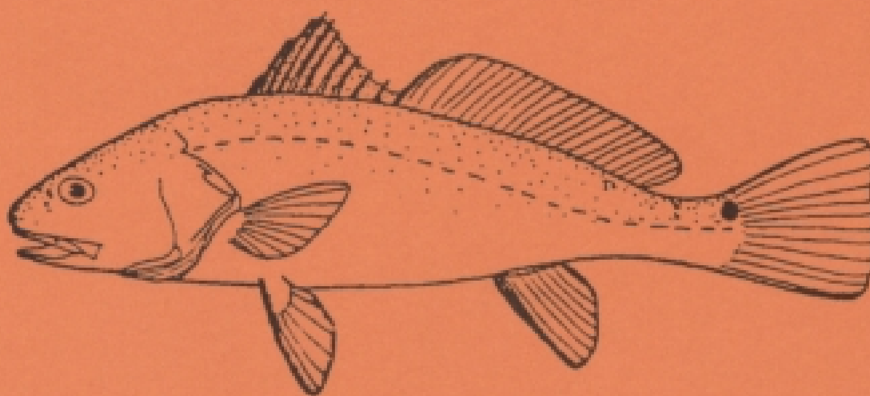
Red Drum

AQUACULTURE CURRICULUM GUIDE
SPECIES SPECIFIC MODULE



Produced By:
The National Council for Agricultural Education
Alexandria, Virginia

With a Grant from
United States Department of Agriculture
Cooperative State Research Service

1995

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1995 Preliminary Edition

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This material is based upon work supported by the Cooperative State Research Service, U.S. Department of Agriculture, under Agreement No. 90-38816-5653.

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:

Red Drum Aquaculture, compilers Chamberlain et al., Texas A&M University, Sea Grant Program, Publication #90-603, p. 236, 1990.

Transparencies.

Additional:

Laboratory Spawning and Larval Rearing of Red Drum and Southern Flounder, Proceedings of Annual Conference S.E. Association, by Arnold, C.R., J.D. Williams, A. Johnson, W.H. Bailey, and J.L. Lasswell, Fish and Wildlife Agencies. 31:437-441, 1977.

Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms, by Bardach, John E., John H. Ryther, and William O. McLarney, Wiley-Interscience, NY, 1972.

Aquaculture - An Introduction, by Lee, Jasper S. and Michael E. Newman, Interstate Publishers, Inc., Danville, IL, 1992.

Indoor Intensive Red Drum Aquaculture: A Stochastic Sensitivity Analysis, by Thacker, S.G. and W.L. Griffin, Department of Agriculture Economics, Texas A&M University, in press.

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, *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.
3. J.C. Pearson published "Natural History and Conservation of Red Fish and Other Commercial Sciaenids on the Texas Coast" in 1929 (Bur. Fish. Bull. 44:129-214).
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.

TM A1

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)

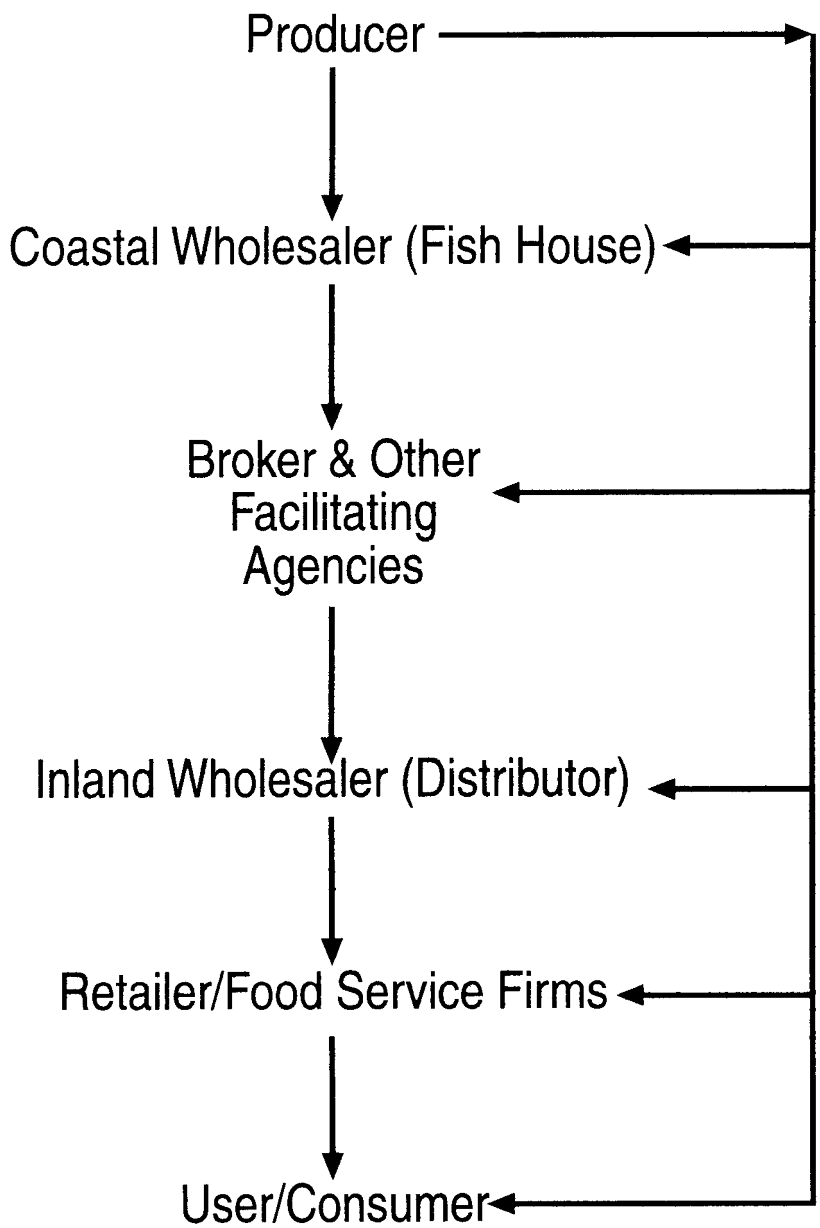
Red Drum Landings

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)

	Recreational[1]			Commercial[2]					
Year	State Waters[3]	EEZ	Total[4]	State Waters	EEZ	Totals[4]	State Waters	EEZ	Total
1979	8,536	34	3,570	2,691	80	2,771	11,227	114	11,341
1980	6,863	1,282	8,145	2,681	48	2,729	9,544	1,330	10,874
1981	5,351	306	5,657	2,717	31	2,748	8,068	337	8,405
1982	10,259	475	10,734	2,348	77	2,425	12,607	552	13,159
1983	5,397	2,065	7,462	2,881	206	3,087	8,278	2,271	10,549
1984	4,964	1,491	6,425	3,347	987	4,334	8,281	2,478	10,759
1985	6,212	324	6,536	2,886	3,457	6,343	9,098	3,781	12,879
1986[2]	3,484	232	4,080	5,346	8,184	13,535	10,223	7,268	17,615
Total[3]	47,552	5,977	53,524	19,551	4,886	24,4378	67,103	10,863	77,960
Ave[3]	6,793	854	7,647	2,793	698	3,491	9,580	1,552	11,138

[1]Marine Recreational Fishery Statistics Survey data provided to NMFS Southeast Fisheries Center by D. Duel, Dec. 3, 1986.
[2]NMFS Landing Statistics, 1979-1985; 1985 data are preliminary and subject to change; Texas data and headboat data not available.
[3]Landings in state waters include landings for which the area of capture is unknown, 1979-1985.
[4]May not equal column totals due to rounding off.

Marketing Channels for Seafood



TM A4

Production Methods

- Ponds
- Tanks
- Net Pens

TM A5

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 l950s.
4.	T	F	Red drum is considered a serial spawner.
5.	T	F	The species name of red drum in *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.

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

Introduction to Aquaculture, by Landau, M. Mathew, John Wiley & Sons, Inc., NY, 1992.

Additional:

Red Drum Aquaculture, Proceedings of a Symposium on the Culture of Red Drum and Other Warm Water Fishes. University of Texas at Austin, Marine Science Institute, Editors: G.R. Arnold, G.J. Holt, and P. Thomas, 1988.

Laboratory Spawning and Larval Rearing of Red Drum and Southern Flounder, by Arnold et al., Proceedings Annual Conference S.E. Association. Fish Wildlife Agencies, 31:437-441.

The Life History of Red Drum. In: Red Drum Aquaculture, by Madock, G.C., Texas A&M University, Sea Grant College Program, Publication #90-603 pp. 1-21, 1990.

Red Drum Farming in Texas, by Ann Henderson-Anapalo et al., Perry R. Bass Marine Fisheries Research Station, Palacios, Texas (a Texas Parks & Wildlife Publication), 1987.

Red Drum Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Gulf of Mexico), Reagan, R.E. Editor, U.S. Fish & Wildlife Service Biol. Report 82:1-16, 1985.

Environmental Requirements of Red Drum, by Neill, W.H. In: Red Drum Aquaculture, Texas A&M University, Sea Grant College Program, Publication #90-603, pp. 105-108, 1990.

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.

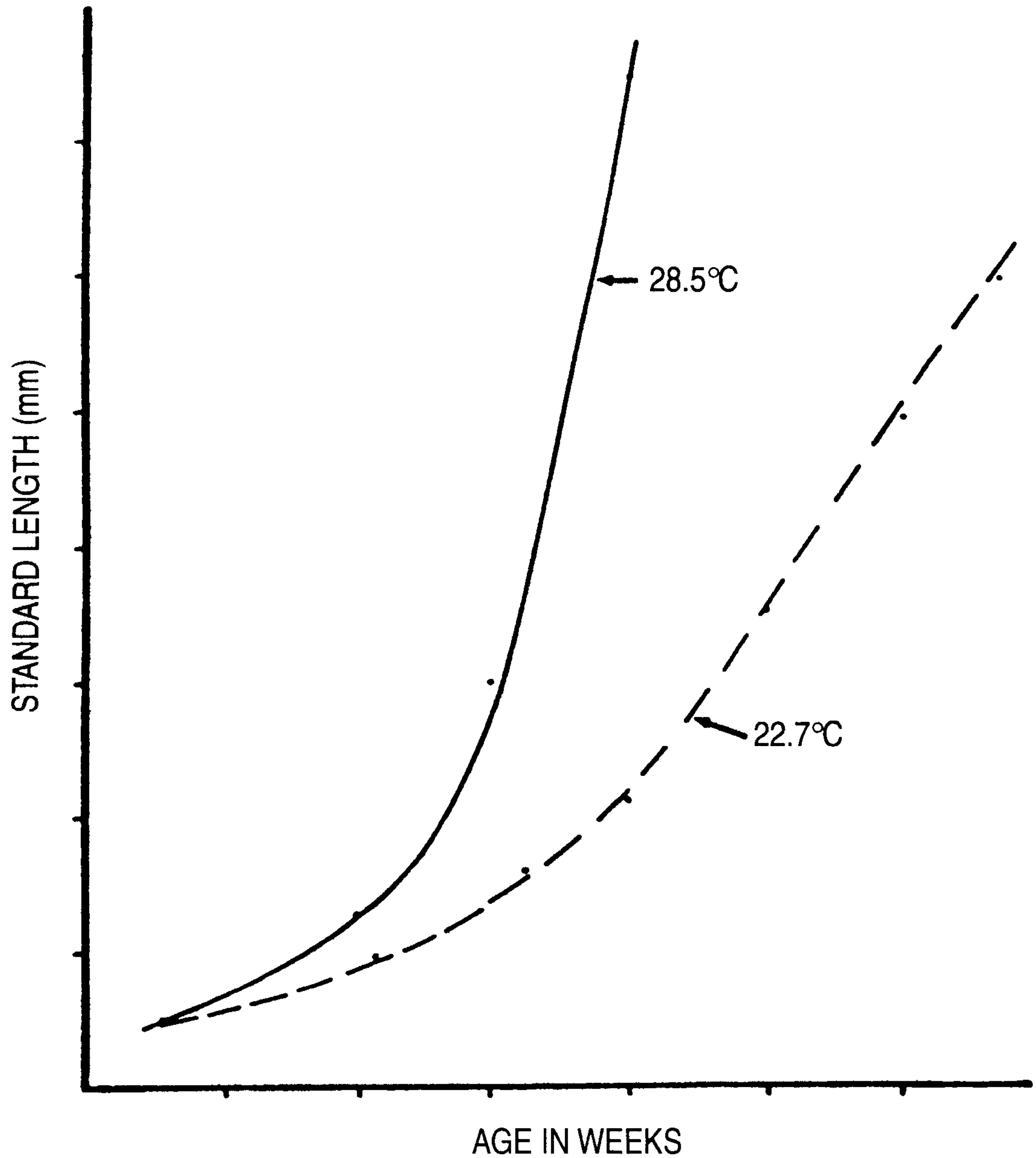
Application Activities:

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.

Size of Red Drum

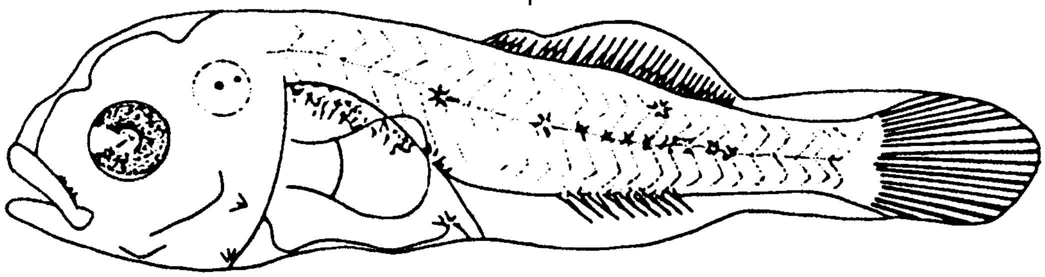


Red drum grown in 20-foot diameter tanks in greenhouse under two temperature regimes. Solid line-temperature ranged from 27°C to 30°C; dashed line-temperature varied from 20°C to 24°C during the grown-out period.

(Holt 1990)

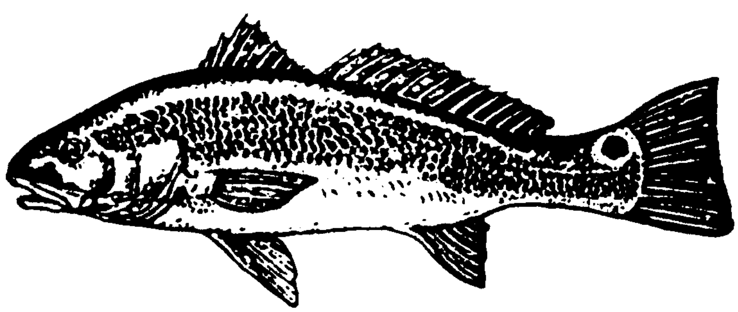
Red Drum Larval Fish and Adult

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

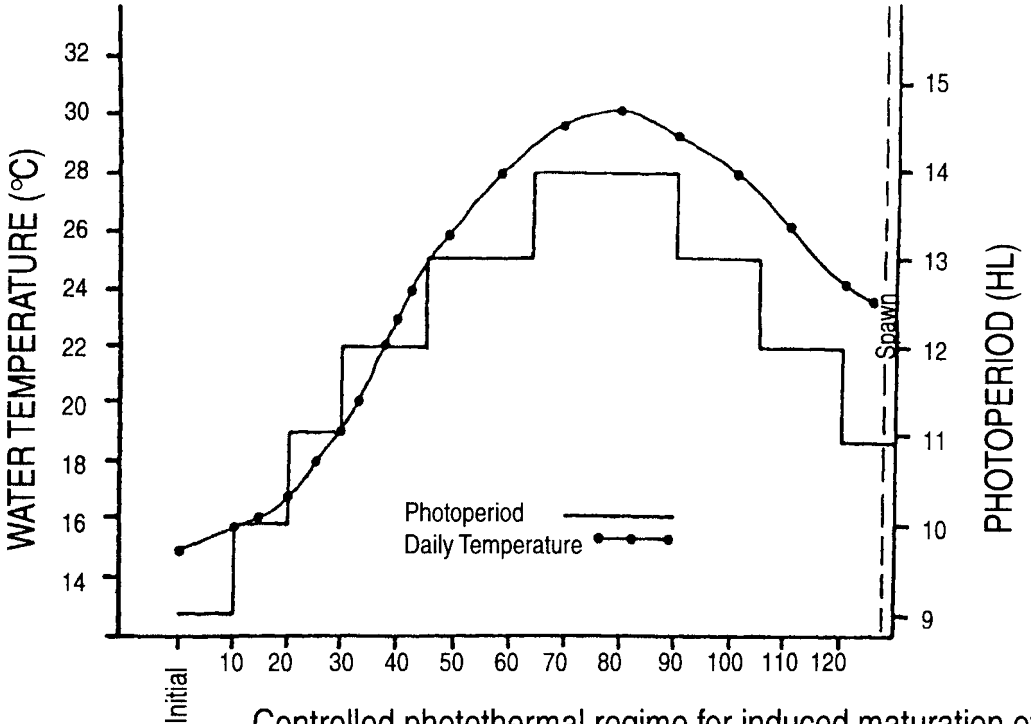


1 mm

Red Drum Adult Fish (slightly concave tail)

