity of artificial feed and feeding frequency should vary with water temperature. Bluegill broodfish readily accept pelleted floating feed of 3.0–6.3 mm (0.12–0.25 in) in diameter. The diet should contain at least 20% protein (Engelhardt and McCarty 1990). The approximate feeding rates based on water temperature are in Table 1.

Monitoring.—Holding ponds should be checked daily for water level, fish mortality, saran sock (filter) condition, vegetation problems, etc. These activities may be combined with routine water quality monitoring. Fish in holding ponds should be sampled monthly to evaluate the general condition and health of the fish.

Harvesting.—Holding ponds should be drained early in the morning to reduce stress of fish due to high temperatures. Ponds should be harvested when water temperatures are consistently above 26°C (78.8°F). Transfer tanks should be equipped with compressed oxygen and should contain a 0.25% salt solution and an anti-foaming agent (Engelhardt and McCarty

1990). If holding ponds contain mixed sexes, separation of the sexes should be done at this time to minimize overall handling of the fish. As spawning time approaches, males in good condition take on distinctive colors and emit sperm when palpated and females in good condition develop full, rounded abdomens. A second method for verifying sex is probing for eggs. A capillary tube 5–10 cm (2–4 in) long and 1.1–1.2 mm inner diameter is used to sample eggs (Engelhardt and McCarty 1990). More information on distinguishing sex characteristics can be found in Morris et al. (2002).

CHAPTER 2

Spawning Procedures

Pond Preparation

For plastic-lined ponds, spawning substrates (e.g., gravel) must be provided. Because bluegills are colonial spawners and male territorial behavior is not an issue, spawning substrates can be grouped together. Spawning substrates should be placed in shallow water (2–3 ft or 61-91 cm deep) preferably at the pond corners.

In earthen ponds, pond bottoms should be disked, bladed, packed, and allowed to dry thoroughly before filling them with water. Ponds are started filling 3–5 d prior to stocking broodfish. Water should be screened through a 500-µm screen material to prevent undesirable fish contamination. Twenty-four hours prior to filling, pond bottoms should be sprayed with an approved herbicide to retard growth of unwanted aquatic vegetation (Fassett 1966).

Pond Fertilization

Ponds should be fertilized to provide appropriate sizes and adequate quantities of zooplankton for bluegill fry and small fingerlings. Fertilizer application rates and frequency are determined by water quality conditions, zooplankton quality and quantity, fish stocking density, desired fish growth rate, and condition of the fish. Both spawning and rearing ponds should be fertilized, and the timing of fertilizer application is important. Fertilization of spawning ponds should be timed such that smaller zooplankters are available for first-feeding fry, whereas rearing ponds should be fertilized and managed for larger zooplankton. Listed below is a general fertilization regimen developed by Geiger (1983) and adopted for the production of 25-mm fingerlings (Engelhardt and McCarty 1990):

- Initial treatment – 14 d before fry stocking use 224 kg/ha (200 lb/acre) of cottonseed meal (CSM), 0.5 mg/L of liquid ammonium nitrate, and 1.0 mg/L of phosphoric acid.
- Follow-up application – Use 22 kg/ha (20 lb/acre) of CSM (twice/week), 0.17 mg/L liquid ammonium nitrate (three times/week), and 0.33 mg/L of liquid phosphoric acid (three times/week), or as needed.

Fertilization regimens are usually site specific, and fertilization regimes developed by each hatchery for species such as striped bass or largemouth bass should work for bluegill. Perhaps the most important difference with regard to bluegill culture (as mentioned above) is the need to manage for smaller zooplankton during fry rearing compared to larger (adult) zooplankton during fingerling rearing. This can be accomplished by shortening the time between anticipated fry feeding and initiation of pond fertilization. This strategy should favor rotifers and copepod nauplii. For fingerling rearing (starting out with 25-mm fingerlings to produce 50-mm fingerlings), the duration between fertilization and initial stocking should be extended to allow time for adult zooplankters to dominate the community.

Organic fertilizer is applied at the windward side of the pond by broadcasting along the full length of the pond. Organic fertilizer should never be applied in or near the pond harvest structure. Fertilization should be discontinued if the dissolved oxygen reading at sunrise is below 5.0 mg/L or the Secchi reading is less than 20 cm or 7.9 in (Warren 2002).

