

CULTURE OF RED DRUM FINGERLINGS

by

Robert L. Colura
Britt W. Bumgardner
Anne Henderson-Arzapalo
and
Joseph D. Gray



MANAGEMENT DATA SERIES

No. 22

1990

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

CULTURE OF RED DRUM FINGERLINGS

by

Robert L. Colura
Britt W. Bumguardner
Anne Henderson-Arzapalo
and
Joseph D. Gray

MANAGEMENT DATA SERIES

No. 22

1990

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

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	ii
ABSTRACT	iii
INTRODUCTION	1
MATERIALS AND METHODS	1
RESULTS AND DISCUSSION	1
LITERATURE CITED	2
APPENDIX A	4
Procedures for Culturing Red Drum Fingerlings	
Overview	5
Broodfish Tank Systems	6
Broodstock Procurement	10
Broodfish Care	12
Spawning	16
Egg and Prolarvae Care	18
Transportation of Larvae	20
Larva to Fingerling Culture	21
Transportation and Stocking of Fingerlings	31
Advanced Fingerling Culture	32
Regulations	35
APPENDIX B	38
Metric - English Measurements Conversion Table	39

ACKNOWLEDGEMENTS

The authors wish to thank Messers Gene McCarty, Mike Ray and Robert Vega of the Texas Parks Wildlife Department, Hatcheries Branch, for providing information on operation of the GCCA/CPL Marine Development Center. The authors also wish to thank Mr. Willie Younger, Matagorda County Marine Extension Agent, and Ms. Linda Smith, Texas Agriculture Experiment Station, Research Associate, for their assistance in outlining current rules and regulations concerning red drum culture. Special thanks to Mr. David Piña of the Texas Parks and Wildlife Department's Perry R. Bass Marine Fisheries Research Station for preparation of line drawings.

This study was conducted with partial funding from the U.S. Department of the Interior, Fish and Wildlife Service under D.J. 15.605 (Project F-36-R).

ABSTRACT

The Texas Parks and Wildlife Department has investigated red drum fingerling culture since the mid-1970's. Using photoperiod and temperature manipulation to induce spawning and fingerling culture in earthen ponds personnel at the Perry R. Bass Marine Fisheries Research Station obtained an average 52% survival of red drum fingerlings (~ 25-mm total length) from 1985 through 1987. Advanced fingerling (230-mm total length) production averaged 63% after a 229 day production period.

INTRODUCTION

The Texas Parks and Wildlife Department (TPWD) has been investigating the culture of red drum for the purpose of supplementing natural stocks or developing aquaculture since the mid-1970's (Colura et al. 1976, Lasswell et al. 1977, Matlock 1986). Procedures for pond culturing fingerlings were originally developed at the TPWD Perry R. Bass Marine Fisheries Research Station (PRB). In 1983 the procedures were modified to suit conditions at the TPWD/Gulf Coast Conservation Association/Central Power and Light Company Marine Development Center (MDC), located near Corpus Christi, Texas. The MDC currently produces in excess of 7 million red drum annually for stocking into Texas bays (McCarty et al. 1986).

The purpose of this paper is to describe procedures currently used by the TPWD to spawn and to rear red drum fingerlings in earthen ponds. Step by step procedures describing care and spawning of broodfish, egg to ~ 25 mm total length (TL) fingerling culture and advanced fingerling (~ 230 mm TL) culture are provided. The paper is intended for use by the practicing fish culturist but will also be of use to those interested in acquiring a general knowledge of red drum culture.

MATERIALS AND METHODS

Spawning procedures were adapted from the general methods of Arnold et al. (1977). Pond culture methods are modifications of procedures described by Colura et al. (1976). All pond culture was conducted in 0.1 to 1.2 ha earthen ponds located at the PRB and MDC (Colura et al. 1976, McCarty et al. 1986). Procedures for the culture of advanced fingerlings generally followed those reported by Hysmith et al. (1983).

RESULTS AND DISCUSSION

The fingerling production procedures used and described in detail in Appendix A resulted in an average 52% return of approximately 25-mm TL fish from PRB ponds stocked with 750,000 larvae/ha during the years 1985 through 1987. Production of advanced fingerlings resulted in 63% return of 230-mm TL fish after a 229-day production period.

Methods described in Appendix A are a synthesis of almost 16 years of research by TPWD, universities, the National Marine Fisheries Service, and other state conservation agencies. It provides the reader with a detailed description of equipment and procedures currently used by TPWD to spawn and rear red drum.

LITERATURE CITED

- Arnold, C. R., J. L. Lasswell, W. H. Bailey, T. D. Williams, and W. A. Fable, Jr. 1976. Methods and techniques for spawning and rearing spotted seatrout in the laboratory. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies. 30:167-178.
- Arnold, C. R., W. H. Bailey, T. D. Williams, A. Johnson, and J. L. Lasswell. 1977. Laboratory spawning and larval rearing of red drum and southern flounder. Proceedings Southeastern Association of Fish and Wildlife Agencies. 31:437-440.
- Bowen, J. T., and N. Studdard. 1970. English and metric length-weight relationships for rainbow, brown and brooktrout. Appendix A, part 1. Manual of Fish Culture. Bureau of Sport Fisheries and Wildlife. Washington District of Columbia.
- Colura, R. L., B. T. Hysmith, and R. E. Stevens. 1976. Fingerling production of striped bass (Morone saxatilis), spotted seatrout (Cynoscion nebulosus), and red drum (Sciaenops ocellatus) in saltwater ponds. Proceedings of the World Mariculture Society. 7:79-92.
- Farquhar, B. W., and J. G. Geiger. 1984. A portable zooplankton sampling apparatus for use in hatchery rearing ponds. Progressive Fish-Culturist. 46:209-211.
- Henderson-Arzapalo, A. 1987. Red drum egg and larva incubation. Pages II-40 to II-42. In: G.W. Chamberlain, R. J. Miget and M. G. Halby editors. Manual on red drum aquaculture. Preliminary draft of invited papers presented at the Production Shortcourse Red Drum Aquacultural Conference 22-24 June 1987, Corpus Christi, Texas.
- Holt, J., P. Godbout and C. R. Arnold. 1981. Effects of temperature and salinity on egg hatching and larval survival of red drum Sciaenops ocellata. Fisheries Bulletin. 79:569-573.
- Holt, J. and C. R. Arnold. 1983. Effects of ammonia and nitrite on growth and survival of red drum eggs and larvae. Transactions of the American Fisheries Society. 112:314-318.
- Hysmith, B. T., G. C. Matlock, and R. L. Colura. 1984. Effects of stocking rate and food type on growth and survival of fingerling red drum. Pages 133-141. In: R.R. Stickney and S. P. Meyer, editors. Culture of Warm Water Fishes. Proceedings Warmwater Fish Culture Workshop. Special Publication No. 3., World Mariculture Society, Charleston, South Carolina.
- Johnson, S. K. 1987. Recognition and control of diseases common to growout aquaculture of red drum. Pages IV-18 to IV-53. In: G. W. Chamberlain, R. J. Miget and M. G. Halby editors. Manual on red drum aquaculture. Preliminary draft of invited papers presented at the Production Shortcourse Red Drum Aquaculture Conference 22-24 June 1987, Corpus Christi, Texas.

