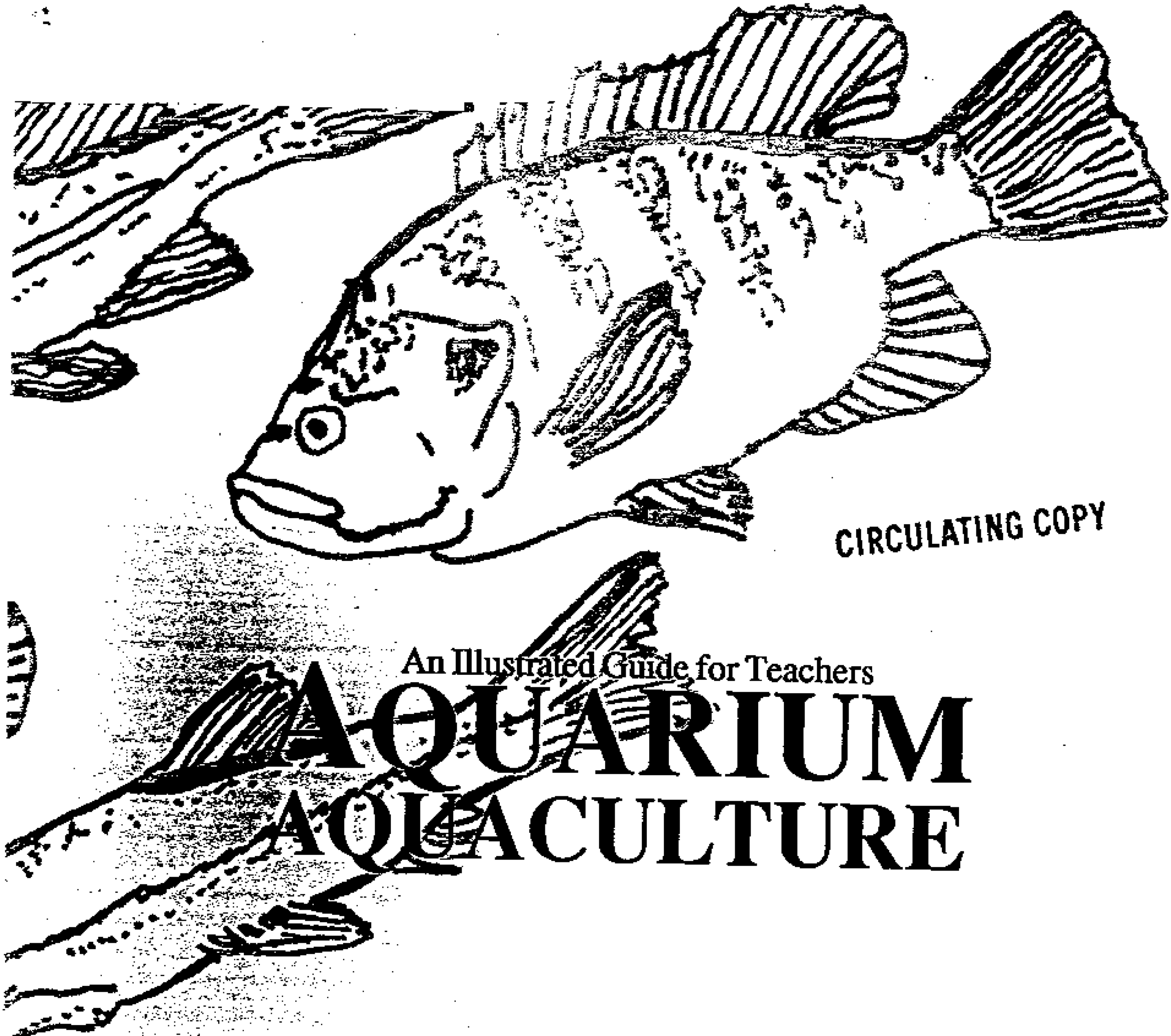

An Illustrated Guide for Teachers

AQUARIUM AQUACULTURE

by Michael J. Brody & Barbara P. Patterson

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The broad purpose of marine education is to develop a marine literate citizenry; that is, to educate students about the fundamental importance of the connections of human culture to aquatic environments. This curriculum on aquarium/aquaculture is intended to facilitate teachers' use of freshwater or marine aquaria to enable students to learn the importance of our marine environment.

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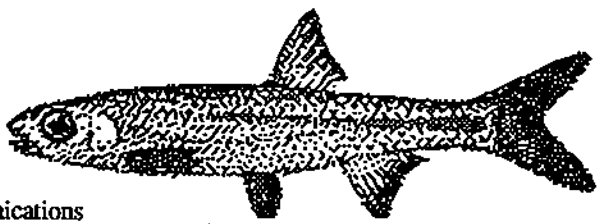

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Contents

University of Maine Sea Grant College Program

The Sea Grant College Program at the University of Maine (UM) is a major proponent for aquaculture in Maine, where the cold clean waters of the 3500-mile coastline provide an ideal setting for such development.

The University's Sea Grant College Program is a joint program with the University of New Hampshire. It is a statewide cooperative effort in marine research, education, and advisory service activities which focus on the coastal and marine opportunities of the Gulf of Maine. The UM Sea Grant College Program is recognized as a regional leader in research on fisheries enhancement and development, and it is practically synomous with shellfish aquaculture.