Control of Prymnesium parvum

At hatcheries affected by *P. parvum* toxicity, production ponds must be managed according to a *P. parvum* management plan (Appendices A and B). Control of *P. parvum* with ammonium sulfate is associated with elevated pH and UIA (Barkoh and Fries 2005), either of which can be toxic to eggs, fry, fingerlings, and adult fish at varying levels of concentration. Therefore, intense monitoring of these variables may be necessary to ensure bluegill survival in ponds treated with ammonium sulfate. Perhaps the best strategy is to spawn and produce bluegill fingerlings during the summer when water temperatures are high enough (≥28ºC) to inhibit *P. parvum* blooms and toxicity (Barkoh and Fries 2005). This target temperature of 28ºC is slightly above the optimum spawning temperature (26ºC) for bluegills.

Broodfish Pairing

For the production of 38–50-mm (1.5–2.0-in) fingerlings, broodfish should be paired at 100 pairs/ha (40 pairs/acre). The Jasper State Fish Hatchery (JSFH) and Dundee State Fish Hatchery (DSFH) have paired bluegills at 160–185 pairs/ha (65–75 pairs/acre), whereas the A. E. Wood Fish Hatchery (AEWFH) has used 1301–1916 pairs/ha (527–776 pairs/acre) in some ponds. These different stocking rates have been used because of limited pond space or different production objectives. The preferred sizes of broodfish for spawning are 140–285 g (4.9–10.1 oz) each, and the optimum sex ratio is 1:1.

Bluegills are multiple spawners that may spawn 4–5 times per year in southern states (Willis 2005). According to Piper et al. (1989), bluegill fecundity is about 110,000 eggs/kg female (50,000 eggs/lb female). Females lay 2,000–63,000 eggs which hatch within 3 d after fertilization by males. Fry should be seen in about three weeks after broodfish pairing. The fingerlings should reach 25 mm in 30–40 d and 38–50 mm in 40–60 d. With a broodfish stocking rate of 100 pairs/ha (40 pairs/acre) and assuming a 50% hatch rate, approximately 774,074 advanced fry/ha (313,500/acre) can be produced from a well-managed pond. However, Huner and Dupree (1984) reported that under normal circumstances about 300,000 fingerlings/ha (120,000 fingerlings/acre) are produced.

Because bluegills spawn multiple times over an extended season, predation on eggs or later-hatched fish by earlier-hatched fish can reduce production (Breck 1996). Steps should be taken to minimize predation, including fry transfer.

Water Quality

Water quality variables should be managed for the target ranges mentioned above and in a manner similar to broodfish holding ponds (see Chapter 1). Temperature, pH, and dissolved oxygen levels should be monitored twice daily.

Feeding

Bluegills will eat small aquatic animals such as insects, small minnows and worms, as well as commercial feed. Bluegill adults may be fed throughout the spawning season with a wide range of feed sizes, but the preferred feed is 1.5–5.5-mm floating feed (Table 1). Bluegill adults will also consume a #4 sinking feed; however, with sinking feed it may be difficult to monitor feeding behavior. Bluegill fry should readily accept #0 and #1 high-protein feeds but perhaps not at first feeding (Morris et al. 2002). Therefore, zooplankton populations should be monitored and artificial feed offered as needed. Currently, the JSFH, DSFH, and AEWFH feed bluegill fry in spawning ponds a #0 starter at a rate of approximately 2 kg/pond/d (4.4 lb/pond/d). A suggested regimen for feeding bluegill fry and fingerlings in spawning ponds is provided in Table 2.

Harvesting

Harvesting of spawning ponds can be complicated because they contain a mixture of adults, fingerlings, and fry. High water temperatures and excessive handling can be stressful to bluegills, especially the juveniles. Therefore, ponds should be harvested as early in the morning as possible and handling should be minimized.

***Fry transfer*.**—Spawning ponds should be harvested as soon as fingerling rearing space is available and fry approach an average size of 25 mm (~1 in), or if there is large numbers of fry in the pond. Hatcheries that have Kansas-style kettles can allow the entire pond to drain into the kettle and with separator screens, segregate adults, fingerlings, and fry. Often, there will be considerable variation in the sizes of the juvenile fish, so effort should be made to stock similar size fish in a rearing pond. Larger fingerlings may be used as forage for largemouth bass, stocked into separate rearing ponds, or stocked as 50-mm fingerlings into designated public waters. Spawning ponds may be refilled and restocked with broodfish for a second round of spawning, if desired.