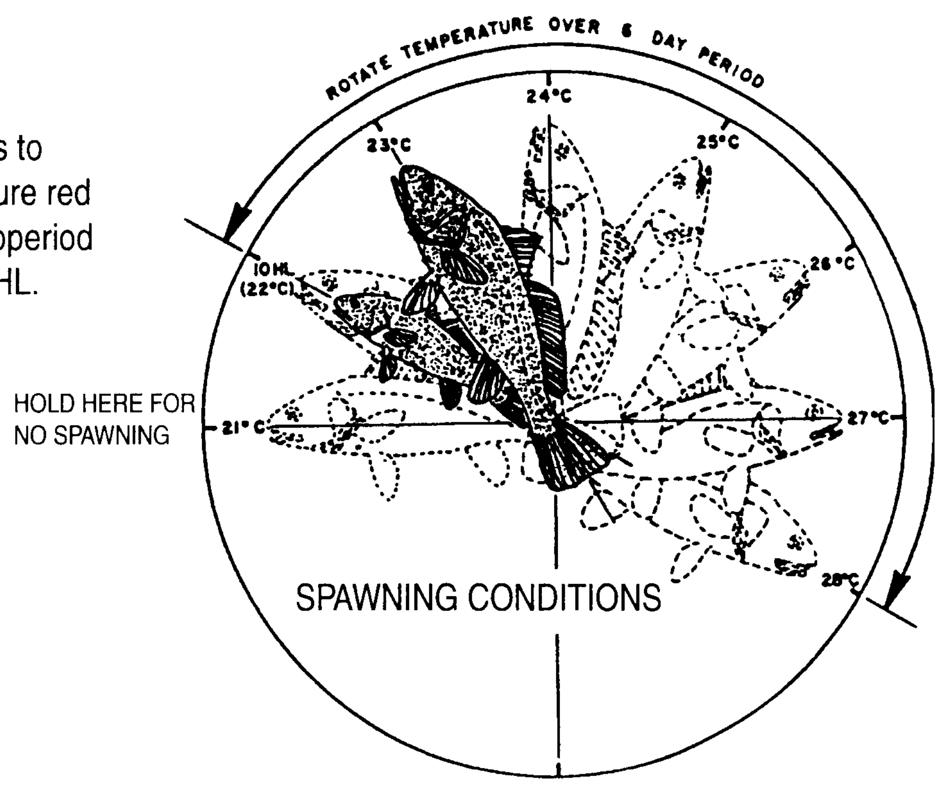


120-Day Time Regime



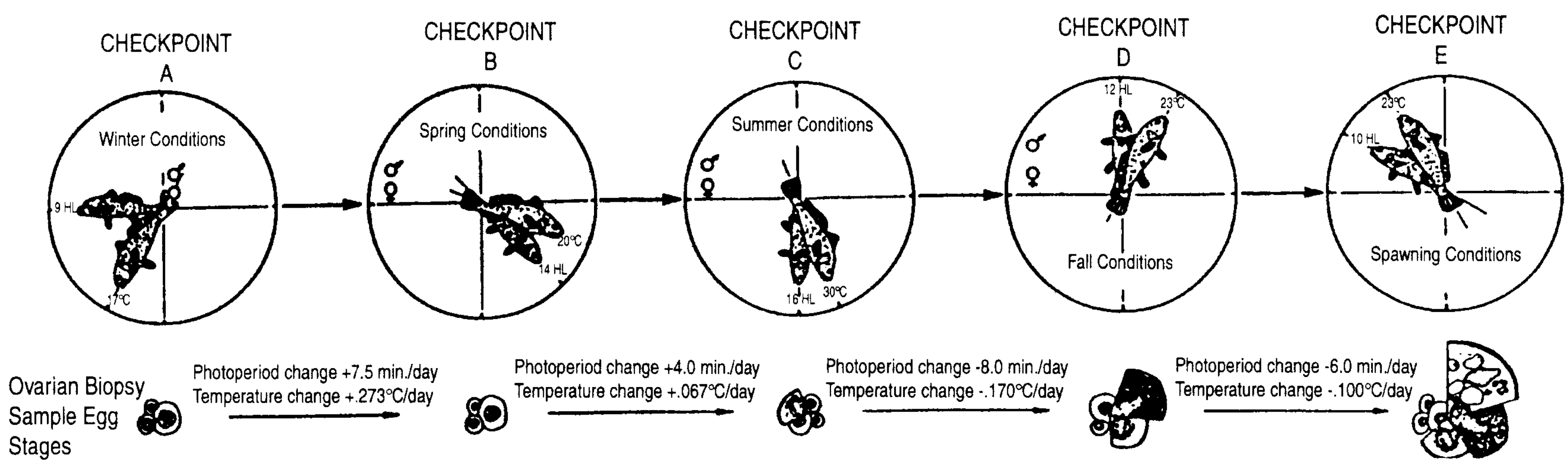
Controlled photothermal regime for induced maturation of red drum at John Wilson Marine Fish Hatchery.

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



(From McCarty et al. 1986)

Timetable for Red Drum Maturation



Timetable for red drum maturation. Demonstration of photoperiod and temperature changes necessary to induce reproductive maturation of red drum from winter condition (checkpoint A) to spawning condition (checkpoint E), and diagrammatic sample of oocyte stages for each checkpoint from ovarian biopsies of females.

(From McCarty 1986)

3 Locations and Systems for Spawning Red Drum

Summarized methods for photothermal induction of maturation and spawning of red drum at the John Wilson Marine Fish Hatchery, Perry R. Bass Fisheries Research Station and Florida Bureau of Marine Research.

	JWMFH	Perry R. Bass	Florida Bureau Marine Research
Tank Size (Metric tons)	13	10-20	5-20
Filtration system	RBC, FB, SH, S, UV	PT, TF	S, CB, DE
Fish/Tank	4	4-6	4-6
Sex ratio (M:F)	2:2	2:2, 2:1, 1:2	3:3, 3:2, 2:2
Mean fish size (Kg)	13	11	11
Regime duration (days)	150	120	120
Max. regime temperature (°C)	30.3	30.0	30.0
Min. regime photoperiod (°C)	15.0	18.0	18.0
Max. regime photoperiod (HL)	14.0	14.0	16.0
Min. Photoperiod (HL)	9.0	10.0	9.0
Spawning photoperiod (days)	22	30	100
Mean no. eggs/spawn period (millions)	20	20	100
Biopsy interval (weeks)	4	12	2-4
Feeding regime (% bw.day)	1.07	3.00	2.85

CB	Conventional biofilter	SH	Shell
DE	Diatomaceous earth	TF	Trickle filter
FB	Fluidized bed	RBC	Rotating biological contractor
PT	Packed tower	UV	Ultraviolet filtration
S	Sand		

(From McCarty 1986)

Quiz for Section B

Name:

Date:

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.

Fingerling Production of Spotted Seatrout *Cynosciaon nebulosus,* and Red Drum, *Sciaenops ocellata,* in Saltwater Ponds, by Colura, R. and B. Hysmith, Annual Report Marine Fish Res. Stat., Texas Parks and Wildlife Department, Palacios, Texas, 39 pp. ,1976.

Additional:

Laboratory Spawning and Larval Rearing of Red Drum and Southern Flounder, by Arnold, CR., W. H. Bailey, T.D. Williams, A. Johnson, and J.L. Lasswell. Proc. Ann. Conf. of the S.E. Assoc. of Fish & Wildlife Agencies, 31:347440, 1977.

Red Drum Farming in Texas, by Ann Henderson-Arzapalo et al., Perry R. Bass Mar. Fish Res. Stat. Palacios, Texas (Texas Parks & Wildlife Publication), 1987.

Production of Live Food Organisms for Fishes, Chapter 24 In: Production of Aquatic Animals-Fishes, by Treece, G.D., World Animal Science Series, Elsevier Science Publishers, B.V., 1993.

Design and Operation of a Photoperiod/Temperature Spawning System for Red Drum, by McCarty, C.E., In: Red Drum Aquaculture, Texas A&M University, Sea Grant College Program, Publication #90-603, pp. 44-45,1990.

Photoperiod/Temperature Control in the Commercial Production of Red Drum *(Sciaenops ocellatus)* Eggs, by Roberts, D.E. pp. 35-43 In: Red Drum Aquaculture, Texas A&M University, Sea Grant. College Program, Publication #90-603,1990.

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 imholf 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 that 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 plicatelus.* 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, Imholf 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. Diatomacious 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.

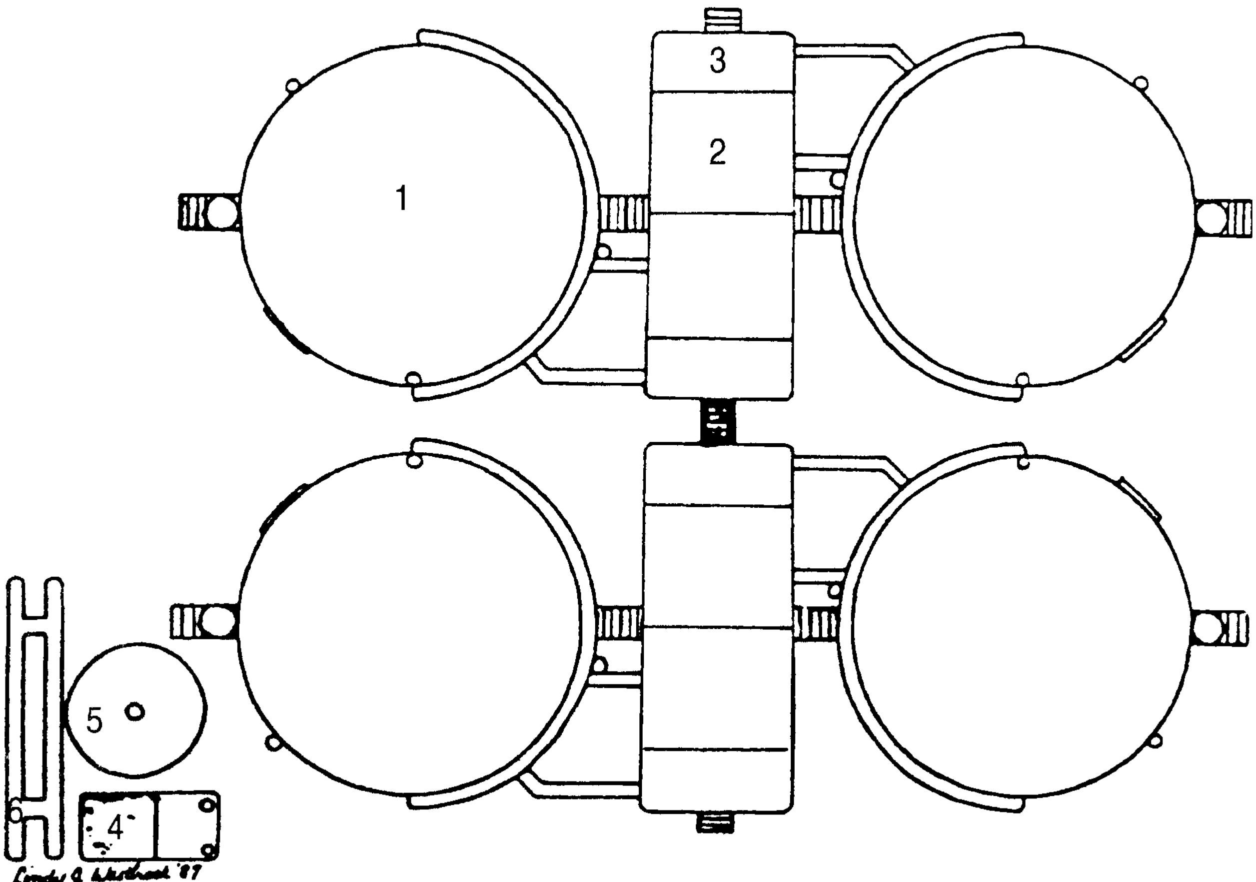
Application Activities:

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

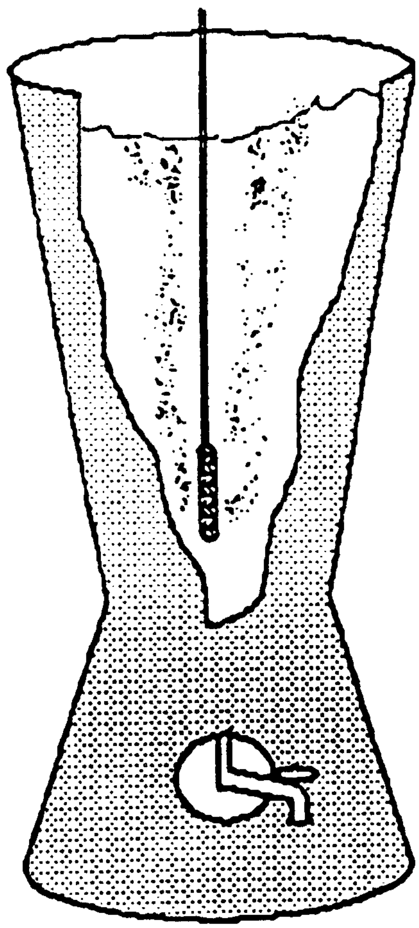


Typical red drum spawning room, John Wilson Marine Fish Hatchery

1. Fiberglass brood tank
2. Bio-disc filter
3. Water basin
4. Pump
5. Rapid sand filter
6. Ultraviolet filter

(McCarty 1990)