Through its first funded projects, the University of Maine introduced shellfish aquaculture to Maine. At the flowing seawater facility at the Ira C. Darling Marine Research Center, faster growth and diminished predation of shellfish grown suspended in the water column was documented. These initial growth studies, using the economically desirable European oyster, sparked immediate interest; and several aquaculture firms were started near the Darling Center to put into practice what the researchers were still testing in their laboratories. This enthusiasm led to problems in procurement of "seed," because at that time there were only two U. S. hatcheries that supplied European oyster seed.

Thus the stage was set for the next step of the Sea Grant work: development of an in-state supply of seed. In a spirit of cooperation which continues today between the University and the aquaculture industry, the Darling Center began growing seed and making it available to oyster growers, who in turn kept accurate growth records for the researchers.

By 1984, there were four commercial shellfish hatcheries in the state of Maine, with an investment in plant and equipment approaching $700,000. These hatcheries were the major source of seed for a number of in-state aquaculture operations, with close to $1,000,000 invested in facilities and equipment.

Today, there are two commercial hatcheries still operating in Maine. In response to changing market demand, current emphasis is on production of the American oyster and hard-shelled clam seed, although European oysters and bay scallops are still supplied. In addition, the Darling center continues to produce a variety of seed for experimental purposes.

1. Introduction

Aquaculture, Science, Technology, & Society

Science education is redefining itself. No longer do all goals that guide instruction emanate from the internal structure of the discipline. Instead, some instructional goals are derived from a consideration of how science and technology influence societal well-being and human affairs.

Based on this new rationale, two overriding instructional goals for science education have emerged. One is to provide students with an understanding of the interrelationship of science, technology and the environment, so they will become informed citizens, capable of making decisions that will improve, rather than threaten, their quality of life. A second goal is to familiarize today's students with tomorrow's career options based on scientific and technological advances.

In Maine, the culturing, growing, and maintaining of contained populations of shellfish, lobsters, and fish is an important new industry. Yet unless Maine's students are informed of the promise and problems involved in aquaculture, the industry may not realize its potential for growth that a 3,500 mile coast rich in estuaries can provide. Increased yields from aquaculture and mariculture practices could be negated by agricultural, industrial, thermal, and household pollution.

It is the goal of this curriculum to foster an understanding of the principles of aquaculture among Maine's K-12 students, through the use of inexpensive equipment, easily maintained organisms, and simple aquacultural systems that may be set up, monitored, and manipulated by students in the classroom. All information in this booklet is directed towards understanding, through experiential learning, the physical, biological, and ecological checks and balances needed to foster successful aquacultural endeavors.

Becoming aquaculturists on a small scale will help increase student career awareness about the aquaculture industry. It will also provide students with the fundamental understandings of scientific and cultural principles they must consider in making informed decisions that will affect the future of Maine's aquaculture industry, and the general quality of life in Maine.

Aquariums

An aquarium creates tremendous interest and enthusiasm in the classroom and can greatly enhance the study of science, mathematics, and social studies[1] in an interdisciplinary manner through simulation of a local aquaculture operation. More and more teachers are using aquaria in their classrooms. They serve as fascinating instructional foci for classes in both inland and coastal locations.

It is important to note that most concepts and principles associated with aquaculture can be simulated in the classroom using either fresh- or saltwater aquaria. This guide is intended for teachers who are novices in the field of aquarium-keeping, and as such, it focuses on low cost/low maintenance operational design applicable to either salt- or freshwater systems. Knowledge gained through the use of local species may be applied to general principles of basic ecology and aquaculture technology.

Some basic scientific principles that may be addressed through aquaria study include: 1) aquatic organisms' structure, function, and interaction in complex ecosystems; 2) plant and animal structural, physiological, and behavioral adaptations to the environment; 3) complex balances and interactions of the physical and biological components in an aquatic ecosystem; and 4) science, technological, and societal (STS) interactions associated with the business of aquaculture.

