

Shellfish Culture

AQUACULTURE CURRICULUM GUIDE

YEAR TWO SPECIES MODULE

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Description: The module consists of the following two problem areas:

Module: Shellfish Culture

Problem Areas: Discovering Clam Aquaculture
Discovering Oyster Aquaculture

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

- A. Discovering Clam Aquaculture
- Describe anatomy, biology, and life cycle of clams
 - Identify commercially important clam species
 - Explain selection, management, and culture of broodstock
 - Describe spawning methods and procedures
 - Describe hatchery and growout operations and management
- B. Discovering Oyster Aquaculture
- Describe anatomy, biology, and life cycle of oysters
 - Identify commercially important oyster species
 - Explain selection, management, and culture of broodstock
 - Describe spawning methods and procedures
 - Describe hatchery and growout operations and management

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Teaching Plan:

Module: Shellfish Culture - Section A

Problem Area: Discovering Clam Aquaculture

Estimated Time: 15-18 hours

Goal: The goal of this problem area is to become familiar with basic clam biology and methods used for its controlled production.

Learning Objectives: Upon completion of this problem area, students will be able to:
describe the anatomy, biology, and life cycle of clams
identify commercially important clam species
explain the selection, management, and culture of broodstock
describe spawning methods and procedures
describe hatchery and growout operations and management

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

Essential:
Transparencies.

Crustacean & Molluscan Aquaculture in the United States, by Brown, E. Evan & Huner, Jay V., AVI Publishing Company, Inc., Westport, CT, 1985.

Aquaculture: The Farming & Husbandry of Freshwater & Marine Organisms, by Bardach, McClarney & Ryther, Wiley-Interscience Publishers, 1972.

Record Keeping for Aquaculture: Clam Farming, by Vaughan, Donna; Flimlin, Gary and Korsko, Kim, Editors, New Jersey Sea Grant Marine Advisory Service, #NJSG-88-172, 1988.

Additional:

The World Market for Bivalves: Oyster-Mussel-Clam-Scallop, FAO/GLOBEFISH Research Program, Vol. 4, Publications Division, FAO/United Nations, Rome, Italy, 1990.

Culture of Bivalve Molluscs, by Walne, P.R. Farnham, Surrey, England, Fishing News Books, Ltd., 1979.

Aquaculture in Shallow Seas: Progress in Shallow Sea Culture, Imai, Takeo, Rotterdam: A.A. Balkema Publishers, 1982.

Clam Mariculture in North America, by Manzi, John & Castagna, Michael, Elsevier Science Publishing Company, Amsterdam, 1989.

Introduction to Shellfish Aquaculture in the Puget Sound Region, by Magoon, Charles et al., Washington, DNR - Division of Land Management, 1980.

Manual for the Design & Operation of a Low Budget Hatchery for the Hard Clam *Mercenaria* in Florida, by Hartman, Michael, Ph.D., Florida Department of Agriculture & Consumer Services - Aquaculture Market Development Aid Program, 1988.

Content and Procedures

Preparation (Interest Approach):

Show TM A1 and discuss the objectives for this problem area.

To develop student interest in this module, give students a historical perspective on mollusk cultivation, harvest, and utilization in their region and the world. Pass around examples of different plant, animal, and mineral items found in your region. Mountainous areas will have rocks, coastal areas shells, some areas trees, etc. Use specimens that are unique to that area, but have relatives in other regions.

Ask students to determine what group (animal, vegetable, or mineral) that each item belongs in and where it might be found. They will see that they all came from their local area, and they are important natural resources.

Ask students what the early settlers coming to this country might have looked for (trees for wood, plants and animals for food or medicine, gold and gems). Explain that the settlers would look for plants, animals, trees, and minerals that were similar to those found in their home country. Hold up a clam and an oyster shell. Explain that clams, oysters, and other mollusks are found in coastal areas throughout the world, and the commonly eaten types are all very similar. Continue to explain that the cultivation of mollusks is one of the oldest forms of aquaculture.

Presentation:

- A. What are the types of clams that are commercially important to fisheries and aquaculture and what are the unique characteristics of each?

Show TM A2 and discuss external features of commercially important clams.

1. Hard clam or quahog (*Mercenaria mercenaria*).
2. Manila clam (*Tapes japonica*).
3. Butter clam (*Saxidomus giganteous*).
4. Littleneck clam (*Protothaca staminea*).
5. Softshell clam (*Mya arenaria*).
6. Surf clam (*Spisula solidissima*).

- B. What general characteristics in anatomy, biology, and life cycle do all clam species share?

Show TM A3, Lab #1, and have students complete the exercise on the clam's external and internal anatomy. Show TMA4 and discuss external and internal characteristics of clams.

1. External anatomical characteristics of clams:
 - a. They are bivalves.
 - b. Shells are smooth or uniformly ribbed.
 - c. Shell valves are equal.

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- d. Shells are oval or elongated.
- e. They have a noticeable hinge.
- 2. Internal anatomical characteristics:
 - a. A muscular foot.
 - b. 2 similar adductor muscles.
 - c. A large gut.
 - d. 2 siphons.
 - e. A fringed, translucent mantle.

C. What are the life processes of clams?

Show TM A5 and discuss the life processes of clams. Show TM A6 and discuss life cycle of clams.

- 1. Feeding - Clams are filter feeders.
 - a. They have a pair of siphons that pump water across the gills and the tongue-like labial palp.
 - b. Food particles (algae, detritus) are filtered out and transported to the stomach.
 - c. Waste products are eliminated via the excurrent siphon.
- 2. Locomotion - Adult clams burrow into the substrate using their muscular foot.
 - a. They may even swim for short bursts using their siphons for jet propulsion.
 - b. Larval clams are free-swimming initially and eventually settle onto the substrate.
- 3. Gas exchange - Clams have a pair of gills that pick up oxygen and other gases dissolved in water. Capillaries in the lamella pick up oxygen from the water by diffusion and release carbon dioxide as a waste product.
- 4. Reproduction - Clams are dioecious.
 - a. The males and females are separate and protandrous.
 - b. A clam may change its sex.
 - c. Clams reach maturity within 1-2 years.
 - d. Males and females spawn in the spring by releasing their gametes into the water.
 - e. Fertilization is external.
- 5. Growth and development.
 - a. The zygote develops into a veliger larvae within 48 hours.
 - b. The veliger stage feeds on microscopic algae and drifts/swims in the water for 7-14 days.
 - c. The veliger metamorphoses into a pediveliger (pedi=foot) and begins testing the substrate to find a suitable spot for setting on.
 - d. Continued development depends on the presence of suitable substrate for the pediveliger to set on.

D. What are the biological requirements of clams?

Show TM A7 and discuss the biological requirements of clams.

1. Growth in clams is dependent on food availability, temperature, and water quality.
 - a. Food - Adequate concentrations of microscopic algae and detritus must be available.
 - b. Algae growth peaks in the summer.
 - c. Spawning is triggered by food availability.
 - d. Different types of algae are needed throughout a clam's life.
2. Temperature - Clams grow faster in the summer than in the winter.
 - a. Different clams species have different temperature tolerances.
 - b. Spawning is triggered by temperature.
3. Water Quality - Clams require good water quality, especially if they are to be used as food by people. Waters should have salinity in the range of 25-35 parts per thousand (ppt).
4. Substrate - Clams burrow into sand or mud and will grow without suitable bottom.

E. What is the seed production method used for the controlled production of clams?

Show TM A8 and discuss phases of farming (producing) clams. Take class on field trip to a local hatchery/clam seed production operation to observe these processes firsthand.

1. Commercial operations for producing clam seed are fairly intensive, land-based systems close to a coastal river or estuary.
 - a. Areas with natural populations of clams, a buildable site, and ready access to good quality, flowing water are best for establishing hatchery facilities.
 - b. The hatchery facility has areas for holding and conditioning broodstock, spawning, algae culture, and larval culture. Space is also needed for water quality monitoring.
 - c. Broodstock are held in shallow tanks or raceways.
 - d. Spawning is done in shallow trays.
 - e. Larvae are reared in cone bottom tanks.
 - f. Algae are cultured in clear fiberglass tanks in a sanitary cooled area.
2. The nursery may be linked to the hatchery or a separate system.

Show TM A9 and discuss the schematics for nursery holding systems.

- a. Post-set/nursery clams are held in shallow trays or upwellers.
 - b. These systems may be land-based or floating structures.
3. Two operational strategies are used in producing clam larvae:

Show TM A10 and discuss clam hatchery strategies. Show TM A11 and discuss Milford and Wells-Glancy methods.

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- a. The Milford method uses filtered, sterilized seawater for culturing algae to feed clam larvae.
 - b. The Wells-Glancy method uses raw, filtered seawater (no sterilization), and natural algae blooms to feed the clam larvae.
 - c. Most commercial operations use the Milford method for the larval stages, and the Wells-Glancy method with post-set/nursery stages.
4. Hatchery systems are flow-through.
- a. Raw seawater is pumped up to the facility and filtered through settling and mechanical filtration.
 - b. Water is then distributed to each phase of the operation and further processed as needed.
 - c. The used water is then discharged as wastewater.
5. Large adult clams are held and conditioned for spawning.

Show TM A12 to discuss broodstock conditioning and spawning.

- a. The water temperature, food, and salinity are controlled so that the clams can be induced to spawn at any time of year.
 - b. The clams are held in cool water (12-15°C) for several weeks.
 - c. Spawning is triggered by increasing the water temperature to 18-20°C and adding certain algae.
 - d. The clams are placed in trays and observed to separate the males from the females.
 - e. Males release sperm in a cloudy, white trail, like cigarette smoke.
 - f. Females release eggs in puffs that are off-white and grainy.
 - g. The eggs are fertilized by adding a controlled amount of sperm solution to egg solution.
 - h. The fertilized eggs are rinsed on a fine mesh screen and then stocked into a tank with filtered, sterilized seawater.
6. It is important to know the number of clam larvae stocked.

Show TM A13 and TM A13A, Lab #2, and have students determine larval density. Show TM A14 and outline larval rearing operations.

- a. Samples are taken to determine the concentration of larvae.
- b. A Sedgewick-Rafter counting cell is used with a microscope to count the number of larvae per milliliter.
- c. Young larvae are stocked at rates of 30 larvae/mm in static tanks with gentle aeration for 2 days.
- d. The larvae are rinsed through another screen to remove dead larvae and debris, and resuspended in clean tanks and water at a rate of 5-15 larvae/mm.
- e. Regular screening allows clams to be sorted by size. This screening/culling process continues throughout production.
- f. Within 7-10 days the larvae begin to set. At this point they are only 200-240 microns.
- g. Post-set clams are stocked into shallow trays with a low flow rate or daily water changes.
- h. In 2-4 weeks the clams will be 500-800 microns and ready to transfer to the nursery system.
- i. Nursery clams are stocked into upwellers or downwellers and held until they reach 6-12 mm.

7. Clam larvae require a continuous supply of algae for food.
 - a. Algae are cultured using sterilized, nutrified seawater and controlled lighting conditions, or by stimulating natural blooms in sunlit tanks.
 - b. Larval clams need a combination of different types of algae in their diet such as isochrysis, dunalliella, platymonas, tetraselmis, and thalassiosira.
 - c. The larvae are fed a suspension of algae at a rate of 30,000-80,000 cells/ml/day.
 - d. Post-set to nursery clams are weaned on to natural seawater.

8. Clam larvae are sensitive to poor water quality and numerous pathogenic organisms including bacteria, fungi, and toxic algae.

Show TM A15 and discuss health management strategies for seed production.

- a. The larvae should be rinsed through screens and resuspended in clean tanks and water daily.
 - b. Good sanitation must be maintained throughout the hatchery facility to prevent the growth of disease causing microorganisms.
 - c. Water quality must be monitored and constant temperature and salinity levels maintained.
 - d. Regular samples should be examined for signs of disease or other problems.
 - e. Healthy larvae will be active; post-set clams will attach together in clumps with byssal threads.
-
9. The clam seeds are ready for transfer or sale for growout when they reach 10-12 mm in length.
 - a. The time needed to produce a plantable-size clam ranges from 6-8 weeks depending on food and temperature.
 - b. The seed are transported in mesh bags in insulated boxes with ice. It is important that they stay cool and moist.
 - c. Commercial producers often prefer to sell clam seed at 4-6 mm to improve their profit. This means that growout producers may have to incorporate nursery rearing into their operations.

Ask students why producers want to sell smaller sizes, whereas growers want larger sizes.

- F. What is the growout method for producing market-size clams?

Show TM A16 and discuss site selection. Take class on field trip to a local clam growout operation to observe these processes firsthand.

1. Located in coastal beach/marsh areas on intertidal mudflats or subtidal hardbottom. Must have:
 - a. Good water quality (check on water classifications and shellfish harvest restrictions).
 - b. Protection from wave and storm effects.
 - c. Salinity levels of 25-35 ppt.
 - d. Ready access by producer but not others.

2. Permits and licenses must be obtained to harvest and sell clams from the site.

3. The site chosen will depend on the system to be used and should use systems suitable to the sites available.

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4. Systems for clam growout are categorized as follows:

Show TM A17 and discuss clam growout systems. Distribute pictures and diagrams of different growout systems.

- a. Bottom planting entails spreading the clam seed onto a prepared bottom plot.
 - b. The plot can be plowed with gravel to improve the growth and survival of the clams.
 - c. Protective netting can be placed beneath and above the plot to protect clams from predators, and prevent clams from migrating to other spots.
5. Trays are screened boxes made of wood, rebar, and mesh. Trays may be placed on the bottom, stacked, or suspended from a raft and provide better protection from predators and are easier to harvest. Fouling is a major concern in maintaining tray cultures.
6. Mesh bags and lantern nets are also used.
- a. Bags can be suspended or placed on the bottom.
 - b. The bags are often connected to form belts.
 - c. Lantern nets are small triangular nets that are suspended in a vertical chain in open waters.
 - d. Bags and floating nets provide protection from predators and are easily maintained and harvested.
 - e. Problems with these systems are that they are difficult to protect from human poachers, boat traffic, and they are susceptible to storm effects.
7. Stocking rates will depend on the system used, the intensity of the operation, water quality, and food availability, and size of the clams.
- a. Bottom plots should be planted at a rate of 400-1000 clams/sq ft.
 - b. The clams must be thinned to less than 250/sq ft when they reach half of their final harvest size or about 25 mm.
 - c. Stocking rates for trays are similar to those for bottom plots. Clams should be thinned as they progress through the growout process.
 - d. For bags and lantern nets, stocking rates average 200-1000/bag or net.
8. Growout systems require regular maintenance and monitoring.