Hatcheries that have Texas-style kettles may seine broodfish from ponds, relocate them, or hold them until the ponds are refilled for restocking. Fry and fingerlings are then harvested by dip-netting as the pond drains.

***Broodfish transfer*.**—Removing broodfish from spawning ponds before harvesting fingerlings will minimize handling stress on the fingerlings. Broodfish are removed by seining. Alternatively, use of spawning enclosures, a technique that the JSFH is developing, allows quick removal of broodfish with relatively little or no disturbance of the juveniles. The main disadvantage of the broodfish transfer method is lack of control over the densities and sizes of fish left in ponds for grow-out.

Fry Enumeration

Fry and fingerlings should be enumerated using the most valid methods. All fry should be weighed gravimetrically in a tarred bucket of water onto transport trailers. A random sample of no less that 30 fish should be taken and measured individually for average length. Three random samples of at least 100 fish each should be weighed and counted to determine the number of fish per kilogram.

CHAPTER 3

Fingerling Rearing Procedures

Stocking

Bluegill fry or fingerlings are stocked at approximately 250,000 fish/ha (100,000 fish/acre) for the production of 50-mm (2-in) fingerlings (Warren 2002). The fry transfer method should be used for producing bluegill fingerlings.

Zooplankton Monitoring

Zooplankton populations should be monitored to evaluate pond productivity. In spawning-rearing ponds, samples should be taken during spawning activity, when fry are observed, then every seven days. Typically, zooplankton samples are taken at or near the pond kettle structure prior to sunrise. Hatcheries should have standard methods and equipment for zooplankton monitoring. When fry are observed, the number of preferred organisms (rotifers, copepod nauplii) should be approximately 200–250 organisms/L (750–950 organisms/gal) (Siefert 1972). Rearing ponds should preferably contain higher densities of large adult zooplankters.

Feeding

Prescribed feeding regimes for bluegill fingerling production are lacking in the literature. Hatchery personnel have observed that bluegill fingerlings readily accept #1, #2, #4, and 1.5-mm (1/16 in) floating feeds. At the JSFH, fish in rearing ponds are fed a #1 high-protein feed at a rate of 2–3 kg/pond (4.4-6.6 lb/pond) twice daily, and this rate is gradually increased as the fish grow. The AEWFH staff offers a variety of feed sizes that change as the fish grow, and the feeding frequency varies from four times daily initially to three times daily. Feed amounts are increased from 5 to 10 kg/pond (11 to 22 lb/pond) daily. The DSFH staff feeds high-protein feed twice daily: the feed size varies from #0 to #2 based on fingerling size. Table 3 contains a suggested feeding regimen for fingerling production.

Water Quality

Water quality variables should be managed for the target ranges mentioned above and in a manner similar to broodfish holding ponds (see Chapter 1). Temperature, pH, and dissolved oxygen levels should be recorded twice daily.

Fish Sampling and Harvesting

The growth rates of fingerlings should be monitored a least weekly after the first three weeks by dip-netting at the kettle area or by seining and taking sub-samples of the fish. This information is used to adjust feeding rates and feed sizes and determine time to harvest the fish. Production of 50-mm (2-in) fingerlings should take approximately 45–60 d if ponds are stocked at 247,000–370,500 fish/ha (100,000-150,000 fish/acre). When the target size is reached or fish growth stops, the fish should be harvested as soon as possible, following these guidelines:

- Harvest boxes and basins should be cleaned of mud or other debris before fish are harvested.
- Ponds should be harvested as early in the morning as possible to reduce thermal stress on the fish.
- Fish should not be exposed to sudden temperature changes during harvest.
- Harvested fingerlings should be loaded directly into transport tanks and stocked the same day. This will eliminate multiple-handling stress on the fish and reduce mortality.
- If fish are to be transported for stocking into public waters immediately after harvest, they should not be fed artificial feed for about 48 h before harvest.