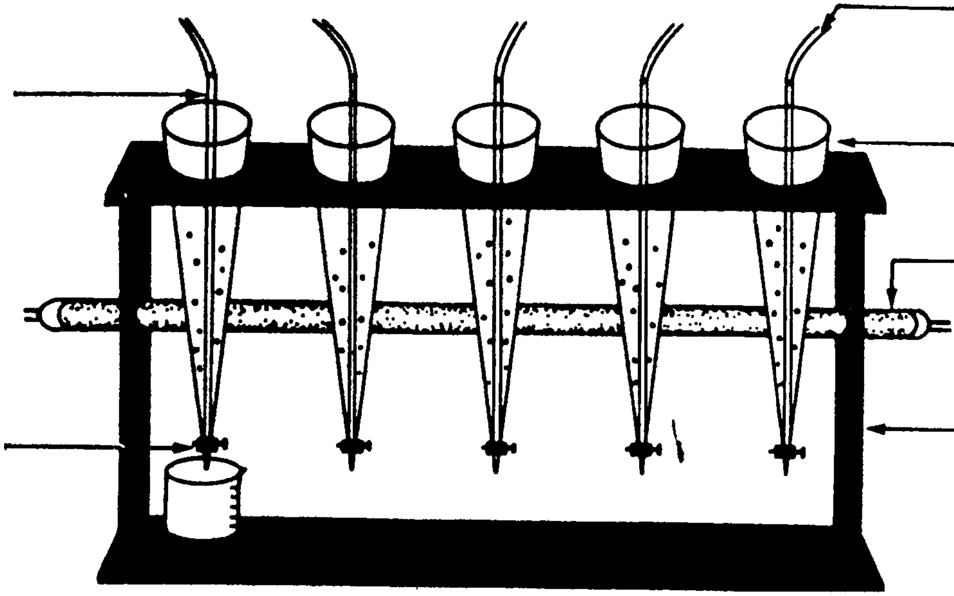
Larval Rearing Tank



150-liter fiberglass tank

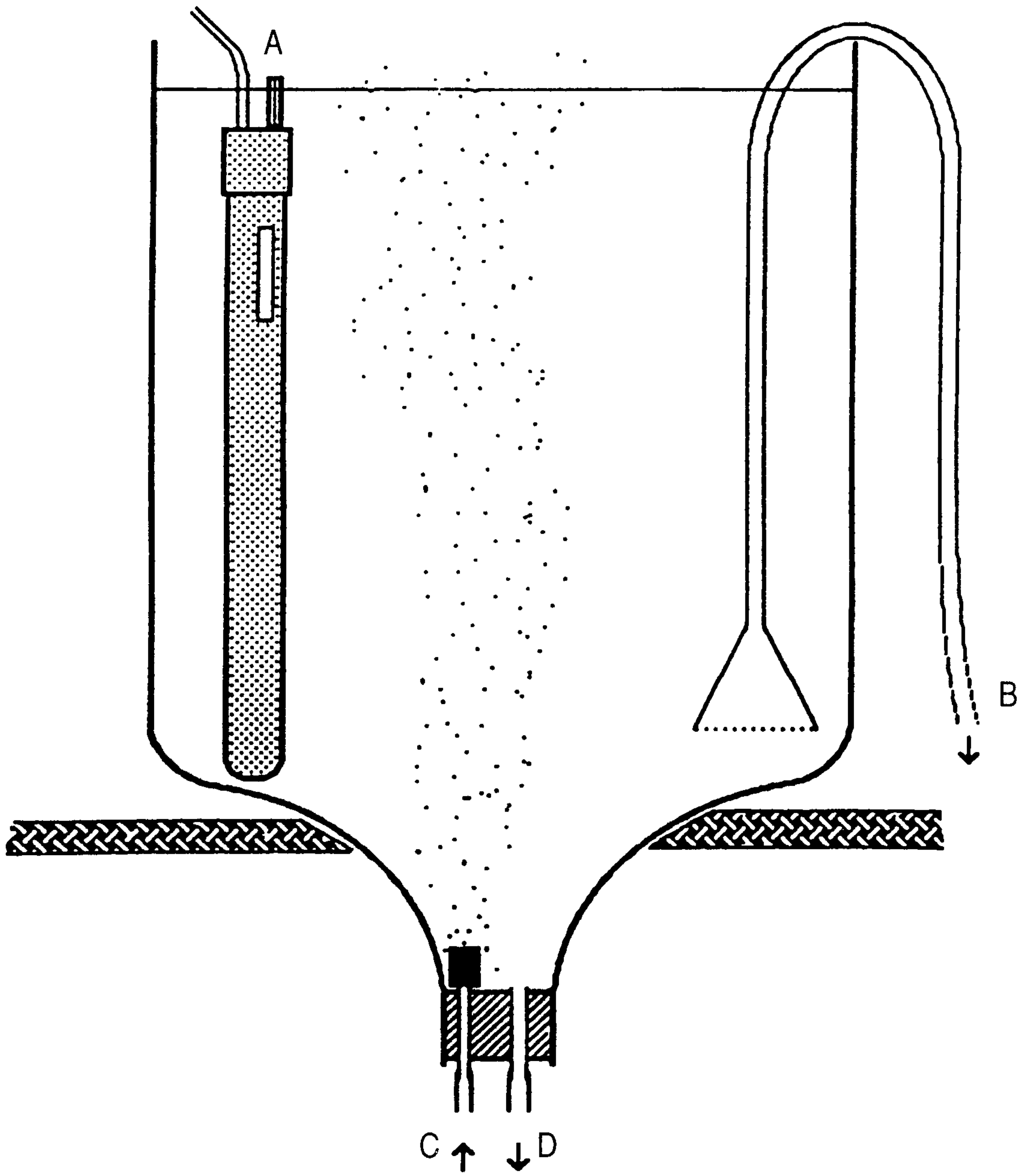
(Holt et al. 1990)

Imholf Cone Rack



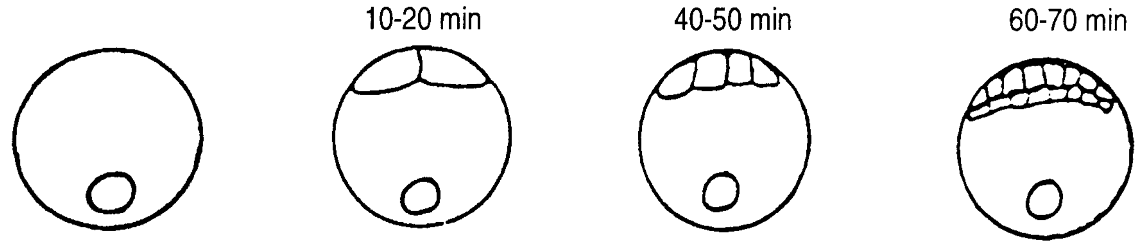
Artemia Hatching Cones

Plastic Drinking Water Bottle Inverted With Air, Water, etc.

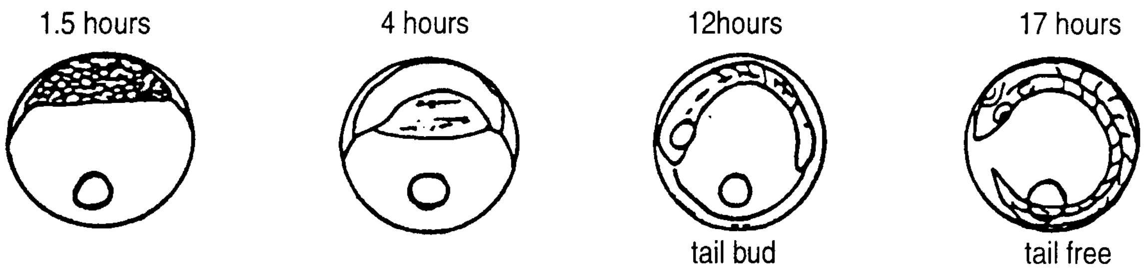


A Thermostatically controlled heater
B Siphon with mesh sieve
C Aeration with airstone
D Drainage pipe; do not use

Lab-Spawned Larval Red Drum



Timing of sciaenid egg stages at 25°C



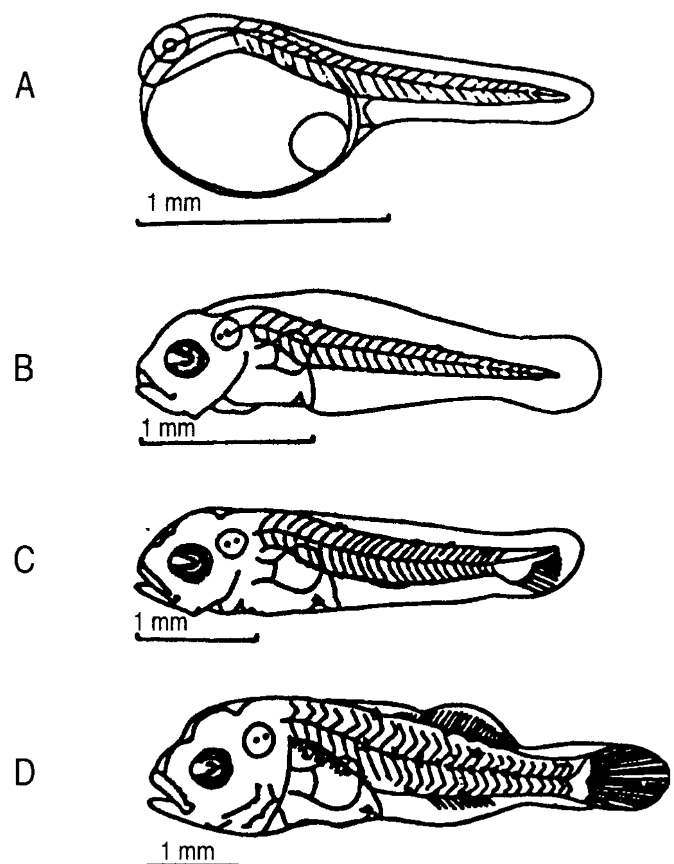
Lab-spawned larval red drum hatched and raised at 25°C

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

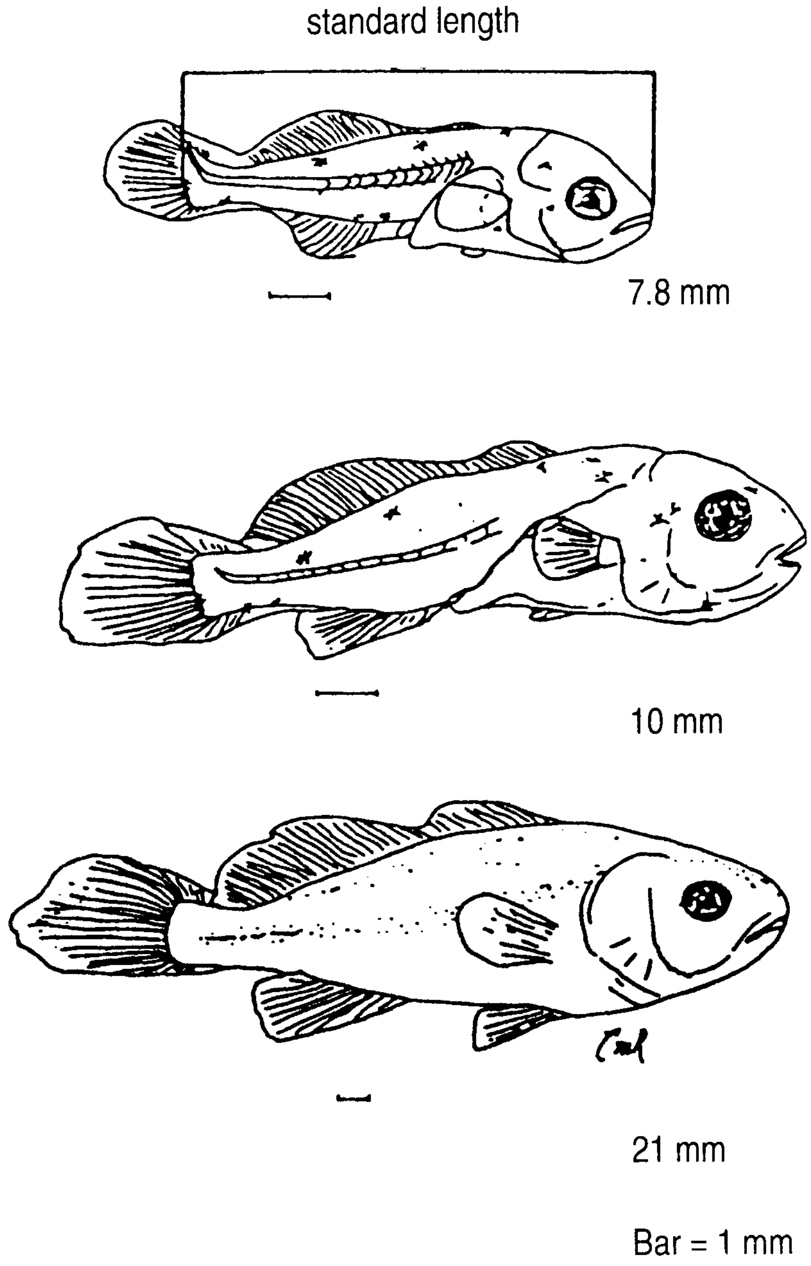
B 3-day-old first feeding larva (2.5 mm SL)

C 10 days old (4.2 mm SL)

D 2 weeks old (5.1 mm SL)

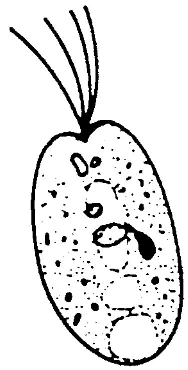


Developmental Stages of Red Drum



(Holt 1990)

Microalgae and Zooplankton



Tetraselmis sp. (10-15 μm)

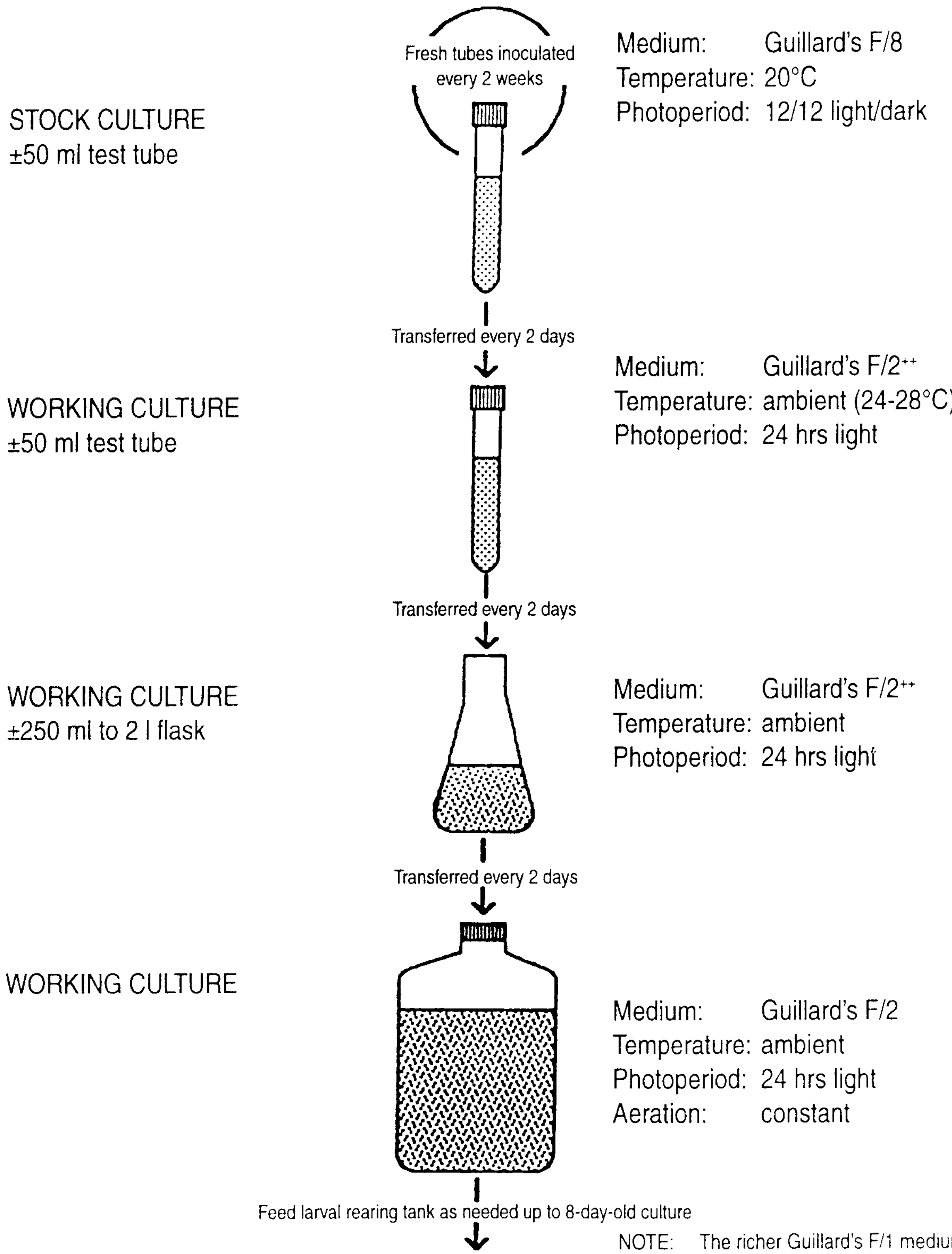
Isochrysis sp. (3-5 μm)

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)