Show TM A18 and discuss system maintenance tasks.

- a. Trays, bags, lantern nets, and other systems containing clams in a screened/mesh container must be scrubbed and hosed down regularly. This controls fouling by algae, sea squirts, and other organisms and maintains circulation around the growing clams.
 - b. Regularly check screening, anchor lines, frames, support structures, and markers to insure they are secure and haven't been damaged or tampered with by poachers or vandals.
 - c. For bottom plots and container systems situated in intertidal areas, monitoring and maintenance must be conducted during low tide when the systems are exposed.
 - d. Subtidal container systems are lifted onto a work boat for checking and maintenance using a winch. Bottom plots are monitored using SCUBA gear.
 - e. Regularly sort clams by size and thinning the stocking rate as they grow. This promotes uniform harvest sizes and optimum growth.
9. Controlling predators, particularly with young seed clams, is a major concern in clam growout.

Show TM A19 and discuss predators.

- a. Bottom plots are most susceptible to crabs and snails. Screening, planting marsh grass borders, using wood borders, or a gravel substrate help to keep crabs and snails out.
 - b. Subtidal plots are least susceptible to predation by raccoons and birds.
 - c. Trays, bags, and lantern nets provide the best protection from predators.
 - d. Container systems should be checked regularly to remove any crabs or snails that may enter as larvae and grow with the clams.
 - e. Man is another predator of concern. Vandals and poachers must be watched for.
10. Clams reach harvest size (approximately 50 mm) in 18-24 months depending on food, species, and water temperature.
- a. Bottom plots are harvested using manual rakes or mechanical dredge-type rakes with conveyors.
 - b. Clams are sorted by size and hosed down to remove mud and debris.
 - c. The clams can then be packed in bushel baskets, mesh sacks, Styrofoam, or cardboard boxes.
 - d. Clams must be kept cool and moist to stay alive. Dead clams are of no value.
11. Depending on the harvest restrictions and permits for a given region, clams harvested from certain areas may require depuration.

Explain to the class that depuration relates to site selection and permitting. Also review the life cycle and feeding of clams.

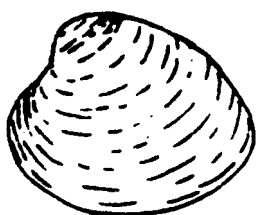
- a. Depuration is the process by which clams are purged of contaminants.
- b. Clams are held in tanks or trays and monitored for contaminants.
- c. Filtered sterilized seawater is flushed through the tanks and clams, thus removing contaminants.
- d. This purging is possible because each clam filters thousands of gallons of water each day.
- e. The result is a healthy, delicious, and safe to eat product.

TM A1

Unit Objectives

- Describe the anatomy, biology, and life cycle of clams
- Identify commercially important clam species
- Explain the selection, management, and culture of broodstock
- Describe spawning methods and procedures
- Describe hatchery and growout operations and management

Commercially Important Clams



Mercenaria mercenaria



Tapes japonica



Saxidomus giganteus



Protothaca staminea



Mya arenaria



Spisula solidissima

Not Drawn to Scale

Six candidate species for clam AQUACULTURE in the United States: the hard clam, or quahog, (*M. mercenaria*); Manila clam (*T. japonica*); butter clam (*S. giganteus*); littleneck clam (1? *staminea*); soft-shell clam (*M. arenaria*); and surf clam (*S. solidissima*).
Courtesy of K. Swanson

TM A3

Lab #1: Clam External and Internal Anatomy

Purpose: In this activity students will become familiar with the external and internal anatomy of a representative clam species.

Materials:

Newspaper, paper towels, or dissecting trays. Clam knife, scalpel, forceps, and pointers. Assorted live (preferable) or preserved clams.

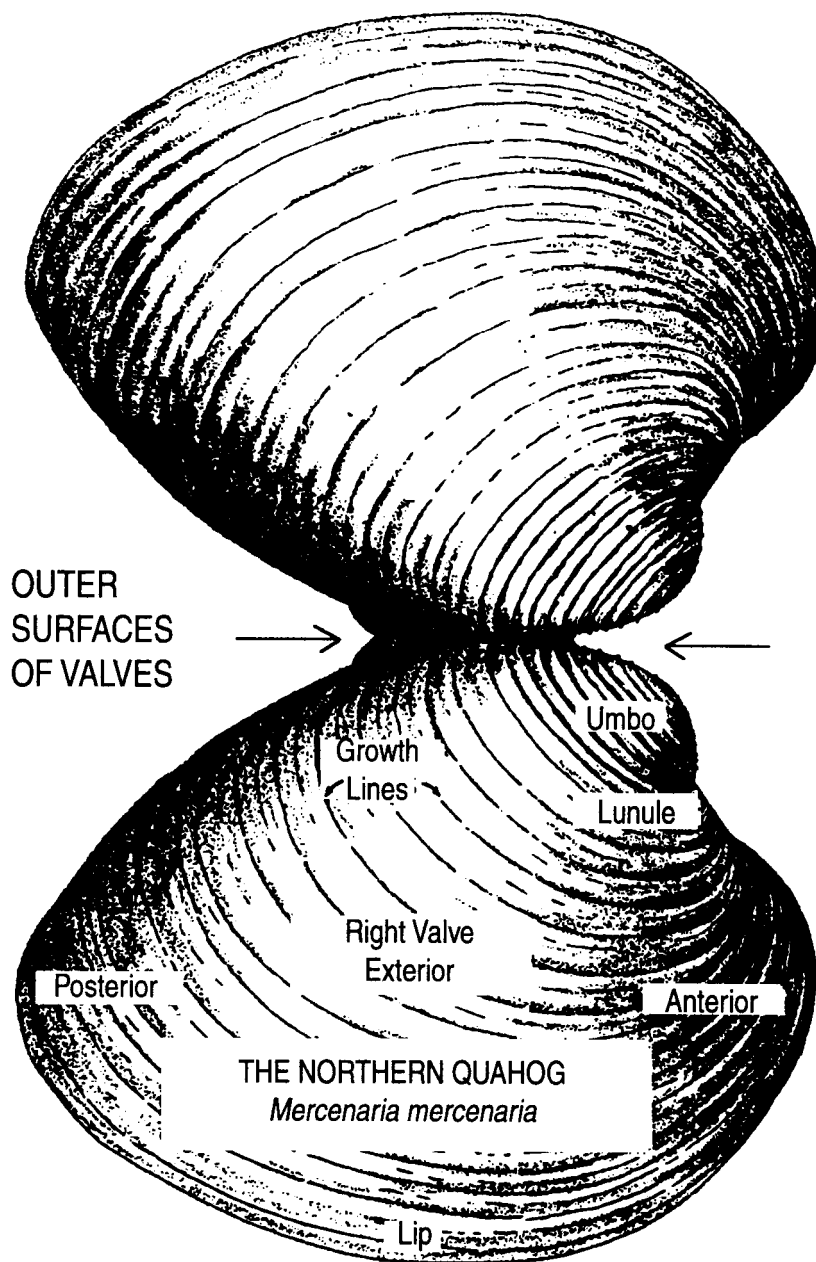
Method:

1. Organize students into teams of 3-4, each equipped with the materials listed above.
2. Each team should examine clams externally to identify the characteristics outlined in TM A4 and on the accompanying labeled diagrams of a clam (TM A3A and TM 3B).
3. The instructor will demonstrate to the students how to safely open a clam using a clam knife.
4. Each team will open its clams and examine them internally to identify the characteristics outlined in TM A4 and on TM A3A and TM 3B.
5. If different types of clams or even oysters are available they are to be examined for comparison.

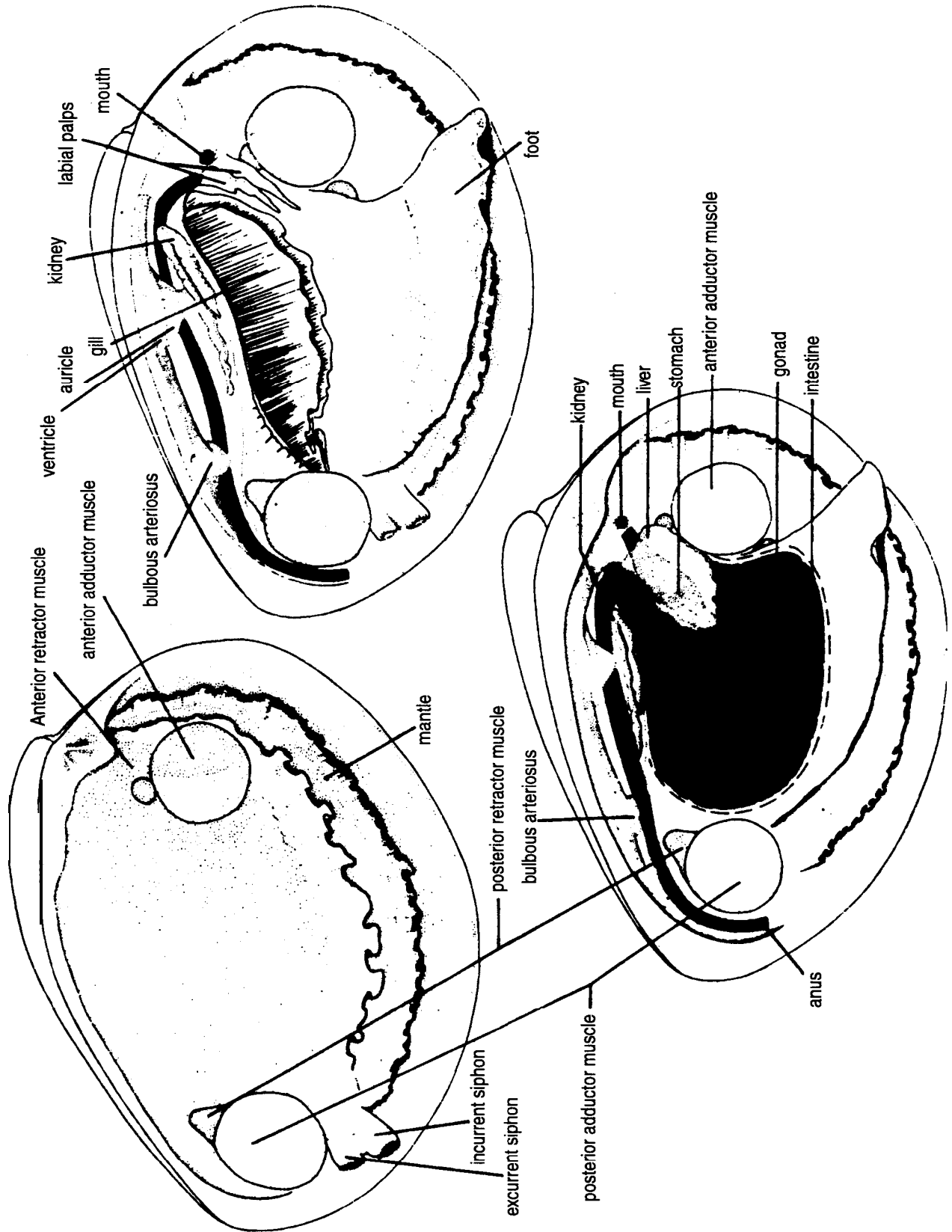
Discussion:

Relate the clam's anatomy to its life processes and life cycle. Compare the anatomy of different types of clams and/or oysters. Do differences relate to lifestyle? What potential consumer problems can be seen based on a clam's anatomy and lifestyle?

Lab #1: External Clam Anatomy



Lab #1: Internal Clam Anatomy



TM A4

Anatomy of Clams

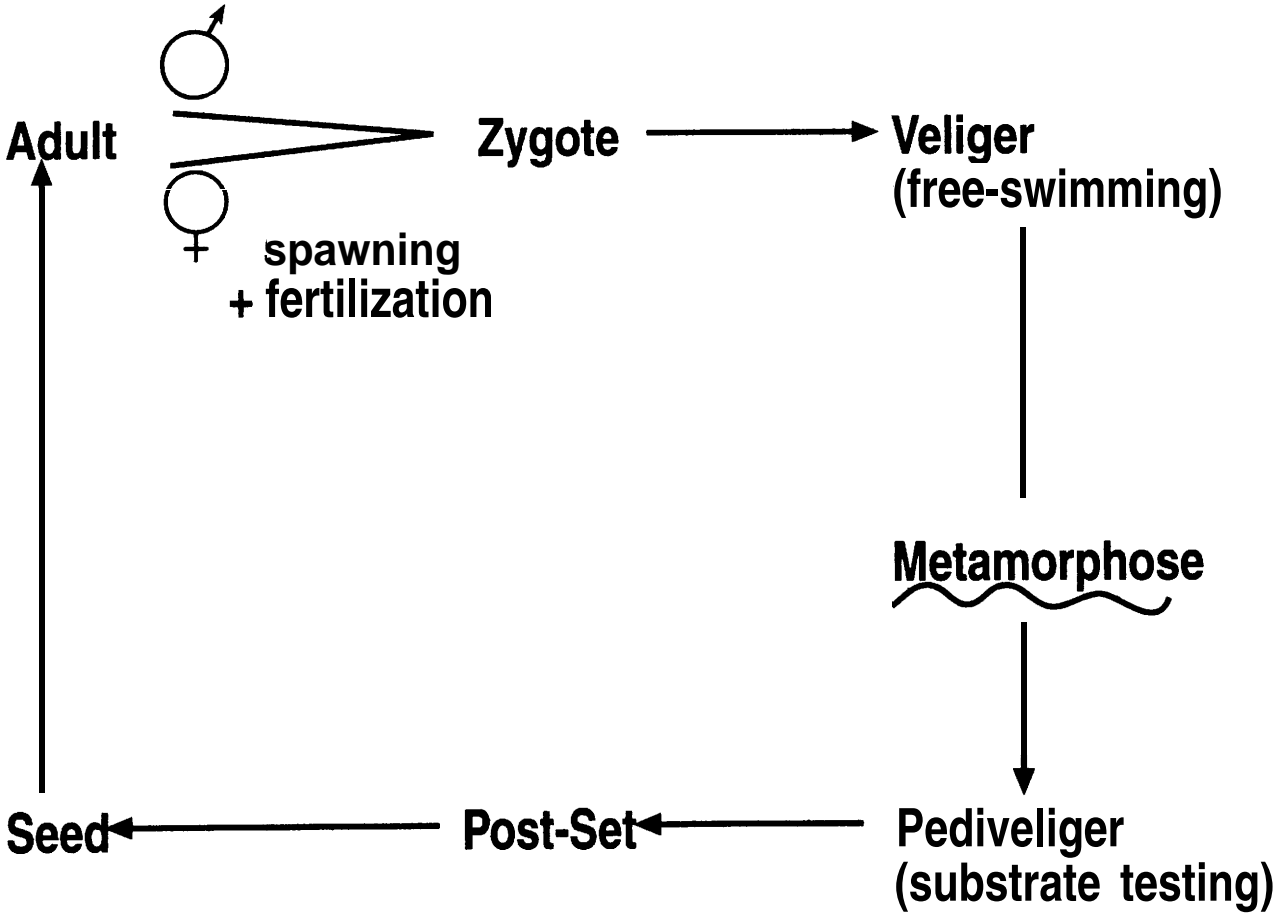
- External Characteristics:
 - Bivalves
 - Shells smooth or concentrically ribbed
 - Valves equal
 - Oval or elongated shells
 - Noticeable hinge
 - White, peachy, or blue-black shell
- Internal Characteristics:
 - Muscular foot
 - 2 similar adductor muscles
 - Large gut
 - 2 siphons
 - Fringed, translucent mantle
 - Gills and labial palp
 - Gonads (if mature)