Fingerling Enumeration

Fingerlings should be enumerated using the most valid methods. All fingerlings should be weighed onto transport trailers in a tarred bucket of water. A random sample of no less that 30 fish should be measured individually for average length. Three samples of at least 100 fish each should be weighed and counted to determine the number of fish per kilogram. The latter metric is used with the total weight of the fish to calculate the total number of fingerlings harvested.

CHAPTER 4

Fish Transportation

Preparation and Loading

Fish should not be offered artificial feed beginning approximately 48 h before they are harvested and transported for stocking into public waters. Loading factors to consider are water temperature, hauling time, condition and size of fish, transport equipment, and fish species (McCraren 1978). All transport equipment should be checked for proper operation on the day before a trip. Transport tanks should be equipped with compressed oxygen and 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. Recommended loading rates for transporting sunfish at temperatures of 18–30°C (64.4–86°F) (McCraren 1978) are shown in Table 4. For every degree above 21°C (69.8°F), the loading rate should be reduced by 4%. Ice can be used at a rate of 60 g/L (0.5 lb/gal) for each 5°C (9°F) decrease in water temperature. The dissolved oxygen levels during the first hour of fish confinement are the most critical; therefore, measurements should be taken frequently and the oxygen flow adjusted as needed during this time. The dissolved oxygen concentrations in transport tanks should be maintained above 6.0 mg/L and below super-saturation. Hauling water should contain a 0.25% by weight salt solution and an anti-foaming agent (Engelhardt and McCarty 1990).

Transportation

Drivers should take the most direct and safe route from the hatchery to the stocking site. The oxygen delivery system, dissolved oxygen concentration, temperature of the hauling water, and the condition of the fish should be checked every hour during transport. The dissolved oxygen concentration should be maintained at 6 mg/L and below saturation by proper adjustment of the oxygen delivery system. The temperature should be maintained in the 18–30 C range with ice, if necessary. For high hauling densities or long hauling distances, cooler temperatures should be maintained in transport tanks.

Stocking

Fish should be acclimated to the environment into which they are to be stocked. Temperature and dissolved oxygen levels should be particularly monitored during the acclimation process. Proper tempering requires 20 min for every 3°C (37.4 F) change in water temperature. Fish should be acclimated for at least one hour when tempering for temperature. 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. 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 stocking events 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 5

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. Appendix C 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.

Information gathering and storage is an important part of the hatchery protocol. This information is important in making management decisions, exchanging information, and report writing. Water quality data stored in monitoring equipment should be downloaded regularly and uploaded into the FHDS. All pertinent fish production activities or data have a place in the hatchery database. These include but are not limited to: pond filling, water quality, fertilizer treatment, chemical treatment, fish length sampling, and pond harvest. Trip sheet information should be entered into the database no later than seven days after fish delivery. Bluegill production reports are due by December 1 of each year.

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Table 1.—Feeding rates of artificial feed for adult bluegills.

Water temp (C)	% TBW[a] to feed	Feeding frequency
21	3	5-7 times/week
12 - 21	1 - 2	Alternate days
<12	0	No feeding required

[a]TBW = Total body weight

Table 2.—Suggested feeding regimen for 25-mm fingerling production in spawning ponds. TL is total length.

Days	Activity	Feed type	Feed rate	Feeding frequency
0 – 7	Spawning			
8 – 14	Sample fry for TL	#0	3 kg/d	Mon – Sat
15 - 22	Sample fry for TL	#0	5 kg/d	Mon - Sat

Criteria for this feeding regimen include (on a per acre basis) production of 311,000 fingerlings at 4,900 fish/kg (2,228 fish/lb), FCR of 2.4, growth rate of 0.5 mm/d.

Table 3.—Suggested feeding regimen for 50-mm fingerling production in rearing ponds.

Days	Activity	Feed type	Feed rate	Feeding frequency
0 – 10		#1	1 kg/d	Mon – Sat
11 – 20	Sample fingerlings for TL	#1 and #2	1 kg/d	Mon – Sat
21 – 30	Sample fingerlings for TL	#2	2 kg/d	Mon - Sat
31 – 40	Sample fingerlings for TL	#2 and 1.5 mm	2 kg/d	Mon – Sat
41 – 50	Sample fingerlings for TL	1.5 mm	3 kg/d	Mon - Sat

Criteria for this feeding regimen include stocking density of 247,097 fish/ha (100,000 fish/ac), 50% return, FCR of 1.7, growth rate of 0.5 mm/d, and size of 50-mm fingerling or 900 fish/kg (409 fish/lb).