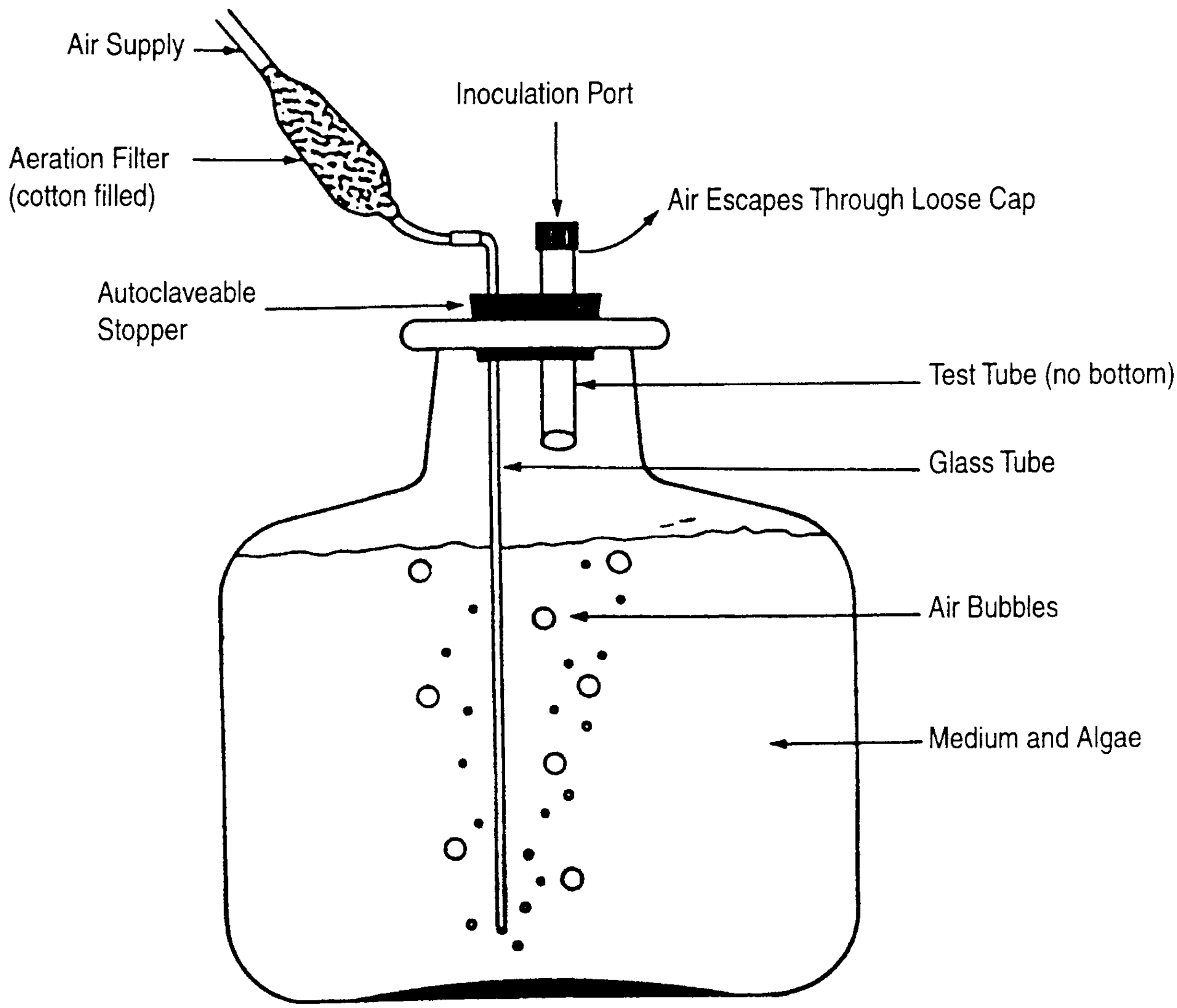
Typical Cycle for Algae Culture



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

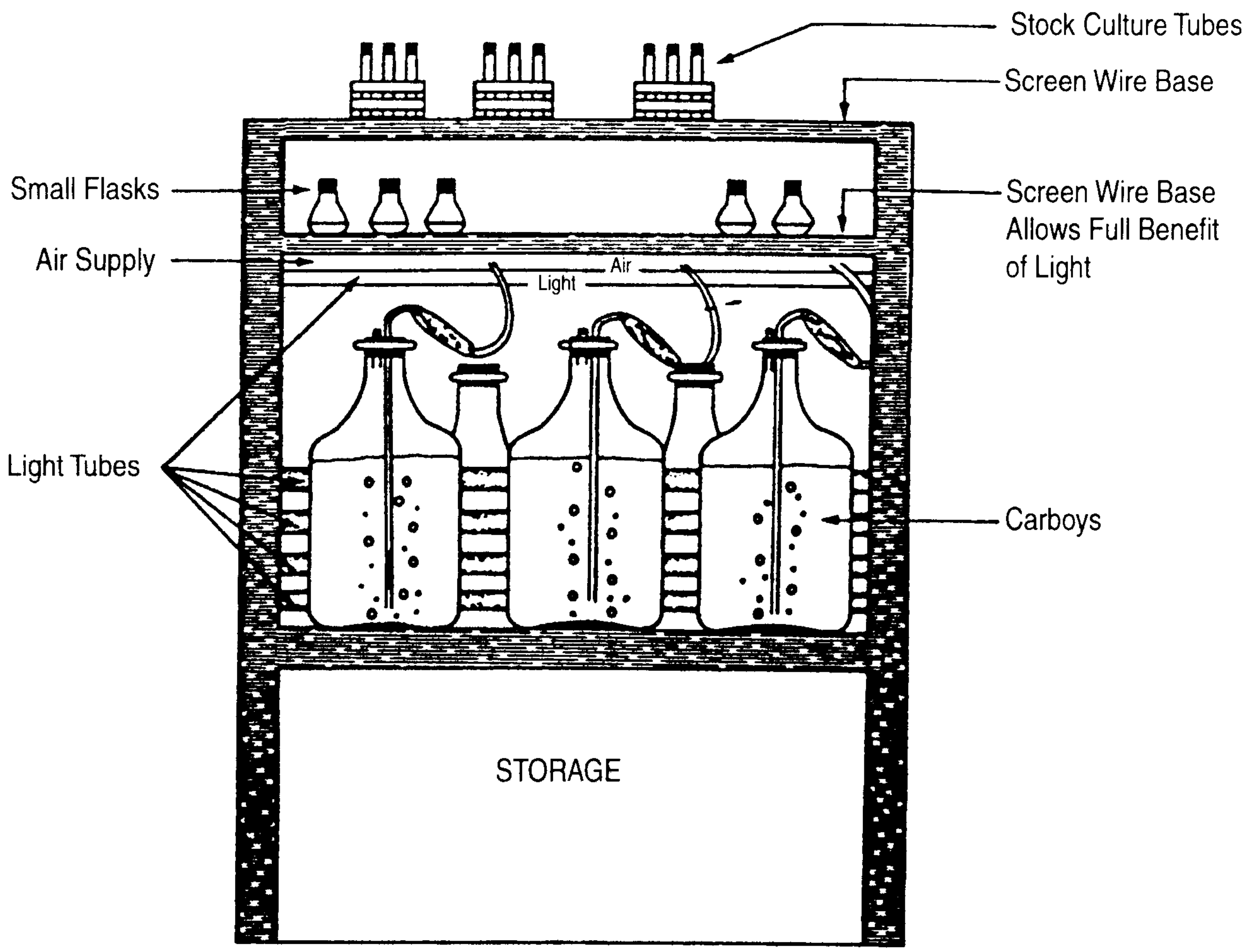
(Treece and Yates 1990)

Glass Carboy



(Treece and Wohlschlag 1990)

Typical Algae Culture Rack



(Treece and Wohlschlag 1990)

Rotifer Culture: Part 1

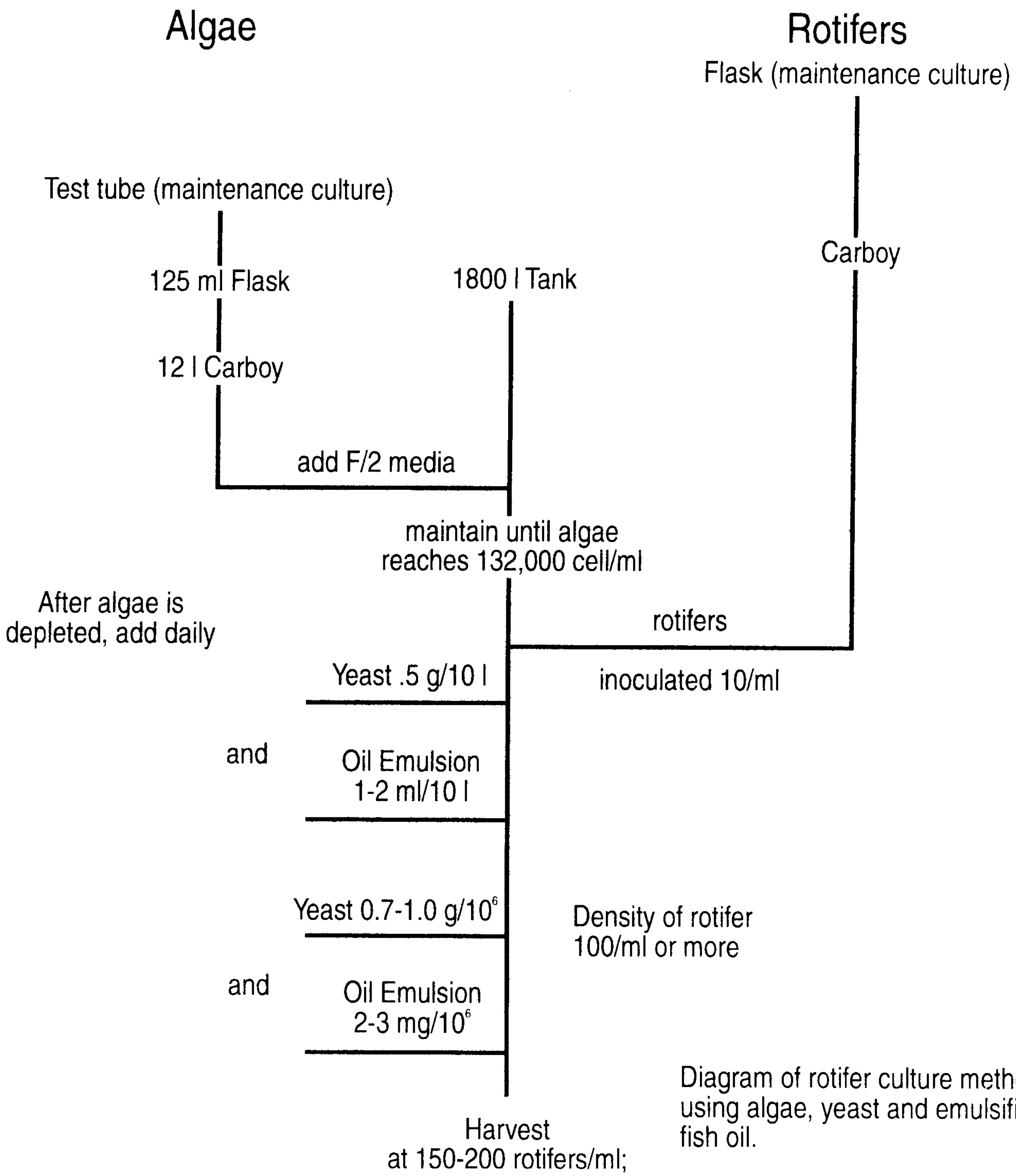


Diagram of rotifer culture method using algae, yeast and emulsified fish oil.

(Treece and Wohlschlag 1990)

Rotifer Culture: Part 2

Rotifers

Flask (maintenance culture)

Carboy

inoculate rotifers
10-40 ml

190 l Conical Tank

Yeast 0.6-0.8 g/l

and

Oil Emulsion 1 ml/10 l

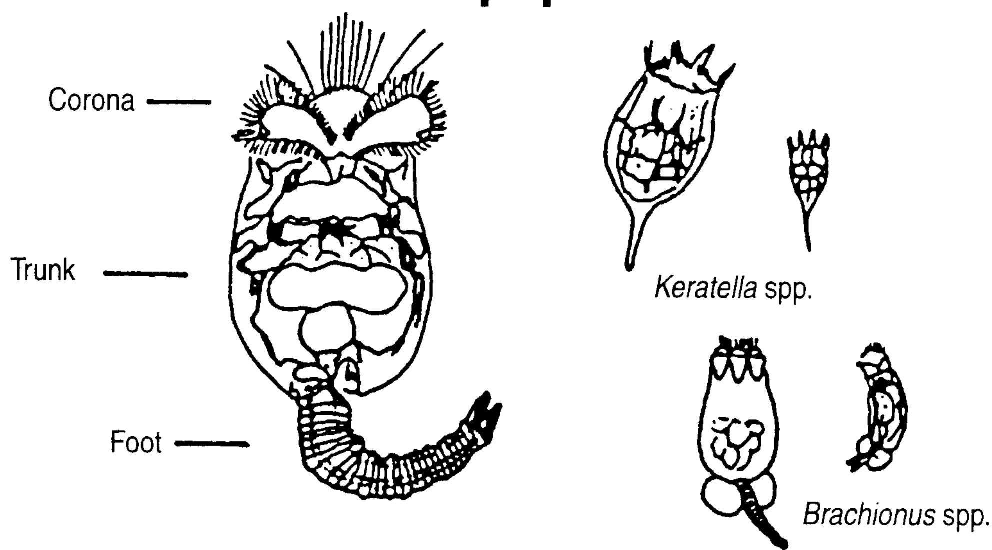
Adjust feeding rates
to density (see text)
until density reaches
150-200/ml

Harvest
at 150-200 rotifers/ml

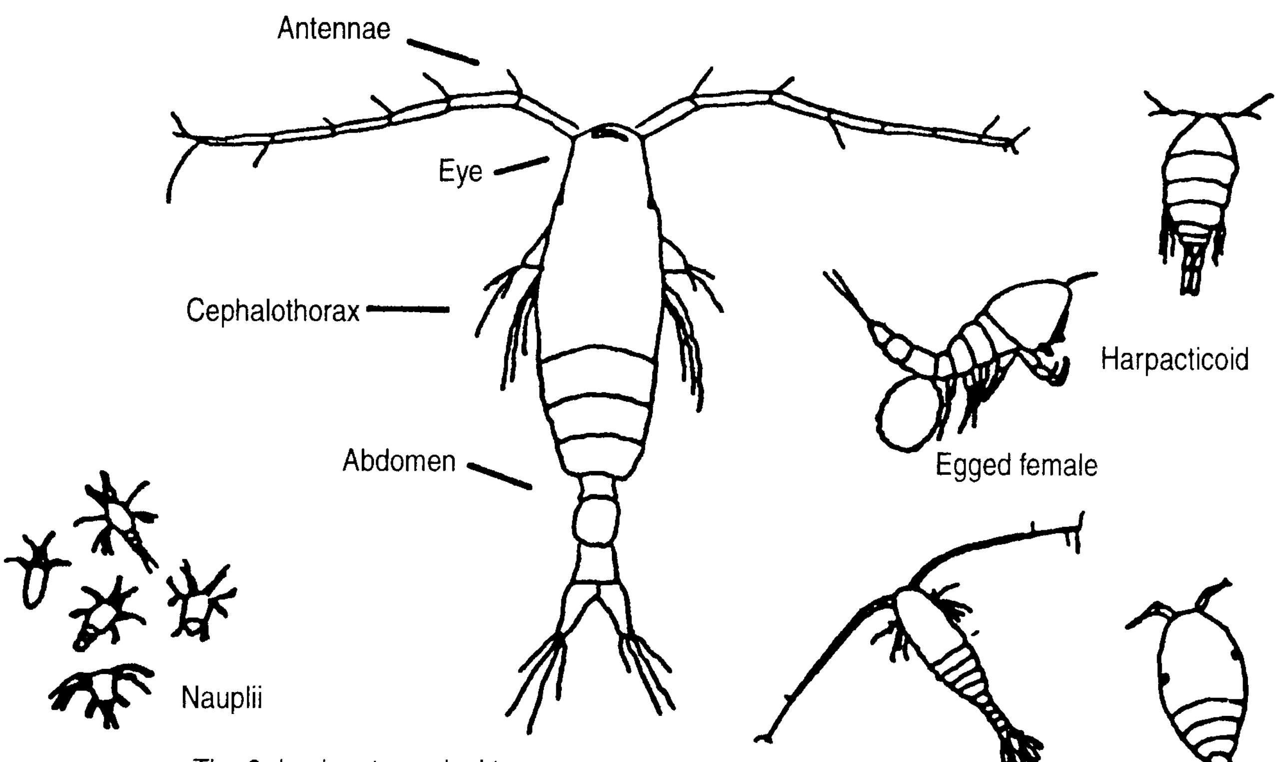
Diagram of rotifer culture using bakers yeast and emulsified fish oil.

(Wohlschlag et al 1990)

Distinguishing Characteristics of Rotifers and Copepods



Rotifers

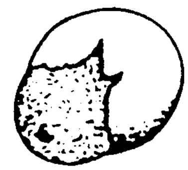


The 2 dominant zooplankton groups in saltwater-rearing ponds (not to scale).