TM A5

Life Processes of Clams

- Feeding:
Siphons
Labial palp and gills
Stomach and intestine
- Locomotion:
Larvae are free-swimming
Adults have muscular foot
- Respiration:
Gills for gas exchange
- Reproduction:
Separate males and females
Can change sex (protandrous)
External fertilization
- Growth and Development:
Metamorphose as larvae into adult form
Mature in 2-3 years (fertilization to spawn)

Life Cycle of Clams



TM A7

Biological Requirements of Clams

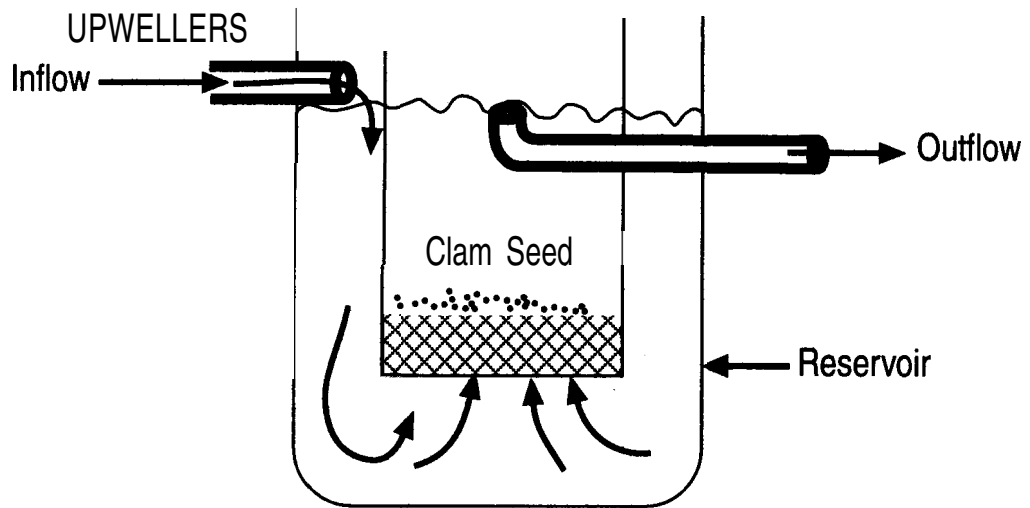
- Plentiful food
- Cool - warmer water temperature
- Good water quality
- Suitable substrate

TM A8

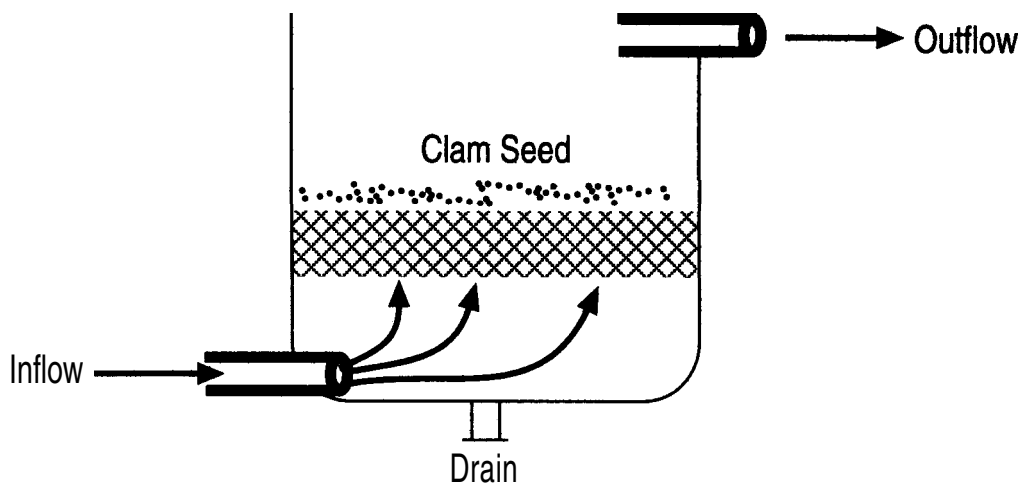
Phases in Clam Farming

- Seed Production:
Broodstock conditioning
Spawning
Larval rearing
Algae food culture
- Nursery:
Post-set to seed for planting
- Growout Production:
Seed to market size clam
Harvest and transport

Nursery Holding Systems



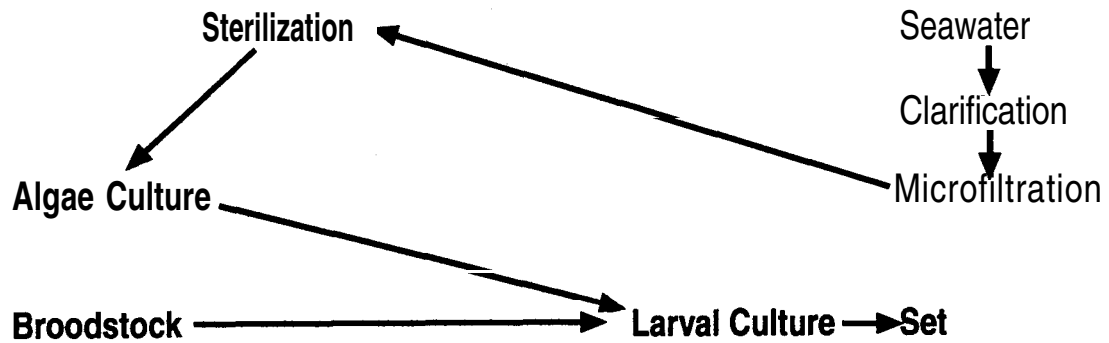
Passive Flow



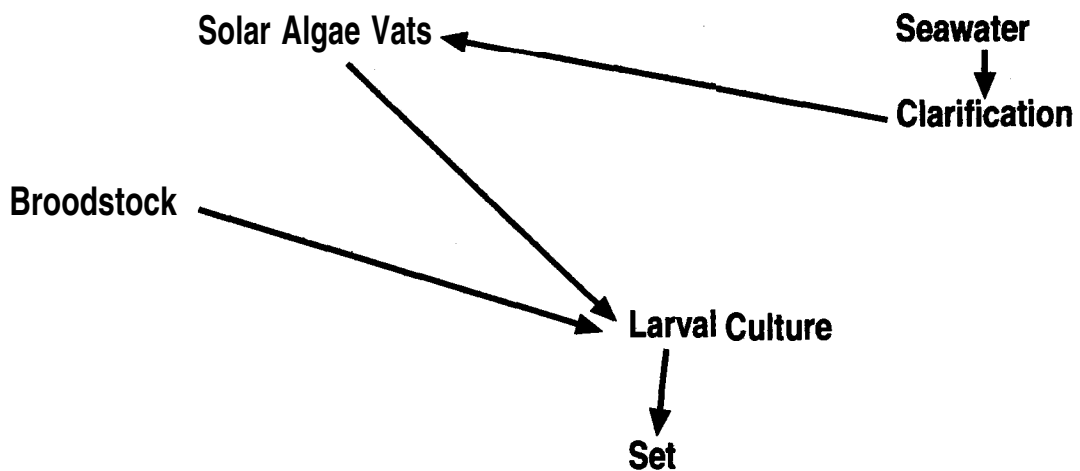
Active Flow

Clam Hatchery Strategies

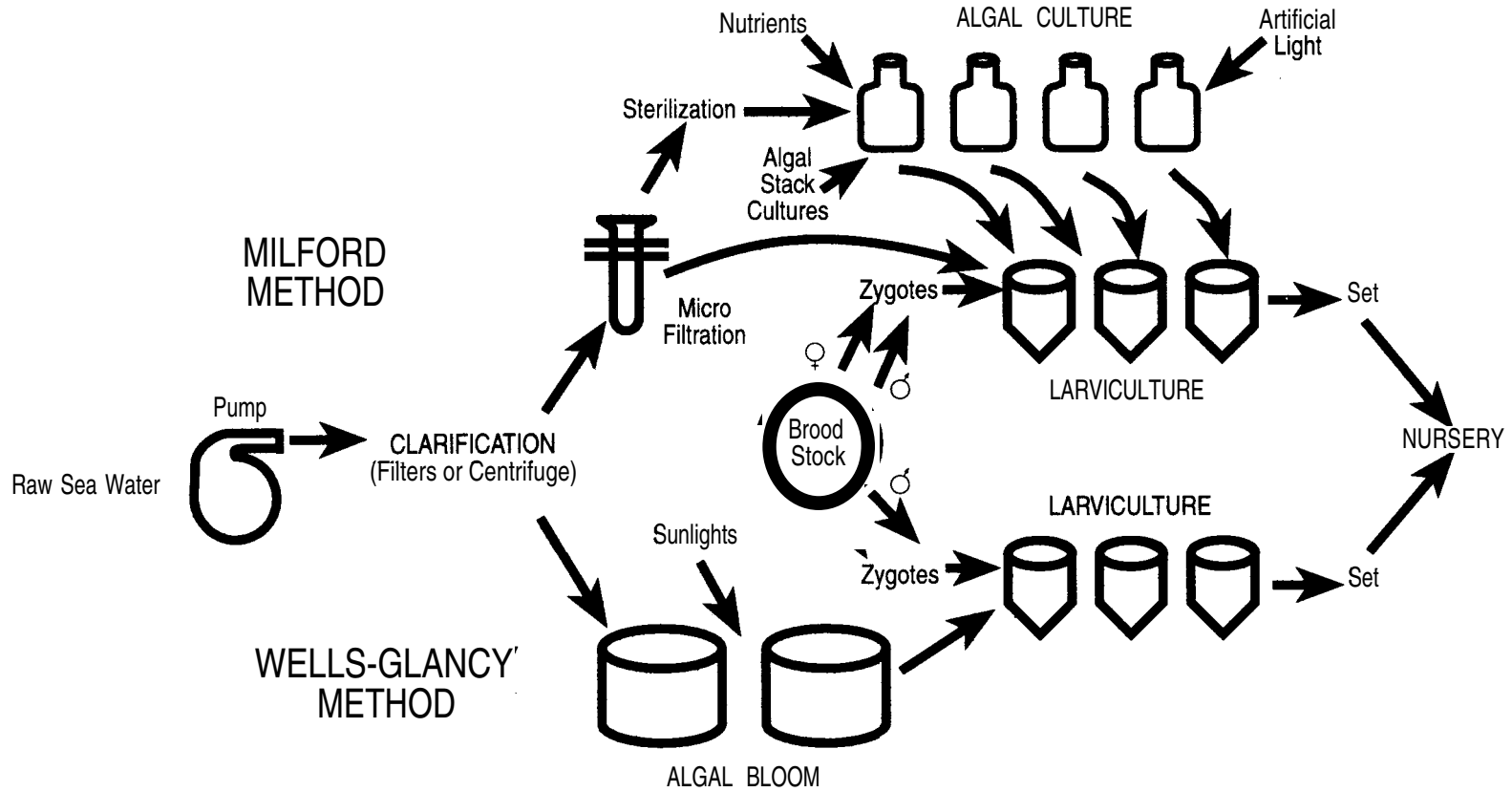
THE MILFORD METHOD



THE WELLS-GLANCY METHOD



The Milford and Wells-Glancy Methods



Schematic representation of the Milford and Wells-Glancy methods of bivalve larval culture.
 Courtesy of *K. Swanson*

TM A12

Broodstock Conditioning Phases

- Controlled temperature, food, and salinity
- Spawning triggered
- Spawners sorted by sex
- Controlled fertilization
- Larval collection

TM A13

Lab #2: Larval Stocking Determination

Purpose: To become familiar with the process and calculations used in determining larval stocking and feeding rates in a hatchery system.

Materials: Larval and algae culture samples, Sedgewick-Rafter counting cell, microscope, sampling containers, and pipet.

Method:

1. Organize the students into teams of 3-4.
2. Each team is to collect a sample from both the larval and algal culture vats. Make sure the tanks are well mixed to get good samples.
3. Use the pipet to fill the Sedgewick-Rafter cell chamber with the clam larvae sample and place a coverslip over it.
4. Examine the cell under a microscope. Count and record the number of clam larvae in the grid-marked area.
5. Rinse out the cell and now use the algae sample for examination.
6. Count and record the number of algae cells in the grid-marked area.
7. Using the formulas on the data sheet provided, calculate the larval stocking and feeding rates.

Discussion: Determine average stocking and feeding rates for the class. Convert measured density to metric or English units. Discuss appearance and behavior of the different larval stages. If you have regular access to a hatchery, repeat this activity using older larvae or different algae.

