Red Drum

AQUACULTURE CURRICULUM GUIDE
SPECIES SPECIFIC MODULE

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## Red Drum Landings

Reported commercial and estimated recreational red drum landings (thousands of pounds) in the Gulf of Mexico, 1979-1986 (from Swingle, 1990 Status of Fishery In: Red Drum AQUACULTURE).

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<th>Year</th>
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<th>EEZ</th>
<th>Total</th>
<th>State Waters</th>
<th>EEZ</th>
<th>Totals</th>
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Marine Recreational Fishery Statistics Survey data provided by NMFS Southeast Fisheries Center by D. Delf, Dec. 3, 1986.
NMFS Landing Statistics, 1979-1985; 1985 data are preliminary and subject to change; Texas data and headboat data not available.
Landings in state waters include landings for which the area of capture is unknown, 1979-1985.
May not equal column totals due to rounding off.
Marketing Channels for Seafood

Producer

Coastal Wholesaler (Fish House)

Broker & Other facilitating Agencies

Inland Wholesaler (Distributor)

Retailer/Food Service Firms

User/Consumer
Size of Red Drum

Red drum grown in 20-foot diameter tanks in greenhouse under two temperature regimes. Solid line-temperature ranged from 27°C to 30°C; dashed line-temperature varied from 20°C to 24% during the grown-out period.

(Holt 1990)
Red Drum Larval Fish and Adult

Red Drum Larval Fish (300 hours post hatch)
Note pointed tail

Red Drum Adult Fish (slightly concave tail)
Controlled photothermal regime for induced maturation of red drum at John Wilson Marine Fish Hatchery.

Temperature fluctuations to induce spawning in mature red drum broodstock. Photoperiod remains constant at 10 HL.

From Roberts, 1990
3 Locations and Systems for Spawning Red Drum


<table>
<thead>
<tr>
<th></th>
<th>JWMFH</th>
<th>perry R. Bass Marine Research</th>
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<tr>
<td>Tank Size (Metric tons)</td>
<td>13</td>
<td>10-20</td>
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<tr>
<td>Filtration system</td>
<td>RBC, FB, SH, S, UV</td>
<td>PT, TF</td>
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<td>Fish/Tank</td>
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<td>4-6</td>
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<td>Sex ratio (M:F)</td>
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<td>2:2, 2:1, 1:2</td>
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<td>Max. regime photoperiod (HL)</td>
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<td>Spawning photoperiod (days)</td>
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<td>Mean no. eggs/spawn period (millions)</td>
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<td>Biopsy interval (weeks)</td>
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<td>Feeding regime (%bw.day)</td>
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<td>Conventional biofilter</td>
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<td>Diatomaceous earth</td>
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<tr>
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<td>Packed tower</td>
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<tr>
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<tr>
<td>RBC</td>
<td>Rotating biological contractor</td>
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<tr>
<td>UV</td>
<td>Ultraviolet filtration</td>
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</table>

From Roberts, 1990
Timetable for Red Drum Maturation

Timetable for red drum maturation. Demonstration of photoperiod and temperature changes necessary for reproductive maturation of red drum from winter condition (checkpoint A) to spawning condition (checkpoint D). Diagrammatic sample of oocyte stages for each checkpoint from ovarian biopsies of females.
Description: The module consists of the following four problem areas:

Module: Red Drum

Problem Areas: Determining Opportunities in Red Drum Culture
Exploring the Life Cycle of Red Drum and Aquaculture
Obtaining Seedstock and Spawning for Fingerling Production
Culturing Red Drum; Producing Eggs/Fingerlings; Growing Red Drum to Market Size

Objectives: The objectives for each problem area are given below:

A. Determining Opportunities in Red Drum Culture
   • identify areas where red drum occur naturally
   • describe how red drum reach the consumer in the United States
   • discuss economics and problems of producing red drum in the United States

B. Exploring the Life Cycle of Red Drum and Aquaculture
   • describe when and where red drum spawn
   • discuss environmental requirements to raise red drum
   • discuss factors controlling maturation/reproduction
   • discuss water quality requirements of red drum larvae
   • discuss food used to raise larvae

C. Obtaining Seedstock and Spawning for Fingerling Production
   • describe hatchery system used to spawn and raise red drum
   • describe common procedures for spawning red drum
   • describe common procedures for rearing larval red drum
   • describe procedures used in seawater treatment for hatcheries

D. Culturing Red Drum; Producing Eggs/Fingerlings; Growing Red Drum to Market Size
   • describe tank and filter system in which mature red drum may be held and spawned
   • describe care of broodfish
   • describe care of eggs and larval fish
   • describe how to rear fingerlings to 25 mm total length (TL)
   • describe how to rear advanced fingerlings (230 mm TL) to market size
Teaching Plan:

**Module:** Red Drum - Section A

**Problem Area:** Determining Opportunities in Red Drum Culture

**Estimated Time:** 2-4 hours

**Goal:** The goal of this problem area is to learn the origins of red drum culture and the possibilities for red drum culture in the United States.

**Learning Objectives:** Upon completion of this problem area, students will be able to:

- identify areas where red drum occur naturally
- describe how red drum reach the consumer in the United States
- discuss economics and problems of producing red drum in the United States

**Resources:** The following instructional resources are needed to complete this problem area:

**Essential:**

- Transparencies.

**Additional:**

Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, list the following terms on the board: taste (strong, fishy, or mild), texture (flaky or chewy), feeding (commercial feeds can be used or natural food only), survival rate (survives well or high loss in confinement), spawning (difficult or easy in captivity), water temperature requirements (lives well in warmwater or requires coldwater).

Ask the students through a show of hands to indicate their choice for an ideal fish for aquaculture. Record their choices on the board. Ask them if they have ever heard of red drum. Ask if anyone has ever eaten red drum. Explain to the students that they will learn the positive and negative attributes of red drum as an aquaculture species.

Presentation:

A. How are red drum classified?

Write the family Sciaenidae and the genus and species Sciaenops ocellatus, Linnaeus, on the board.

1. Red drum are members of the family Sciaenidae, are considered serial spawners, and release eggs several times over several weeks.
2. In the United States, \textit{Sciaenops ocellatus} is commonly called red fish, red drum, or less commonly, channel bass or spot tail bass.
3. The largest red drum recorded weighed 94 lbs.
4. The red drum normally have a characteristic reddish-orange color with one or more black spots on the tail. Their color can also range from silver to red-bronze.