Table 4. –Recommended bluegill loading rates for hauling temperatures of 18-30 C.

Total length (mm)	Number of fish/L	kg/L
25	88	0.04
50	60	0.06
74	18	0.08
100	7	0.12

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 toxigenic 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 15ºC 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 15ºC. 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 plastic-lined ponds totaling 33 ha (82 acres) of surface water. Other culture units include 12, 1.8-m-diameter fiberglass round tanks, 90-jar egg incubation system and 4-trough (970-L) rearing system indoors and four concrete raceways outdoors. 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 white bass *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 sauger *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 stocking.
- 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 Treatment of P. parvum in Ponds

- Measure pond water temperature and pH.
- If pond water temperatures are consistently above 28ºC
  - *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 28ºC
  - 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 28ºC, consult an ammonia ionization table (Piper et al. 1992) or hatchery ammonia spreadsheet to determine the 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 is toxic. High dosage UV (180 – 200 mJ/cm^2) and ozone treatments are 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 is 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 that is free of *P. parvum* cells or toxins, or treated water to transfer fish between hatchery culture units.

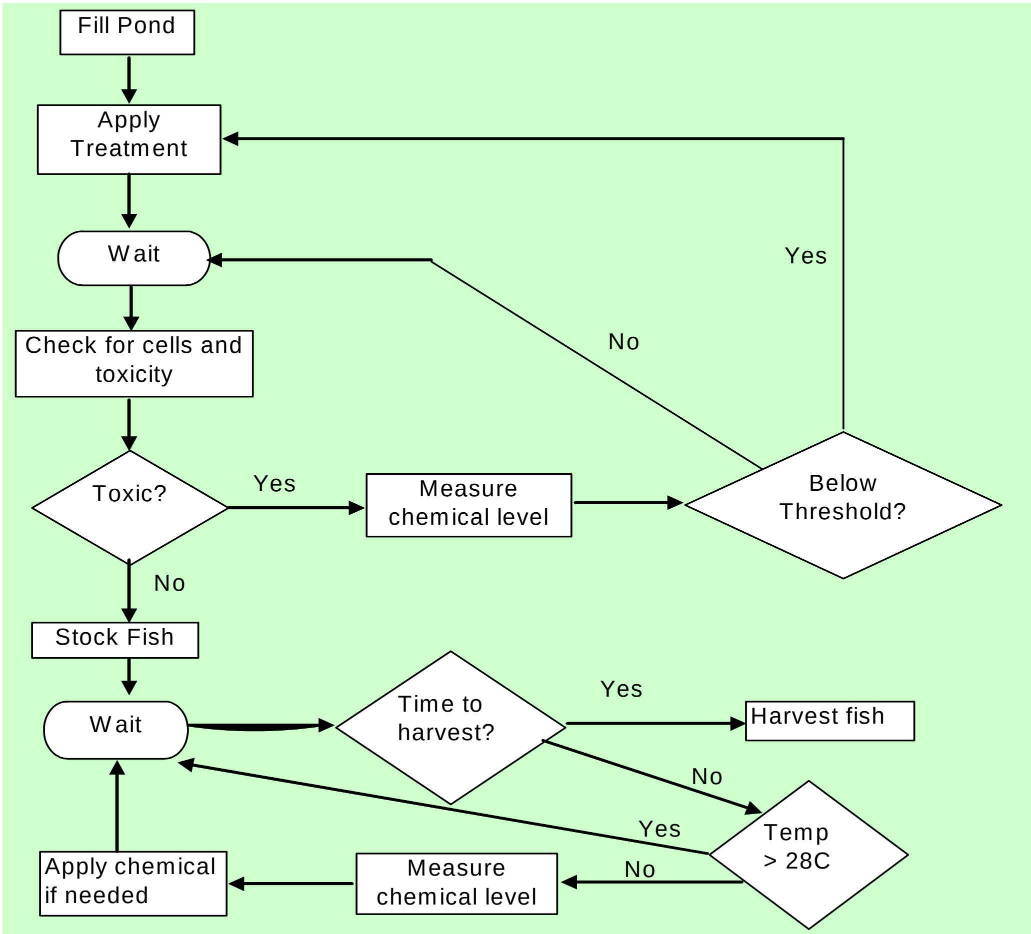

FIGURE 1.—A schematic diagram of the Dundee State Fish Hatchery pond management plan.