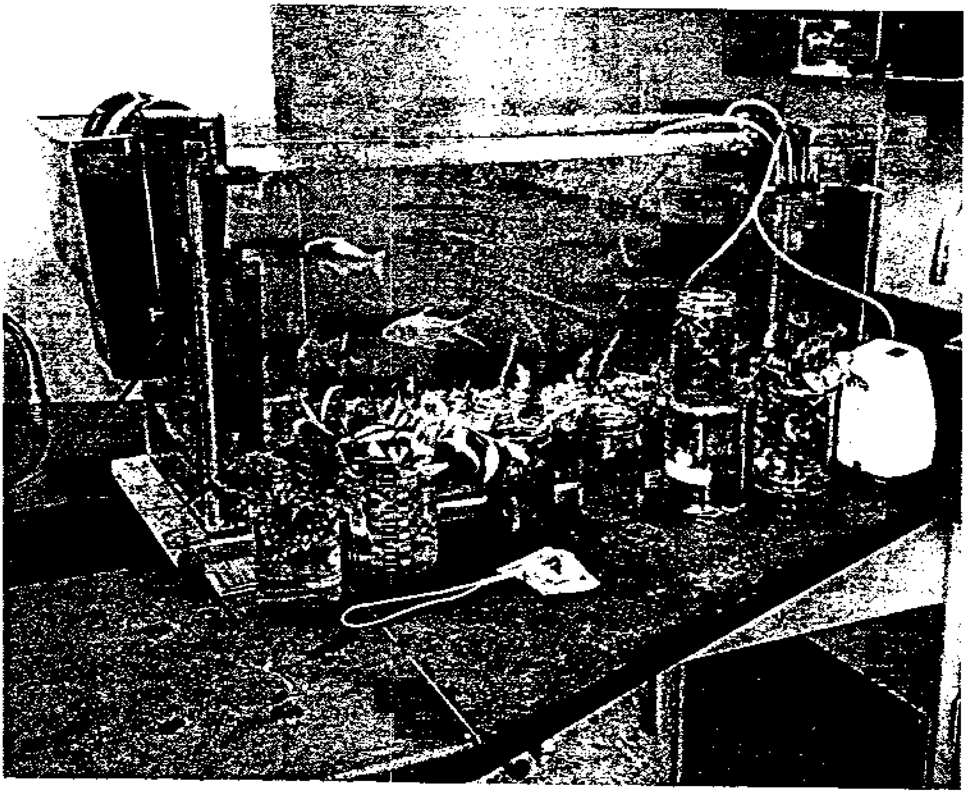
Class participation in setting up, maintaining, monitoring, and manipulating an aquarium will give students a sense of ownership of the aquarium and provide a high degree of student motivation for subsequent multi-disciplinary, aquarium-centered activities. These types of hands-on learning activities foster development of practical manipulative and thinking skills which can help students develop an understanding and appreciation of complex interactions in ecosystems, as well as practical knowledge about the technology of aquaculture.

One of the best features of aquarium-keeping is that the teacher can put as much, or as little, effort and money into the system as may be afforded. Anyone can start with a minimal investment in a gallon jar, some sand, air pump, filter, and some locally collected plants and animals. There is no reason, however, why after starting small, expansion cannot occur. Tremendous progress has been made in the maintenance of aquaria over the past decade. This information has led to the

[1] Carolina Biological Supply Company, Carolina Marine Aquaria (Burlington, NC: Carolina Biological Supply Company, 1975).

design of many new products to facilitate the keeping of water plants and animals.[2]

This book is intended as a primer for teachers and classrooms getting started in an aquarium-centered aquaculture endeavor. As expansion or interest in a particular system or species grows, more detailed technical and scientific information may be desired. Teachers and students are referred to the resources cited in the footnotes for further information .



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2 Barker, Craig, Starting a Marine Aquarium (Neptune City, NJ: T. F. H. Publications, 1972).

2. Principles of Aquaculture

What is Aquaculture?

Aquaculture is the application of agricultural principles to the growing of aquatic organisms. Freshwater aquaculture is practiced in land-based systems where a complete ecosystem is established to produce fish such as carp, mullet, and catfish. Commercial fertilizers, animal wastes, fish wastes, and even sewage are used to produce phytoplankton. Zooplankton and bottom animals consume phytoplankton; and they, in turn, are eaten by fish. Lakes, ponds, marshes, irrigation ditches, and rice paddies are utilized for land-based aquaculture throughout the world.[1]

Marine aquaculture, known as **mariculture**, is a branch of aquaculture that deals with the cultivation of marine organisms. Two different approaches are used in mariculture.

The first approach involves efforts to improve efficiency of growth and harvest in the natural environment. Overfishing in New England has somewhat abated as a result of fisherman becoming better informed about the dangers of overfishing and the natural cycles of the species of fish they seek. As a result, harvesting schedules and methods have been altered to insure continual good harvest.

The second approach attempts to duplicate nature artificially, using such things as enclosed buildings with running seawater to culture desired organisms.

Ranching is another practice of mariculture that combines these two approaches. Recognizing that the greatest mortality for marine species occurs early in life, hatchlings of various species are often reared in artificial environments and then released or "planted out," into the natural environment as juveniles. Another ranching practice, used on species whose reproductive cycles are still relatively unknown, is to collect young from the natural environment and place them in a safer, more accessible natural environment. Salmon are commonly reared in hatcheries for later release; and small clams and mussels are often collected and transplanted into other areas that will promote survival and growth.

Less is known about life cycles, nutrient requirements, or diseases among marine organisms. This is the current thrust of much fisheries and shellfish research, which has as its eventual goal, the improvement of aquacultural techniques and practices.

[1]Lerman, Matthew, *Marine Biology. Environment, Diversity and Ecology* (Reading, Mass.: Benjamin/Cummings Publishing Co., 1986).

Aquaculture and Society

To keep pace with the annual population increase of 3%, the world's food supply must increase each year by 4%. [1] Arable land availability is not keeping pace with population increase.[2] Open oceans have extremely low productivity; but coastal wetlands and estuaries are highly productive, and they serve as sinks for nutrients flowing from the land to the sea. Land-based aquaculture systems and mariculture systems that take advantage of this high coastal productivity offer great promise as "farmlands" of the future. For centuries, the Japanese and Chinese have supplemented their cultures' need for protein by practicing aquaculture in both fresh and salt waters.