TM A13A

Lab #2 Data Sheet:

Background:

The Sedgewick-Rafter counting cell is a slide that has a recessed chamber with a grid impressed on it. The chamber holds exactly 1 ml of fluid. Density can be determined by counting the number of organisms in the grid area and expressing the concentration as number of organisms per milliliter (#/ml). This density can then be converted into liters and gallons, or other units as needed.

Data:

1. Larval Density = _____ # clam larvae/ml

#/ml divided by 1000 = #/liter _____

#/l x .2642 = #/gallon = _____

#/gallon x .1337 = #/cubic ft = _____

2. Algal Density = _____ # alga cells/ml

#/liter = _____ #/gallon = _____

3. Feeding Determination:

Larval Tank Volume = _____ gallons

= _____ ml

Volume (ml) x 50,000 (feed rate) = _____ # cells needed

#Cells needed divided by algal density = _____ ml of algae needed

TM A14

Larval Rearing Operations

- Larval stocking
- Monitor health/condition of larvae
- Rinsing, screening, and restocking
- Transfer to post-set trays
- Algae food culture sanitation

TM A15

Health Management Strategies

- Regular screening, rinsing, and water changes
- Good sanitation and regular disinfection
- Water quality monitoring
- Adequate feeding
- Regular examination of larvae

TM A16

Site Selection

- Intertidal mudflat or subtidal hardbottom
- Good water quality
- Protection from waves and storms
- Salinity 25-35 ppt
- Readily accessible
- Secure

TM A17

Clam Growout Systems

- Bottom Planting:
Sand, mud or gravel plowed substrate
May have borders or screen cover
Problems with predators and migration
Harvest with rakes
Stocking rates 400-1000/sq ft at planting
Thinned to 250/sq ft
- Trays:
Set on the bottom or stacked
Wood and plastic-covered wire or polyethylene mesh
Problems with fouling and more costly
Predator and poacher protection
Easier harvest and better yields
Stocked at same rate as bottom planting
- Mesh Bags or Belt Systems:
Floating bags or nets
Framed bags or belts on the bottom
Good for high silt areas
Light weight and durable
Innovative systems
Efficient harvest and good yields
Stocking varies with system

TM A18

System Maintenance Tasks

- Scrubbing and hosing down mesh and frames
- Check:
 - Screening
 - Anchor lines
 - Markers
 - Frames
 - Stakes
 - Stocking rate
- Predator removal and control
- Regular grading and sorting
- Watch for:
 - Vandals
 - Predators
 - Wear and tear
 - Health and growth of clams

TM A19

Common Predators

- Crabs
- Snails and whelks
- Raccoons
- Otters
- Stingrays
- Fish
- Sea stars
- Birds
- Poachers and vandals
- Fouling organisms

Teaching Plan:

Module: Shellfish Culture - Section B

Problem Area: Discovering Oyster Aquaculture

Goal: The goal of this problem area is to become familiar with basic oyster biology and methods used for its controlled production.

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

- describe anatomy, biology, and life cycle of oysters
- identify commercially important oyster species
- explain selection, management, and culture of broodstock
- describe spawning methods and procedures
- describe hatchery and growout operations and management

Content and Procedures

Preparation (Interest Approach):

To develop student interest in this module, ask the students if they have eaten oysters. Did they like them or not? How were they prepared? Ask them how many forms of oyster products they have seen for retail sale. What were the forms? Were any of them value-added? Where did they see them? Was the form attractive? What about the packaging?

Ask the students if they can imagine being the first person to try an oyster. What circumstances would have stimulated the desire to try one? How would they have prepared it for eating given the primitive conditions?

Explain that oysters have been eaten by coastal people since before recorded historical times. They are a staple of many cultures and a gourmet item of many others. Some cultures even consider them an aphrodisiac.

Presentation:

A. How are oysters classified?

Show TM B1 and discuss the classification of oysters. Show TM B2 and discuss the 2 different types of oysters.

1. Oysters belong to the phylum Mollusca, class Bivalvia, and family Ostreidae.
2. The two most commonly cultured types are the cupped oysters, genus *Crassostrea*, and the flat oysters, genus *Ostrea*.
3. The more important species of cultured oysters are the following:
 - a. *Crassostrea gigas* (Pacific or Japanese oyster).
 - b. *C. angulata* (Portuguese oyster).
 - c. *C. virginica* (American oyster).
 - d. *C. commercialis* (Sydney rock oyster).
 - e. *C. eradelie* (slipper oyster).
 - f. *C. rivularis* (Chinese oyster).
 - g. *Ostrea edulis* (European flat oyster).
 - h. *O. chilensis* (Chilean oyster).
 - i. *O. lurida* (Olympia oyster).

B. What are the external anatomical features of oysters?

Show TM B 3 and discuss the external anatomy of oysters. Using an oyster or oyster shell, as well as the oyster section in Smith's Introductory Anatomy & Biology, explore the external anatomy of the oyster.

1. All oyster species exhibit the same general anatomical orientation.
2. Since they are bivalves, they have 2 shells hinged together. The hinge is located at the anterior end of the animal so the shell opens posteriorly. The left shell is normally the more curved or cupped of the two. The left shell is also the one normally attached to the substrate.
3. Shell is made up of 3 layers, all produced by the mantle. The outermost layer is a thin proteinaceous covering called the periostracum (peri=around; ostracum=shell). This can best be seen around the hinge area. The middle layer is the prismatic layer composed of calcium carbonate. The innermost layer is the nacreous, or mother-of-pearl layer.
4. Located at the hinge is the umbo, the portion of the shell formed first. Growth lines surround the umbo concentrically. These lines are similar to those found in trees. These lines are not put down uniformly. Many factors such as temperature, food, stress, and disease affect the oyster's ability to produce shell.
5. The hinge is made up of two parts:
 - a. Flexible ligament, which is the axis of movement for the two shell halves.
 - b. Resilium, which is a pad between the shell pushing the shells apart. This is needed because the muscle in the oyster can only pull the shells together, not push them apart.

C. What are the internal anatomical features of oysters and what are their functions?

Use fresh or preserved oysters in the shell and Smith's Introductory Anatomy & Biology to explore the internal anatomy of oysters.

1. The mantle of the oyster is the colored portion closest to the ventral and posterior edges of the shell.
 - a. Covers the internal organs and may also function to hold gonadal tissue during reproduction.
 - b. Its primary function is to secrete the layers of the shell.
2. The single large adductor muscle is centrally located.
 - a. Its function is to close the shell or keep the shell closed.
 - b. It is comprised of 2 regions, the quick and the catch. The quick is made of striated muscle and closes the shell by contracting or by relaxing, allowing the resilium to push the shells open. The catch is made of smooth muscle and holds the shells shut for a long period of time.
3. The gills run roughly parallel to the mantle from the ventral margin to the middle of the visceral mass.
 - a. Although the gills function for respiration, they are better suited for capturing and sorting food.
 - b. They are heavily ciliated and produce large quantities of mucous. Food particles are trapped in the mucous and moved by ciliary action to the labial palps.
4. The labial palps are next to the dorsal end of the gills where final sorting and selecting food particles takes place.
 - a. Food particles move to the mouth, which is located at the extreme dorsal attachment of the labial palps.
 - b. Food then passes through a short esophagus and into the visceral mass.
5. The visceral mass lies under the mantle, dorsal to the gills, and anterior to the adductor muscle.
 - a. It is composed of the stomach, crystalline style, digestive gland, intestine, kidney, and gonad.
 - b. The food travels from the esophagus into the stomach where further sorting and digestion occur.

- c. The crystalline style, a gelatinous rod, projects into the stomach and stirs the contents as well as produces digestive enzymes to aid digestion.
 - d. The digestive gland is dark green and further digests food particles. The intestine loops several times in the visceral mass and terminates at the anus.
 - e. Waste particles are carried through the intestine and expelled from the anus into the excurrent opening. The kidney functions to rid nitrogenous wastes from the oyster.
 - f. The gonads occupy the dorsal-most area of the viscera and adjacent parts of the mantle. Eggs or sperm are produced here for reproduction.
6. The heart is in a pericardial cavity immediately dorsal and anterior to the adductor muscle. It is composed of one auricle and one ventricle. The heart circulates the blood through the gills and other organs and body parts.
7. The nervous system is simple, consisting of two paired ganglia.
- a. The major sensory area is located along the edge of the mantle where single photoreceptor cells are located in the epidermis.
 - b. These cells can sense light and dark.

D. How do oysters feed and breathe?

Show TM B4 and discuss the water flow and feeding process.

1. Oysters are filter feeders. They feed on microscopic algae or phytoplankton.
 - a. Water enters the oyster on the ventral side.
 - b. The oyster pumps water through the incurrent opening, allowing water to flow over the gills dorsally and anteriorly toward the mouth.
 - c. In the ventral portion of the gills are partitions between the gills that form channels guiding the water through the oyster. The water then flows posteriorly and dorsally, exiting the excurrent opening on the dorsal side.
2. The water going through the oyster contains oxygen, which is taken up by the gills, absorbed into the blood, and distributed to necessary organs and body parts. Food particles are processed in the same manner.
3. As food particles enter the oyster, they are trapped by the gills. The gills are ciliated and produce large quantities of mucus.
 - a. Food particles are moved by ciliary action toward the labial palps.
 - b. Particles that are too large or unsuitable for digestion are coated with mucus and periodically discharged out the incurrent opening by a sudden, strong contraction of the adductor muscle.
 - c. The internal faces of the labial palp have folds where the final sorting of food takes place.
 - d. Heavier particles settle into the grooves formed by the folds, where they will be expelled.
 - e. Lighter particles flow over the ridges of the grooves to the mouth. Food then passes through the esophagus into the stomach.
 - f. The stomach wall is also grooved to provide a greater surface area for intracellular digestion.
4. Another form of digestion, microphagy, is performed in the stomach by wandering amoebocytes.
 - a. The crystalline style projects into the lumen of the stomach and performs extracellular digestion.

- b. The style stirs the contents of the stomach and releases a digestive enzyme called amylase which breaks down carbohydrates.
- c. As the finer food particles enter the digestive gland, tubules made up of phagocytic cells ingest them and complete the digestive process.
- d. Waste products and undigestible particles move through the intestine and out the anus where they are expelled out the excurrent opening.

E. How do oysters reproduce?

1. Oysters are protandrous. They can change their sex between spawning seasons (*Crassostrea*) or even within seasons (*Ostrea*).
 - a. Generally they develop first as males, then change to females.
 - b. This adaptation occurred probably because sperm cells are smaller than eggs and can be produced efficiently by smaller animals, whereas eggs are produced more efficiently and in large enough numbers by larger animals.
 - c. A female oyster can produce 1-10 million eggs depending on size.
2. Gradually warming water temperatures cause oysters to start production of gametes, or ripen. Spawning occurs when oysters are ripe and water temperatures are optimal. Water temperatures vary between species.
3. In *Crassostrea*, fertilization and larval development take place externally.
 - a. Both males and females release their gametes into the water column where fertilization occurs.
 - b. After fertilization, the larvae develop as plankton, then settle to the substrate as post-larvae.
4. In *Ostrea*, fertilization and larval development take place internally.
 - a. Once the male releases sperm cells, the female draws them into the pallial cavity near the gills where the eggs are fertilized.
 - b. Egg development and hatching occur there and further larval development may take up to 3 weeks.
 - c. The larvae are then expelled from the female into the water column.

F. What is the life cycle of oysters?

Show TM B5 and discuss the life cycle of oysters.

1. After the oyster egg has been fertilized by the sperm, larval development takes place. On an average, development takes about 3 weeks, depending on temperature.
2. The first stage of development occurs within hours of fertilization. The trochophore larvae have cilia at one end that make them motile. Although they can move, they are still planktonic and subject to the whims of the currents.
3. Within about 4 days, the next larval stage is reached. The larvae assume a characteristic "D" shape, and become veliger larvae.
 - a. The veligers have complete digestive systems and eat voraciously to aid their development.
 - b. The veliger stage lasts about 15 days.

4. The larval oysters now resemble adults and are sometimes referred to as eyed larvae. They have an eye spot that is light sensitive and aids the larvae in dropping from the water column to the bottom.
 - a. At this point they will settle to the bottom and search for a suitable place to attach themselves.
 - b. The material to which they attach is called cultch.
 - c. The attached oyster is referred to as spat. Spat will attach to most hard surfaces, but prefer a calcareous material.

5. Upon finding a suitable site to spend the rest of their lives, the larvae will crawl along the material with their foot to survey the surroundings.
 - a. Once the exact location of attachment is chosen, the larvae will lay on their left (cupped) shell and hold on with the tip of their foot.
 - b. The byssus gland is located at the tip of the foot and is responsible for secreting the cement that will hold the oysters permanently to the substrate.

6. After adhesion, the foot and eye spot are adsorbed because the oysters will never need them again.
 - a. Shell formation and growth are now the main concerns of the spat.
 - b. Within about 3 months the spat will reach the size of a dime.

7. If food supply and growth conditions are favorable, the oysters will reach sexual maturity in about a year.
 - a. The growth rate is highest for the first 3 years, after which it tapers off. The highest fecundity occurs between the 4th and 7th years, after which it again tapers off.
 - b. The life cycle is now complete and begins again every year.

G. What are the biological requirements of oysters?

Show TM B6 and discuss the variance of water quality requirements between species.

1. The water that oysters live in must meet certain quality requirements such as temperature, salinity, and turbidity. When water quality does not meet the individual tastes of oysters, they will usually shut themselves tight and wait until conditions improve.

2. Temperature requirements of individual oyster species vary widely.
 - a. Temperate zone oysters can range from 4 to 30°C, whereas tropical zone oysters can range from 15 to 35°C.
 - b. The temperature at which most oysters start to spawn is around 20°C.

3. Salinity requirements also vary widely. Ranges of salinity tolerance are from below 10 ppt to 40 ppt. Optimum salinities range from 15 to 35 ppt.

4. In general, the tropical species are more tolerant of silty or turbid water than temperate. Silt poses problems because it plugs up oysters' gills and is difficult to sort from food particles due to their small size.