B. What is the distribution of red drum and where are they cultured?

Show TM A1 and discuss red drum being cultured in the United States. Use a map of North America and have students locate the areas involved.

1. The red drum are quasi-catadromous scianid (Rounsefell 1975) and range from Tuxpan, Mexico, in the Gulf of Mexico to Massachusetts in the Atlantic Ocean.
2. Red drum have been aquacultured in the United States, Mexico, Panama, Belize, the Bahamas, Ecuador, and other Latin American and South American countries.
3. In the United States red drum can be cultured in extreme southern and geothermal regions, in power plant cooling water, indoor systems, pond/tank systems, and in West Texas (brackish aquifers).

C. What is the history of the red drum industry in the United States?

1. Major conflicts occurred for 100 years over allocating red drum.
2. Size limits were enacted in the 1920s.
4. Seasonal and area net closures were expanded over time to protect spawning adults.
5. In 1981 Texas regulations prohibited the sale of native red drum and effectively limited commercial fishing of red drum in Texas.
6. According to fisheries statistics, 13.5 million lbs of red fish were harvested commercially from the Gulf of Mexico waters in 1986, much of which came from Louisiana and Texas. Reported commercial and estimated recreational red drum landings from the Gulf increased from 11 million lbs in 1979 to 78 million lbs in 1986.

Show TM A2 and discuss the reported commercial and estimated recreational red drum landings.

7. The average yearly Texas harvest of red drum has been 3 million pounds, if the harvest from the years 1985-1986 is not included.
8. Harvesting red drum commercially was no longer allowed in Texas after 1986. Other states followed Texas in regulating the fishery.
9. Research in red drum has been conducted by various private companies and state governments in all 5 Gulf states (Florida, Mississippi, Alabama, Louisiana, and Texas). Along the Atlantic seaboard, South and North Carolina have conducted research, as well as several universities, the federal government (especially agencies such as the National Marine Fisheries Service and the Fish and Wildlife Service).
10. Red drum aquaculture officially began in South Carolina in the 1950s when a few fish entered an impoundment pond (Lunz 1951 and 1955). Bearden (1967) also demonstrated that red drum were a potential candidate for pond culture. True commercial development did not begin until the 1980s (after technology for controlled spawning was developed in 1975 and 1976 by C.R. Arnold and published in 1977, Arnold et al.).

D. Who eats red drum?

1. Red drum exist in wild populations as well as in aquaculture environments.
2. Red drum are very popular food fish and are now considered game fish in most states where they are found.
3. Red drum are sold at many fish markets, but most commonly at seafood restaurants with specialty items on the menu. (Red Lobster restaurants, for example, often have rainbow trout, grouper, and red drum on the menu.)

E. What are the marketing channels for red drum in the United States?

Show TM A3 and discuss the marketing channels for seafood.

1. The producer of seafood has several marketing channels available to get the product to the consumer. The producer can send it through a wholesaler, broker or other facilitating agency, retailer, or provide the product directly to the consumer.
2. Red drum reach the consumer in several ways. They may be imported from producers in Mexico, Panama, Ecuador, or other parts of the world or more commonly they may originate from U.S. producers. Ten U.S. producers were listed in Aquaculture Magazine’s Buyer’s Guide and Industry Directory for 1993 that have market size red drum for sale. Fingerling producers were also listed.
If available, prepare red drum and other species for a taste test. It is suggested that the filets be grilled.

3. International producers market their products much the same as seafood producers. Several corporations are involved. Granada Cattle Corp. of Houston, Texas, was growing red drum at one time on its farm in Agua Dulce, Panama, for U.S. sales. Other producers grow them in Mexico, Ecuador, and Belize for sale to U.S. markets. Also there are several red drum producers in the United States.

4. The preferred market size is either 3-4 lbs (for dress-out of two 9.5-10 oz filets; rib bones must be pulled out of belly flap) or 1.5 lbs (for serving in the headed, gutted, and scaled form). The 1.5-lb size is probably the more appropriate target size for aquaculture because it can be reached in approximately 12-18 months.

5. There are no red drum processing plants, so the producers must process the product or send it to a coastal wholesaler (fishhouse) if they will agree to process the fish.

6. Most U.S. consumers are familiar with red drum. Where high-quality red drum have been marketed, they have found good consumer acceptance. Red drum flesh is white, flaky, mild and not too fishy. In short, it is suitable for U.S. tastes because these consumers prefer fish that are somewhat bland and do not taste like fish. Red drum take on the taste of the spices used during preparation. Paul Prudhomme's recipe for blackened red fish created a national awareness and increased the demand for the species.

7. Farm raised red drum are usually 1 lb or larger when sold to fish wholesalers (fishhouses) or brokers and are usually delivered whole on ice. Prices paid to the producer are highly variable, but rose from $0.54/lb in 1977 to about $0.75/lb in 1984. Wholesale prices were up to $1.20/lb (range $0.80-1.40/lb) in 1986. It climbed to $4.00/lb for a while but settled to $1.75-3.50/lb (whole fish), sometimes bringing $3.50-4.50/lb for gilled and gutted fish (on the round). But more often the wholesale price for filets is $3.50-5.00/lb and $3.99-7.99/lb for retail.

F. Is it economically feasible to produce red drum?

Show TM A4 and discuss production methods for red drum.

1. Red drum are produced in ponds, tanks, and more recently in net pens offshore in the Gulf of Mexico. Production costs vary widely because of the varied input costs associated with each form of production. More commercial ventures fail in this business than have survived, but a few companies in the United States remain in the red drum aquaculture/production and marketing business. Fee fishing operations have grown more popular in recent years and have provided some potential for growth in this industry.

2. Principal problems in culturing red drum in the United States are the availability of low-cost, high-quality diet, high land and labor costs, regulations, and overwintering the fish.

3. Because of the cold climate, year-round outdoor culture in the United States is not possible. Therefore, the fish must be overwintered in some manner (by placing them in a greenhouse or heating the culture water or simply moving the fish indoors). In a few isolated situations warm water is available, i.e., geothermal regions and power plant cooling water, but not on a large scale. Several producers grow fish in intensive raceways indoors during winter and stock the fish in ponds for final growout during summer. The economics of this procedure still depends upon the varied input costs associated with each individual operation.