- Lasswell, J. L., G. Garza, and W. H. Bailey. 1977. Status of marine fish introductions into the fresh waters of Texas. Proceedings Southeastern Association of Fish and Wildlife Agencies. 31:399-403.
- Matlock, G. C. , B. T. Hysmith, and R. L. Colura. 1984. Returns of tagged red drum stocked into Matagorda Bay, Texas. Management Data Series No. 63. Texas Parks and Wildlife Department, Coastal Fisheries Branch. Austin, Texas.
- Matlock, G. C. 1986. A summary of ten years of stocking fishes into Texas bays. Management Data Series Number 104. Texas Parks and Wildlife Department, Coastal Fisheries Branch. Austin, Texas.
- Matlock, G. C. , C. E. McCarty, and R. R. Vega. 1986. Accuracy of estimated number of red drum fry stocked into rearing ponds. Management Data Series Number 113. Texas Parks and Wildlife Department, Coastal Fisheries Branch. Austin, Texas.
- McCarty, C. E., J. G. Geiger, L. N. Sturmer, B. A. Gregg, and W. P. Rutledge. 1986. Marine finfish culture in Texas: A model for the future. Pages 249-262. In: R. Stroud, editor. Fish culture in fisheries management. The proceedings of a symposium on the role of fish culture in fisheries management at Lake Ozark, Missouri, March 31 - April 3, 1985. Fish Culture Section and Fisheries Management Section of the American Fisheries Society, Bethesda, Maryland.
- Meyer, F. P. 1968. Dylox^R as a control for ectoparasites of fish. Proceedings of the Twenty-Second Annual Conference Southeastern Association of Game and Fish Commissioners. 22:392-396.
- Roberts, D. E., Jr., B. V. Harpster, and G. E. Henderson. 1978. Conditioning and induced spawning of the red drum (Sciaenops ocellata) under varied conditions of photoperiod and temperature. Proceedings of the World Mariculture Society. 9:311-332.
- Spotte, S. H. 1970. Fish and invertebrate culture water management in closed systems. Wiley-Interscience, New York, New York, USA. p. 145.
- Ulmer, R. 1987. Pond design and construction. Pages IV-84 to IV-93. In: G. W. Chamberlain, R. J. Miget and M. G. Halby editors. Manual on red drum aquaculture. Preliminary draft of invited papers presented at the Production Shortcourse Red Drum Aquaculture Conference 22-24 June 1987, Corpus Christi, Texas.
- Weber, C. L. 1973. Biological field and laboratory methods for measuring the quality of the surface waters and effluents. U.S. Environmental Protection Agency, National Environmental Research Center, 67014-13-001. Cincinnati, Ohio.

Appendix A Procedures for Culturing Red Drum Fingerlings

Procedures for Culturing Red drum Fingerlings

OVERVIEW

Introduction The primary purpose of this paper is to provide prospective red drum culturists with step by step procedures used by the TPWD to spawn and rear red drum fingerlings to 230 mm TL.

- Specific Objectives**
- Describe a tank and filter system in which mature red drum may be held and spawned.
 - Describe the care of broodfish.
 - Describe procedures for spawning red drum.
 - Describe care of the eggs and prolarvae.
 - Describe procedures for rearing fingerlings to approximately 25-mm TL.
 - Describe procedures for rearing advanced fingerlings (approximately 230-mm TL).
 - Provide the prospective red drum culturist with current rules and regulations concerning culture of red drum.
-

Metric Measurements All measurements used in this manual are metric. As an aid to those readers unfamiliar with metric measurement, conversion tables are provided in Appendix B.

Procedures for Culturing Red drum Fingerlings

BROODFISH TANK SYSTEMS

Introduction

A properly working broodfish tank system, consisting of the tank, assorted filters, heaters, and chillers, etc., is essential for successful spawning of red drum. The system should be installed and operating before broodfish are collected. A number of systems ranging from 9500-20,000 liters have been used to spawn red drum (Arnold et al. 1977, Roberts et al. 1978, McCarty et al. 1986). None of the systems have been shown to be superior for red drum spawning and were generally designed around existing equipment and available space. The following description is of a general broodfish tank design. Where appropriate specific information on equipment used at PRB is included. The use of brand names does not imply endorsement by TPWD.

Design

The system should be of a recirculating design (Figure 1) with water flowing in the following order:

- Broodfish tank
- Egg collector
- Bio-filter
- Ultraviolet-Germicidal lamp
- Chiller reservoir (optional)
- Return to the broodfish tank by pump

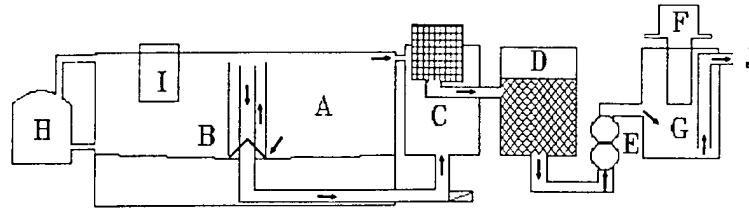
Water should be cycled through the system approximately 3-8 times per day, using either an airlift or centrifugal pump system.

Incoming water should pass through a sand filter and Ultraviolet-germicidal lamp before it enters the broodfish tank.

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODFISH TANK SYSTEMS (Continued)



A	Broodfish Tank	F	Chiller
B	Venturi Drain	G	Chiller Reservoir
C	Egg Collector	H	DE Filter
D	Bio-Filter	I	Heater
E	UV-Germicidal Lamp	J	Return to Tank

Figure 1. Schematic of red drum broodfish conditioning and spawning system used at the Perry R. Bass Marine Fisheries Research Station. Arrows show direction of water flow.

Broodfish Tank

A general description of red drum broodfish tanks used by TPWD are as follows:

- Volume at least 9500 liters
- 1 to 1.5 m in depth
- Circular fiberglass construction with a central drain 75-100 mm in diameter is preferred by TPWD but not mandatory.
- Water level may be controlled with a central standpipe or outside standpipe.
- With a central standpipe a venturi may be used to help clean the tank. This method is used by PRB.

Egg Collector

The egg collector may be of special fiberglass construction or built from any available tank at least 185 liters volume. A 0.5-mm mesh net must be placed between the incoming water and the discharge from the collector to retain the eggs.

Bio-filter

A biological filter should be placed in-line after the egg collector.

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODFISH TANK SYSTEMS (Continued)

Bio-filter
(Cont.)

Numerous designs of biological filters are available (Spotte 1970, Arnold et al. 1976, McCarty et al. 1986). Selection of the filter to be used usually will be determined by space available.