5. Oysters' food consists mainly of microscopic algae: flagellates and diatoms.

- a. Larval oysters need smaller food particles than adults so their choices of phytoplankton vary.
 - b. Some common genera of flagellates that oysters eat include isochrysis and monocrysis. Some common genera of diatoms include chaetoceros, dunaliella, and phaeodactylum.
- H. How does the obtaining/producing seed method work for propagating oysters?

Arrange a field trip to a local oyster hatchery during spawning and setting time to observe the processes.

1. Oyster larvae to be grown out may be collected as wild spat or hatchery offspring.
 - a. Spat collected in the wild are obtained by providing cultch material near spawning wild adults.
 - b. Materials used for cultch vary with the species of oyster and the region in which the spat are collected. Examples are bamboo and mangrove branches, concrete, tiles, wood posts, and shells of oysters and scallops. Glass and plastic have also been used to separate individuals for the single growout market.
2. Oyster hatcheries are fairly intensive, land-based systems close to a coastal river or estuary.
 - a. Areas with natural populations of oysters, a buildable site, and access to good quality water are best for establishing hatchery facilities.
 - b. While no two hatcheries are alike, all have certain areas for particular aspects of oyster seed production: broodstock holding and conditioning, spawning, larval culture and setting, algal culture, and water quality monitoring.
3. Adult oysters are held in shallow flow-through trays in which the temperature may be controlled.
 - a. The water is generally heated in stages to the preferred spawning temperature of the particular species.
 - b. When ripe, the oysters will gape and begin emitting sperm or egg cells.
 - c. If the oysters do not spawn readily, the water may be drained and the temperature conditioning process may be begun again.
 - d. Another method is to strip the gonads of a ripe male, place them in a blender, and dribble the resulting puree into the water. This will result in the forced spawning of the broodstock.
 - e. In the *Crassostrea*, as soon as spawning is evident, the males and females are removed and placed in individual spawning pans. The sperm and egg cells are then concentrated, counted, and mixed in a ratio of about 2 ml of dense sperm solution to about a million eggs. This is done to avoid polyspermy, or fertilization of an egg by more than one sperm, or to avoid underfertilization.
 - f. In *Ostrea*, the adults are allowed to spawn together in the same tray because fertilization and incubation take place in the female.
4. Fertilized *Crassostrea* larvae are kept in large tanks that are well aerated, temperature controlled, and fed phytoplankton that have been grown under controlled conditions.
5. Female *Ostrea* adults are held and fed until the larvae are expelled from the pallial cavity.
 - a. When the larvae exhibit eye spots and are ready to settle onto cultch, suitable materials are introduced to the holding tanks for them to set on.
 - b. After setting has occurred, the spat may be hardened or periodically exposed to air to toughen them for transport or planting on the beds.
6. Algae for feeding are produced in pure batches.

Aquaculture Curriculum Guide

Show TM B7 and set up a small algae culturing system. Have students set up, manage, grow, and count algae cells. Obtain the starter cultures from a local hatchery or from a biological supply company.

- a. Individual strains are isolated and used to inoculate small quantities of sterilized seawater.
 - b. They are held in temperature-controlled rooms with light banks to substitute for sunlight.
 - c. Progressively larger quantities of water are inoculated until a large number of algae cells is growing.
 - d. Typical containers used for algal cultures are laboratory flasks, Pyrex carboys, and clear acrylic or fiberglass large-diameter tubes.
 - e. When a batch is complete, algae cells are strained and introduced into the larval development tanks. Cells may also be concentrated and refrigerated for later use.
 - f. Some hatcheries use a centrifuge or milk separator for this task.
 - g. Concentrations for feeding start at 30,000 algal cells/ml of water for the 1st week, 50,000 cells/ml the 2nd week, and 80,000 cells/ml the 3rd week.
 - h. After setting, feeding rates increase to 100,000 to 150,000 cells/ml. Feedings occur once a day during the 1st week and 2 times a day thereafter. Progressively larger strains of algae are fed during development of the oyster.
7. Larvae are transferred out of water. The larvae are concentrated by screening, placed in successive layers of cheese cloth, and kept moist and cool.
- a. At 1-4°C larvae can be held for up to a week. A golf ball-sized clump of larvae will contain as many as 3 million larvae and look like a ball of sand.
 - b. Spat are transferred on their cultch material in a damp and cool atmosphere. Cultchless spat are transferred in much the same way as larvae.

I. How does the growing out method work for raising crops of oysters?

Plan a visit to a local oyster farm where a variety of growout techniques may be observed. Show TM B7 and discuss the steps involved. Show TM B8 through TM B15 to illustrate the growout methods discussed.

1. Growing out oysters to market size involves planting spat in protected areas with suitable temperature, salinity, and high primary production.
2. During the growout period other duties are required such as grading and replanting, protecting from predators, and fattening for market.
3. Many different techniques are available to the oyster farmer for growout. Oysters may be cultured on the bottom, stakes, umbrellas, racks, rafts, long lines, or suspended trays and nets.
4. Cupped oysters are usually grown between the -1 and +3 foot tide levels because they are more hardy than the flat oysters that are usually grown below the low tide level. Off-bottom culture allows the oysters to feed more efficiently and shields them slightly from the effects of silt.
5. The most common and economical technique is bottom culture.
 - a. Spat-laden cultch are scattered on the bottom. Need a reasonably firm substrate and protection from high wind and waves.

- b. In areas of high wind and wave action, the oysters tend to pile up in windrows, necessitating rescattering the crop. This method also uses the least amount of labor.
6. Other than bottom culture, stake culture is probably the oldest form still used today.
 - a. Spat-laden shells are attached to bamboo, wooden, cement, or PVC pipe stakes and driven into the substrate or laid out horizontally.
 - b. Spat may be allowed to settle directly on the stakes. This method is particularly useful in areas with soft bottoms that would not allow bottom culture.
7. Umbrella culture uses oysters that have been attached to ropes and suspended from a central post radiating to anchors like spokes on a wheel, thus taking the shape of an umbrella.
8. Rack culture is accomplished by constructing racks of treated lumber, steel rebar, or concrete blocks. Ropes, sticks, or nylon mesh bags with oysters attached or contained are placed on the racks for growout. The mesh bag technique is used quite extensively for single oyster production. Useful in areas that are too shallow for raft culture and too soft for bottom culture.
9. Raft culture incorporates floating structures to suspend oysters off the bottom.
 - a. Rafts can be made of logs, bamboo, Styrofoam, or 55-gallon drums. Raft materials are lashed together to allow flexing with wave action.
 - b. Rafts are anchored to the bottom securely. Strings, ropes, nets, trays, and bags of oysters are suspended below the raft. This method allows the use of nontidal areas rich in primary production for growout.
10. The long line technique also involves suspending oysters off the bottom.
 - a. Spat-laden cultch are attached to polypropylene rope and strung between wooden, metal, or PVC plastic stakes inserted into the substrate.
 - b. Long lines are visibly the most like traditional row farming on land. At low tide, rows of parallel long lines can be seen suspended just above the substrate.
11. Trays and nets are used mainly from rafts or buoys.
 - a. Advantage: Single oysters are easily grown for the half-shell market. Harvesting and maintenance are easy.
 - b. Disadvantage: The cost of the trays and nets is not as economical as some of the other methods.
12. Must protect crops from predators and pests.

Show TM B16 and discuss shellfish predators.

- a. Predators include starfish, crabs, oyster drills (snails), rays, skates, and oyster-eating birds.
- b. Starfish are the most abundant predators; they can eat adult as well as young oysters. Prevention methods include hand picking the beds and spreading quicklime on the beds, which destroy the starfish.
- c. Crabs can kill small oysters by crushing their relatively thin shells and eating the oysters. Trapping will remove these predators.
- d. Oyster drills can be removed by suction dredging, plowing them under the substrate, or by treating the beds before planting with a chlorinated hydrocarbon pesticide.
- e. Choose a culture method that involves trays, nets, bags, or by using suspended techniques.
- f. Fouling organisms such as barnacles, mussels, and algae can compete with oysters for food and space. Clean by hand, dip in hot water, and air dry. Fouling is mainly a problem with trays, nets, and

- bags but can plague any of the methods.
- g. Ghost shrimp soften the substrate. They burrow in the bottom, producing numerous burrows and stirring up large quantities of silt. Oysters then sink and disappear into the mud; long-line stakes and posts will fall over; and oysters can suffocate from silt. Spray beds with a pesticide, Sevin, and harvest the shrimp by pumping water into the beds, flushing the shrimp out.
13. Oysters can be fattened for market by placing them in areas of extremely high primary productivity. This technique allows the oysters to put on extra weight and store extra glycogen, thus giving them an extra sweet flavor.
 14. A recent development is the production of triploid oysters.
 - a. The larvae of these oysters have been subjected to temperature and pressure treatments during development that causes them to have 3 sets of chromosomes rather than the normal 2.
 - b. This extra set renders them sterile. Sterility allows them to put all of their energy into growth, with no energy put into reproduction.
 - c. The result is an oyster that grows faster and does not lose meat quality during normal reproduction. A triploid oyster can usually be differentiated by its slightly lighter flesh and a larger adductor muscle.
 13. Several diseases that affect oysters concern the oyster farmer.
 - a. MSX (Multinucleate Sphere Unknown) is caused by a single-celled protozoan called *Haplosporidium nelsoni*. It thrives in water with a salinity of 15 ppt or higher.
 - b. The protozoa prefer to attack the gonadal tissues of the oyster. The visceral mass where the oyster occupies only a portion of its shell is wasted and thin, watery mucus is produced, rather than the normal thick oyster liquor.
 - c. Although the oyster is edible and harmless to consumers, its appearance and off-flavor negates its market value because it is infected.
 - d. Fungi can also affect oysters, generally in areas that have high temperature and salinity. The fungi attack the gonadal and connective tissues, eventually leading to death. Like MSX, the fungus-infected oysters are safe to eat, but do not appear edible, rendering them unmarketable.
 14. Another organism of concern is the dinoflagellate *Gonyaulax*, which is responsible for "red tides."
 - a. Contains a strong toxin that is released when an oyster consumes and digests it. The toxin is harmless to the oyster but produces Paralytic Shellfish Poisoning in humans.
 - b. After the dinoflagellate bloom dies off, the oyster retains the toxin for some time before flushing it out of its system. Monitoring toxin levels is important for oyster growers in order to produce a safe product.
- J. How are oysters harvested?

Show TM B17 and discuss different harvesting methods.

1. Oysters cultured on the bottom may be harvested by hand picking, diving, dredging, and tonging. Oysters grown on long lines, racks, rafts, or in nets or trays may be harvested mechanically or manually.
2. The oldest method of harvesting oysters is by hand picking.
 - a. In areas of high tidal exchange, harvesters may wait until the tide ebbs, exposing the beds, and slosh out onto the beds picking oysters off of the substrate.

- b. Oysters are often gathered into bags or baskets and deposited into a large tote with a line and float attached. When the tide comes in, a barge retrieves the float and line and hoists the tote onto the deck. Smaller producers may hand carry the bags or baskets off the beds.
3. In certain areas, divers may be used to harvest oysters.
 - a. A diver will descend to the beds and hand pick oysters into a basket that is tethered to the support boat.
 - b. When the basket is full, the deckhand hoists the basket to the deck, dumps it for sorting, then sends it back down to the diver for another load.
4. The most common and efficient method for harvesting oysters is dredging.
 - a. A boat or barge is used to pull a triangular metal frame with teeth along the front bar and a chain bag behind it.
 - b. Usually, the dredge is dragged behind the craft at a length 6 times the depth of the water. This prevents the dredge from digging too deep into the bed and burying nonharvested oysters and from sliding over the top of the oysters and breaking them.
 - c. When a successful tow is made and the dredge is full, it is hoisted to the surface and deposited on the deck of the barge.
 - d. On private beds the catch is then hauled to the processing plant for sorting and opening.
 - e. On public beds, the catch is sorted immediately and undersized oysters and shells are returned to the bed.
 - f. In Chesapeake Bay a unique system is used on the public beds. The boats, skipjacks, are allowed to dredge only under sail, powered by the wind, and are used to prevent overharvesting.
5. Another harvesting method is called tonging. Hand or patent tongs may be used. Hand tongs are scissor-shaped devices with long flat baskets attached to the ends.
 - a. Long shafts allow the operator to work in varying depths of water. The tongs are jammed down into the oysters with the baskets open.
 - b. When the oysters are piled up between the baskets, the tong handles are spread and the baskets enclose the oysters.
 - c. The tongs are then raised to the surface and the contents emptied onto the deck of the boat.
 - d. Patent tongs are basically the same, except the shafts have been replaced by rope, and the device is hoisted by winch.
6. Oysters grown using off-bottom methods are harvested a little more conveniently.
 - a. Most harvesting is done by boat or barge.
 - b. Long-line harvesters may pull the lines manually or by using a specially designed reel at the bow of the boat. The line with oysters is laid over the powered reel and pulled onto the deck. The rope is cut into shorter lengths for easier handling once it is on deck.
 - c. Oysters grown on lines hung from rafts are pulled by hand or winch.
 - d. Oysters grown in bags or racks are lifted off the racks and placed on the deck of the barge.
 - e. Oysters grown in nets or trays are emptied from their growing containers. All harvested oysters are then taken back to the processing plant.

J. How are oysters processed?

Plan a visit to a local oyster processing plant to observe the oyster shucking and packaging process.

1. Oysters can be processed and sold in the shell, shucked, or cooked.
2. Oysters to be sold in the shell are separated into singles, scrubbed clean, and kept cold for transport to market.
3. Oysters to be sold out of the shell are shucked by hand. No efficient method has been developed to shuck oysters by machine.
 - a. Oyster shuckers work on an opening line with a central bin that holds the oysters.
 - b. Each shucker will place the oyster on the table and stab at the shell with an oyster knife at the lip of the shell opposite the hinge.
 - c. When a hole is formed, the knife is inserted and used to sever the adductor muscle, releasing the upper shell. The shell is torn away and the knife is used to sever the remaining adductor attachment at the bottom of the shell and the oyster is placed in a tub.
 - d. Oyster shuckers are paid by volume, not by piece work or by the hour.
4. Shucked oysters are washed in chilled water to remove sand, grit, and bits of shell.
 - a. They move across a sorting table where they are graded by size and condition and packed into containers for retail.
 - b. Retail containers are packed in boxes, then kept under refrigeration or are frozen until shipment.
5. Oysters to be sold cooked are steamed until they open, then removed from the shell. These oysters may be smoked, canned, or boiled down into oyster sauce.