4. Economics of red drum aquaculture did not look good in the 1970s because with feed costs at $1.00/lb and red drum prices at $1.00-1.60/lb even the low feed conversion (1.1:1) reported by Trimble (1979) did not provide room for profits. With feed costs down and the price of fish up, the economics of red drum
Aquaculture is still questionable and must be addressed on an individual (farm by farm or system by system) basis.

Show TM A5 and discuss the economics of production.

5. Two- to 4-inch red drum fingerlings cost $0.25 each.

6. The producers’ selling price for whole red drum is still highly variable and producers must actively work with marketing to obtain the highest price possible for the product.

7. Yields from red drum are as follows: 88% of total weight remains after fish is gilled and gutted, skin-on filets from a 3.5-lb fish yield 34% of the total weight, and skinless filets yield 28% of the total weight. Two skinless filets weighing 0.5 lb can be produced from a 3.5-lb fish.

8. Although some growout trials have produced 2-lb fish in 1 year and 4-lb fish in 2 years, the average is 1.5 lbs in 18 months. A South Carolina research project produced 20,000 lbs of fish per acre, but economics was not a consideration (cost of pumping, feeding, aeration, etc).

9. Intensive operations are usually indoors with very high operating costs.

10. Red drum aquaculture is not automatically lucrative even with favorable prices. Primary restrictions to aquaculture are related to winter pond temperatures:

   a. Red drum fry (1 g) require 12 to 20 months of growth to reach a minimum market size of 0.9 kg.

   b. Although red drum are adaptable to a wide range of temperatures (Ross et al. 1983, Reagan 1985, Neill 1990), they are intolerant to abrupt decreases in water temperature (Gunter 1941, Gunter and Hildebrant 1951, Neill 1990).

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Application Activities:

Application can be addressed in several ways. Ask students to survey their parents and friends to determine if they have eaten red drum. Obtain red drum from a commercial source, prepare them, and conduct a taste test with the public. Students can survey the community to determine if red drum are sold in stores or served in restaurants.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning and a class debate on the merits of producing red drum in an aquaculture environment. Example exam questions are attached.
Where Red Drum Can Be Cultured in the United States

- Extreme southern regions of continental United States (from South Carolina to Texas)
- Geothermal regions
- Power plant cooling water
- Indoor systems
- Summer pond/tank production
- West Texas (brackish water aquifers)
Reported Commercial and Estimated Recreational Red Drum Landings

(Thousands of pounds) in the Gulf of Mexico, 1979-1986 (from Swingle, 1990)
Marketing Channels for Seafood
Production Methods

• Ponds
• Tanks
• Net Pens
Economics of Production

• Prices paid for whole red drum to the producer vary from $4.32 to 7.41/kg (approximately $2.00-3.50/lb)

• Prices for filets: $3.50-5.00/lb (wholesale) and $3.99-7.99/lb (retail)

• Feed costs vary from $0.50-1.50/lb

• 2- to 4-inch fingerlings cost $0.25 each

• Pond yield: Up to 4,000-9,000 lbs per acre per year

• Average growth rate of red drum in a pond is 1.5 lbs in 18 months

• Filet yields: Skin-on filets = 34% of total
Skinless filets = 28% of total
Quiz for Section A

Name:

Date:

Quiz on Determining the Opportunities in Red Drum Culture

Directions: Circle a T for True statements or an F for False statements.

1. T F Red drum are naturally found from North Carolina to Mexico.
2. T F Major conflicts have never occurred over allocating red drum.
3. T F Red drum were first produced using aquaculture in South Carolina in the 1950s.
4. T F Red drum is considered a serial spawner.
5. T F The species name of red drum is ocellatus.
6. T F The market prefers either a 3-4-lb fish for filets or a 1-1.5 lb fish served headed, gutted, and scaled.
7. T F Two- to 4-inch fingerlings cost $0.25 each.
8. T F Red drum is distributed to the consumer much the same as seafood.
9. T F The price paid to farmers for red drum range from $12.00- 13.50/lb.
10. T F There have been more failures than successes in red drum aquaculture since commercial development began in the 1980s.
Key for Quiz - Section A

1. T
2. F
3. T
4. T
5. T
6. T
7. T
8. T
9. F
10. T
Teaching Plan:

**Module:** Red Drum - Section B  
**Problem Area:** Exploring the Life Cycle of Red Drum and Aquaculture  
**Estimated Time:** 5-10 hours  
**Goal:** The goal of this problem area is to understand the biology and life cycle of red drum and learn the requirements for culturing red drum.  
**Learning Objectives:** Upon completing this problem area, students will be able to:  
- describe when and where red drum spawn  
- list environmental requirements to culture red drum  
- discuss major factors controlling maturation/reproduction  
- discuss water quality requirements of red drum larvae  
- discuss feeds used to raise larvae

**Resources:** The following instructional resources are needed to complete this problem area.

**Essential:**
- Transparencies.

**Additional:**
A Study of Redfish (*Sciaenops ocellatus*) and Black Drum (*Pogonias chromis*), by Simmons, E.G. and J. P. Breuer, Publication Marine Science Institute, University of Texas 8:184-211, 1962.
Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students the following question: What conditions are necessary to sustain the life of a person? List their answers on the board. Possible answers include air, water, food, shelter, clothing. How does this list differ when applied to red drum? Discuss their answers. Explain that all living organisms have environmental requirements. Explain that the class is going to learn about the particular cultural requirements of red drum so that we can understand how they can be aquacultured by humans.

Presentation:

A. Why is red drum being aquacultured in the United States and other countries?

1. Nutritional benefits of eating seafood becoming known.
2. In recent years red drum have attracted nationwide attention as a gourmet table fare.
3. Red drum are considered game fish in most states, and the commercial harvest of wild populations is severely restricted and/or prohibited in some states.
4. Demand is greater than supply in the United States.