Regardless of design, the filter must have:

- sufficient surface area for the growth of adequate amounts of bacteria which will break down nitrogenous waste produced by the fish,
- sufficient water flow and air to prevent the filter from becoming anaerobic.

A simple system used at the PRB consists of a 110 to 185-liter polyethylene barrel filled with bulk air conditioning filter material to provide surface area for bacterial growth.

Ultraviolet-
Germicidal Lamp

An Ultraviolet-germicidal lamp should follow the bio-filter. Size of the lamp to be used will depend on the flow rates. The manufacturer's literature should be consulted before purchase and installation to insure the lamp is of proper size.

The Ultraviolet-germicidal lamp should never be run overnight when the fish are spawning.

The PRB uses an Aquanetics model 60IL (Aquanetics, San Diego, CA).

Diatomaceous
Earth Filter

A diatomaceous earth (DE) filter is useful for removing organic colloids, suspended micro-organisms, and maintaining water clarity.

The system need not be placed in-line with the biofilter. Operate the DE filter at least 1 to 2 days/week. The DE filter should never be run overnight when the fish are spawning.

The PRB uses a Turbo^R Model 44 (Pac-Fab Inc., Sanford, NC).

Temperature
Control

Two methods are used for temperature control:

- Water temperature is controlled by room air conditioning.
-

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODFISH TANK SYSTEMS (Continued)

Temperature Control (Cont.)

- Separate thermostatically controlled heaters and chillers are used. This method is used at the PRB. The PRB uses 4500 watt Glo-Quartz Model 3N45-222-CH quartz heaters (Glo-Quartz, Mentor, OH) mounted in the tank and controlled with a Glo-Quartz Series 400 temperature controller.

The PRB uses a one horsepower chiller (Frigid Units Model BHL-1089-2, Frigid Units, Inc., Toledo, OH). The chiller is placed in a reservoir tank in-line with and immediately after the filter system.

Photoperiod Control

Lighting is controlled by an electric time switch.

Lighting may be from either:

- Standard room lighting, fluorescent or incandescent
- each tank may be lighted separately

The PRB lights each tank separately. A 100 W incandescent and a 15 W fluorescent light mounted on a beam which is placed across and rests on the side of the tank. The tank is then covered with sheets of 100 mm thick styrofoam to shield the tank from extraneous light.

Airlift Pump

The PRB employs a 3 hp Rotron DR6KJ72 regenerative blower to operate an airlift pump located in the chiller reservoir which cycles water back to the brood fish tank. The blower also provides aeration to maintain dissolved oxygen levels.

Emergency Power

Red drum spawning facilities are typically located in coastal areas and are subject to periodic power failures due to storms. Therefore, provision should be made for an alternate source of electrical power to insure tank aeration and circulation are not interrupted and to prevent death of broodfish.

Procedures for Culturing Red drum Fingerlings

BROODSTOCK PROCUREMENT

Collection	Broodstock are typically wild fish preferably collected with hook and line. Captured fish are dip netted from the water and immediately placed in a well-aerated transport tank.
------------	--

Hatchery Rearing of Broodstock	Broodstock may also be reared in the hatchery. But, because it usually requires several years for red drum to mature, only small numbers of cultured broodstock are currently being used experimentally by the TPWD. As commercial red drum hatcheries increase in numbers use of hatchery reared red drum broodfish in selective breeding programs will probably become more common. Hatchery reared broodstock may in the future become the only source of broodstock for commercial hatcheries.
--------------------------------	--

Size of Broodfish	Broodfish should be at least 750 mm TL. However, fish approximately 1000 mm TL are preferred.
-------------------	---

Determination of Sex	<p>Males</p> <ul style="list-style-type: none"> • Males usually produce a drumming sound when captured. • The male vent exhibits an anteriorly located anus and posteriorly located urogenital pore. • Applying light pressure along the sides and belly during the fall will cause milt to be extruded and confirm identification of sex. <p>Females</p> <ul style="list-style-type: none"> • Females generally do not drum but on occasion may produce faint drumming sounds. • Examination of the vent of the female will reveal, anteriorly to posteriorly, the anus, genital pore, and urinary pore, respectively. • If not immediately apparent, the genital pore may be located by probing with a 2-mm ID (inside diameter) glass tube. • Intra-ovarian samples of eggs can be taken by inserting a 2-mm ID glass tube (150-200 mm length) into the ovary through the genital pore and oviduct. A small amount of
----------------------	---

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODSTOCK PROCUREMENT (Continued)

Determination of Sex (Cont.)	tissue may then be removed for microscopic examination and confirmation of sex of the animal.
Quarantine	Newly captured fish should be quarantined for 10-14 days to prevent introduction of disease into the hatchery.
Prophylactic Treatment	The tank water may be treated with 0.2 parts per million (mg/l) Cu^{++} (eg., Cutrine, Applied Biochemist, Inc., Mequon, WI) from a chelated copper compound to reduce the chances of disease caused by external parasites.
Comment	BEFORE USING ANY CHEMICAL OR MEDICATION ON FISH THAT MAY ULTIMATELY BE USED FOR HUMAN CONSUMPTION, FDA REGULATIONS CONCERNING REGISTRATION OF THE CHEMICAL FOR FOOD-FISH USE SHOULD BE CONSULTED.

Procedures for Culturing Red drum Fingerlings

BROODFISH CARE

Feeding

Frequency:

- Three to seven times per week at 2-3% of body weight.

Food types:

- Shrimp (Penaeus sp.)
- Fish, for example mullet (Mugil sp.), Shad (Dorosoma sp.) and Menhaden (Brevoortia sp.)
- Squid (Loligo sp.)
- Beef liver

The PRB feeds equal amounts of shrimp and fish 5-7 days/week at 3% of body weight.

The MDC feeds 50% shrimp, 25% squid, and 25% beef liver at 2.5% of body weight three times weekly (McCarty et al. 1986).

Water Quality

Critical levels for most water quality parameters have not been adequately identified. The following water quality standards have been used at the PRB with good results.

- Salinity 28-35 parts per thousand (o/oo). May be controlled by the addition of fresh water or artificial sea salts.
- pH 7.0-8.5. May be controlled by water exchange or the addition of 5 mg/l sodium bicarbonate (Na_2CO_3) will raise pH ~ 0.5.
- Total ammonia-N less than or equal to 0.5 mg/l; preferred total ammonia-N less than or equal to 0.2 mg/l. High levels of ammonia-N may be reduced by flushing with clean salt water.
- Dissolved oxygen greater than or equal to 5 mg/l. In a properly designed tank system, dissolved oxygen concentration should not be a problem.

Diseases

Diseases of parasitic or bacterial origin are encountered occasionally in captive red drum but few have been identified (Johnson 1987). The most common diseases

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODFISH CARE (Continued)

Diseases
(Cont.)

encountered at the PRB and their treatment are presented below. Other diseases common to culture of other warm-water marine fish might also be expected. Identification of potential diseases and their treatment are reviewed by Johnson (1987).