But overfishing and pollution are very real threats to the potential of these two industries. To assure a future that will have enough food, future citizens need to be educated about the potential of aquaculture and mariculture to provide low cost, high quality protein. They must also be made aware of the basic ecological principles that underlie the practice of aquaculture and mariculture; as well as the threats that careless use of the enviornment might pose to future endeavors.

Over the past 15 years aquaculture has become a small, but significant, industry in Maine with over 50 businesses that produce shellfish such as blue mussels, clams, oysters and finfish such as sea-run rainbow trout and salmon.[3] As aquaculture has grown, areas of the sea bottom that were traditionally open to all fishermen have been leased by the state for the industry; and free access has become a political issue.

[1]Northern New England Marine Education Project. *Aquaculture.* (A New Hampshire Sea Grant publication, in conjunction with the University of Maine College of Education, 1978).

[2]Miller, G. Tyler, Jr. *Living in the Environment. An Introduction to Environmental Science* (Belmont, California: Wadsworth Publishing, 4th edition, 1985).

The Ecosystem Concept in Aquaculture

Although aquatic habitats are subject to different types of physical environments and differ according to the the size and depth of the "container" which holds them, they all possess four spatial and functional subsystems that account for energy flow. Each of these subsystems must exist in balance with the other three if the particular habitat is to be self-sustaining and realize maximum productivity. The four subsystems are : 1) **photosynthesis**, 2) **nutrients**, 3) **detritus**, and 4) **food webs**.

Three communities of organisms, each inhabiting its own spatial and functional niche, are found in all aquatic ecosystems: **fringing communities**, **pelagic communities**, and **benthic communities**. Fringing communities comprise those plants and animals that live adjacent to the shore. Pelagic communities are those plants and animals that inhabit the water column, and benthic communities are made up of those plants and animals that inhabit the various substrata of the system. Each of these communities contains producers, consumers, and detritovores that function to drive one of the four subsystems mentioned above.[1]

Every species of aquatic organism, through its own unique maintenance processes, plays a role in the conversion of energy through each subsystem. Food synthesized by producers in fringing, pelagic, and benthic communities using sunlight and nutrients in the water, drives photosynthesis. Nutrients are consumed, produced, and re-cycled in the water column by pelagic organisms, and detritovores of the benthos re-cycle and make available nutrients that sink. Each of these organisms participates at some level (producer, primary consumer, secondary consumer, etc.) in the various food webs of the system.

Figure 1 shows the interrelationships of a stylized aquatic system of the four subsystems and three communities. When all components are balanced, maximum energy transfer to the higher levels in the food web is promoted.

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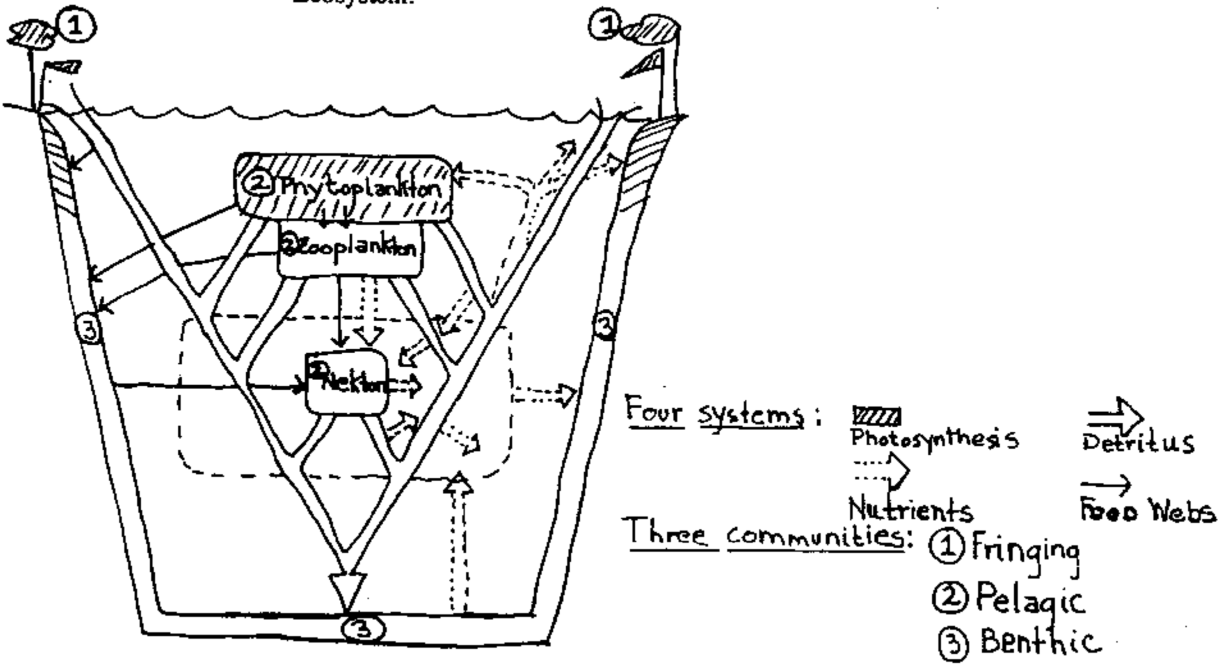
[1]Barnes, R. S. K. and K. H. Mann, eds., *Fundamentals of Aquatic Ecosystems* (Boston: Blackwell Scientific Publications, 1987).