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 applying chemical treatments as needed. Ammonium sulfate is applied at 10 mg/L or at quantities to raise the un-ionized ammonia nitrogen concentrations to 0.25–0.40 mg/L when water temperatures are 15ºC or higher. Cutrine-Plus® is applied to achieve a copper concentration of 0.2 mg Cu^{2+}/L when water temperatures are below 15ºC. 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 a temporary 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 ac), 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*, koi carp *Cyprinus carpio*, bluegill *Lepomis macrochirus,* crappie *Pomoxis* spp., rainbow trout *Oncorhynchus mykiss*, and walleye *Stizostedion vitreum*.

Prymnesium parvum was first confirmed in Possum Kingdom Lake in 2001 following extensive toxin-related fish kills in the reservoir. This alga was found in the hatchery ponds in 2002 when ponds were filled with lake water following a renovation in

2001. P. parvum 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 28ºC, 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 hatchery, 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 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, even if the density is as low as 2,000 cell/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 ($\geq 28^{o}C$) and thrice weekly when temperatures are $<28^{o}C$, and P. parvum 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 (AS) or Cutrine-Plus®. Because non-target substances, such as debris and other organic matter, can consume 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 ($KMnO_4$) are applied at 0.3 mg/L to achieve the target concentration of 0.2 mg/L (active ingredient basis) since the demand is 1 mg/L.

Currently, three chemicals are used in controlling *P. parvum* and its toxicity. Ammonium sulfate (AS) is a common fertilizer that consists of 21% nitrogen. Because it is the 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 $15^{o}C$.

Cutrine-Plus® is a liquid copper compound and an algaecide that quickly and easily disperses in cold water. It is used at water temperatures $<15^{o}C$ because the cheaper AS is not effective. 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 is an oxidizer that appears to neutralize the *P. parvum* ichthyotoxin. It is used to provide a quick but temporary relief to fish exhibiting stress due to *P. parvum* toxicity.

Broodfish Holding (striped bass or white bass)

- Fill indoor holding troughs with well water and operate as a 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 test on all ponds before stocking.
- Check all ponds with fish for *P. parvum* three times per week.
    - Treat ponds containing *P. parvum* with AS 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 of 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 ºC or higher, or treat to raise Cu^{2+} to achieve 0.2 mg/L if temperature is below 15 ºC.
- After stocking fish monitor pond temperatures and pH daily and *P. parvum* 2–3 times per week.
    - If pond temperatures are consistently above 28ºC.
        - No treatment should be necessary but monitor *P. parvum* twice per week.
    - If pond temperatures are 15–28ºC.
        - Monitor UIA-N and treat to raise UIA-N to 0.4 mg/L if *P. parvum* present.
    - If pond temperatures are below 15ºC.

        - Monitor copper levels and toxicity, and treat with Cutrine-Plus to raise Cu^{2+} to 0.2 mg/L if *P. parvum* is present. If toxicity is present (determined via bio-assay or stressed fish), treat with $KMNO_4$ at 0.3 mg/L for a target concentration of 0.2 mg/L since the demand is 1 mg/L.

Winter Holding Ponds

- Monitor ponds for *P. parvum* three times per week.
    - If water temperatures are <15ºC 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 15ºC, Cutrine-Plus is still recommended because AS is ineffective at low pH levels even if temperatures are near 15ºC.

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 or trough as flow-through.
        - If lake water is toxic, do not use raceway or trough (Go to Trout Production in Ponds).

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 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 15ºC. This pond should be *P. parvum*-free and should also have ≤ 0.12 mg/L residual Cu^{2+} to receive trout.
    - Treat with 10 mg/L AS if temperatures are 15ºC 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 trout 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 re-circulation water.
    - Fish leaving the hatchery must be rinsed with 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 with 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, ponds, and indoor culture units in use.

APPENDIX C

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 are 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 are 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.

- The data analyst at Austin headquarters 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 from November 1 to October 31.

Common trip sheet errors

- The miles and man-hours should only be entered once for 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 that of 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 number

- 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.

- Ponds should be grouped 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.

PWD RP T3200-1691 (10/10)