Amyloodinium
ocellatum

Amyloodinium ocellatum is the most common protozoan parasite affecting red drum.

It's affect on the fish is characterized by:

- rapid gasping
 - irregular opercular beat
 - mouth not closed
 - scratching on side and bottom of tank; Scrapings of gill filaments will reveal ovoid-shaped trophonts when examined with a microscope (Figure 2).
-

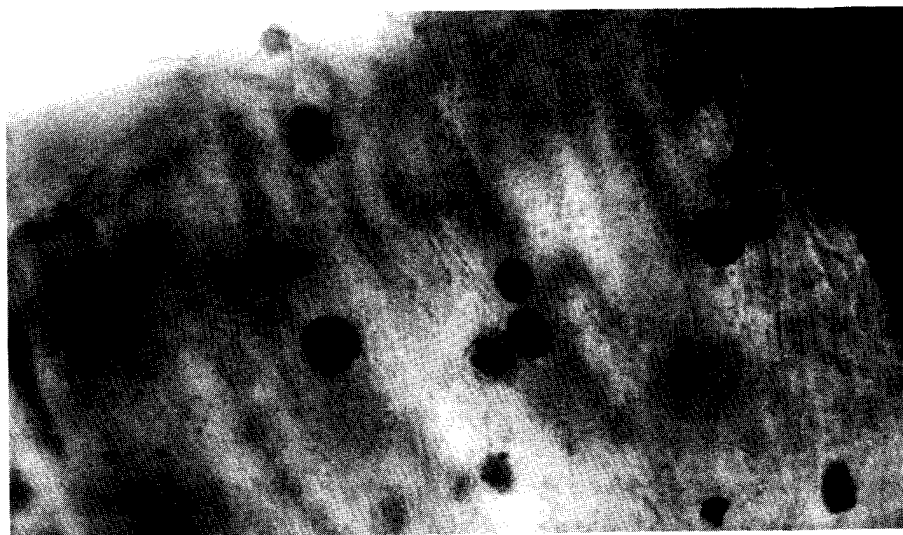


Figure 2. Amyloodinium ocellatum in gill tissue of a red drum.

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODFISH CARE (Continued)

Amyloodinium
ocellatum

- Treat the tank with 0.2-1.0 mg/l of Cu⁺⁺ from a chelated copper compound (e.g., Cutrine, Applied Biochemists, Inc., Control Mequon, WI) (Johnson 1987).
- Flush the tank 2 days after treatment and repeat the treatment 7 days after initial treatment.

Treatment for
Bacterial
Infections

Following handling, red drum are susceptible to bacterial infection, generally thought to be Vibrio sp. It is characterized by ulcers and redness of the body and fins.

Antibiotics, primarily oxytetracycline hydrochloride (OTC), can be used in several different ways to treat infections.

- Injection - Broodfish can be injected with 0.5 ml/kg body weight of OTC after handling to decrease the likelihood of bacterial infection; or infections can be treated with OTC injections at the same rate.
- Feed - injectable OTC can be placed in cut fish or shrimp fed to broodfish. Each food item is injected with 0.1-0.2 ml OTC and about 10 ml of OTC is added to the feed daily for 7-10 days.
- Immersion - immerse in 10-20 mg/l OTC for 2 hours.

Parasitic
Copepods

Parasitic copepods representing several genera and often called anchor parasites or anchor worms frequently attach to red drum and feed on blood. The addition of 0.25 mg/l Dylox^R (Chemargo Corp., Kansas City, MO) or any brand of pesticide with 80% trichlorfon as the active ingredient will kill anchor parasites (Meyer 1968).

Fish lice

Caligus sp., a copepod and Argulus sp., a branchiurian, collectively, known as fish lice are found moving freely over the body of the fish and can be seen without the aid of a microscope. They puncture the skin and feed on blood. The addition of 0.25 mg/l Dylox^R will kill fish lice (Meyer 1968).

WARNING

No product containing 80% trichlorfon is approved by the FDA for use on red drum.

(Continued)

Procedures for Culturing Red drum Fingerlings

BROODFISH CARE (Continued)

Comment

BEFORE USING ANY CHEMICAL OR MEDICATION ON FISH THAT MAY
ULTIMATELY BE USED FOR HUMAN CONSUMPTION, FDA REGULATIONS
CONCERNING REGISTRATION OF THE CHEMICAL FOR FOOD-FISH USE
SHOULD BE CONSULTED.

Procedures for Culturing Red drum Fingerlings

SPAWNING

Introduction Red drum are most easily spawned by the use of photoperiod and temperature manipulation. Several photoperiod and temperature regimes have been developed all of which have been equally successful (Arnold et al. 1977, Roberts et al. 1978, McCarty et al. 1986).

Photoperiod and Temperature Regime The following photoperiod temperature regime developed by McCarty et al. (1986) is used by the TPWD to spawn red drum in approximately 150 days.

PHOTOPERIOD - TEMPERATURE REGIME

Day	Temperature (°C)	Hours of light/day
0-9	20	11
10-14	18	10
15-19	16	10
20-24	16	9
25-29	15	9
30-39	16	10
40-49	17	11
59-59	20	12
60-64	22	12
65-69	24	13
70-79	26	13
80-84	28	13
85-89	28	14
90-99	29	14
100-109	30	14
110-119	29	13
120-124	28	13
125-129	27	12
130-134	26	12
135-139	25	12
140-150	11	12

Egg Number Estimation Eggs are removed from the egg collector the morning following the spawn at the PRB and enumerated as follows:

- Remove eggs from egg collector with dip net
-

(Continued)

Procedures for Culturing Red drum Fingerlings

SPAWNING (Continued)

Egg Number
Estimation
(Cont.)

-
- Place eggs in an aquarium with a known volume of water
 - Mix eggs thoroughly
 - Remove at least three 5-ml samples from the mixture and count the number of eggs in each sample
 - Calculate the mean number of eggs/ml
 - Extrapolate the number of eggs using the formula:

$$NE = V \times ME$$

where:

NE = Total number of eggs

V = Total volume (ml) water containing eggs

ME = mean number eggs/ml (as sampled)

Alternate Method
of estimating
egg numbers

An alternate method reported by Henderson-Arzapalo (1987) may also be used to estimate numbers of eggs. This method, which is less time consuming, is generally used in production hatcheries.