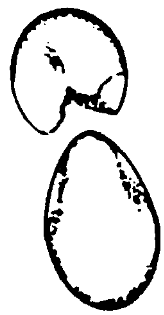
Copepods

(Sturmer 1990)

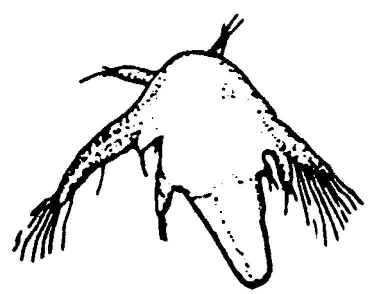
Artemi Cyst and Nauplii



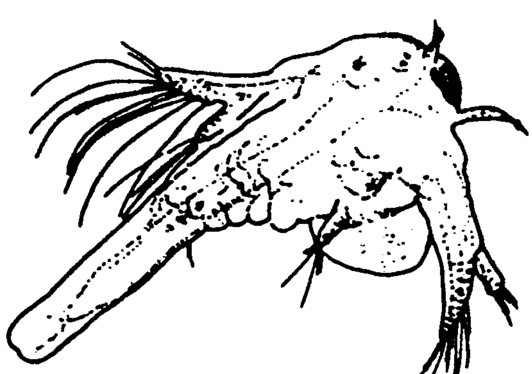
300 µm
Pre-nauplius in E-1 stage



Pre-nauplius in E-2 stage



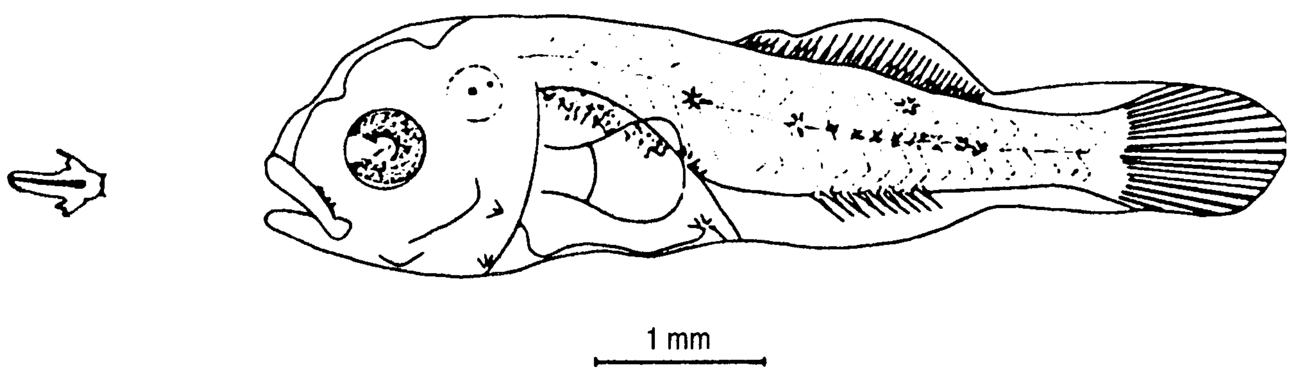
Freshly hatched Instar I nauplius



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 for Section C

Name:

Date:

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.
2. Rotifers, *Artemia*, or brine shrimp.
3. Temperature and photoperiod.
4. Filtration and UV treatment.

Teaching Plan:

Module: Red Drum - Section D

Problem Area: Culturing Red Drum; Producing Eggs/Fingerlings; Growing Red Drum to Market Size

Estimated Time: 10 hours

Goal: The goal of this problem area is to understand how to care for red drum, how to induce adults to produce eggs and offspring, and to describe the procedure used to rear fingerlings to 230 mm total length for growout.

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

describe tank /filter system for holding/spawning mature red drum
describe care of broodfish
describe procedures for spawning red drum
describe care of eggs and larval fish
describe procedures for rearing fingerlings to 25 mm total length (TL)
describe procedures for rearing advanced fingerlings and growout to market size.

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

Essential:

Transparencies.

Culture of Red Drum Fingerlings, by Colura, R.L., B.W. Bumguardner, A. Henderson-Arzapalo, and J.D. Gray, Management Data Series. No. 22., Texas Parks and Wildlife Dept., Austin, Texas, 1990.

Pond if available. (An indoor raceway can also be used, but managing raceways will not be covered in this module.) (Acknowledgment: Much of the material in this module came directly from Colura et al. 1990.)

Additional:

Laboratory Spawning and Larval Rearing of Red Drum and Southern Flounder, by Arnold, C.R., W.H. Bailey, T. D. Williams, A. Johnson, and J.L. Lasswell, Proceedings Southeastern Association of Fish and Wildlife Agencies, 31: 437-440, 1977.

Recognition and Control of Diseases Common to Growout Aquaculture of Red Drum, by Johnson, S. K., In: Red Drum Aquaculture. Texas A&M University, Sea Grant College Program, Publication #90-603. pp. 113-130, 1990.

Marine Fish Culture in Texas: A Model for the Future, by McCarty, C.E., J.G. Geiger, L.N. Sturmer, B.A. Gregg, and W.P. Rutledge. Editor R. Stroud, In: Fish Culture in Fisheries Management, pp. 249-262, 1986.

Principles and Practices of Pond Aquaculture, Editors, Iannan, J.E. et al., Oregon State University Press. Corvallis, OR, 252 pp. 1986.

Conditioning and Induced Spawning of the Red Drum Under Varied Conditions of Photoperiod Temperature, by Roberts, D.E. Jr., B.V. Harpster, and G.E. Henderson, Proceedings of World Aquaculture Society, 9:311-332, 1978.

Water Quality in Warmwater Fish Ponds, by Boyd, C.E. Auburn University, AL, 1979.

Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, present the students with the following scenario: A man phones you, the teacher, and asked if your class would like to have some live red drum. He is the manager of a red drum farm and knows that your class is studying new and emerging agricultural technologies. To keep from offending him, you agree to take the red drum. He tells you that he will deliver them to the school in 3 weeks. You hang up the phone and realize that you know nothing about raising red drum and you should have refused the contribution.

Now that you have agreed to take the red drum, what is your class going to need to know to keep the red drum alive? What are the questions that need answering? Answers should include the following: What do red drum eat? How much do they eat? What kind of facility will be needed to house them? What water quality is required? What temperature do they require? Ask the class where the answers can be found. Books, periodicals, producers, researchers, and experiences of others may be some of the responses. In this module, you will learn how most red drum are cultured and recent developments.

The following procedures used to produce red drum fingerlings are the exact methods used by Texas Parks and Wildlife Department (TPWD), which have been described by Colura et al. (1990). Note: All measurements used in Section D are metric.

Presentation:

A. What are the requirements of broodfish tank systems?

1. 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.

2. Many systems ranging from 9,500 to 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 by TPWD is included.

3. Design: The system should have a recirculating design with water flowing in the following order:
   a. Broodfish tank.
   b. Egg collector.
   c. Biofilter.
   d. Ultraviolet-germicidal lamp.
   e. Chiller reservoir (optional).
   f. Return to the broodfish tank by pump.
   g. Water return to the broodfish tank by pump should be cycled through the system approximately 3-8 times per day, using either an airlift or centrifugal pump system.
   h. Incoming water should pass through a sand filter and ultraviolet-germicidal lamp before it enters the broodfish tank.

Show TM D1 and discuss the schematics of red drum broodfish conditioning and spawning system and high density recirculating system.

4. Broodfish tank:
   a. Volume at least 9,500 liters.
   b. 1 to 1.5 m in depth.
   c. Circular fiberglass construction with a central drain 75-100 mm in diameter is preferred but not mandatory.
   d. Water level may be controlled with a central standpipe or outside standpipe.
   e. With a central standpipe a venturi may be used to help clean the tank.

5. Egg collector:
   a. May be of special fiberglass construction or built from any available tank at least 185 liters volume.
   b. A 0.5-mm mesh net must be placed between the incoming water and the discharge from the collector to retain the eggs.

6. Biofilter:
   a. Should be placed in-line after the egg collector.
   b. Numerous designs of biological filters are available (Spotte 1970, Arnold et al. 1976, 1990, McCarty et al. 1986). Filter selection usually will be determined by space available.
   c. Must have sufficient surface area for the growth of adequate amounts of bacteria that will break down nitrogenous waste produced by the fish.
   d. Must have sufficient water flow and air to prevent the filter from becoming anaerobic.
   e. A simple system consists of a 110-185 liter polyethylene barrel filled with bulk air conditioning filter material to provide surface area for bacterial growth.

7. Ultraviolet-germicidal lamp:
   a. Should follow the biofilter. 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.
   b. Never run lamp overnight when the fish are spawning.

8. Diatomaceous earth (DE) filter:
   a. DE filter is useful for removing organic colloids, suspended microorganisms, and maintaining water clarity. The system need not be placed in-line with the biofilter.
   b. Operate the DE filter at least 1 to 2 days/week. The DE filter should never be on overnight when the fish are spawning.

9. Temperature control through 2 methods:
   a. Water temperature is controlled by room air conditioning.
   b. Separate thermostatically controlled heaters and chillers are used. 4,500 W Glo-Quartz Model Series 400 temperature controller. A 1 HP chiller is placed in a reservoir tank in-line with and immediately after the filter system.

10. Photoperiod control: Lighting is controlled by an electric time switch. Lighting may be from either:
    a. Standard room lighting, fluorescent, or incandescent.
    b. Each tank may be lighted separately.
    c. A 100-W incandescent and a 15-W fluorescent light mounted on a beam that 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.

11. Airlift pump:
    a. A 3-HP regenerative blower is used to operate an airlift pump located in the chiller reservoir that cycles water back to the broodfish tank.
    b. The blower also provides aeration to maintain dissolved oxygen levels.

12. Emergency power:
    a. Red drum spawning facilities are typically located in coastal areas and are subject to periodic power failures.
    b. Therefore, provisions 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.

B. How are broodstock procured?

1. Collection:
    a. Broodstock are typically wild fish, preferably collected with hook and line.
    b. Captured fish are dip netted from the water and immediately placed in a well-aerated transport tank.
    c. Proper brood collection permits must be obtained from controlling agencies.

2. Hatchery rearing of broodstock:
    a. Broodstock may also be reared in the hatchery. But it usually requires several years for red drum to mature.
    b. As commercial red drum hatcheries increase, use of hatchery reared red drum broodfish in selective breeding programs will probably become more common.
    c. Hatchery reared broodstock may in the future become the only source of broodstock for commercial hatcheries.

3. Size of broodfish:
    a. Broodfish should be at least 750 ml TL.
    b. However, fish approximately 1,000 mm TL are preferred.

4. Determination of sex:
    a. Males usually produce a drumming sound when captured.
    b. 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.
    c. Females generally do not drum but occasionally may produce faint drumming sounds.
    d. Examination of the vent of the female will reveal, anteriorly to posteriorly, the anus, genital pore, and urinary pore, respectively.
    e. If not immediately apparent, the female's genital pore may be located by probing with a 2-mm ID (inside diameter) glass tube.
    d. Intraovarian 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 oviducet. A small amount of tissue may then be removed for microscopic examination and confirmation of sex of the animal.

5. Quarantine: Newly captured fish should be quarantined for 10-14 days to prevent introduction of disease into the hatchery.

6. Prophylactic treatment: The tank water may be treated with 0.2 ppm (mg/l) Cu^{++} (e.g., Cutrine, Applied Biochemist, Inc., Mequon, WI) from a chelated copper compound to reduce the chances of disease caused by external parasites.

C. How should broodfish be cared for?

1. Feeding frequency and types:
   a. Three to 7 times per week at 2-3% of body weight.
   b. Shrimp *(Penaeus* sp.*).*
   c. Fish, for example mullet *(Mugil* sp.*),* shad. *(Dorosoma sp.)* and Menhaden *(Brevoortia* sp.*).*
   d. Squid *(Loligo* sp.*).*
   e. Beef liver.

2. Feed equal amounts of shrimp and fish 5-7 days/weeks at 3% of body weight or feed 50% shrimp, 25% squid, and 25% beef liver at 2.5% of body weight 3 times weekly (McCarty et al. 1986).

3. Water quality:
   a. Critical levels for most water quality parameters have not been adequately identified. The following water quality standards have produced good results:
   b. Salinity 28-35 ppt (o/oo). May be controlled by adding fresh water or artificial sea salts.
   c. pH 7.0-8.5. May be controlled by water exchange or adding 5 mg/l sodium bicarbonate (Na_2CO_3) will raise pH 0.5.
   d. 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.
   e. Dissolved oxygen (DO) greater than or equal to 5 mg/l. In a properly designed tank system, DO concentration should not be a problem.

4. Diseases:
   a. Diseases of parasitic or bacterial origin are encountered occasionally in captive red drum but few have been identified (Johnson 1987,1990).
   b. The most common diseases encountered and their treatment are presented below. Other diseases common to culture of other warmwater marine fish might also be expected. Johnson identified potential diseases and their treatment (1987,1990).
   c. *Amyloodinium ocellatum*: the most common protozoan parasite affecting red drum. Its effect 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.
   d. Treat the tank with 0.2-1.0 mg/l of Cu^{++} from a chelated copper compound (e.g., Cutrine, Applied Biochemsts, Inc., Control Mequon, WI) (Johnson 1987).
   e. Flush the tank 2 days after treatment and repeat 7 days after initial treatment.

Show TM D2 and compare dinoflagellates commonly parasitizing fish.

5. Treatment for bacterial infections:
   a. Following handling, red drum are susceptible to bacterial infection, generally thought to be *Vibro* sp. It is characterized by ulcers and redness of the body and fins.
   b. Antibiotics, primarily oxytetracycline hydrochloride (OTC), can be used in several different ways to treat infections.
   c. 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.
   d. 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.
   e. Immersion: immerse in 10-20 mg/l OTC for 2 hours.

6. Parasitic copepods:
   a. Parasites or anchor worms frequently attach to red drum and feed on blood.
   b. Adding 0.25 mg/l DyloxR (Chemargo Corp., Kansas City, MO) or any brand of pesticide with 80% trichlorfon as the active ingredient will kill anchor parasites (Meyer 1968).

7. Fish lice: *Caligus* sp., a copeod, and *Argulus* sp., a branchiuran, 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 will kill fish lice (Meyer 1968).

Show TM D3 and discuss some reported or probable internal parasites of red drum. Show TM D4 and discuss reported or probable crustacean parasites of red drum. Show TM D5. *Ptychodiscus brevis* and *Gonyaulax monilata,* two known toxin-producing algae of the Gulf.

D. How do red drum spawn?

1. Red drum are not easily spawned by 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).

2. Photoperiod and temperature regime:

Show TM D6 and discuss how McCarty et al. (1986) developed the photoperiod temperature regime that the TSWPD used to spawn red drum in about 150 days.

3. Egg number estimation: Eggs are removed from the egg collector the morning following the spawn and enumerated as follows:
   a. Place eggs in an aquarium with a known volume of water.
   b. Mix eggs thoroughly.
   c. Calculate the mean number of eggs/ml.
   d. 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)

4. Alternate method of estimating egg numbers:
   a. 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.
   b. Collected eggs along with sufficient water to allow the eggs to float are poured into a graduated cylinder.
   c. The mixture is allowed to sit undisturbed for several minutes.
   d. Eggs will float to the surface and the separation between eggs and water will become visible.
   e. The volume (ml) of eggs is measured.
   f. Volume of eggs is multiplied by 998 eggs/ml to estimate the total number of eggs.

E. How show red drum eggs and prolarvae be cared for?

1. Incubator
   a. An approximately 1,900-liter tank with a 45° cone bottom has been used most often to incubate eggs and hold prolarvae. More recently, incubators as small as 100 liters have been used experimentally with good results.
   b. A center standpipe (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.
   c. 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.

2. Stocking density: A single spawn (approximately1 million eggs) can usually be incubated in a 1,900-liter tank. If smaller incubators are used, several may be required for each spawn.

3. Stocking: Eggs are gently poured into the incubator from the aquarium in which they were placed for enumeration.

4. Water quality parameters to be maintained:
   a. Temperature: 22-30°C. Best temperature for hatching and 24-hour survival is 25°C (Holt et al. 1981).
   b. Salinity: 28-25 o/oo. Best temperature for hatching and 24-hour survival is 30 o/oo (Holt et al. 1981).
   c. Total ammonia-N less than 0.55 mg/l (Holt and Arnold 1983).
   d. DO greater than or equal to 5.0 mg/l.
   e. 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.
   f. Dead eggs are siphoned from the incubator daily or whenever they concentrate in the cone bottom.

5. Harvesting the incubator:
   a. Larvae are maintained in the incubator until the alimentary tract is complete (approximately 48 hours after hatching at 25°C).
   b. The incubator is then drained slowly into a harvest tank.

F. What are the requirements for the harvesting tank?

1. 60-80 liters capacity.
2. Equipped with a 25-mm diameter internal stand pipe to drain overflow.
3. Place a screen constructed with 0.33-mm mesh filter cloth around the standpipe to prevent loss of larvae during draining.

G. How is the number of larvae estimated?

1. When draining is complete, adjust water level in the harvest tank to a known volume (e.g., 20 liters) by siphoning through a 0.33-mm mesh sieve.
2. Apply gentle aeration to mix the larvae.
3. Collect 3-10 samples that are 1-5 ml, depending upon relative density of larvae.
4. Count the number of larvae in each sample.
5. Calculate the mean number of larvae/ml.
6. 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)

According to Colura (1990), the above-described method of estimating numbers of larvae for stocking may overestimate the true number of larvae being stocked.

H. How are larvae transported?

1. Plastic bag method:
   a. 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.
   b. 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.
   c. Fill the remaining volume of the bag with oxygen and seal the bag. Use elastic bands to seal the bag.
   d. 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.
   d. 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.