Figure1. Interrelationships of the Seven Components of an Aquatic Ecosystem.[2]



Thus, the task in aquaculture is 1) to discover the nature of the interrelationships of these seven components for any aquatic ecosystem where a species is being raised for consumption, and 2) to promote a balance of these interrelationships that will provide for maximum, sustained yields of biomass with minimum energy input from outside the system.

Since the ecological principles and components of marine and freshwater aquatic systems are the same, knowledge gained by students using more easily maintained freshwater aquaria and species in the classroom is readily transferred to the understanding of marine ecosystems and attendant maricultural practices.

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[2] *Ibid.*

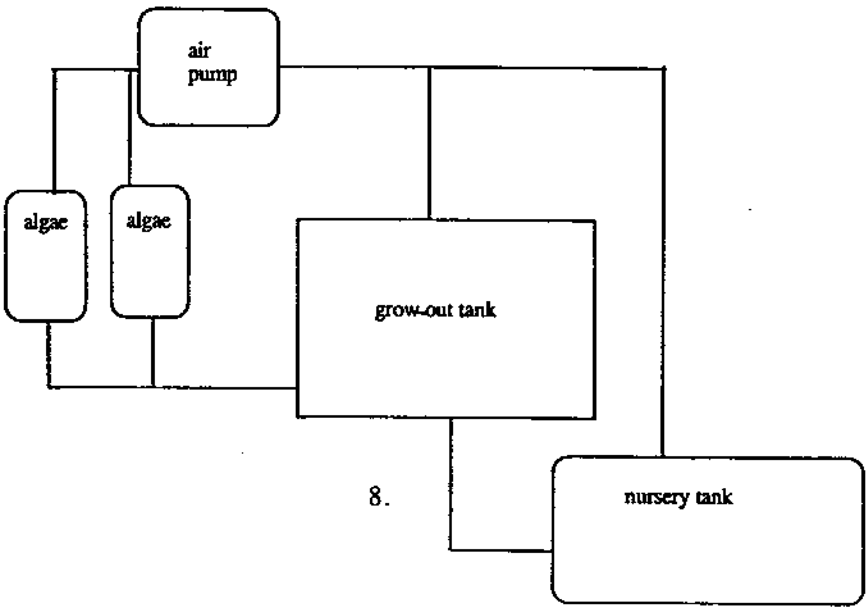
3. A Classroom Aquarium System

System Components

An ideal aquaculture set-up includes between one and four glass containers, aquaria, pickle jars, or large flasks. An entire set-up can utilize only one tank that will serve as a nursery, grow-out tank, and algal growth chamber; or these may be done in separate containers (see schematic below). An air pump large enough to supply the system should be used. Two kinds of filters are recommended: biological filters and mechanical filters. Air stones, plastic tubing, and brass gang valves are also used in conjunction with the pumps to provide air to the system.

Gravel purchased in a pet store, or obtained from a natural site, should be thoroughly washed before it is added to the system. Gravel should cover the bottom to a depth of two inches. Water from a natural site may be used, or tap water is fine, to initially fill the system. Both kinds of water should be allowed to "season," or sit, for at least two days before adding organisms to the system. Plants should be added first and allowed to establish themselves for approximately five to ten days before adding animals.