- Collected eggs along with sufficient water to allow the eggs to float are poured into a graduate cylinder.
 - The mixture is allowed to sit undisturbed for several minutes.
 - Eggs will float to the surface and the separation between eggs and water will be come visible.
 - The volume (ml) of eggs is measured.
 - The volume of eggs is multiplied by 998 eggs/ml to estimate the total number of eggs.
-

Procedures for Culturing Red drum Fingerlings

EGG AND PROLARVAE CARE

Incubator	<p>An approximately 1900-liter tank with a 45° cone bottom has been used most often to incubate eggs and hold prolarvae at the PRB. More recently incubators as small as 100 liters have been used experimentally with good results.</p> <p>A center stand pipe (50 mm diameter) maintains depth and is covered with 0.33-mm mesh filter so that water may be exchanged without loss of eggs or prolarvae.</p> <p>One to several air stones are placed around the perimeter of the tank and light aeration used to increase circulation and prevent the buoyant eggs from rafting.</p>
<hr/>	
Stocking Density	<p>A single spawn, (approximately 1 million eggs) can usually be incubated in a 1900 liter tank. If smaller incubators are used, several may be required for each spawn.</p>
<hr/>	
Stocking	<p>Eggs are gently poured into the incubator from the aquarium in which they were placed for enumeration.</p>
<hr/>	
Water Quality	<p>The following water quality parameters should be maintained:</p> <ul style="list-style-type: none"> • Temperature 22-30 C. Best temperature for hatching and 24- hour survival is 25 C (Holt et al. 1981). • Salinity 28-35 o/oo. Best salinity for hatching and 24 hour survival is 30 o/oo (Holt et al. 1981). • Total ammonia-N less than 0.55 mg/l (Holt and Arnold 1983). • Dissolved oxygen greater than or equal to 5.0 mg/l. <p>To help maintain water quality approximately 3 liters of water per minute are exchanged as soon as hatching begins and continues until fry are removed from the incubator.</p> <p>Dead eggs are siphoned from the incubator daily or at whenever they concentrate in the cone bottom.</p>
<hr/>	
"Harvest" of Incubator	<p>Larvae are maintained in the incubator until the alimentary tract is complete (approximately 48 h after hatching at 25 C). The incubator is then drained slowly into a "harvest" tank.</p>

(Continued)

Procedures for Culturing Red drum Fingerlings

EGG AND PROLARVAE CARE

"Harvest" Tank Description A general description of the "harvest" tank is as follows:

- Sixty to eighty liters capacity.
- Equipped with a 25-mm diameter internal stand pipe to drain overflow.
- Place a screen constructed with 0.33-mm mesh filter cloth around the stand pipe to prevent loss of larvae during draining.

Estimation of Larvae Procedures for estimating the number of larvae are as follows:

- When draining is complete adjust water level in the "harvest" tank to a known volume (eg. 20 liters) by siphoning through a 0.33 mm mesh sieve.
- Apply gentle aeration to mix the larvae.
- Collect 3 to 10 1- to 5-ml samples depending upon relative density of larvae.
- Count the number of larvae in each sample.
- Calculate the mean number of larvae/ml.
- Extrapolate the number of larvae using the formula:

$$NL = V \times ML$$

where:

NL = Total number of larvae

V = Total volume (ml) of water in harvest tank

ML = mean number of larvae/ml (as sampled).

Comment

The above described method of estimating numbers of larvae for stocking may overestimate the true number of larvae being stocked. Matlock et al. (1986) found that estimating the number of larvae using a full 48.5-liter aquarium and counting ten 10-ml samples resulted in overestimating by 28.6% when stocking 50,000 larvae. The percent of overestimation decreased as the number to be stocked increased. For example, the overestimate was only 5.8% when stocking estimate was 350,000.

Procedures for Culturing Red drum Fingerlings

TRANSPORTATION OF LARVAE

Plastic Bag Method

The following procedures are used to transport larvae in plastic bags:

- Add about 10 liter of water to a 37-liter plastic bag. Water should be the same salinity and temperature as that from which the larvae are to be taken.
 - Place approximately 100,000 larvae in the bag by dipping the estimated volume of water from the "harvest" tank that would contain that number of larvae. Base this on the mean number of larvae/ml in the harvest tank.
 - Fill the remaining volume of the bag with oxygen and seal the bag. PRB uses elastic bands to seal the bags.
 - Transport the bag to stocking site and float the bag for sufficient time to allow temperature within the bag to equal that of the water at the stocking site.
 - If salinities of transport water and water at the stocking site differ by more than 5 o/oo, slowly add water from the stocking site to the bag for 15-30 minutes until the salinities between transport water and stocking site water are within 5 o/oo.
-

Tank Transport of Larvae

An alternate method of stocking is used at the MDC (C.E. McCarty, Personal Communication).

- Larvae are concentrated, counted, transported to the pond in the same tank.
 - A lid is secured to the top of the tank and sealed to prevent water loss during transport.
 - The addition of oxygen has not been found to be necessary.
 - At the pond site approximately 10-15 liters of water is added over a 15-minute period before releasing the larvae.
-

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE

Introduction

Procedures described in this section are used to rear red drum in ponds to approximately 25 mm TL. This is the smallest size at which fingerlings will survive handling stress and transport. Larger fingerlings may be produced by these methods but the quantity produced will generally be reduced.

Description of PRB Ponds

A general description of ponds at the PRB is as follows:

- 0.1 to 1.2 hectares (ha).
- Levee slope 3:1. A 4:1 or 5:1 slope is currently recommended in windy coastal areas to reduce erosion (Ulmer 1987).
- Approximately 1.2-2.0 m maximum depth.
- Clay lined.
- A single fill line goes to each pond. Fill lines are 10-25.4 cm depending on size of pond.
- Each pond is constructed with a single concrete drain box with a 10-61 cm drain pipe depending on pond size. (Figure 3).
- Dam boards inserted in 5 cm vertical slots located approximately 90 cm in front of the drain pipe retain water.
- A screen placed in a second set of vertical slots located approximately 15 cm in front of the dam boards prevents loss of fish. A 0.5-mm mesh screen is used for the first two weeks of the culture period. An 8-mm mesh screen is used during the final weeks of culture.

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

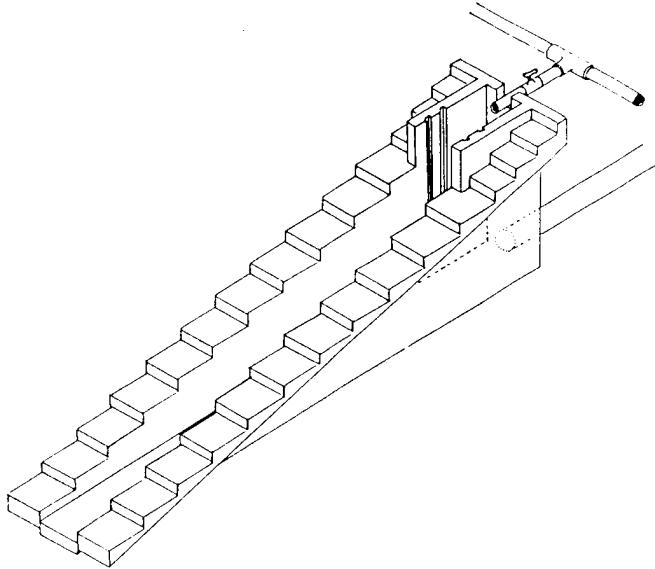


Figure 3. Concrete drain structure used at the Perry R. Bass Marine Fisheries Research Station.