2. Tank transport of larvae:
   a. Larvae are concentrated, counted, transported to the pond in the same tank.
   b. A lid is secured to the top of the tank and sealed to prevent water loss during transport.

c. The addition of oxygen has not been found to be necessary.
d. At the pond site approximately 10-15 liters of water is added over a l5-minute period before releasing the larvae.

I. How are larva cultured to fingerlings?

1. Procedures described in this section are used to rear red drum in nursery 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.

2. Red drum ponds and red drum commercial farms:
   a. 0.1 to 1.2 hectares (ha).
   b. Levee slope 3:1. A 4:1 or 5:1 slope is currently recommended in windy coastal areas to reduce erosion (Ulmer 1987).

Show TM D7 and discuss typical outside levee section.

   c. Approximately 1.2-2.0 m maximum depth.
   d. Clay lined.
   e. A single fill line goes to each pond. Fill lines are 10-25.4 cm depending on size of pond.
   f. Each pond is constructed with a single concrete drain box with a 10-61 cm drain pipe depending on pond size. (Refer to TM D3.)
   g. Dam boards inserted in 5-cm vertical slots located approximately 90 cm in front of the drain pipe retain water.
   h. 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-cm mesh screen is used for the first 2 weeks of the culture period. An 8-mm mesh screen is used during the final weeks of culture.
   i. A cross-section of pond levee showing recommended dimensions for red drum growout pond (from Ulmer 1990).

Show TM D8-TM D11 and discuss various layouts and drain structures.

3. Pond filling:
   a. Begin filling approximately 10 days to 2 weeks before anticipated stocking.
   b. Filter all incoming water with 0.5-mm mesh filter.
   c. Salinity range of incoming water should be 10-45 o/oo with 20-35 o/oo preferred.
   d. Water temperature should be at least 20°C.

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

Show TM D12 and discuss the red drum pond fertilization schedule. All fertilization rates are calculated on a per hectare basis.

5. Zooplankton sampling:
   a. Culture of red drum from larvae to 25 mm TL fingerlings is dependent upon the zooplankton forage base. Therefore, these zooplankton are routinely sampled by all hatcheries 3 times weekly by collecting 25 liters of water using a flexible impeller pump apparatus (Farquhar and Geiger 1984).

b. The water is filtered through a 64-micron mesh Wisconsin plankton net to concentrate the zooplankton. The sample is then preserved in a 50% formalin solution.
c. The preserved sample is then subsampled and major zooplankton groups are identified and enumerated as follows:
d. The sample is placed in a graduated 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 Weber1973.)
e. The sample is stirred to uniformly distribute the zooplankton and a 1-ml subsample is withdrawn with a Hensen-Stemple pipet.

Show TM D13 and discuss the Hensen-Stemple pipet.

f. The subsample is placed in a Ward plankton counting wheel.
g. Using a stereomicroscope, the following major zooplankton groups are identified and counted: coppods, coppodids, coppod, nauplii, and rotifers, polychaete larvae, total zooplankton (all of the above groups plus minor taxa).
h. The number of organisms per liter are then calculated using the formula:

$$\text{Number of organisms/liter} = \frac{N \times 300 \text{ ml } /251}{1 \text{ ml}}$$

where:

N = number of organisms in the subsample

i. 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.

6. Stocking:
   a. Larvae are stocked approximately10-15 days after initial filling and fertilization to coincide with approximate times at which zooplankton population densities are nearing their peaks.
   b. 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 2 and 29°C.
   c. Stocking densities are approximately 750,000/ha to 1,250,000/ha. 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).
   d. Pond temperature at stocking should be at least 20°C. Larval red drum will not survive when temperatures are cooler than 20°C (Holt 1981).

7. Pond water quality:
   a. Collect samples each morning beginning at sunrise. The following are the preferred water quality parameters to be collected and levels:
   b. DO concentration (mg/l) should be at least 4 mg/l. If DO is less than 4 mg/l, discontinue fertilization and pump new water into pond. Emergency aeration may also be necessary.
   c. Salinity 10-45 o/oo. 20-35 o/oo is preferred.
   d. Temperature (°C) at least 20°C.

8. Production period:

8. Production period:
   a. Fingerling red drum can be produced in approximately 21-33 days depending on temperature.
   b. 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.

9. Sampling: Twenty red drum are sampled weekly by either seining or dipping a net to monitor growth.
   a. Collecting with a dip net is easiest.
   b. Water is pumped into the pond.
   c. 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.

10. Supplemental feeding: Supplemental feeding of red drum in the nursery pond is not necessary.

11. Harvest: Procedures to harvest fingerling ponds:
    a. Screen the discharge with an approximately 8-mm mesh wire screen.
    b. Drain the pond as rapidly as possible without penning fish on the screen.
    c. The catch basin should be cleaned of hydrogen sulfide laden mud before removing fish by sweeping the box with a stiff brush during draining.
    d. Fish are harvested by concentrating them in the catch basin and removing them with a dip net.

12. Estimating numbers of fish harvested:
    a. Determined by mass weighing fish by taring the dip net and weighing each net full of fish.
    b. Determined also by transferring fish from the dip net to a bucket of water that has been previously tared and then weighing the bucket and fish.
    c. Number of fish per kilogram is then determined by weighing 3 to 5 100-fish samples and calculating a mean weight per 100 fish.
    d. Number of fish harvested is extrapolated by the formula:

NF = WT x MWT+ 100

NF = Total number of fish

WT = Total weight of harvested fish

MWT = Mean weight of 100 fish

13. Use of weight-length information:
    a. Frequently used by fish culturists to rapidly estimate biomass and numbers of fish harvested (Bowen and Studdard 1970).
    b. An average length is calculated and weight determined using the appropriate formula (not discussed here).
    c. Total weight of fish harvested is then divided by the calculated average weight to estimate the number of fish harvested.

J. How are fingerlings in growout ponds transported and stocked?

1. Transport density:
   a. Red drum fingerlings may be transported to stocking sites in any available fish delivery tank. The tank should be equipped with compressed oxygen.
   b. Stocking densities should be less than or equal to 150 g of fish/liter during transport.
   c. Maximum time at which red drum can be hauled at this density is unknown, but researchers have successfully hauled fish at 150 g of fish/liter for 11.5 hours at 28°C water temperature.
   d. Most fish in a commercial setting will simply be transferred from a nursery or fingerling pond to a larger growout pond such as the ones in TM D7 and D8.

2. Water quality:
   a. Dissolved oxygen should be maintained at 5-10 mg/l during transport by regulating the amount of compressed oxygen released in the tank.
   b. Salinities should be the same as the pond water from which the fish are taken.

3. Supersaturation.
   a. Many culturists use agitators to prevent supersaturation of water with oxygen. Use extreme caution when transporting small (about 25-mm TL) red drum.
   b. Small red drum usually are unable to resist currents created by agitators and are frequently killed.

4. Acclimation procedures of fingerlings to temperatures and salinities at the growout pond:
   a. Exchange water in the hauling tank at approximately 2,600 liters/hour.
   b. Pump water from the growout pond into the hauling tank using a battery (12 V) operated pump with a flow rate of approximately 44 liters/minute.
   c. 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.

K. What procedures are necessary to get red drum growout to market size?

1. Still being developed. The following methods are based on the best results obtained from researchers and commercial operations since 1984.

2. Stocking density: less than or equal to 15,000/hectare to rear fish to approximately 230 mm TL and 140 g.

3. Feeding rate schedule:
   a. Used to rear red drum stocked at 15,000 fish/ha to 143 g (230 mm TL) in 229 days with a 1.5:1 food conversion rate.
   b. Food generally used is Silver Cup Salmon Feed (Murray Elevators, Murray, UT); Rangen, Inc. (Buhl, ID and Houston, TX), Zeigler Bros. Inc.,(Gardeners, PA)., Cargill - Nutrena Feeds, East Texas Feeds, Inc., and others make red drum feed.

Show TM D14 and discuss feeding schedules and TM D15 and discuss suggestions for feeding red drum.

4. Floating feed. If used, the culturist may choose to feed the fish until active feeding ceases rather than use the above feeding schedule.

5. Growth rate: Growth of fish to 230 mm TL using the above feeding program is almost linear.

Show TM D16 and discuss the growth of red drum to 230 mm TL.

6. Winter feeding:
   a. During winter a reduced feeding rate has been found to be appropriate for culture of red drum.
   b. Reducing the feeding rate reduces overfeeding and helps prevent dissolved oxygen depletion when water temperatures rise.

Show TM D14 again and refer to the winter feeding schedule.

7. Overwintering:
   a. Red drum are susceptible to rapid temperature drop. During very cold winters some commercial operations culture fingerlings and sometimes larger fish in raceways indoors until temperatures are high enough to move them back outdoors.
   b. Many techniques have been attempted to overwinter fish (greenhouses, heat exchangers, geothermal or well water, and swimming pool covers which partially cover the pond).
   c. Research is still required to overcome the problem of cold temperatures in shallow ponds.
   d. Cold temperatures are probably the primary restraint to the red drum aquaculture industry.

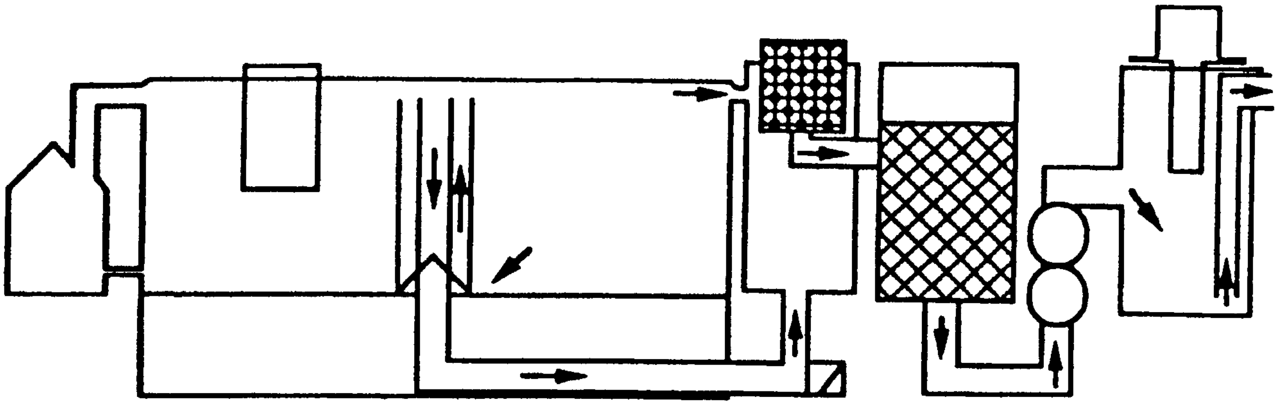
L. How is hybridization accomplished?

1. Hybridization or crossing of red drum and black drum was accomplished by TPWDin the 1980s.
2. Taste tests conducted by Texas A&M University showed no detectable difference in taste or texture between the hybrids and red drum or black drum.

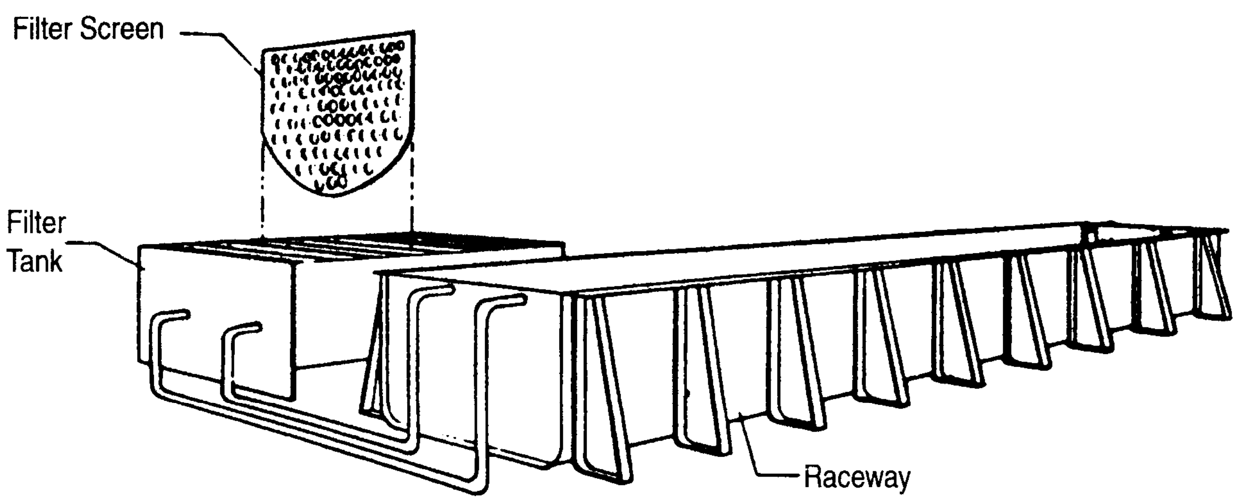
M. What recent research topics have been done on red drum?

1. Cryopreservation of milt.
2. Optical imaging of scales and otoliths to obtain population information.
3. Environmental tolerances of red drum in North Carolina and Texas (showed no difference in groups as far as thermal tolerance is concerned).
4. Juvenile red drum scale pattern analysis show whether fish came from spring or fall spawn.
5. Genetic marking of red drum.
6. Environmentally safe diets for red drum.
7. Overwintering of fish.

Schematics



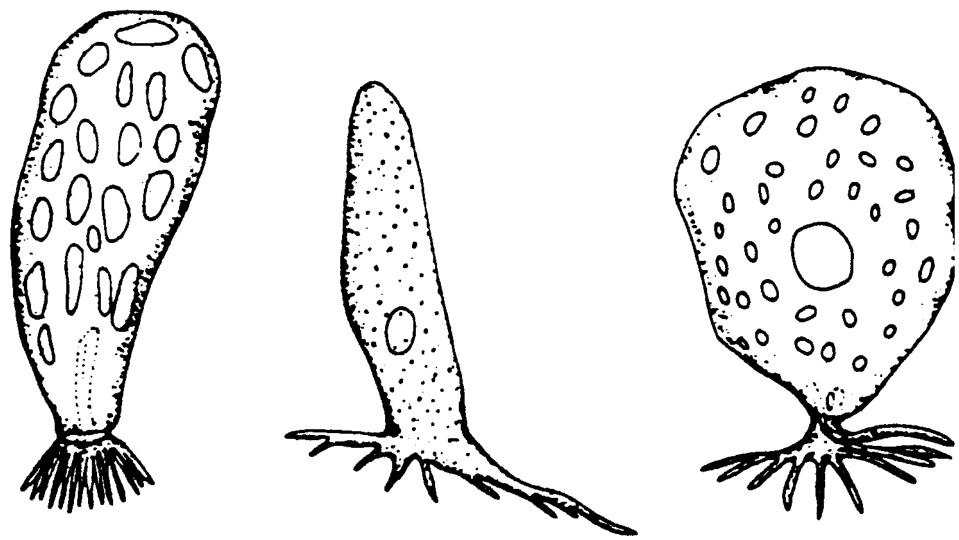
Schematic of red drum broodfish conditioning and spawning system.
Arrows show direction of water flow.



(Arnold and Reed 1990)

Schematic diagram of a high density, recirculating growout system.