SCHEMATIC REPRESENTATION OF AN AQUARIUM AQUACULTURE SET-UP



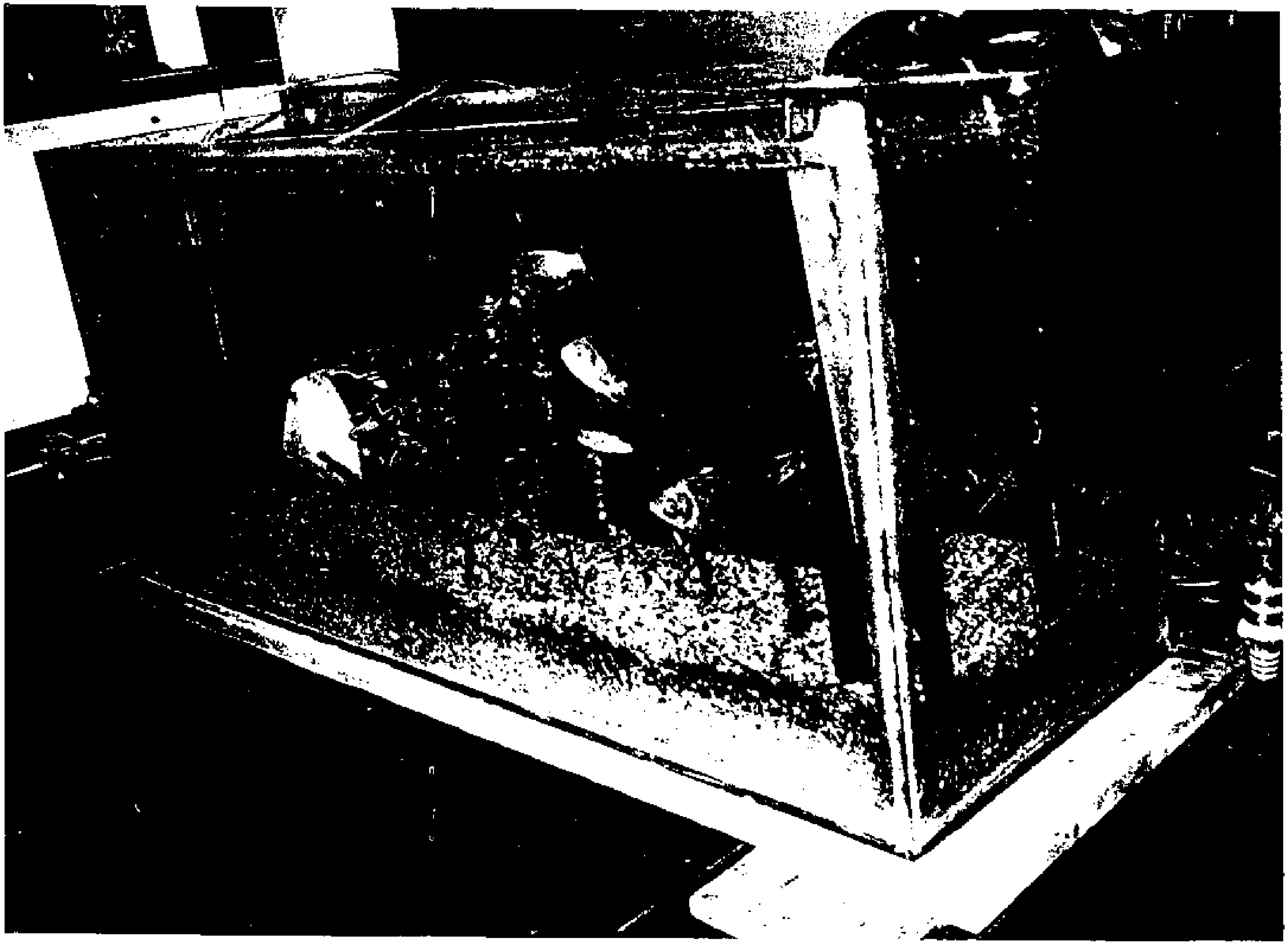
Filtration Systems and Chemical Balance

The filtration system is one of the most important factors in the successful operation of an aquarium or an artificial aquaculture operation. In a freshwater aquarium, it is possible to maintain the system with minimum filtration if a balance of plants and animals is achieved. In a marine aquarium, a great deal of filtration must be applied since marine plants and animals are generally more sensitive to even small variations in water chemistry. It is best to begin with freshwater systems in the classroom, since ease of maintenance and low cost are essential for overall success. There are three types of filtration: biological, mechanical, and chemical. At this time, only biological and mechanical types are practical for classroom use. To insure success, a combination of both types are recommended.

Biological filtration takes place in the gravel as the water is drawn into a sub-gravel filter, and it is virtually essential for a successful aquarium. Aquarium animals excrete urea and ammonia, toxic waste products which must be quickly converted to necessary nutrient nitrates by benthic bacteria living on the substrate above the sub-gravel filter. Nitrates are recirculated to the water through the action of the sub-gravel filter, where they are assimilated by plants and move back into the nitrogen cycle of the system. To assure that there is not too much nitrate available in the system (a condition that could lead to undesirable microalgal blooms that would outcompete other organisms in the system for oxygen and other nutrient resources), one-quarter of the aquarium water should be replaced each month to dilute nitrate concentration.

Mechanical filtration removes particles from the aquarium system, assists in keeping the oxygen levels high, and helps keep the water clear. There are a number of outside filters (those that hang on the top edge of the aquaria) which have power units constructed so that water passes over a fibrous material, such as a porous sponge, and filters out particulate matter. Another inexpensive approach is to use an inside tank-corner filter, which functions the same way as the outside filter but uses air from an air pump to move the water through the filter medium. Most aquarists use a combination of the two filtration approaches.

PLETE SET-UP



11.

Biological Components

Plants

Macroscopic and microscopic primary producers are essential components of an ecologically-balanced aquarium/aquaculture system. They provide food for herbivorous zooplankton and larger invertebrates you may wish to raise some fish species you may wish to culture. Living plants also provide organic and inorganic nutrients in the form of exudates to aquarium water that may be directly absorbed by other organisms; and oxygen, a necessary gaseous component of a balanced system, is a by-product of photosynthesis. Dead plants provide nutrients to decomposers in the benthos, which, in turn, break down plant tissue that can be recycled as system nutrients.

If the organism you wish to raise feeds on microscopic plants, then maintaining a balanced aquarium and occasionally introducing cultured algae into the system will be sufficient for growth. Amounts and kinds of microalgae fed to your culture organisms can be monitored and correlated with growth and/or reproductive rates. "Growing out" simply means innoculating a jar of dechlorinated water with a small amount of aquarium water. Cultures of the naturally-occuring algae will reproduce rapidly and serve as a readily-available food source for species being cultured.

If you are raising fish, such as goldfish, it is desirable to introduce a food source from outside the system. Tubifex worms, planaria, or lettuce seedlings grown in the classroom make an ideal food source for most fish species.