Description of
MDC Ponds

A general description of ponds at the MDC is as follows:

- 0.2 to 0.8 ha.
- Average depth 1.2 m.
- Ponds are clay lined with a plastic liner or clay.
- Each pond equipped with one 20-cm fill line.
- Concrete drain boxes have a 20-cm butterfly drain valve, a 7.5-cm fill line to regulate water levels during harvest and a 5-cm air line for supplemental aeration during harvest. A 5-hp regenerative blower provides the air. A "Kansas Kettle" concrete drain box is used in the 0.2 hectare ponds (Figure 4).

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

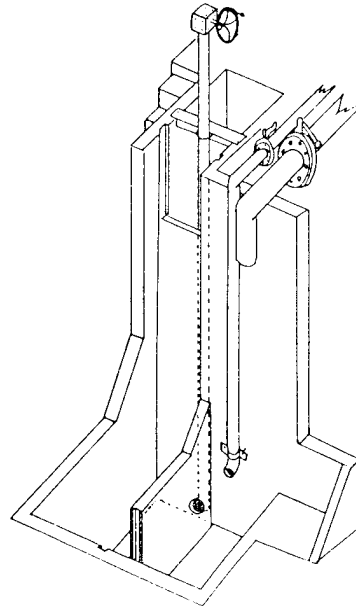


Figure 4. A "Kansas Kettle" concrete drain box used in 0.2 ha ponds at the MDC.

Pond filling

Begin filling approximately 10 days to 2 weeks before anticipated stocking.

Filter all incoming water with 0.5 mm mesh filter.

Salinity range of incoming water should be 10-45 o/oo with 20-35 o/oo preferred.

Water temperature should be at least 20C.

Pond Fertilization PRB

The following red drum pond fertilization schedule is used at the PRB. All fertilizer rates are calculated on a per hectare basis.

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

 POND FERTILIZATION SCHEDULE
 PERRY R. BASS MARINE FISHERIES RESEARCH STATION

Day	Action
1	Spread 282 kg cottonseed meal (CSM) on the dry pond bottom. Fill to approximately 1 m depth.
3	Continue filling. Add 9.0 liters phosphoric acid and 4.6 kg urea.
7	Add 31.3 kg CSM
10	Add 31.3 kg CSM
12	Add 31.3 kg CSM, 3.0 liters phosphoric acid, 4.6 kg urea
15	Add 31.3 kg CSM
17	Add 31.3 kg CSM
19	Add 31.3 kg CSM, 3.0 liters phosphoric acid, 4.6 kg urea
21	Add 31.3 kg CSM
23	Add 31.3 kg CSM
25 ^b	Add 31.3 kg CSM, 3.0 liters phosphoric, 4.6 kg urea

^aPhosphoric acid 55% P₂O₅, Urea 45% N

^bAdditional fertilizer may be added if fry stocking is late or growth is slow.

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

Pond
Fertilization
MDC

The following red drum pond fertilization schedule was used in 1988 by the MDC (M. Ray, Personal Communication). All fertilizer rates are calculated on a per hectare basis.

POND FERTILIZATION SCHEDULE
MARINE DEVELOPMENT CENTER

Day	Action
1	Begin pond filling
2	Add 28.4 liter liquid urea ^a and 11.8 liter phosphoric acid ^b
4	Add 454.5 kg cottonseed meal
5	Add 28.4 liter liquid urea and 11.8 liter phosphoric acid
10	Add 11.8 liter phosphoric acid
13	Add 56 kg cottonseed meal
15	Add 56 kg cottonseed meal
20	Add 56 kg cottonseed meal
21	Add 28.4 liter liquid urea and 11.8 liter phosphoric acid
22	Add 56 kg cottonseed meal
27	Add 56 kg cottonseed meal
29	Add 56 kg cottonseed meal
30	Add 28.4 liter liquid urea and 11.8 liter phosphoric acid
34	Add 56 kg cottonseed meal
36	Add 56 kg cottonseed meal
40	Add 28.4 liter liquid urea and 11.8 liter phosphoric acid

^a Urea = 32% N

^b Phosphoric acid = 54% P₂O₅

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

Comment	Fertilization should be discontinued and water added or exchanged if pond dissolved oxygen is less than or equal to 4 mg/l.
---------	---

Zooplankton Sampling	<p>Culture of red drum from larvae to 25 mm TL fingerlings is dependant upon the zooplankton forage base and as such zooplankton are routinely sampled by all TPWD hatcheries. The PRB currently samples red drum culture ponds three times weekly by collecting 25 liters of water using a flexible impeller pump apparatus (Farquhar and Geiger 1984). The water is filtered through a 64-μm mesh Wisconsin plankton net to concentrate the zooplankton. The sample is then preserved in a 5% formalin solution. The preserved sample is then subsampled and major zooplankton groups identified and enumerated as follows:</p> <ul style="list-style-type: none">• The sample is placed in a graduate cylinder and water added to yield a final volume of 300 ml (this volume has been found to dilute the sample to about 200 organisms/ml as recommended by Weber 1973).• The sample is stirred to uniformly distribute the zooplankton and a 1-ml subsample withdrawn with a Hensen-Stemple pipette.• The subsample is placed in a Ward plankton counting wheel.• Using a stereomicroscope the following major zooplankton groups are identified and counted:<ul style="list-style-type: none">• Copepods• Copepodids• Copepod nauplii• Rotifers• Polychaete larvae• Total zooplankton (all of the above groups plus minor taxa)
----------------------	---

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

Zooplankton using sampling (Cont.) • Number of organisms per liter are then calculated the formula:

$$\text{Number of organisms/l} = \frac{N \times \frac{300 \text{ ml}}{1 \text{ ml}}}{25 \text{ l}}$$

where:

N = number of organisms in the subsample

Comment

Many fish culturists prefer to pull a plankton net horizontally through the pond to obtain a zooplankton sample. If this method is used, the volume of water strained should be calculated and substituted for the 25 liter volume in the above formula. All other procedures for subsampling and counting remain the same.

Stocking

Larvae are stocked approximately 10 days after initial filling and fertilization at PRB and approximately 15 days after initial filling and fertilization at MDC. Dates were selected for each facility based on zooplankton sampling which has shown these dates to coincide with the approximate times at which zooplankton population densities are nearing their peaks.

The larvae are stocked when the alimentary tract is complete. This usually occurs at 2 days of age if the water temperature in the incubator is maintained between 26-29 C.

Stocking densities are approximately 750,000/hectare at the PRB and approximately 1,250,000/hectare at the MDC.

Greater stocking densities will generally result in increased numbers but percent survival is reduced and individual fish size at harvest will be significantly smaller (McCarty et al. 1986).

Pond temperature at stocking should be at least 20 C. Larval red drum will not survive when temperatures are cooler than 20 C (Holt et al. 1981).