B. What is the life cycle of red drum?

1. Red drum spawn from late August to late October near the shore and pass in the Gulf of Mexico and the Atlantic.
2. Normally, females less than 4 years old do not spawn.
3. An average 4-year-old fish weighs 13 lbs and is 32 inches long.
4. A 25-lb female may repeatedly release between .5 million to 2 million eggs.
5. Fertilized eggs hatch in 20 to 40 hours.
6. Larvae are swept to shore by currents where they find adequate food and habitats to grow up in bays and estuaries.
7. Juvenile red drum typically stay in coastal bays until sexual maturity, when they move back into the Gulf or Atlantic waters offshore.

C. What are the potential effects of red drum aquaculture on the seafood industry in the United States?

1. Seafood is the third largest trade deficit in the United States (next to oil and automobiles).
2. Catfish aquaculture has a definite effect on the U.S. seafood industry, but the red drum aquaculture industry is not large enough to have a noticeable effect on the U.S. seafood industry.
3. Red drum aquaculture also uses other industries (grain, etc., in feed) and provides jobs. A feed industry has developed because of aquaculture.

D. What are the advantages of aquacultured red drum?
1. The fish harvested are generally uniform in size, very tasty, and considered a fresh seafood.
2. Aquacultured red drum can be provided near-live or frozen to restaurants that serve seafood.
3. Cultured red drum can be predicted and planned for.
4. Allows industry to adapt to consumers' demand regarding sizes of fish desired.
5. Accordingly, red drum aquaculture provides a means to satisfy consumer demand without depleting natural populations.

E. What are some of the environmental requirements to raise red drum?

1. Red drum will tolerate a wide range of environmental conditions.
2. Salinities from 0 to 1.5 times greater than normal seawater have been tolerated by red drum.
3. The optimal salinity for development of red drum eggs and fry is 25-35 parts per thousand (ppt). Normal seawater is 35 ppt.
4. Eggs hatch over a broad range of salinities (5 to 50 ppt) but larvae successfully develop to first feeding only at 10 to 40 ppt, with best results at 25 to 30 ppt.
5. Fry stocked in greater than 45 ppt or less than 5 ppt show poor survival.
6. Advanced fry (0.3-0.5 inch) or fingerlings show more tolerance to low salinities than earlier life stages.
7. The environmental factor of most concern to red drum culture is temperature.
8. Fry survival is poor as temperature drops below 68°F. Red drum fingerlings and adults stop feeding from 41° to 48°F, and death occurs between 34° and 37°F.
9. The rate of the temperature drop is more devastating than the actual water temperature. A rapid drop will cause death while gradual lowering may not.
10. Red drum maintained in freshwater are more sensitive to cold temperature than those in saltwater.
11. Temperatures from 21° to 28.5°C (70-82°F) seem to support optimum growth of fingerlings to adults, whereas optimal conditions for red drum eggs and larvae are 25-30°C and salinities of 25-35 ppt.
12. Growth is also proportional to temperature, and growth rates can be increased by using heated water. Red drum have grown from 0.1 lb to 1.4 lbs in 5 months using a heated power plant discharge.

Show TM B1 and discuss red drum grown in 20-foot diameter.

13. pH is an important water quality factor in both salt and freshwater, but particularly in freshwater. In saltwater ponds pH should be around 8.0, while in freshwater ponds it can range from 6.5 to 8.0.

F. What are some of the physical characteristics of red drum larvae, juveniles, and adults?

Show TM B2 and discuss red drum larval fish and red drum adults.

1. Red drum larvae are difficult to identify because they are similar to Atlantic croaker except for pigmentation and the anal spines.
2. Juvenile red drum and adults differ externally in caudal fin (tail) shape and external color. Caudal fins are pointed in the young and become slightly concave in adults. Large black spots are distributed over the sides and back in 100-mm fish and enlarge until the fish is 150 mm, then fade and disappear.
3. A pronounced black spot or spots form on the upper caudal fin base when fish are 36 mm and remain on tail throughout life.
4. Adults are elongated, silvery reddish fish with an elevated back. The head is long, rather low, with a large mouth.

G. What are the major factors that control maturation/reproduction of red drum?

Show TM B3 and TM B4 and discuss the 120-day regime and timetable for maturation.
1. Photoperiod (light/dark period).
2. Temperature.

Show TM B5 and compare 3 locations and systems used to spawn red drum.

H. What are the water quality requirements of larvae?

1. Aerated water (gentle aeration not forceful).
2. Total ammonia below 1 ppm (preferable below 0.5 ppm).

I. What are the population density requirements for larval culture?

1. First 10-14 days larvae are stocked at 10-20 per liter.
2. After feeding on brine shrimp starts, larvae are maintained at 1-2 liters for 2 weeks.
3. After 1 month old, larvae are maintained at 1 larvae per 2 liters for final 2 weeks of larval culture.
4. Nets must not be used because they will kill larvae.

J. What food do larval red drum require?

1. At 3 days old red drum have eyes and mouth parts and can begin to feed. (Until this time, they have been living on yolk sac reserves for food.)
2. Larvae are first fed rotifers (a zooplankton from phylum Rotifera, which is approximately 100-300 microns in length).
3. Rotifers are fed to red drum larvae at a rate of 3-5 rotifers/ml (volume), from day 3 to days 9-11 after larvae have hatched.
4. On days 9-11 post-hatch, _Artemia_ (brine shrimp) nauplii are fed to red drum larvae.
5. _Artemia_ nauplii are maintained in the culture tank between 0.5 and 2.0/ml.
6. Larvae may be gradually trained or weaned to eat a prepared food (pellet or crumble feed).

Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Application Activities:

Application can be addressed in several ways. Students can conduct library research on various red drum studies. They can report their findings to the class. Students can also use reference materials to determine the pros and cons of culturing red drum. Emphasize both the positive and negative results. An aquarium project with red drum larvae could be conducted. If a red drum farm exists in the area, a field trip to the farm may be arranged.

Evaluation:
Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning, a class debate on the merits of producing red drum in an aquaculture environment, written reports, and written exams. Example exam questions are attached.
TM B3
TM B5
Quiz on Exploring the Life Cycle of Red Drum and Aquaculture

Circle a T for True statements or an F for False statements.