Macroscopic Plants

In addition to providing nutrients, rooted and floating large plants provide cover and camouflage for smaller organisms. Certain common plant species that are easily collected or bought from aquarium supply stores are hardier and grow better in newly-established aquaria than do others.[1] Once "conditioned," other common species do very well and provide diversity to the system.

First plantings should be the hardy species of *Anacharis* (commonly known as elodea), *Cabomba*, or *Vallisneria*, both common and corkscrew varieties (See Figure 1). These three species root easily and do not grow as rapidly as other species, so they will not tend to take over the tank. After the tank water has been conditioned over a period of several weeks, the water ferns *Salvinia* and *Marsilia* and algae such as *Nitella* will grow well.

Figure1. Common Rooted Plants for Aquaria.[2]

[1]Morholt, Evelyn, Paul F. Brandwein, and Joseph Alexander, *A Sourcebook for the Biological Sciences* (New York: Harcourt, Brace & World, 1966).

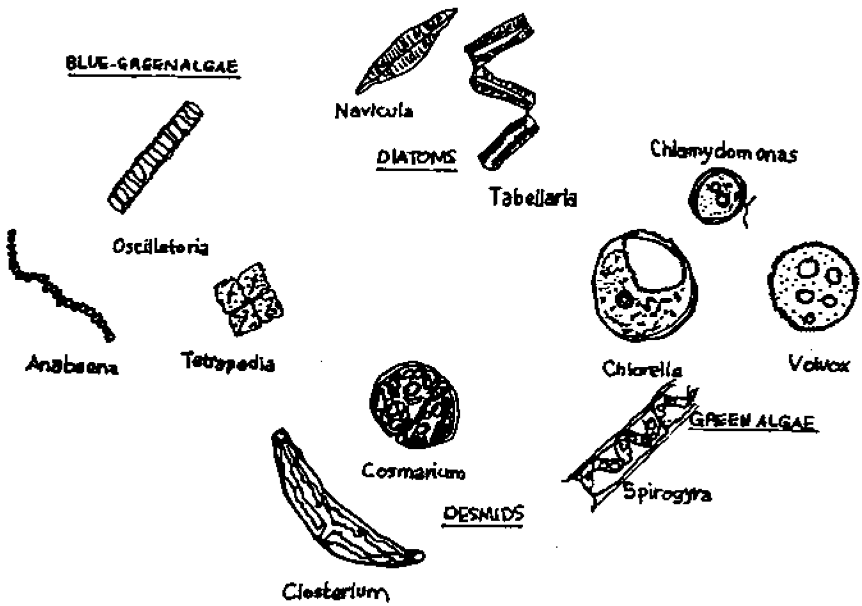
[2]adapted from Andrews, William A., ed., *A Guide to the Study of Freshwater Ecology* (Englewood Cliffs, N. J: Prentice-Hall, 1972).

Microscopic Plants

Microalgae are as important to a well-balanced aquarium as they are in natural aquatic environments. Natural, mixed cultures of algae may be collected from ponds or lakes and introduced directly into an established aquarium, or specific algae may be cultured, using culture solutions, natural or artificial light sources, and well-aerated water to which extra carbon in the form of carbon dioxide gas or bicarbonate solution (5%) has been added.

Microalgae are an important source of food for herbivorous zooplankton, such as *Daphnia*, the common water flea, which are, in turn, eaten by carnivorous zooplankton and the young of larger fish and invertebrates. Figure 2 shows some common, blue-green and green algae that may be found in any well-balanced freshwater aquarium.

Figure 2. Common Aquarium Microalgae.[1]