Have students discuss various oyster product forms. Which are valued-added? What forms could be developed for future markets?

TM B1

Classification of Oysters

- Phylum: Mollusca
- Class: Bivalvia
- Family: Ostreidae

TM B2

Types of Oysters

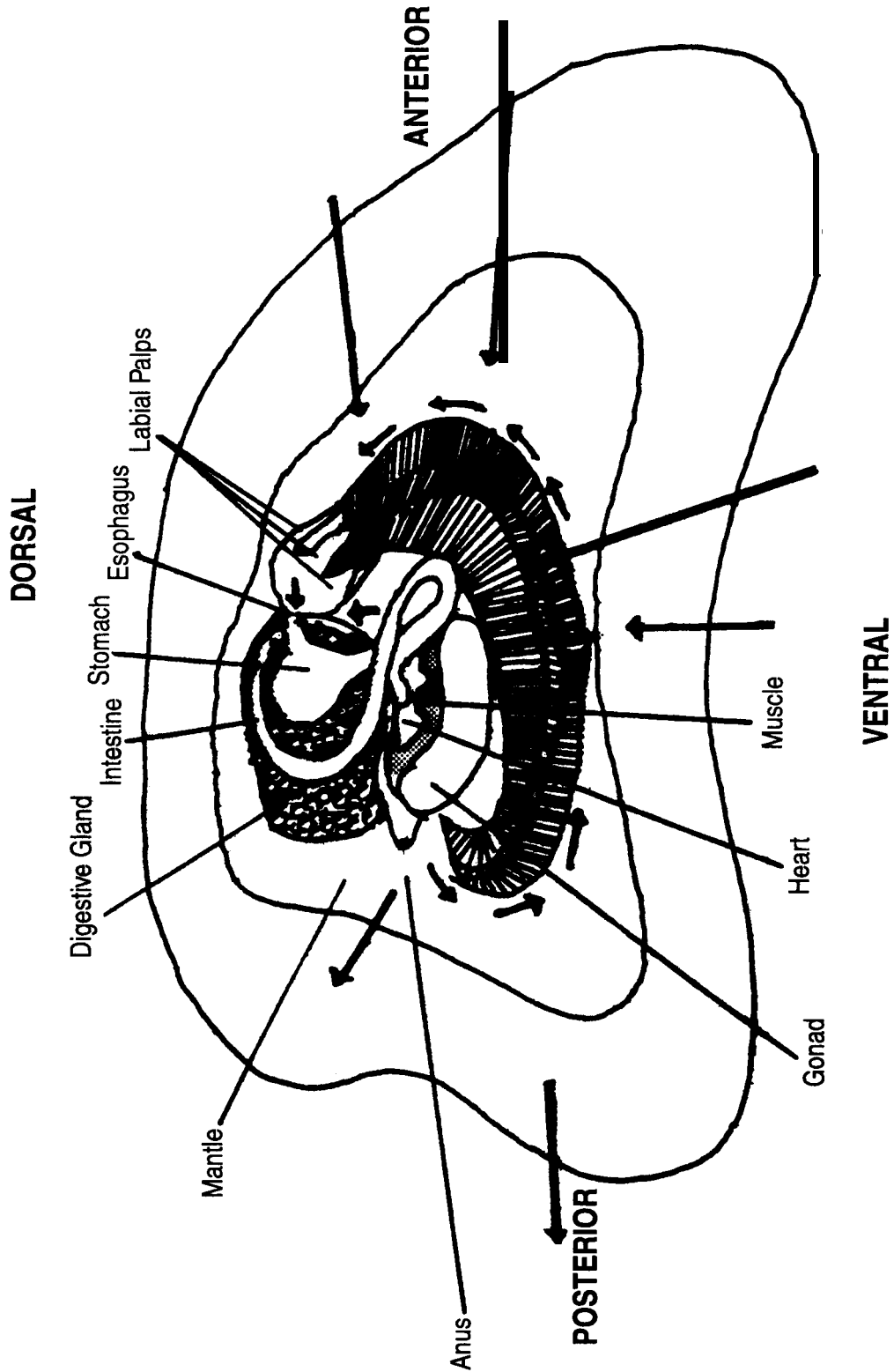
- *Crassostrea gigas* (Pacific or Japanese)
C. angulata (Portugese)
C. virginica (commercialis)
C. eradelie (Sydney rock)
C. rivularis (Chinese)
- *Ostrea edulis* (European flat)
O. chilensis (Chilean)
O. lurida (Olympia)

TM B3 external anatomy of oysters

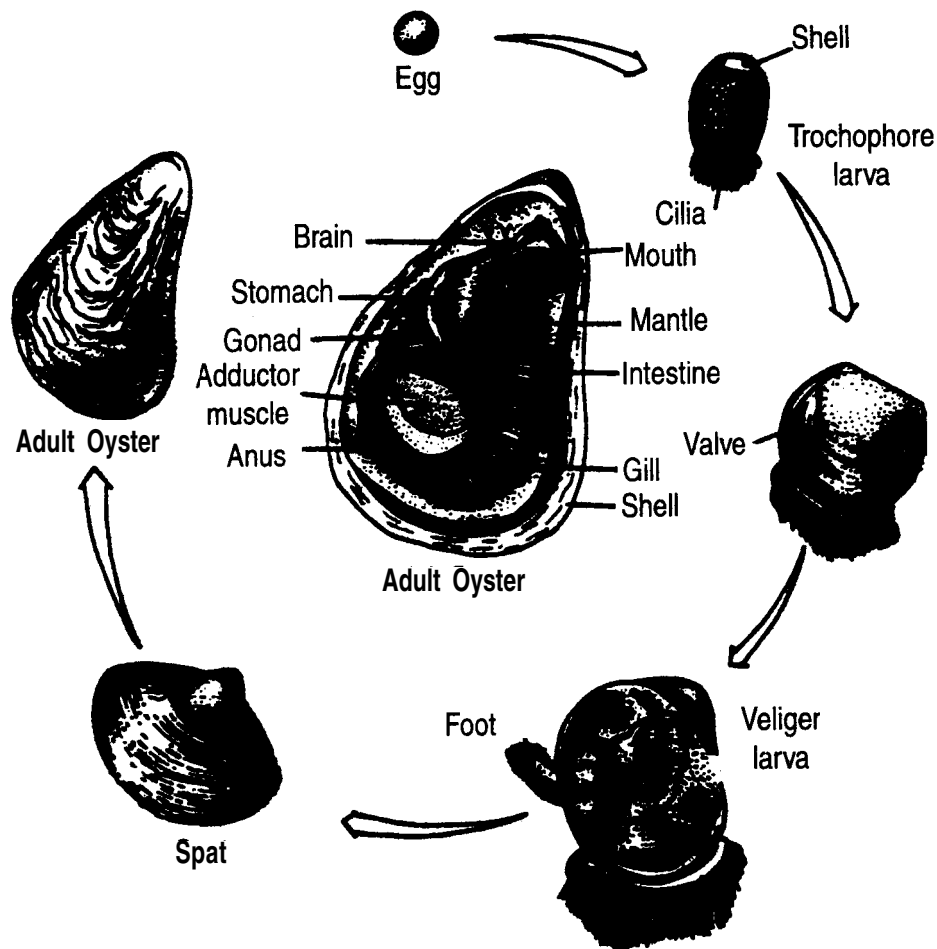
External Anatomy of Oysters



Water Flow and Feeding Process



Life Cycle of the Oyster



TM B6 princ. cult. species

Biological Requirements of Oyster Species

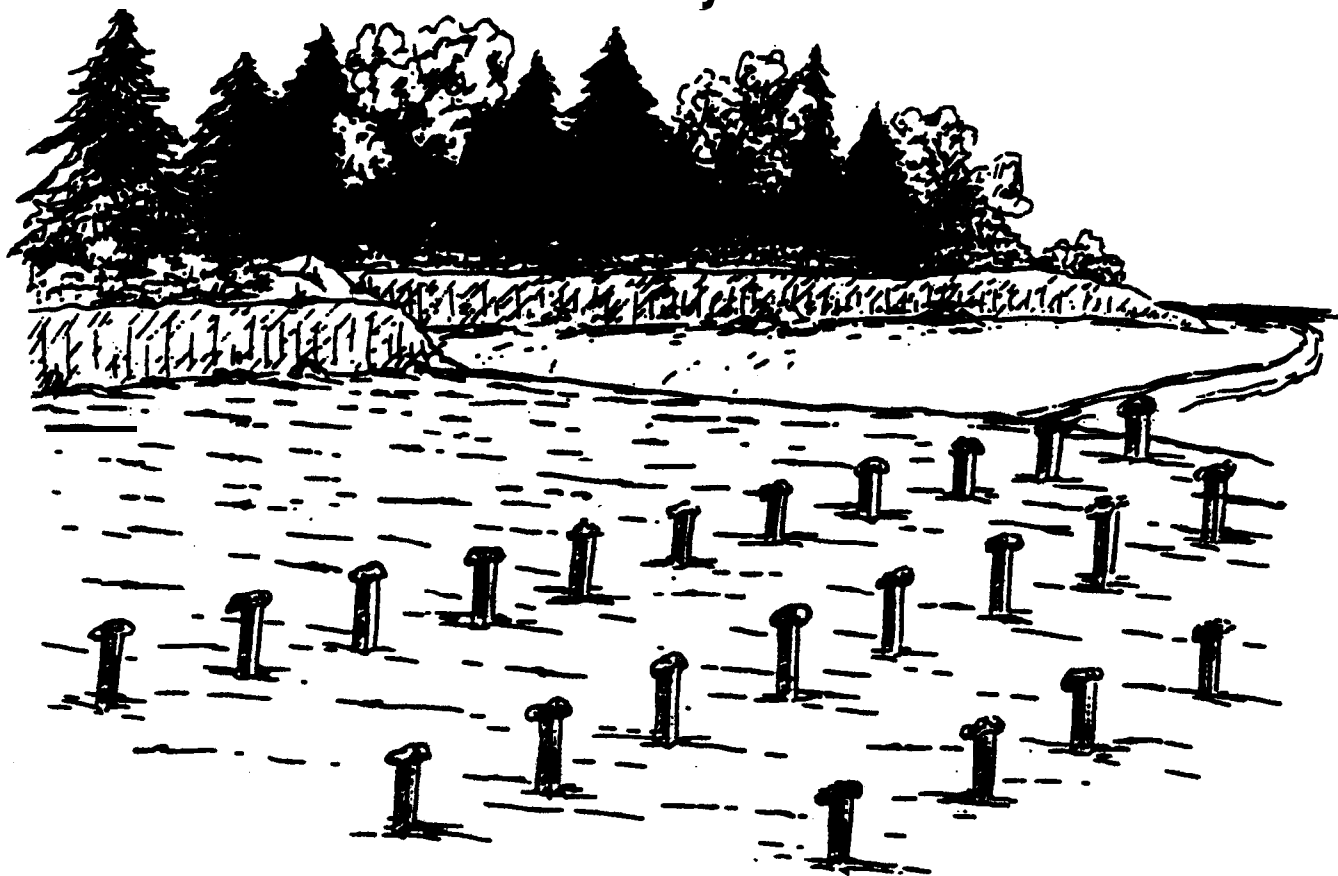
SPECIES	COUNTRIES WHERE CULTURED	SPAWNING SEASON	Spawning TEMPERATURE (°C)	INCUBATION PERIOD	DURATION OF LARVAL PERIOD AND TIME OF SETTING	DEPTH AND TIDAL ZONE	TEMPERATURE TOLERANCE (°C)	SALINITY TOLERANCE (‰)	SUBSTRATE	SIZE MARKETED AND GROWING TIME TO THAT SIZE
<i>Crassostrea angulata</i> (Portuguese oyster)	Portugal, Spain, Atlantic coast of France; experimentally in Japan, Tunisia, and California	Summer	20 or more	*****	15-20 days	Intertidal; in estuaries where current is strong	About 15-25	Optimum 20-50 fails to reproduce about 34	Various quite tolerant of turbidity	85 g (including shell); 3 years in France
<i>C. commercialis</i> (Sydney rock oyster)	Australia, from southern Queensland to eastern Victoria and New Zealand	Summer and fall	Peak at 21-23	6 hours	14-21 days; February-April days	From intertidal 103 m below low tide	Varies widely	varies widely	Hard bottom, usually in the shade	85-100 mm (for consumption on halfshell), 2-12 years in North, 50-65 mm long (for shucking), 2-3 years
<i>C. eradelle</i> (slipper oyster)	Philippines	Summer and fall, peaks during rainy season (July-August)	30-33	*****	7 days	Intertidal	25-33, possibly wider	wide, up to 45, spawns at 15	Usually war mud on sand; very tolerant of silt	75 mm diameter, 8-9 months
<i>C. gigas</i> (Pacific oyster)	Japan, Korea, Taiwan, Pacific coast of United States and Canada; experimentally in Australia, France, Netherlands, Portugal, Thailand, and United Kingdom	Peaks in Japan May-June in Inland Sea, August-September in North Japan	Begins at 19-20, peaks at 23-25	5-6 hours	10-14 days; peak in August	Intertidal	15-30, optimum for larval development 23-28 (varies with temperature) beat sets at 25 or more	Optimum for larval development 23-28	Any hard substrate	30-60 g (including shell), 6-12 months (Inland Sea, 18 months (North Japan) halfshell size, 2 years
<i>C. rhizophorae</i> (mangrove oyster)	Experimentally in Cuba and Venezuela	Continuous, peaks May-September in Venezuela	*****	*****	Continuous setting, pairs in July-August in Venezuela, February-April in Cuba	0.5-3.0 m (intertidal)	18.4-34.0	22-40 (extremes of short duration); optimum 28-37	Associated with mangrove roots, very tolerant of turbidity	75-100 mm diameter, 5-6 months
<i>C. virginica</i> (American oyster)	Atlantic and Gulf coasts of United States, maritime provinces of Canada; experimentally in Japan and California	Long Island Sound mid-July-early October; Chesapeake Bay mid-June-mid-October South Carolina: May-October Gulf of Mexico: April-November	Begins at 20	*****	10-21 days	Intertidal to more than 30 m; spawning and spat settling most successful in estuaries	Larvae develop well at 17.5-32.2	Wide, to at least 32; best larval development above 16.5, some survive at 7.5, maximum for larvae 25	Hard	75 mm diameter, 4-5 years, Northern Atlantic Coast 2-3 years, mid- to South Atlantic Coast and Gulf of Mexico
<i>Osrea edulis</i> (flat oyster)	Atlantic coast of France, Spain, Netherlands, Great Britain, Japan, United States (Maine and Pacific coast)	June-September in Morbihan area of France	20 or more	8 days	12-14 days	Little or no intertidal exposure in estuaries where current is weak	Wide - at least 4-22%; optimum 15-20%; 100% mortality at 26 sensitive to variation	Usually found above 25	Hard, not tolerant of turbidity	65 g (including shell), 75 mm diameter, 4 years