1. T  F  Red drum spawn in the spring of the year.
2. T  F  Normally, females less than 4 years old do not spawn.
3. T  F  A 25-lb female may repeatedly release between .5 million to 2 million eggs and is considered a serial spawners.
4. T  F  Red drum larvae grow to juveniles and juveniles grow to adults in deep ocean water.
5. T  F  The environmental factor of most concern to red drum culture is temperature.
6. T  F  Growth of red drum is proportional to temperature.
7. T  F  The rate of the temperature drop makes no difference to red drum culture.
8. T  F  Two major factors controlling maturation/reproduction of red drum are photoperiod and temperature.
9. T  F  The older red drum larvae are, the less densely they are stocked.
10. T  F  Advanced red drum larvae will not eat anything but live food and cannot be trained to eat a prepared diet (pellets or crumbles).
Key for Quiz - Section B

1. F
2. T
3. T
4. F
5. T
6. T
7. F
8. T
9. T
10. F
Teaching Plan:

**Module:** Red Drum - Section C

**Problem Area:** Obtaining Seedstock and Spawning for Fingerling Production

**Estimated Time:** 5-10 hours

**Goal:** The goal of this problem area is to understand spawning, production of food for larvae, and production of fingerlings.

**Learning Objectives:** Upon completing this problem area, students will be able to:

- describe hatchery systems used to spawn and raise red drum
- describe common procedures used in spawning red drum
- describe common procedures used in larval rearing red drum
- describe procedures used in seawater treatment for hatcheries

**Resources:** The following instructional resources are needed to complete this problem area:

**Essential:**

- Transparencies.
- Red Drum Aquaculture, Texas A&M University, Sea Grant College Program, Publication # 90-603, p. 236, 1990.

**Additional:**


Circular Broodfish Tank 15 ft in diameter or (9,500 gallons or more), bio-disc filter, water heater for maintaining water temperature, water basin, pump, rapid sand filter and ultraviolet filter as depicted in TM C1.

Larval rearing tank (150 l) or aquarium as depicted in TM C2. One-liter imhoff cone placed on a small wooden rack (TM C3) or a larger rack with ten 5-gallon plastic drinking water bottles. The bottles are inverted with the bottoms removed. Bottles are used to rear larvae and are equipped with heater, aeration, and drain (TM C4).

If available a small aquaculture pond (outdoors) or raceway (indoors or outdoors) can be used for red drum growout.
Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students the following questions: Where does one get the seed to plant tomatoes? Where does one get the chicks to stock a broiler house? Where does one get pine seedlings to start a forest?

The answers should include both producing and purchasing the seed, chicks, or seedlings. Why would one choose to purchase seed rather than produce it? Answers should include easier to purchase, less knowledge needed to purchase, more economical to purchase, do not have the facilities to produce seed, do not have the time to produce seed, and purchased seed may be of higher quality than seed produced at home. Finally, explain that red drum seedstock is similar to the above. One can produce it and/or buy it from an outside source. Which is better? That depends on many factors that will be discussed in this problem area.

Presentation:

A. What are the two major categories into which red drum culture can be divided that require different methods and facilities?

1. Hatchery operations entail maintaining and spawning mature broodfish, incubating fertilized eggs and fry (2.5-day-old fish measuring 0.08 inch), and producing fingerlings (3-4-week-old fish measuring 1 to 2 inches) in nursery ponds.

2. Growout operations entail the production of marketable size fish either in raceways or in ponds. Note: Only hatchery operations are covered in this problem area. Red drum growout will be covered in Section D.

B. Where are red drum obtained?

1. Fingerlings may be obtained from U.S. hatcheries in Texas, Florida, and Louisiana.

2. Limited numbers of red drum fingerlings are available in other countries such as Ecuador, Mexico, Bahamas, and Panama.

3. Broodfish may be collected from the wild if the proper broodstock collection permit is obtained.

C. What hatchery systems are used to spawn red drum?

1. In most aquaculture enterprises, obtaining spawns is one of the most difficult tasks the producer faces. Red drum spawn easier under the right conditions. Knowing the proper conditions and adhering to them separates the good hatcheries from the nonproductive ones.

2. Red drum normally become sexually mature once a year in the wild during the fall or in the hatchery environment under simulated fall conditions (shorter day and cooler temperatures).

3. Mature fish are placed in controlled environment tanks (9,500 gallons or more), equipped with appropriate filters and aerators.

4. Fish can subsequently be injected with hormones and allowed to spawn in the tanks or can be strip-spawned or spawned by manipulating photoperiod and temperature.
5. Strip-spawned entails forcing eggs and milt from the fish and mixing them manually to accomplish fertilization.
6. The same methods can be used on red drum that have been caught earlier in the year and held in large outdoor ponds or indoor tanks.
7. Hatchery systems using tanks can be managed more intensively for higher production. Tanks in a controlled environment are the most productive and are used extensively to propagate red drum. They are generally held as small fish over winter months (called overwintering) indoors and moved outside when temperatures are high enough to obtain growth outdoors.
8. Annual climatic changes can be compressed into a 3-month period, inducing the fish to spawn 4 times a year.

D. What do the eggs and larval fish look like?

Show TM C5 and discuss lab-spawned larval red drum hatched and raised at 25°C. Show TM C6 and discuss developmental stages of red drum.

1. Fertile red drum eggs measure 0.04 inch in diameter and must be incubated in natural or high-quality artificial seawater.
2. Fry generally hatch in 1 day, but require another 2 to 3 days to absorb the yolk sac and develop eyes, mouth parts, and a digestive tract.
3. At this point fry are approximately 0.08 inch long and require food.

E. How are fry reared?

1. Tank culture: involves feeding fry several kinds of live zooplankton (microcrustacea and rotifers) supplemented with artificial feeds. This method can be very time consuming and requires technical training because food organisms for fry are cultured separately.
2. Pond culture: more commonly used (saltwater ponds). Ponds are fertilized to stimulate natural zooplankton populations and filled with filtered seawater (filtered through 0.02-inch mesh screen to keep out predators and competitors but allows zooplankton to pass through).

F. What is involved in tank culture of red drum larvae?

Show TM C7 and discuss commonly cultured microalgae and zooplankton.

1. Culturing microalgae and zooplankton separately and feeding microalgae to zooplankton and then zooplankton are fed to red drum larvae.
2. Algae or phytoplankton are cultured in small tubes, then small flasks, then transferred to glass bottles or carboys.