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

Pond Water Quality	<p>Collect samples each morning beginning at sunrise. Water quality parameters to be collected and preferred levels are:</p> <ul style="list-style-type: none"> • Dissolved Oxygen (DO) concentration (mg/l). Should be at least 4 mg/l. If DO less than 4 mg/l discontinue fertilization and pump new water into pond. Emergency aeration may also be necessary. • Salinity 10-45 o/oo. 20-35 o/oo preferred. • Temperature (C) at least 20 C.
--------------------	--

Production Period	<p>Fingerling red drum can be produced in approximately 21-33 days depending on temperature.</p> <p>Fish should be harvested as soon as they are approximately 25 mm TL. Delay will result in reduced survival as zooplankton forage is depleted and fish become cannibalistic.</p>
-------------------	---

Sampling	<p>Twenty red drum are sampled weekly at PRB by either seining, or dip net to monitor growth. Collecting with a dip net is easiest.</p> <p>To collect fish with a dip net:</p> <ul style="list-style-type: none"> • Water is pumped into the pond. • The fish are attracted to the currents created where incoming water is discharged into the pond and up to several hundred individual fish may be collected by passing the dip net through the discharge area.
----------	--

Supplemental Feeding	<p>Supplemental feeding of red drum in the nursery pond is not necessary.</p>
----------------------	---

Harvest	<p>The following procedures are used to harvest ponds:</p> <ul style="list-style-type: none"> • Screen the discharge with an approximately 8-mm mesh wire screen.
---------	--

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

-
- Harvest (Cont.)
- Drain the pond as rapidly as possible without penning fish on the screen.
 - The catch basin should be cleaned of hydrogen sulfide laden mud before removing fish. This is accomplished by sweeping the box with a stiff brush during draining.
 - Fish are harvested by concentrating them in the catch basin and removing them with a dip net.
-

Estimation of
Numbers of Fish
Harvested

The number of fish harvested is determined by either:

- mass weighing fish either by taring the dip net and weighing each net full of fish or;
- transferring fish from the dip net to a bucket of water which has been previously tared and then weighing the bucket and fish.

Number of fish per kilogram is then determined by weighing 3 to 5 100-fish samples and calculating a mean weight per 100 fish.

- Number of fish harvested is extrapolated by the formula:

$$NF = WT \times MWT \div 100$$

where:

NF = Total number of fish
 WT = Total weight of harvested fish
 MWT = mean weight of 100 fish

Use of Weight-
Length Information

Weight-length information is frequently used by fish culturists to rapidly estimate biomass and numbers of fish harvested (Bowen and Studdard 1970). An average length is calculated and weight determined using the appropriate formula (See Weight-Length) below. Total weight of fish harvested is then divided by the calculated average weight to estimate the number of fish harvested.

(Continued)

Procedures for Culturing Red drum Fingerlings

LARVA TO FINGERLING CULTURE (Continued)

Weight-Length

The weight-length relationship for 675, 7-83 mm standard length red drum, reared at the PRB in 1978 and 1979 was:

$$\log W = -5.4366 + 3.4528 \log SL$$
$$r^2 = 0.927$$

Where:

$$W = \text{Weight (g)}$$
$$SL = \text{Standard length (mm)}$$

Total length
Standard length

The total length-standard length relationship for 743 red drum fingerlings, 7-83 mm SL, reared at the PRB in 1978 and 1979 was:

$$TL = 1.0865 + 1.2258 SL$$
$$r^2 = 0.994$$

Where:

$$TL = \text{Total length (mm)}$$

Procedures for Culturing Red drum Fingerlings

TRANSPORTATION AND STOCKING OF FINGERLINGS

Transport Density Red drum fingerlings may be transported to stocking sites in any commercially available fish delivery tank. The tank should be equipped with compressed oxygen.

Stocking densities should be less than or equal to 150 g of fish/liter during transport. Maximum time at which red drum can be hauled at this density is unknown, but PRB personnel have successfully hauled fish at 150 g of fish/liter for 11.5 hours at 28 C water temperature.

Water Quality Dissolved oxygen should be maintained at 5-10 mg/l during transport by regulating the amount of compressed oxygen released in the tank.

Salinities should be the same as the pond water from which the fish are taken.

Comment Many culturists use agitators to prevent supersaturation of water with oxygen. Those planning to use agitators are advised to do so with extreme caution when transporting small (about 25-mm TL) red drum. Small red drum usually are unable to resist currents created by agitators and are frequently killed.

Acclimation of Fingerlings The following procedures are used to acclimate the fingerlings to temperatures and salinities at the release site:

- Exchange water in the hauling tank at approximately 2600 liters/hour. This is most easily accomplished by pumping water from the release site into the hauling tank using a battery (12V) operated pump with a flow rate of approximately 90 liters/minute.
 - Continue to exchange water until hauling tank water is within 5 o/oo and, 2 C of the environment into which the fish will be stocked before releasing them.
-

Procedures for Culturing Red drum Fingerlings

ADVANCED FINGERLING CULTURE

Introduction Culture of larger red drum fingerlings (about 50-250 mm TL) are occasionally required for special studies (Hysmith et al. 1983, Matlock et al. 1984). Procedures for culture of the larger fish are still being developed. The following methods are based on the best results obtained from a limited number of studies conducted at the PRB.

Stocking Density Less than or equal to 15,000/hectare to rear fish to approximately 230 mm TL and 140 g.

Feeding Rate The following feeding schedule was used by PRB personnel to rear red drum stocked at 15,000 fish/ha to 143 g (230 mm TL) in 229 days (27 March 1984 to 14 November 1984) with a 1.5:1 food conversion rate. Food used was Silver Cup Salmon Feed^R (Murray Elevators, Murray, UT).

FEEDING SCHEDULE

Day	Mean weight (g) of individual fish	Percent of estimated total biomass offered as feed
14-82	fry-8	10
82-109	8-20	8
109-138	20-50	5
138-194	50-100	3
194-229	100-143	1

Comment The low feeding rate offered during the last 35 days of the above feeding program was required because of declining temperature and problems in maintaining adequate dissolved oxygen concentrations. A feeding rate of 2-3% of estimated total biomass would have been appropriate if problems with dissolved oxygen concentrations had not been encountered.

(Continued)

Procedures for Culturing Red drum Fingerlings

ADVANCED FINGERLING CULTURE (Continued)

Comment

Red drum will feed on floating feed. If floating feed is used, the culturist may choose to feed the fish until active feeding ceases rather than use the above feeding schedule.

Growth Rate

Growth of advanced fingerlings to 230-mm TL using the above feeding program was almost linear (Figure 5).