Comparison of Dinoflagellates Commonly Parasitizing Fishes

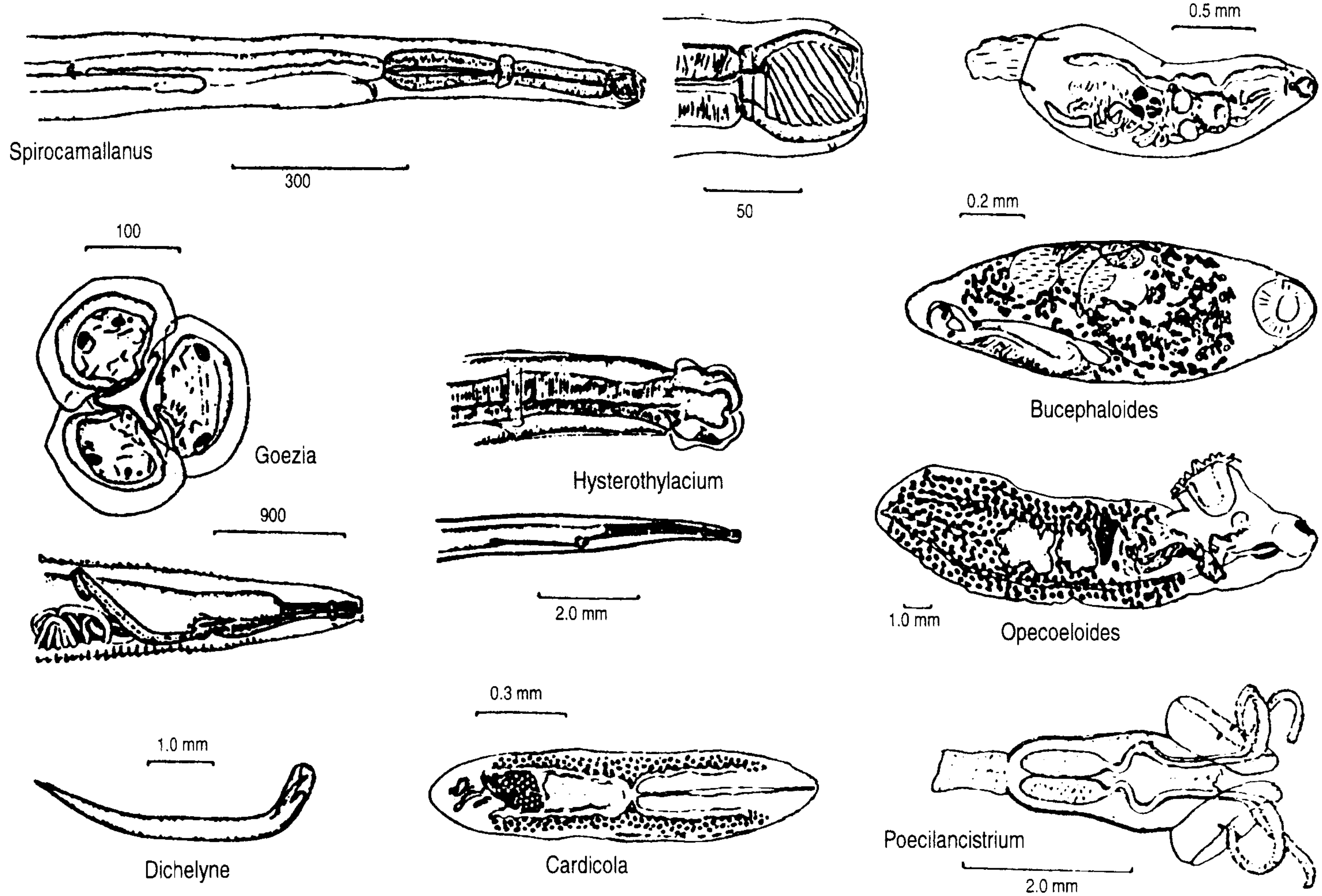


Piscinoodinium Credpidoodinium Amyloodinium

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)

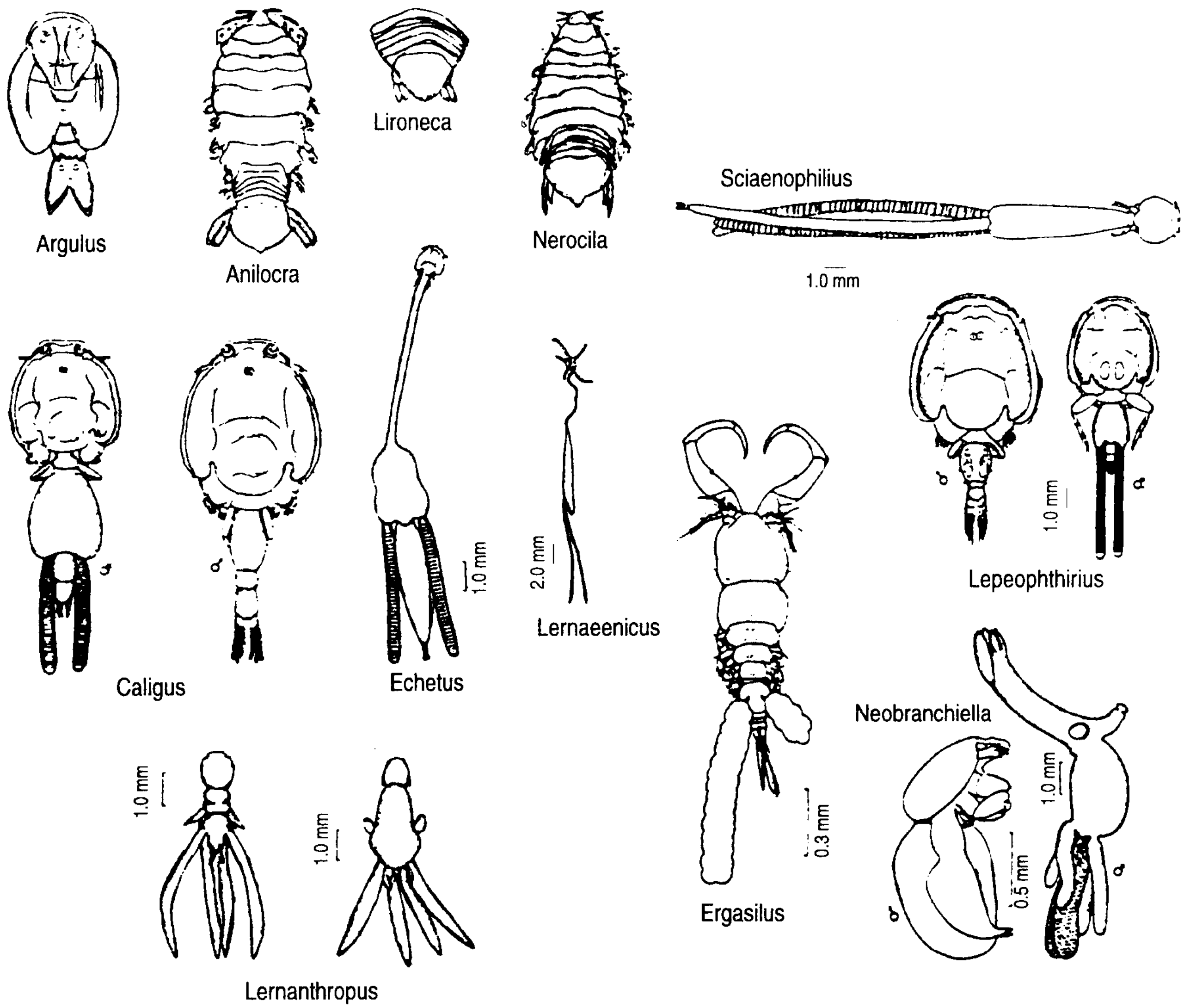
Some Reported or Probable Internal Parasites of Red Drum



Lecithochirium, *Bucephaloides*, *Opecoeloides* and *Cardiocola* 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. *Spirocamallanus*, *Hysterothylacium*, *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* (Sogandares-Bernal and Hutton 1959); *Cardicola* (Schell 1985); *Poecilancistrium* (Thatcher 1960); *Spirocamallanus* (Fusco and Overstreet 1978); *Hysterothylacium* (Deardorff and Overstreet 1981); *Goezia* (Deardorff and Overstreet 1980); *Dichelyne* (Chandler 1935).

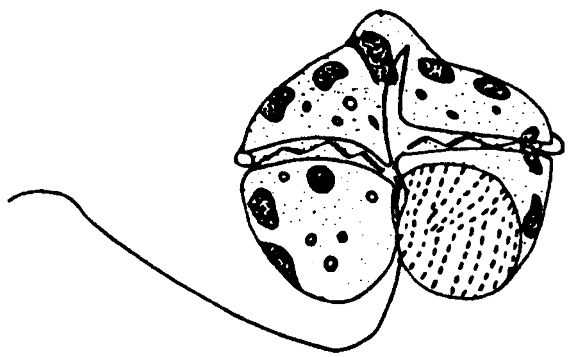
Crustacean Parasites of Red Drum



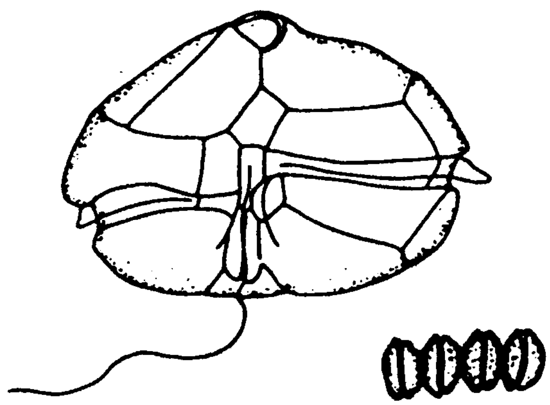
Argulus bicolor parasites affix to skin & surfaces of mouth cavity. Anilocra, Nerocila, & Lironeca are isopod parasites. First 2 are found on skin and latter in the gill cavity of host. Only posterior portion of Lironeca is shown here. Cymothoa, is found within mouth cavity. Caligus, Echetus, Lernaeenicus, 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 may be 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 lunules, 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)]}

Toxin-Producing Algae of the Gulf



Ptychodiscus breve



Gonyaulax monilata

Ptychodiscus brevis and *Gonyaulax monilata*, 2 known toxin-producing algae of the Gulf. *Gonyaulax monilata* will occur free or in groupings as shown.

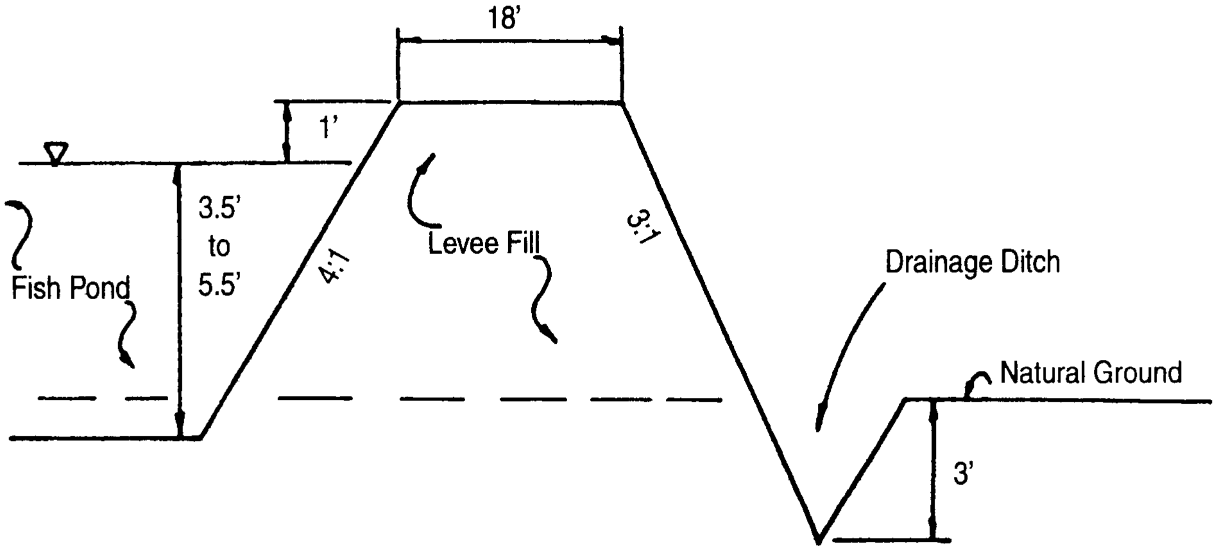
{Johnson 1990 [*Ptychodiscus brevis* (Steidinger and Joyce 1973); *Gonyaulax monilata* (Howell 1953)]}

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
50-59	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	24	11

(McCarty et al. 1986)

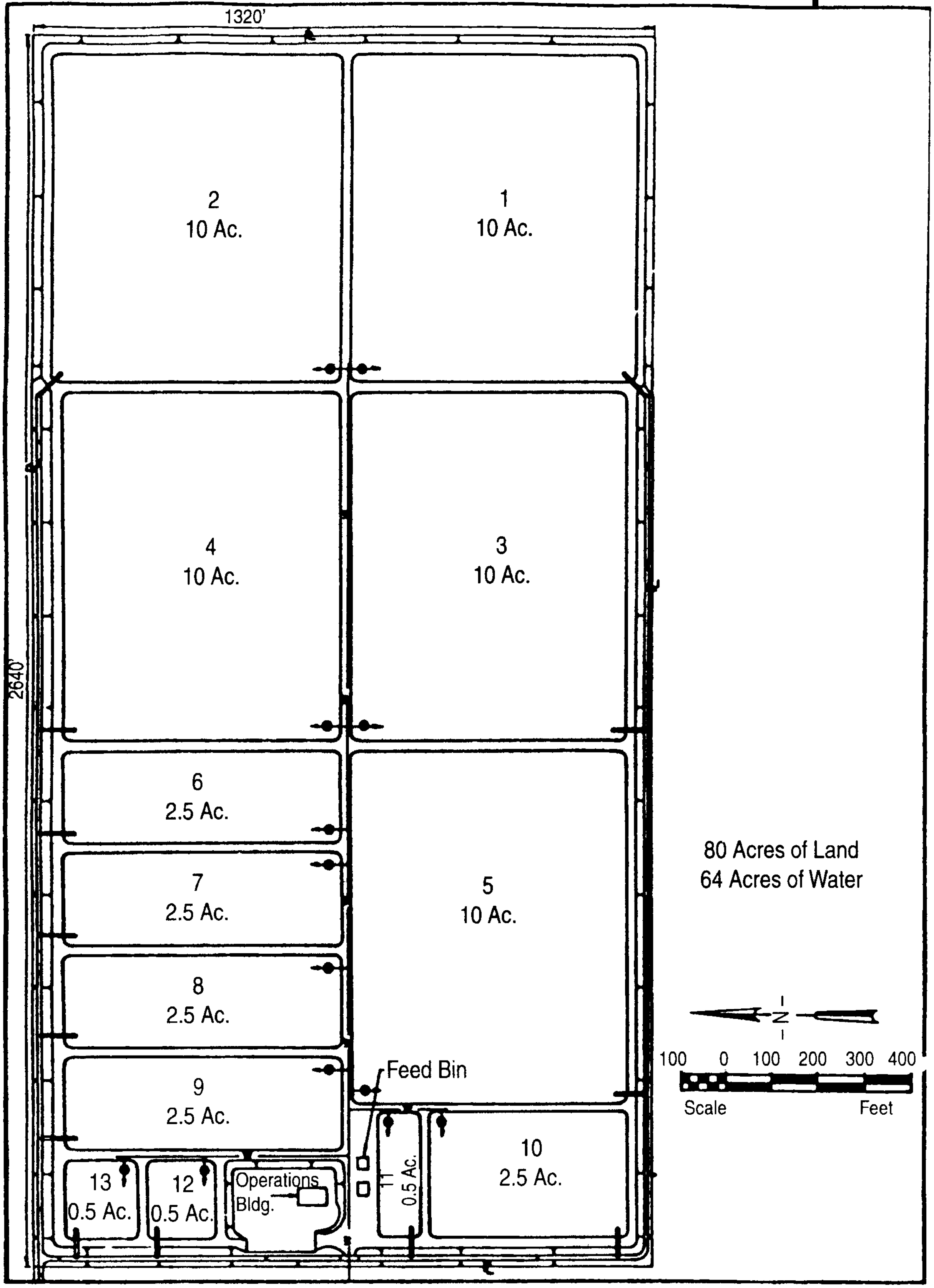
Typical Outside Levee Section



(Ulmer 1990)