Show TM C8, TM C9, and TM C10 and discuss the typical cycle used in algae culture and how glass carboys and culture racks are used.

3. Algae are then fed to zooplankton.
4. Zooplankton (one which is most often used) is the rotifer *Brachionus plicatulus*. Rotifers are cultured using two methods:
   a. Feeding algae, yeast, and emulsified oil.
   b. Feeding baker’s yeast and emulsified oil.

Show TM C11 and TM C12 and discuss the rotifer culture method using algae, yeast, and emulsified fish oil as well as baker’s yeast and emulsified fish oil.

5. Zooplankton (more commonly rotifers) are then fed to larval fish as their first introduced food. Fish larvae begin feeding about day 3 after hatching and are fed 3-5 rotifers/ml.

6. Other zooplankton can be fed to larval red drum, but none are as easily cultured as the rotifer.

Show TM C13 and discuss the distinguishing characteristics of rotifers and copepods, etc.

7. A larger zooplankton (*Artemia* or brine shrimp) is fed to the larval fish after the fish are 9-11 days old. *Artemia* nauplii are fed at a density of 0.5 to 2.0/ml.

8. Freshly hatched *Artemia* nauplii (Instar V larva) are preferred as food because they are high in Highly Unsaturated Fatty Acids (HUFAs).

Show TM C14 and discuss *Artemia* cyst and nauplii.

9. The *Artemia* nauplii are near perfect size food for the red drum larvae's mouth. The *Artemia* nauplii is an active swimmer and is seen and captured easily by larval fish.

Show TM C15 and discuss the features of a 300-hour-old fish and *Artemia*.

10. *Artemia* cysts are purchased in dried form and placed in seawater with aeration and light to hatch. Five grams of cysts per liter of seawater are hydrated in the hatching containers. (Refer to TM C3, Imhoff Cone Rack *Artemia* Hatching Cones.)

11. Larval fish are held in aquariums or in other types of rearing tanks such as those in TM C2.

G. What are the incoming water treatment requirements in red drum hatcheries?

Optional activity: Set up a tank such as an aquarium or a tank like the ones in TM C2 or TM C4. Place 25-35 ppt salinity saltwater in the tank with red drum larval fish as a class project. Follow temperature and other requirements listed in this module. Divide class into groups, depending upon how many tanks and students are available. Feed fish as directed with rotifers obtained from Carolina Biological Supply (North Carolina) and *Artemia* nauplii (hatched in the hatchery).

1. Two basic water treatment steps taken in a red drum hatchery are filtration and ultraviolet (UV) disinfection.

2. Incoming seawater is generally filtered down to 1 micron before use in larval rearing and algae production. To deal with large volumes of water for a large hatchery the following steps are usually taken:
   a. Subsand intake to filter out large debris.
b. Pipeline to inshore (via pumping).
c. Setting and slowsand filter.
d. Pressurized sand filter (~12 microns).
e. Diatomaceous filter (~3 microns).
f. Cartridge filters 5-1 microns.
g. UV treatment.

3. Once the water is in the system and is being recirculated, a biological filter is used.
Review:

Review by having students demonstrate their knowledge and understanding of the objectives for this problem area. Lead a discussion with students by asking questions that cause them to explain the content that goes with each objective.

Application Activities:

Application can be addressed in several ways. If the class has access to a tank or suitable pond, a spawning project or larval rearing project would make an excellent application. A larval rearing project with red drum would probably be the easiest and shortest project. Students can also do library work to locate current articles on spawning and producing red drum. Students can do library work to see what other feed can be given to red drum larvae. Students could design a hatchery system on paper to produce red drum.

Evaluation:

Evaluation should focus on the extent to which students achieved the objectives of the problem area. Examples include oral questioning, a class debate on the merits of spawning red drum in captivity by the method studied versus rearing larvae in captivity, written reports, and written exams. Example exam questions are attached.
Circular Broodfish Tank

Typical red drum spawning room, John Wilson Marine Fish Hatchery
1. Fiberglass brood tank
2. Bio-disc filter
3. Water basin
4. Pump
5. Rapid sand filter
6. Ultraviolet filter

(McCarty 1990)
Larval Rearing Tank

150-liter fiberglass tank

(Holt et al. 1990)
Imholf Cone Rack

Glass Pipet

Plastic Valve

Artemia Hatching Cones
Plastic Drinking Water Bottle
Inverted With Air, Water, etc.

A  Thermostatically controlled heater
B  Siphon with mesh sieve
C  Aeration with airstone
D  Drainage pipe; do not use
**Lab-Spawned Larval Red Drum**

Timing of sciaenid egg stages at 25°C

1.5 hours  
A 1 hour old yolk-sac larva  
(1.7 mm SL)

4 hours  
B 3-day-old first feeding larva  
(2.5 mm SL)

12 hours  
C 10 days old (4.2 mm SL)

17 hours  
D 2 weeks old (5.1 mm SL)

Lab-spawned larval red drum hatched and raised at 25°C
Developmental Stages of Red Drum

standard length

7.8 mm

10 mm

21 mm

Bar = 1 mm

(Holt 1990)
Microalgae and Zooplankton

Tefrase/mksp. (10-15 µm)

Isochrysis sp. (3-5 µm)

Brachionus (Rotifer) with eggs

Adult size range 99-281 µm long (without eggs)
66-182 µm wide
Attached eggs add about 90 µm to rotifer's length

(Treece and Wohlschlag 1990)
Typical Cycle for Algae Culture

STOCK CULTURE
±50 ml test tube

Fresh tubes inoculated every 2 weeks

WORKING CULTURE
±50 ml test tube

Transferred every 2 days

Medium: Guillard’s F/8
Temperature: 20°C
Photoperiod: 12/12 light/dark

+250 ml to 2 l flask

Transferred every 2 days

Medium: Guillard’s F/2
Temperature: ambient (24-28°C)
Photoperiod: 24 hrs light

WORKING CULTURE

Transferred every 2 days

Medium: Guillard’s F/2
Temperature: ambient
Photoperiod: 24 hrs light

Aeration: constant

Feed larval rearing tank as needed up to 8-day-old culture

NOTE: The richer Guillard’s F/1 medium has twice the amount of each nutrient per liter of seawater.