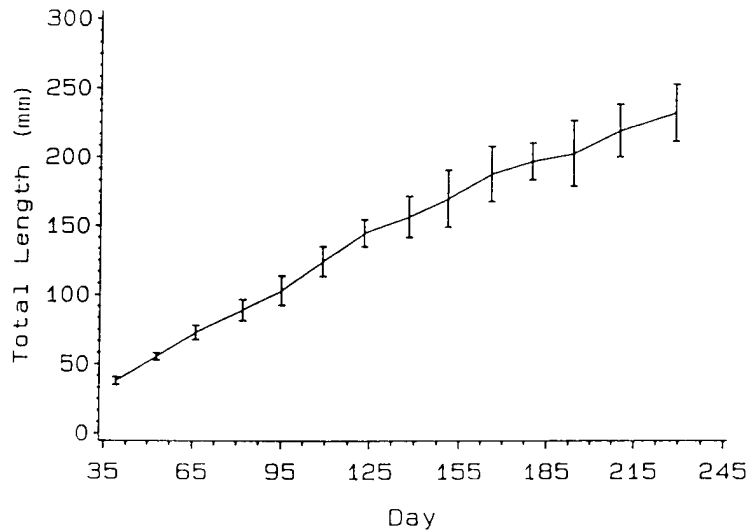


Figure 5. Growth of red drum to 230 mm TL in ponds at the Perry R. Bass Marine Fisheries Research Station 27 March 1984 to 14 November 1984. Points represent mean total length. Bars represent ± 1 SD.

Growth in total length was best described by the equation:

$$\begin{aligned} \text{TL} &= 5.468 + 1.038D \\ r^2 &= 0.9415 \\ n &= 770 \end{aligned}$$

where:

$$D = \text{days in pond}$$

The total weight-length relationship was

$$\begin{aligned} \log W &= -4.9806 + 2.9998 \log \text{TL} \\ r^2 &= 0.9972 \\ n &= 770 \end{aligned}$$

(Continued)

Procedures for Culturing Red drum Fingerlings

ADVANCED FINGERLING CULTURE (Continued)

Winter Feeding

During winter a reduced feeding rate has been found to be appropriate for culture of advanced red drum fingerlings. Reducing the feeding rate reduces overfeeding and helps prevent dissolved oxygen depletion when water temperatures rise. The following schedule has been used successfully at the PRB.

WINTER FEEDING SCHEDULE

Water temperature (C)	Percent of estimated total biomass offered as feed
> 18	2.0
15-18	1.0
10-14	0.5
< 10	No feed

Procedures for Culturing Red drum Fingerlings

REGULATIONS

Introduction Several state and federal licenses or permits are required to culture red drum in Texas. In addition, several agencies of both the state and federal government review and comment on applications for permits. A listing of regulatory, licensing or reviewing agencies is presented below. Included are addresses where the reader may obtain detailed information on procedures for applying for permits or purchasing licenses. Applicants may also contact their local county marine extension agent for assistance in applying for and obtaining permits and licenses. Regulations affecting fish farmers are subject to change, so appropriate local, state, and federal agencies should be contacted concerning the most recent regulations.

Texas Water Commission No permit is required to take brackish or marine water for rearing red drum, however, persons taking water must report their intention to the commission prior to taking the water.

Permit is required to divert fresh water.

Permit may be required to discharge water.

Contact: Texas Water Commission
P.O. Box 13087
Capitol Station
Austin, Texas 78711

General Land Office Permit is required for construction on state lands (i.e. bay bottoms).

A Coastal easement permit is required.

Contact: General Land Office
Land Management Program
Coastal Section
1700 N. Congress Ave.
Stephen F. Austin Bldg.
Austin, Texas 78701

Texas Department of Agriculture

A fish farming license is required.

(Continued)

Procedures for Culturing Red drum Fingerlings

REGULATIONS (Continued)

Texas Department of Agriculture (Cont.)	A permit to operate a processing plant for aquaculture products will be required if the fish are processed by the producer. Contact: Texas Department of Agriculture P.O. Box 12847 Austin, Texas 78711
---	--

Texas State Department of Health	Food Manufacturers Registration is required to process and package fish. Contact: Texas State Department of Health 1100 West 49th Street Austin, Texas 78756
--	---

Texas Parks & Wildlife Department	Administrative review of the project to assess environmental impact. Permit is required to collect broodfish from public waters. If hatchery reared broodstock are available from a commercial hatchery this permit may be denied. A sand, shell, gravel, and marl permit is required if bay bottom is removed to install intake or discharge structures. Contact: Texas Parks & Wildlife Department 4200 Smith School Road Austin, Texas 78744
---	--

Texas Antiquities Committee Texas Historical Commission	Administrative review of project to assess historical significance of site. Contact: Texas Antiquities Committee Texas Historical Commission P.O. Box 12276 Austin, Texas 78711
--	---

U.S. Environmental Protection Agency	A water discharge permit may be required. The Texas Water Commission will notify the applicant if Environmental Protection Agency involvement is necessary.
---	---

(Continued)

Procedures for Culturing Red drum Fingerlings

REGULATIONS (Continued)

U.S. Environmental Protection Agency (Cont.)	Contact:	U.S. Environmental Protection Agency Region 6 First International Bldg. 1201 Elm Street Dallas, Texas 75270
--	----------	---

Army Corps of Engineers	A permit for locating an aquaculture related structure in navigable waters is required.
----------------------------	---

A permit is required if any dredging and/or filling in navigable waters or wetlands are necessary.

Contact:	District Engineer U.S. Army Engineering District, Galveston Corps of Engineers P.O. Box 1229 Galveston, Texas 77553
----------	---

or

Corps of Engineers P.O. Box 2948 Corpus Christi, Texas 78403
--

U.S. Department Interior	Administrative review of the project to assess environmental impact
-----------------------------	---

Contact:	U.S. Department of Interior Fish and Wildlife Service CCSU 6300 Ocean Drive Campus Box 338 Corpus Christi, Texas 78412
----------	--

National Marine Fisheries Service	Administrative review of the project to assess environmental impact.
--------------------------------------	--

Contact:	National Marine Fisheries Service Environmental Protection Service 4700 Avenue U Galveston, Texas 77550
----------	--

Appendix B

Metric - English Measurements Conversion Table

Table B. 1. Conversion units for converting selected metric measurements to their English equivalent and for converting temperature from degrees celsius to degrees Fahrenheit.

Unit	Abbreviation	Equivalent
Length		
Meter	m	39.37 inch
Centimeter	cm	0.39 inch
Millimeter	mm	0.039 inch
Micron	μm	0.000039 inch
Area		
Hectare	ha	2.47 acres
Volume		
Liter	l	1.057 quarts
Milliliter ^a	ml	0.21 teaspoons
Mass and Weight		
Kilogram	kg	2.2 pounds
Gram	g	0.034 ounce
Milligram	mg	0.000034 ounce
Temperature		
Celsius	C	Fahrenheit = $1.8C + 32$

^a 1 milliliter = 1 Cubic centimeter which is frequently abbreviated as cc.

PWD-RP-3400-320-7/90

Dispersal of this publication conforms with Texas State Documents Depository Law, and it is available at Texas State Publications Clearinghouse and Texas Depository Libraries.

PWD-RP-3400-320-7/90

Dispersal of this publication conforms with Texas State Documents Depository Law, and it is available at Texas State Publications Clearinghouse and Texas Depository Libraries.