TM B7

Growout

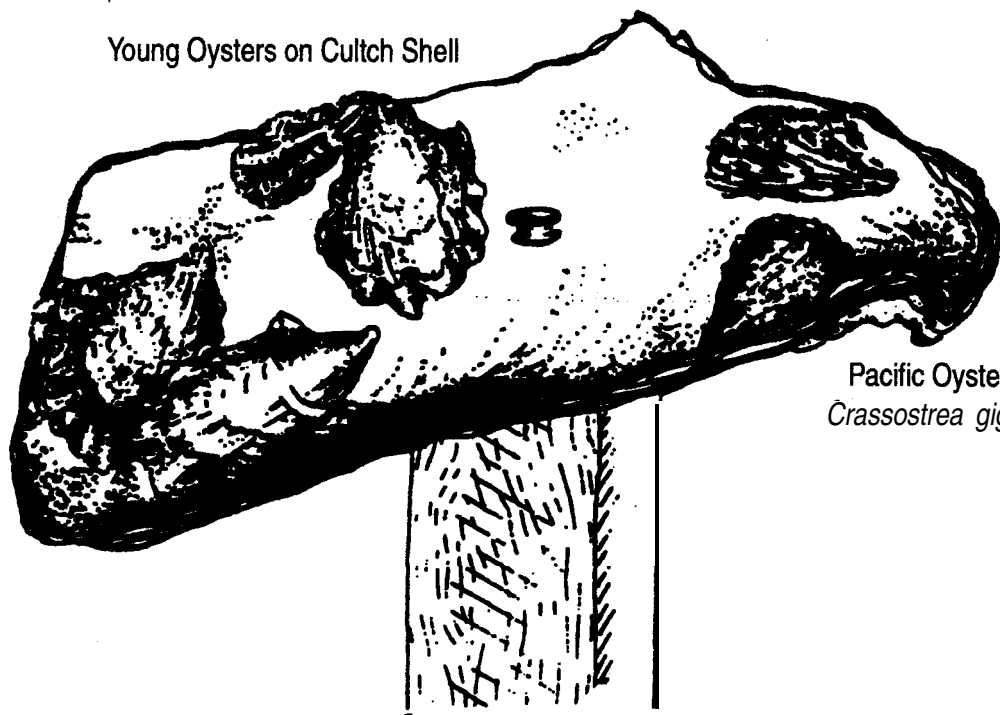
- Planting spat
- Grading and replanting
- Protecting from predators
- Fattening for market

Stake Method of Oyster Culture



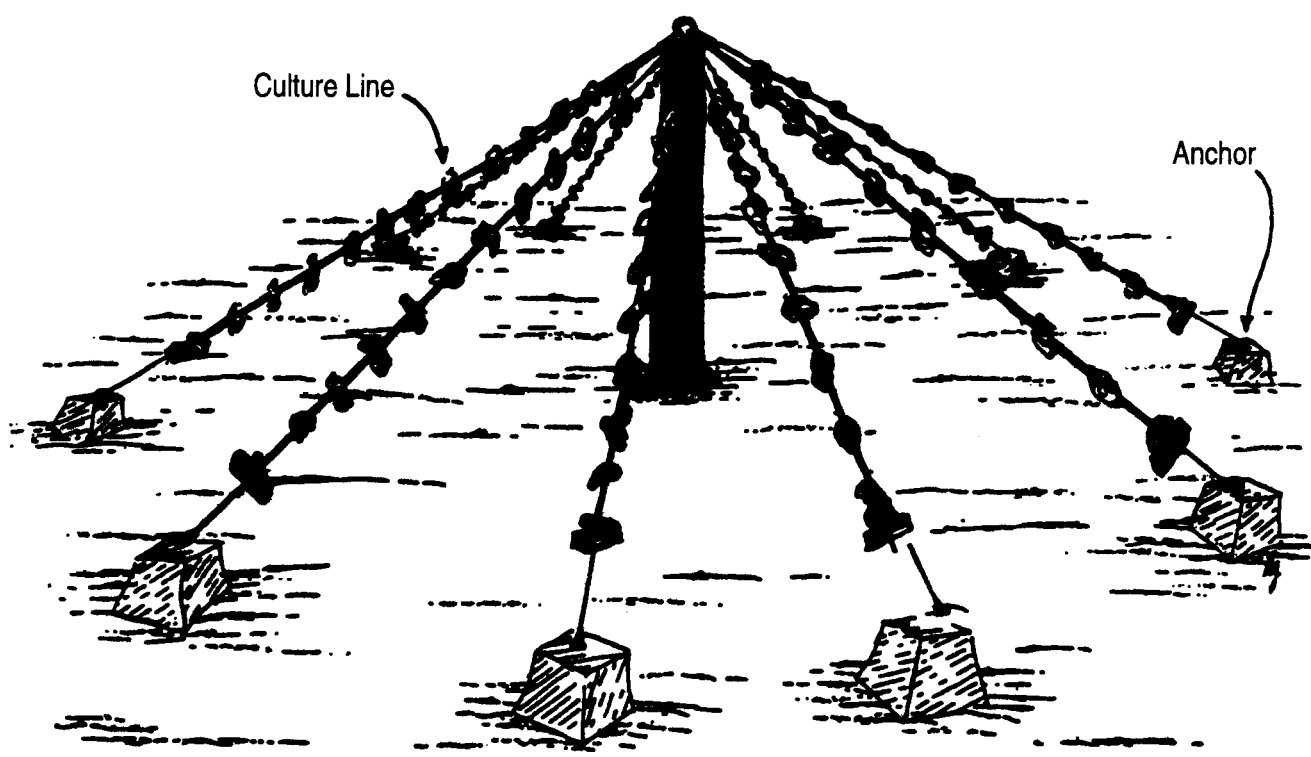
Stakes of wood or plastic pipe can be driven into the substrate with a spat-laden shell attached to each.

Young Oysters on Cultch Shell



Pacific Oyster
Crassostrea gigas

Umbrella Culture

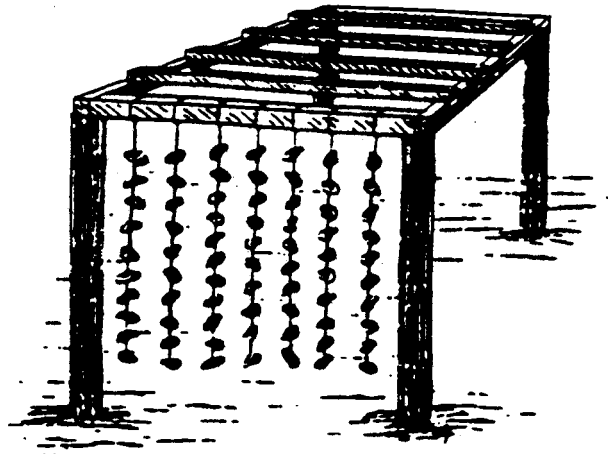


Cultch are suspended along wire or rope ribs and secured by anchors or stakes.

Rack Culture

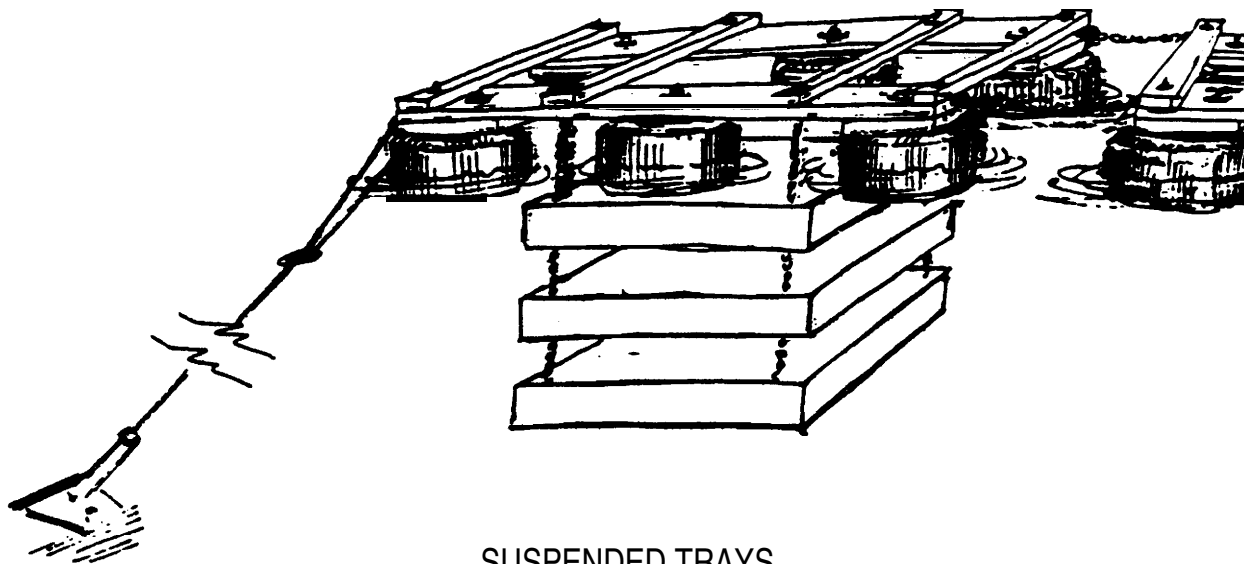


This example combines rack and tray techniques.
Young oysters can be spread across the wire mesh and reared to maturity.

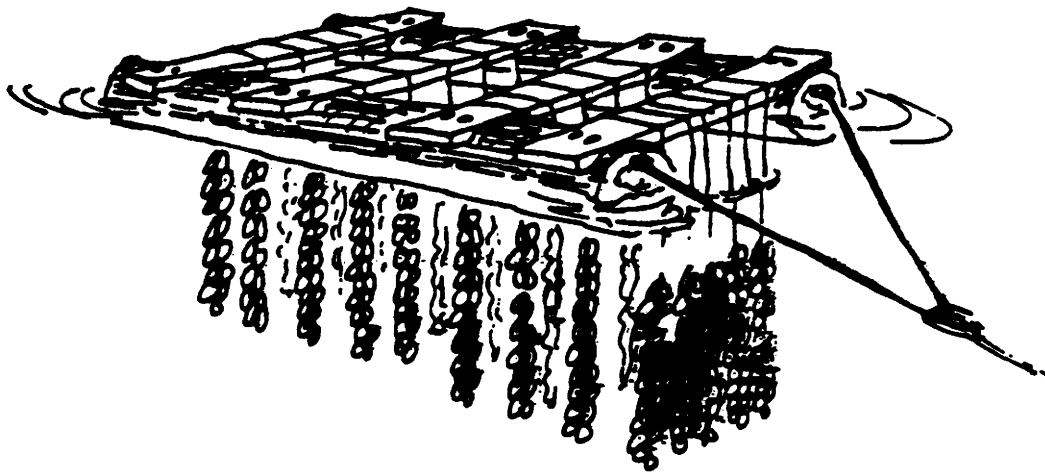


Racks are used extensively for spat collection and/or the growth of young oysters or mussels.
A variety of suspension methods can be used.