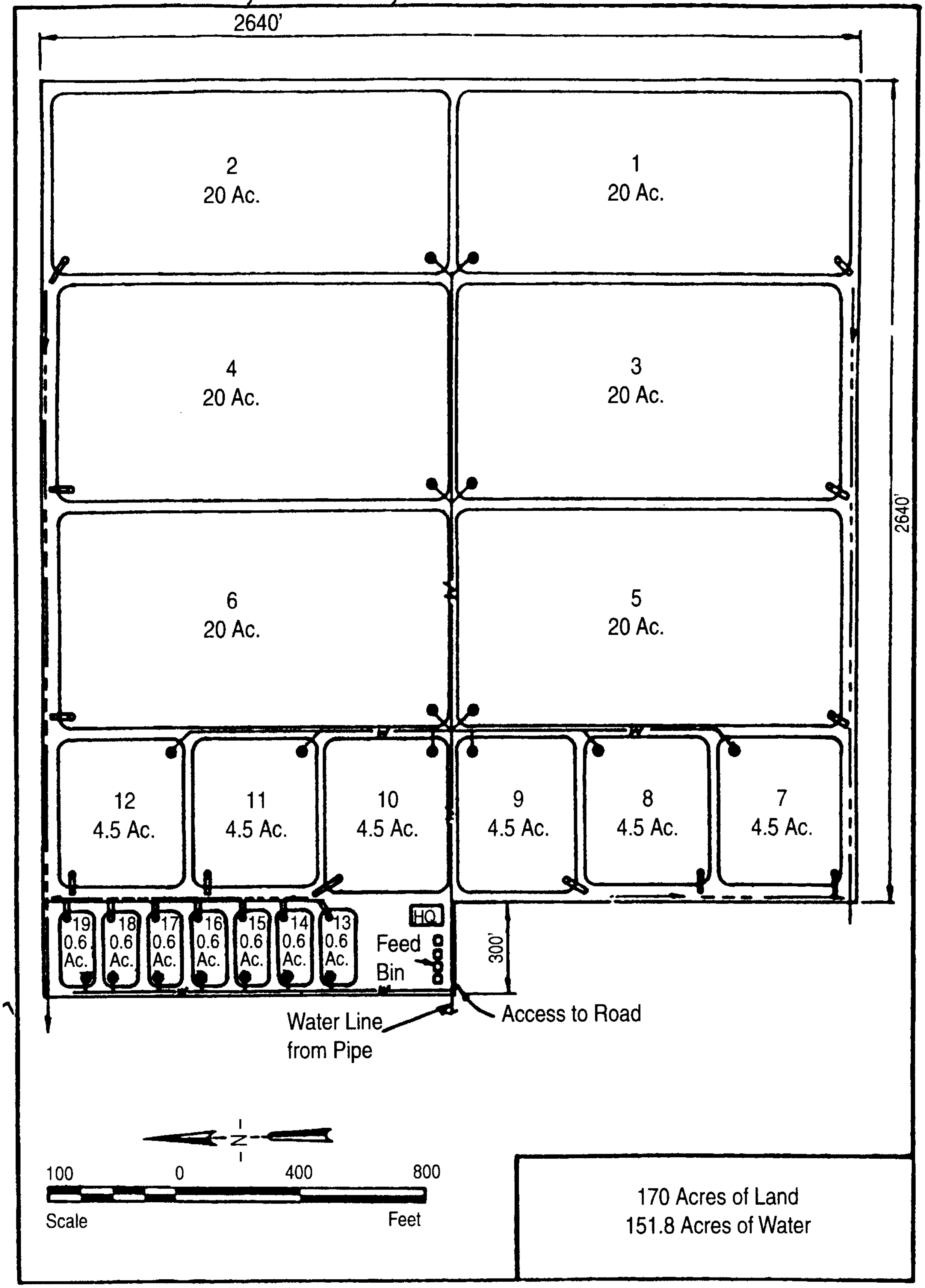
TM D8

80-Acre Red Drum Pond Growout Complex



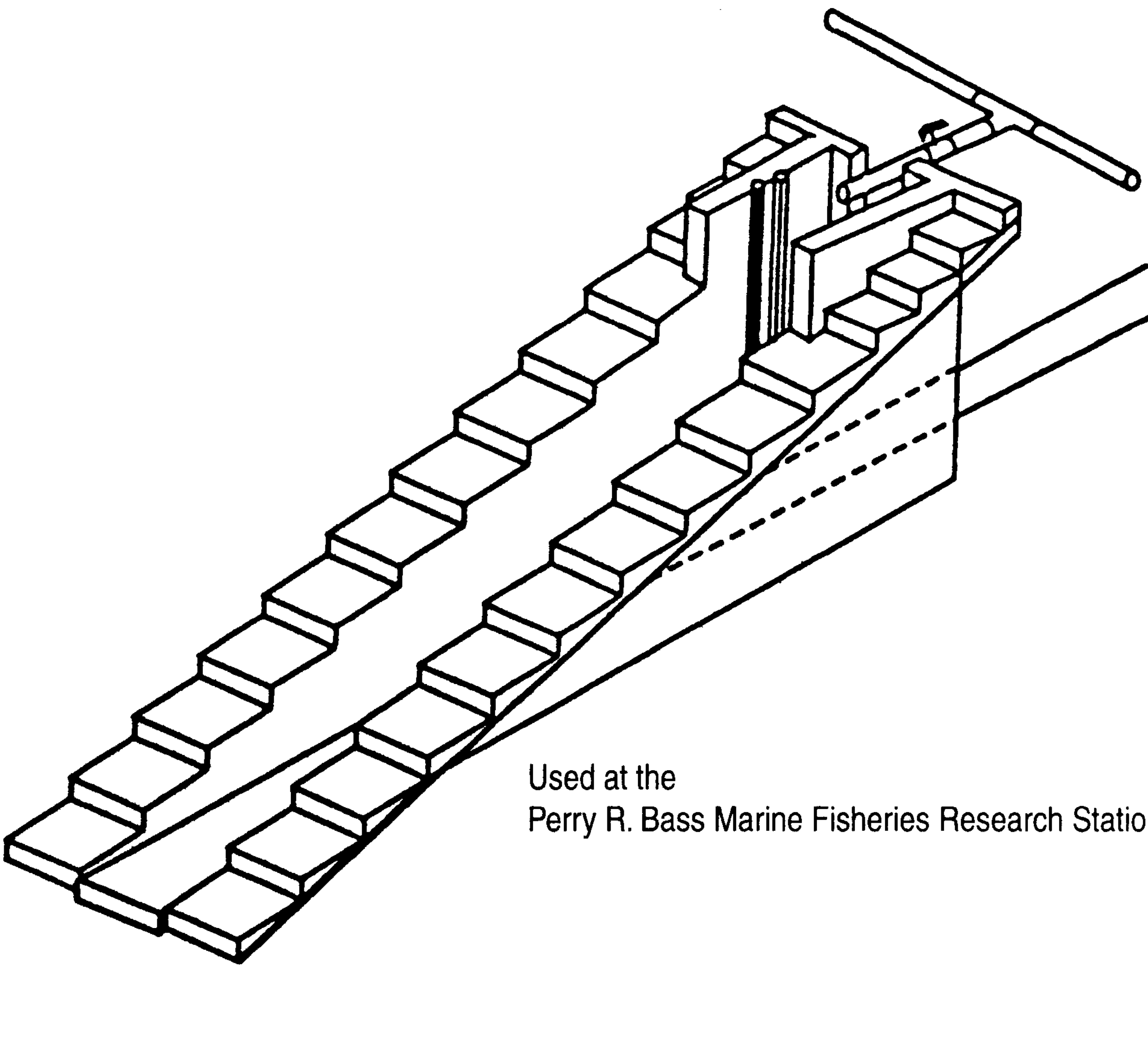
(Ulmer 1990)

170-Acre, 3 Phase, Growout Farm for Red Drum



(Ulmer 1990)

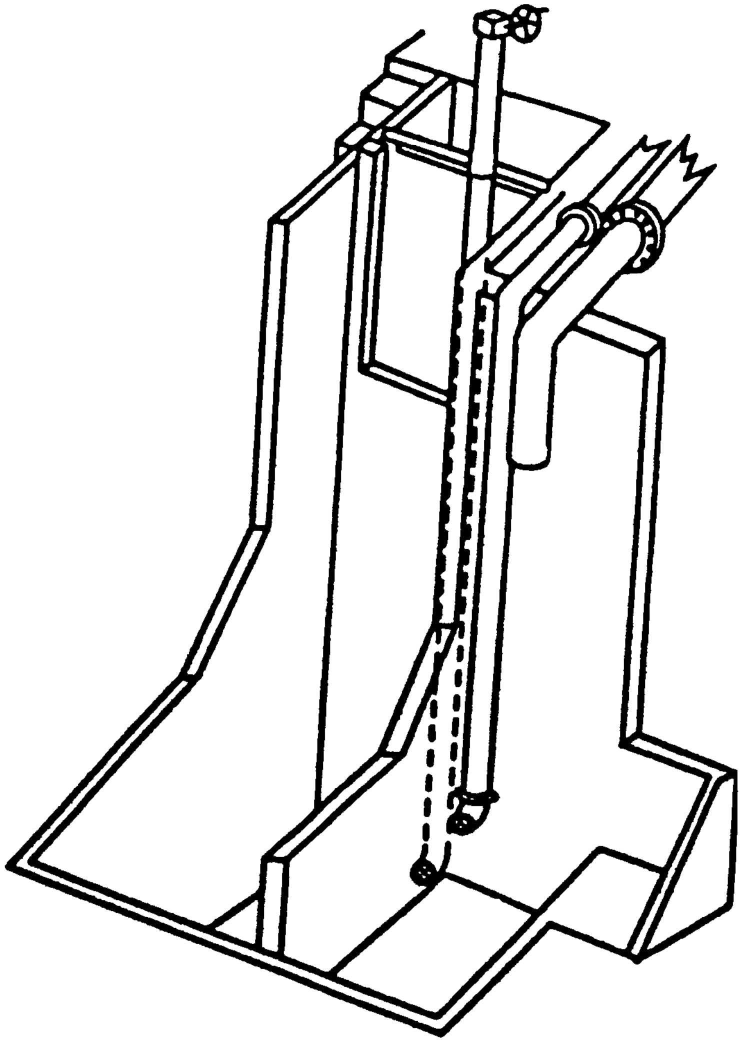
Concrete Drain Structure



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)

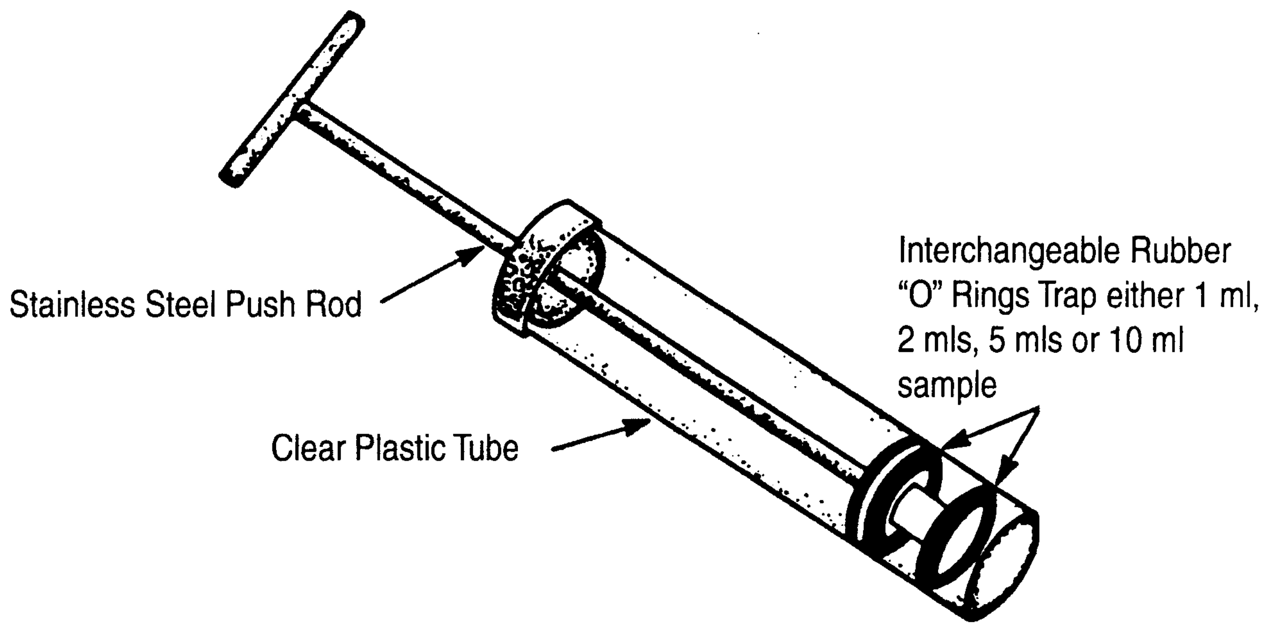
Pond Fertilization Schedule

DAY	ACTION
1	Spread 282 kg cottonseed meal (CSM) on the dry pond bottom. Fill to approximately 1 m depth.
3 [a]	Continue filling. Add 9.0 l (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 l phosphoric acid, 4.6 kg urea
15	Add 31.3 kg CSM
17	Add 31.3 kg CSM
19	Add 31.3 kg CSM
21	Add 31.3 kg CSM
23	Add 31.3 kg CSM
25[b]	Add 31.3 kg CSM, 3.0 l phosphoric, 4.6 kg urea

[a]Phosphoric acid 55% P_2O_5. Urea 45% N

[b]Additional fertilizer may be added if fry stocking is late or growth is slow.

Hensen-Stample Pipet



(Treece and Yates 1990)

Feeding Schedules

FEEDING SCHEDULE AT 15,000 FISH/HA		
Day	Mean weight (g) of Individual Fish	Percentage of Estimated Total Biomass Offered as Feed
14-82	fry-8	10
82-109	8-20	8
109-138	20	5
138-194	50-100	3
194-229	100-143	1

WINTER FEEDING SCHEDULE	
Water Temperature (°C)	Percentage of Estimated Total Biomass Offered as Feed
>18	2.0
15-18	1.0
10-14	0.5
<10	No feed

Suggestions for Feeding Red Drum[1]

Fish size Day	Feed Type[2]	Protein Level (percent)	Feeding Rate[3] (percent)
1-3	#2 crumble	45	5
3-6	#3 crumble or 3/32 to 1/8 inch sinking or floating pellet	45	5
6-8	3/32 to 1/4 inch sinking or floating pellet	35-45	4
8-harvest	3/32 to 1/4 inch sinking or floating pellet	32-38	3

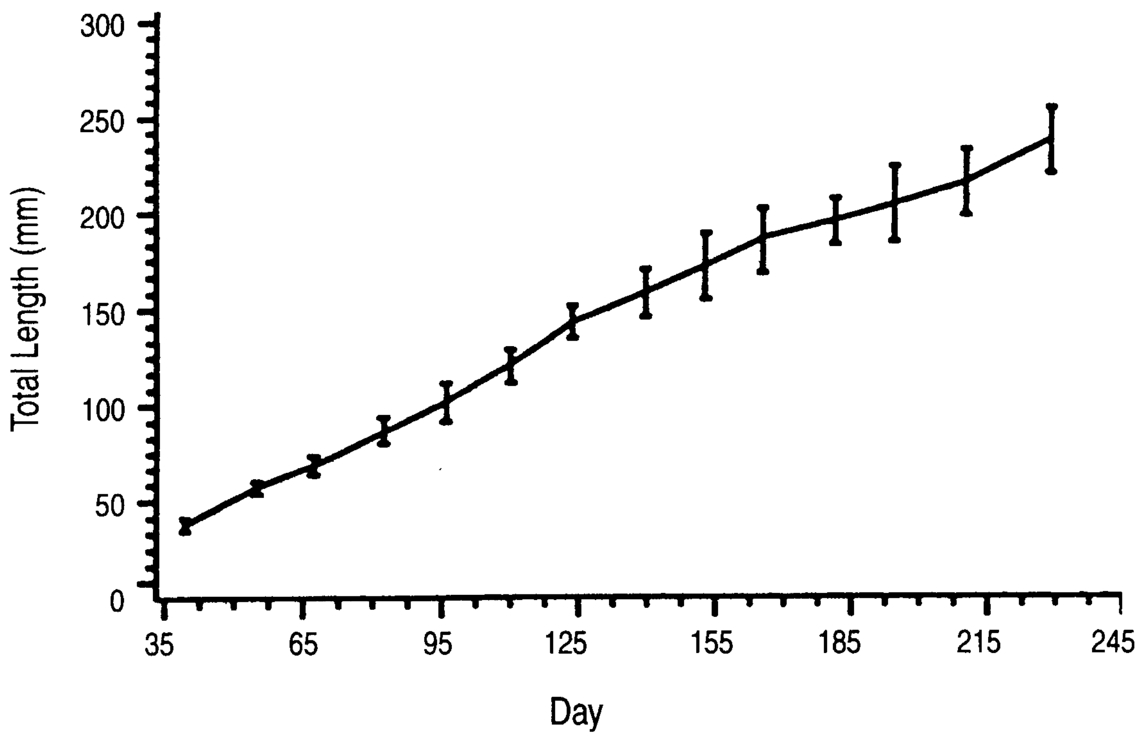
[1]Modified from data provided by Texas Parks and Wildlife Department and Texas A&M University

[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 may be 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)

Quiz for Section D

Name:

Date:

Quiz on Culturing Red Drum; Producing Eggs/Fingerling; Growing Red Drum to Market Size

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

1. T F Brood red drum may be collected from the wild with proper collection permits.

2. T F Males usually produce a drumming sound when captured.

3. T F *Amylooediniurn* is the most common protozoan parasite affecting red drum.

4. T F Red drum are not troubled by any other fish diseases other than protozoan parasites.

5. T F The major zooplankton groups that fingerling red drum feed upon in ponds are copepods, rotifers, polychaete larvae, copepodids, and copepod nauplii.

6. T F Red drum brood fish are fed shrimp, fish, squid, and beef liver.

7. T F Water quality is not important in the maturation of red drum adults.

8. T F Overwintering of red drum is not possible through any means.

9. T F Hybridization or crossing of red drum with other fish has not been possible.

10. T F Fingerling red drum can be produced in approximately 21-33 days depending upon the temperature.

Key for Quiz - Section D

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