(Treece and Yates 1990)
Glass Carboy

(Treece and Wohlschlag 1990)
Typical Algae Culture Rack

(Treece and Wohlschlag 1990)
Rotifer Culture: Part 1

Algae

Test tube (maintenance culture)

125 ml Flask

1800 l Tank

121 Carboy

add F/2 media

maintain until algae reaches 132,000 cell/ml

After algae is depleted, add daily

Yeast 0.5 g/10 l

and

Oil Emulsion 1-2 ml/10 l

Yeast 0.7-1.0 g/10 l

and

Oil Emulsion 2-3 mg/10 l

Density of rotifer 100/ml or more

Harvest at 150-200 rotifers/ml;

Rotifers

Flask (maintenance culture)

Carboy

inoculated 10/ml

Diagram of rotifer culture method using algae, yeast and emulsified fish oil.

(Treece and Wohlschlag 1990)
Rotifer Culture: Part 2

Diagram of rotifer culture using bakers yeast and emulsified fish oil.

(Wohischlag et al 1990)
Distinguishing Characteristics of Rotifers and Copepods

Rotifers

Corona
Trunk
Foot

Keratella spp.
Brachionus spp.

Copepods

Antennae
Eye
Cephalothorax
Abdomen
Nauplii

Harpacticoid
Egged female
Calanoid
Cyclopoid

The 2 dominant zooplankton groups in saltwater-rearing ponds (not to scale).

(Sturmer 1990)
Artemi Cyst and Nauplii

300 pm
Pre-nauplius in E-1 stage

Pre-nauplius in E-2 stage

Freshly hatched Instar I nauplius

Instar V larva

(Treece and Wohlschlag 1990)
300-Hour-Old Fish and Artemia

Larval red drum (300 hours post hatch) and freshly hatched *Artemia* nauplius (428 micrometers standard length).

(Treece and Wohlschlag 1990)
Quiz on Obtaining Seedstock and Spawning Fingerlings to Production

1. What 3 states in the United States most commonly culture the red drum?

2. What are the 2 most common zooplankton used in hatcheries to feed red drum larvae?

3. What are the two main parameters that are manipulated to cause the red drum to spawn?

4. What are two basic incoming water treatment steps taken in a red drum hatchery?
Key for Quiz - Section C

1. Texas, Florida, and Louisiana.
3. Temperature and photoperiod.
Schematics

Schematic of red drum broodfish conditioning and spawning system. Arrows show direction of water flow.

Filter Screen
Filter Tank
Raceway

(Schematic diagram of a high density, recirculating growout system.)

(Arnold and Reed 1990)
Comparison of Dinoflagellates Commonly Parasitizing Fishes

Piscinoodinium is a genus that infects a variety of freshwater fishes and is sometimes encountered in freshwater aquaria. Crepidoodinium is a parasite of cyprinodontid fishes. Amyloodinium is the only dinoflagellate parasite expected on red drum.

(Johnson 1990)
Some Reported or Probable Internal Parasites of Red Drum

Leichthirium, Bucephaloides, Opecoeloides and Cardiola are internal trematodes. The first 3 are in the digestive tract; whereas the latter is found in the heart or major blood vessels. (Stomachola) is sometimes found imbedded in tissues of drums and is large (up to 1/2 inch) and conspicuous (pink). Poecilancistrium is a tapeworm found as an immature stage, one of the “spaghetti worms.” The figure shows only the head or scolex. Spirocammallanus, Hysterothyacium, Goezia, and Dichelyne are nematodes. Except for the latter, views of the anterior are shown. For Goezia, a top view of the head end is shown.

Leichthirium (Mander 1947); Bucephaloides (Riggin and Sparks 1962); Opecoeloides (Soedares-Bernal and Hutton 1959); Cardiola (Schell 1985); Poecilancistrium (Thatcher 1950); Spirocammallanus (Fusco and Overstreet 1978); Hysterothyacium (Deardoff and Overstreet 1981); Goezia (Deardoff and Overstreet 1980); Dichelyne (Chandler 1935).
Argulus bicolor parasites affix to skin & surfaces of mouth cavity. Anilocra, Nerocila, & Lironeca are isopod parasites. First 2 are found on skin and latter in the gill cavity of host. Only posterior portion of Lironeca is shown here. Cymothoa, is found within mouth cavity. Caligus, Echetus, Lernaeenicus, Lernanthropus, Sciaenophilus, Lepeophthirius, Ergasilus, & Neobranchiella are copepods. Most will be found attached to gills or within gill or mouth cavity. Lernaeenicus attaches by embedding anterior into skin on body surface. Caligus maybe found on body surface as adult. Several copepods produce larval stages infesting skin of many fish. The more common Caligus & Lepeophthirius produce a larva with a stage known as chalimus, These anchor to host skin by a filament. Caligus & Lepeophthirius are similar copepod groups, easily distinguished by presence in Caligus of Iunules, which are obvious circular structures lying anterior between the antennae. Ergasilus has not been reported from the red drum; but, because it is a common gill parasite and has been found on other drum species, it is figured as a probable copepod parasite of red drum.

[Johnson 1990 { Argulus & Lernanthropos (Bere 1936); Anilocra, Nerocila & Lironeca (Schultz 1969); Caligus, Echetus, Lernaeenicus, Lepeophthirius, Neobranchiella & Sciaenophilus (Yamaguti 1963); Ergasilus (Roberts 1969) }]
Some Reported or Probable Internal Parasites of Red Drum

Lecithochirium, Bucephaloides, Opecoeloides and Cardioca are internal trematodes. The first 3 are in the digestive tract; whereas the latter is found in the heart or major blood vessels. (Stomachola) is sometimes found imbedded in tissues of drums and is large (up to 1/2 inch) and conspicuous (pink). Poecilancistrum is a tapeworm found as an immature stage, one of the "spaghetti worms." The figure shows only the head or scolex. Spirocammallanus, Hysterothyacium, Goezia, and Dichelyne are nematodes. Except for the latter, views of the anterior are shown. For Goezia, a top view of the head end is shown.