Rafts



SUSPENDED TRAYS



SUSPENDED CULTURE STRINGS

Oyster Culture Lines

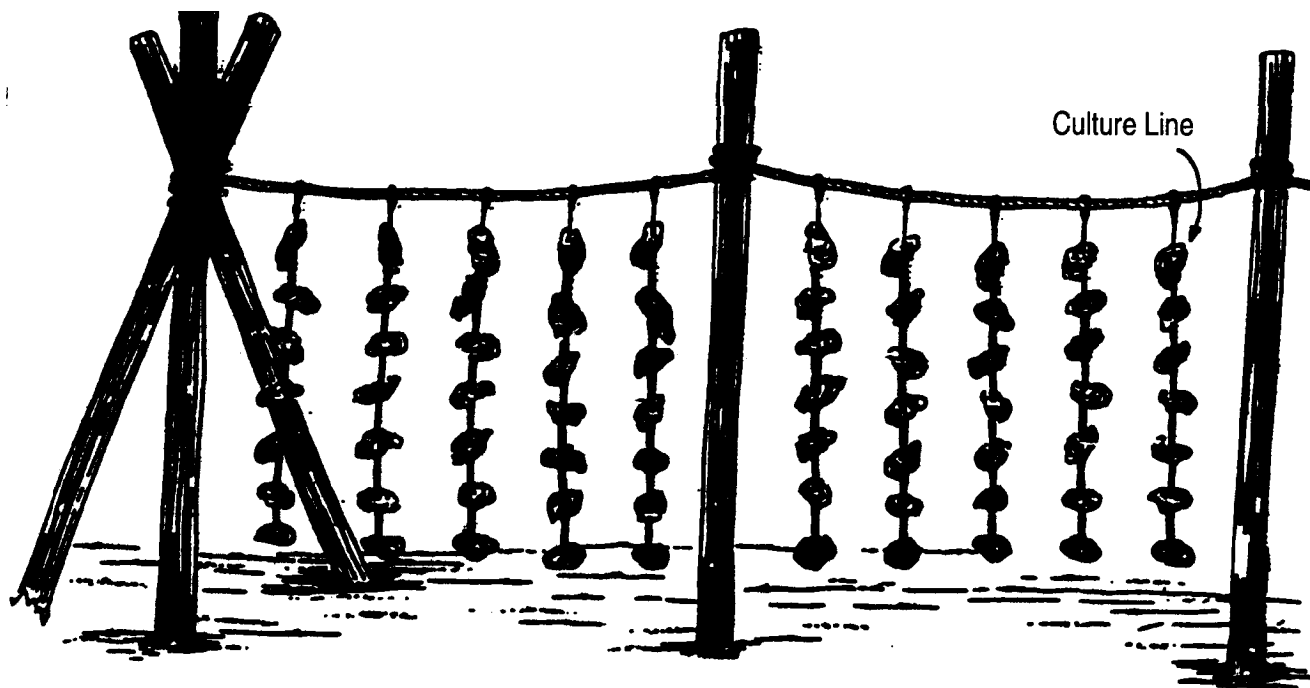


Oyster Culture Line
Using Rope

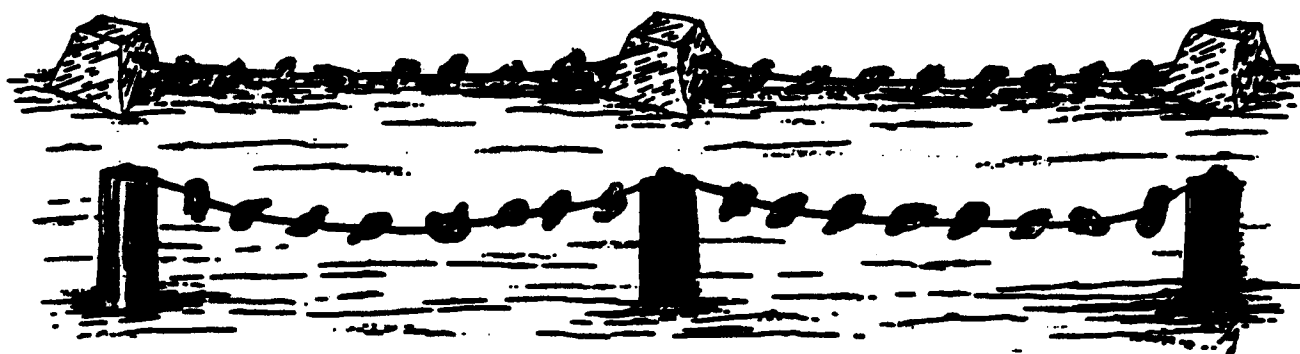


Oyster Culture Line
Using Wire and Spacers

Stake and Bottom Method

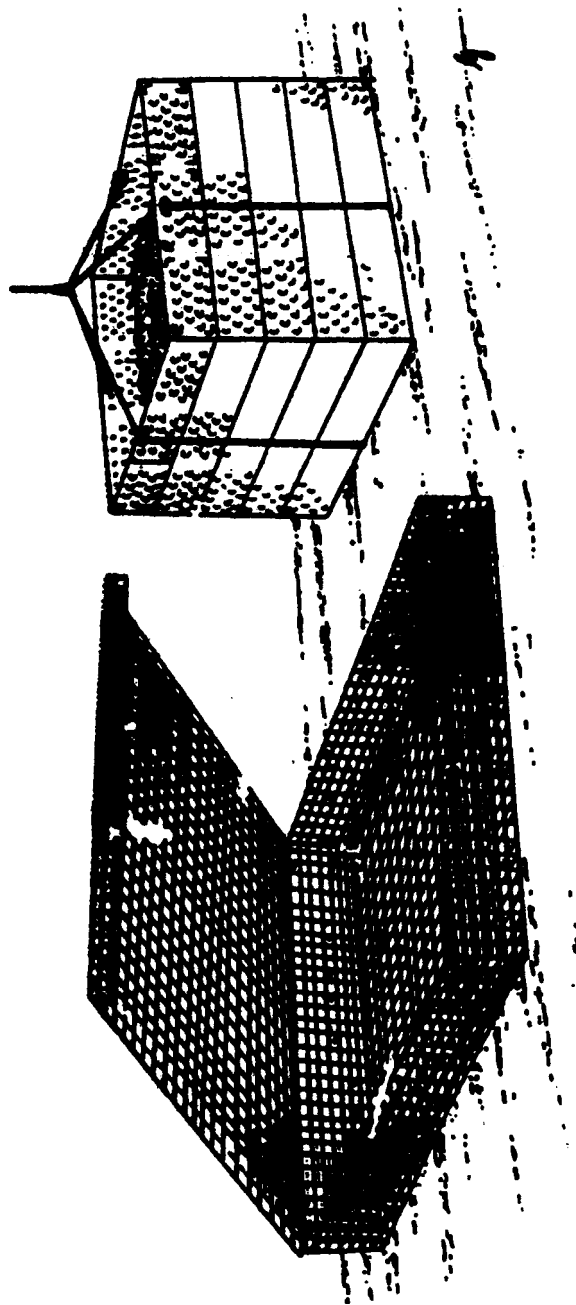


Stake Method: Cultch can be strung vertically or horizontally, shown here using plastic pipe lengths as spacers between shelf.



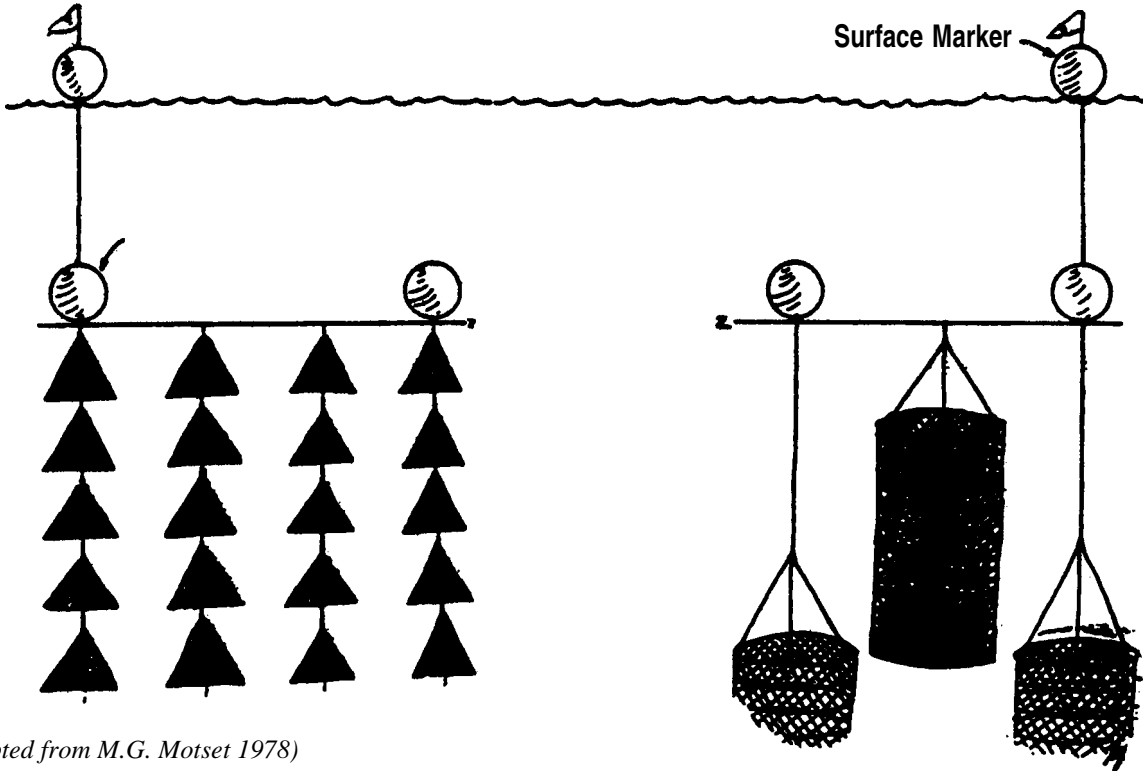
Bottom Method: Cultch are secured to the bottom suspended just above an unstable substrate.

Oyster Culture Trays



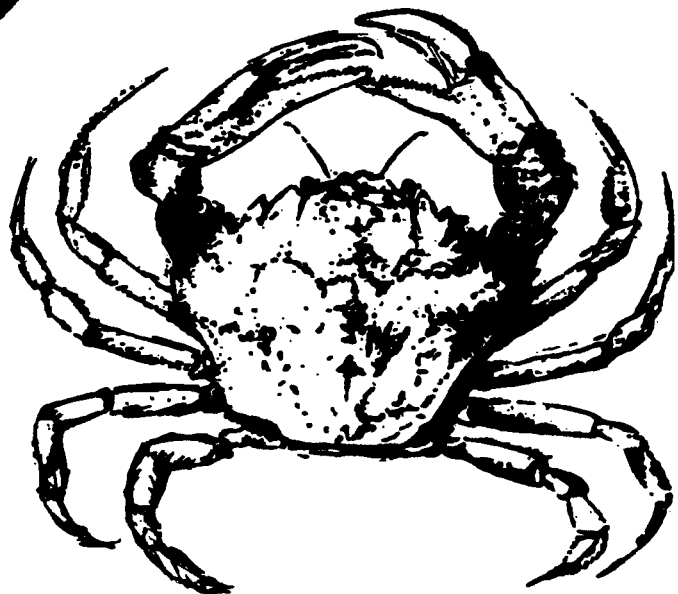
A simple wire or plastic nesting tray (shown stacked here) can be suspended or set on stable sediment. Trays appear to exclude some predators.

Oyster Culture Using Pearl Nets and Lantern Nets

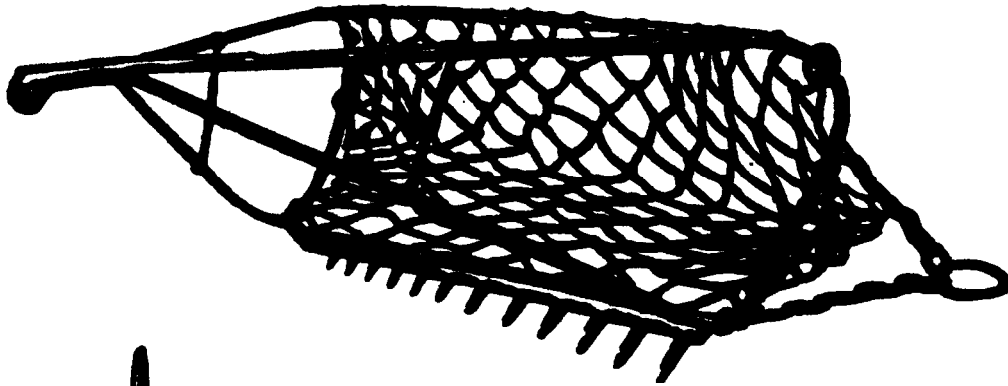


(Adapted from M.G. Motset 1978)

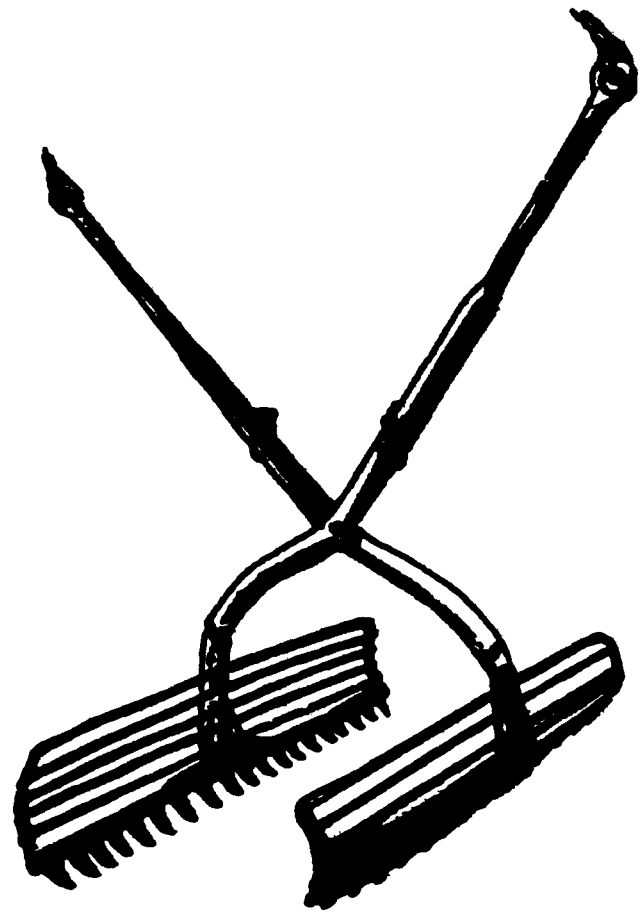
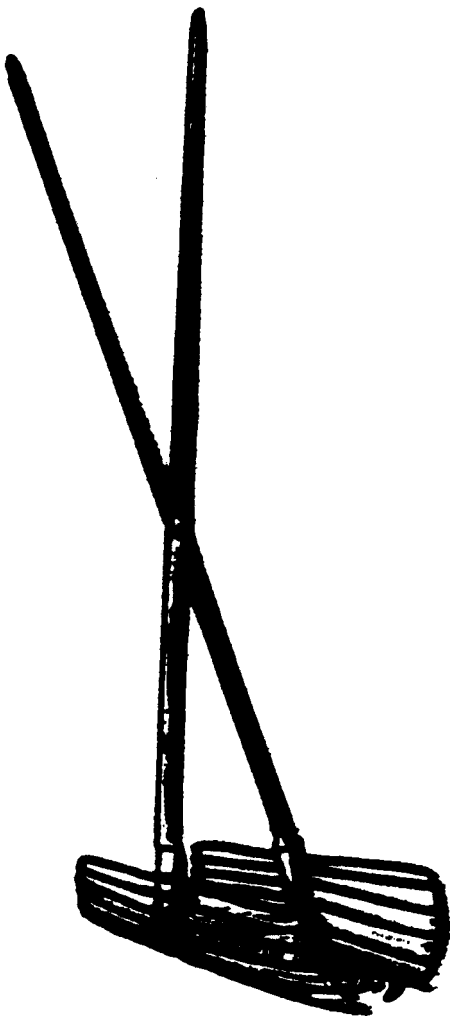
Predators



Harvesting Methods



Dredging



Tonging