Lecithochirium (Manter 1947); Bucephaloides (Riggin and Sparks 1962); Opecoeloides (Gogardes-Bernal and Hutton 1959); Cardioca (Schell 1965); Poecilancistrum (Thatcher 1960); Spirocammallanus (Fusco and Overstreet 1978); Hysterothyacium (Deardoff and Overstreet 1981); Goezia (Deardoff and Overstreet 1980); Dichelyne (Chandler 1935).
# Photoperiod - Temperature Regime

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<thead>
<tr>
<th>DAY</th>
<th>TEMPERATURE (°C)</th>
<th>HOURS OF LIGHT/DAY</th>
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<tr>
<td>0-9</td>
<td>20</td>
<td>11</td>
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<tr>
<td>10-14</td>
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<td>12</td>
</tr>
<tr>
<td>140-150</td>
<td>24</td>
<td>11</td>
</tr>
</tbody>
</table>

(McCarty et al. 1986)
Typical Outside Levee Section

(Ulmer 1990)
80-Acre Red Drum Pond Growout Complex

2
10 Ac.

1
10 Ac.

4
10 Ac.

3
10 Ac.

6
2.5 Ac.

7
2.5 Ac.

8
2.5 Ac.

9
2.5 Ac.

10
2.5 Ac.

Feed Bin

80 Acres of Land
64 Acres of Water

(Ulmer 1990)
170-Acre. 3 Phase. Growout Farm for Red Drum

20 Ac.

1

20 Ac.

3

20 Ac.

4

20 Ac.

5

20 Ac.

6

20 Ac.

12

4.5 Ac.

11

4.5 Ac.

10

4.5 Ac.

9

4.5 Ac.

8

4.5 Ac.

7

4.5 Ac.

Access to Road

Feed Bin

Water Line from Pipe

170 Acres of Land
151.8 Acres of Water
Concrete Drain Structure

Used at the
Perry R. Bass Marine Fisheries Research Station

(Texas Parks & Wildlife)
“Kansas Kettle” Concrete Drain Box

Used in 0.2 ha ponds at Texas Parks and Wildlife Hatchery

(Texas Parks & Wildlife)
### Pond Fertilization Schedule

<table>
<thead>
<tr>
<th>DAY</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Spread 282 kg cottonseed meal (CSM) on the dry pond bottom. Fill to approximately 1 m depth.</td>
</tr>
<tr>
<td>3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Continue filling. Add 9.0 l (phosphoric acid and 4.6 kg urea)</td>
</tr>
<tr>
<td>7</td>
<td>Add 31.3 kg CSM</td>
</tr>
<tr>
<td>10</td>
<td>Add 31.3 kg CSM</td>
</tr>
<tr>
<td>12</td>
<td>Add 31.3 kg CSM, 3.0 l phosphoric acid, 4.6 kg urea</td>
</tr>
<tr>
<td>15</td>
<td>Add 31.3 kg CSM</td>
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<tr>
<td>17</td>
<td>Add 31.3 kg CSM</td>
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<tr>
<td>19</td>
<td>Add 31.3 kg CSM</td>
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<td>Add 31.3 kg CSM</td>
</tr>
<tr>
<td>23</td>
<td>Add 31.3 kg CSM</td>
</tr>
<tr>
<td>25&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Add 31.3 kg CSM, 3.0 l phosphoric, 4.6 kg urea</td>
</tr>
</tbody>
</table>

<sup>a</sup>Phosphoric acid 55% $\text{P}_2\text{O}_5$. Urea 45% N  
<sup>b</sup>Additional fertilizer may be added if fry stocking is late or growth is slow.
Hensen-Stample Pipet

Stainless Steel Push Rod

Clear Plastic Tube

Interchangeable Rubber "O" Rings Trap either 1 ml, 2 mls, 5 mls or 10 ml sample

(Treece and Yates 1990)
# Feeding Schedules

## FEEDING SCHEDULE AT 15,000 FISH/HA

<table>
<thead>
<tr>
<th>Day</th>
<th>Mean weight (g) of Individual Fish</th>
<th>Percentage of Estimated Total Biomass Offered as Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>14-82</td>
<td>fry-8</td>
<td>10</td>
</tr>
<tr>
<td>82-109</td>
<td>8-20</td>
<td>8</td>
</tr>
<tr>
<td>109-138</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>138-194</td>
<td>50-100</td>
<td>3</td>
</tr>
<tr>
<td>194-229</td>
<td>100-143</td>
<td>1</td>
</tr>
</tbody>
</table>

## WINTER FEEDING SCHEDULE

<table>
<thead>
<tr>
<th>Water Temperature (°C)</th>
<th>Percentage of Estimated Total Biomass Offered as Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;18</td>
<td>2.0</td>
</tr>
<tr>
<td>15-18</td>
<td>1.0</td>
</tr>
<tr>
<td>10-14</td>
<td>0.5</td>
</tr>
<tr>
<td>&lt;10</td>
<td>No feed</td>
</tr>
</tbody>
</table>
## Suggestions for Feeding Red Drum

<table>
<thead>
<tr>
<th>Fish size</th>
<th>Feed Type</th>
<th>Protein Level (percent)</th>
<th>Feeding Rate (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>#2 crumble</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>3-6</td>
<td>#3 crumble or 3/32 to 1/8 inch sinking or floating pellet</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>6-8</td>
<td>3/32 to 1/4 inch sinking or floating pellet</td>
<td>35-45</td>
<td>4</td>
</tr>
<tr>
<td>8-harvest</td>
<td>3/32 to 1/4 inch sinking or floating pellet</td>
<td>32-38</td>
<td>3</td>
</tr>
</tbody>
</table>

1. Modified from data provided by Texas Parks and Wildlife Department and Texas A&M University
2. Recommended feed for small fish (1 or 2 inches) is a feed containing high levels of animal protein, such as a salmon feed. Other feeds containing high levels of animal protein can be used. Larger fish (6 inches or more) may be fed a pelleted feed that contains lower amounts of fish meal; that is, a feed formulated for redfish, a trout feed, or a high-quality catfish feed.
3. Daily feeding rate based on percentage of body weight of standing crop. Fish maybe fed to satiation if so desired. If satiation feeding is used, comply with cautions given in the feeding section of this paper. These rates are based on temperatures that are in the optimum range for red drum growth.

(Modified from data provided by Texas Parks and Wildlife Dept. and Texas A&M University)
Growth of Red Drum to 230 mm TL in Ponds

(Colura et al. 1990)