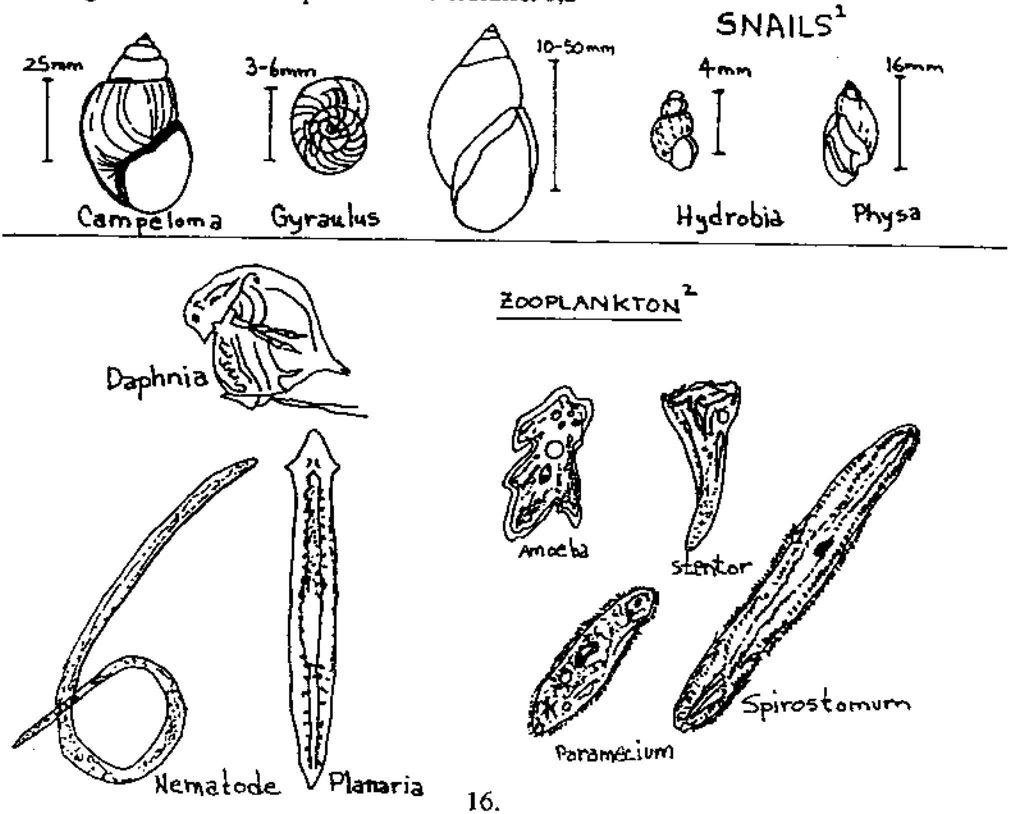


[1]adapted from Andrews, 1972.

Invertebrate Consumers

Microscopic and macroscopic invertebrate consumers are an important biological link in the energy flow of any aquatic system. They not only serve as a food source for small organisms in the system, but they also serve to concentrate and cycle other nutrients, such as nitrogen, through the system. Herbivorous zooplankton like the water flea serve to check population explosions of blue-green and green algae that could foul an aquarium. These and other herbivorous zooplankton may serve as food for other invertebrates you may wish to culture for study,such as the fresh water mussel. Snails such as *Physa* and *Planorbis* serve to prevent fouling of tank sides and bottoms, while they also serve as a food source for fish, such as goldfish. Figure 3 shows some common aquarium invertebrates.

Figure 3. Common Aquarium Invertebrates. 1,2



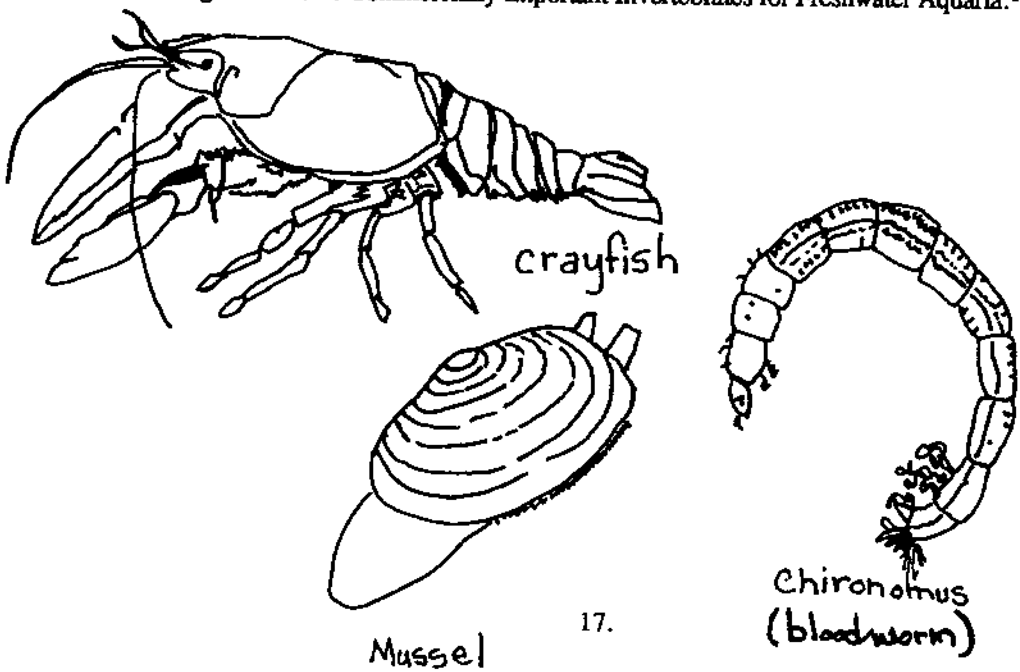
[1] adapted from: Needham and Needham, 1970. *Ibid.*

[2] adapted from: Andrews,1972. *Ibid.*

Commercially-Important Invertebrates

Aquaculture can produce organisms for food as well as for other purposes, such as medical research and fish bait. Invertebrate species that are commercially important in Maine as food are molluscs such as the clam, mussel, snail, and lobster. In freshwater aquaria, the common freshwater mussel may be studied in lieu of its commercially-important marine counterparts, the blue mussel, American and European oysters, and hard-shell clam. Mussels are filter feeders, and the maintainance of a healthy and varied plankton population in the tank is vital to their growth. Drawbacks of using mussels for growth studies are that they, like their marine counterparts, grow relatively slowly, and are somewhat sensitive to extreme conditions a given system may be periodically subject to. Growing small crustaceans such as crayfish utilizes consideration and manipulation of the same system parameters as lobster culturing (Figure 4).

Figure 4. Some Commercially Important Invertebrates for Freshwater Aquaria.[1]



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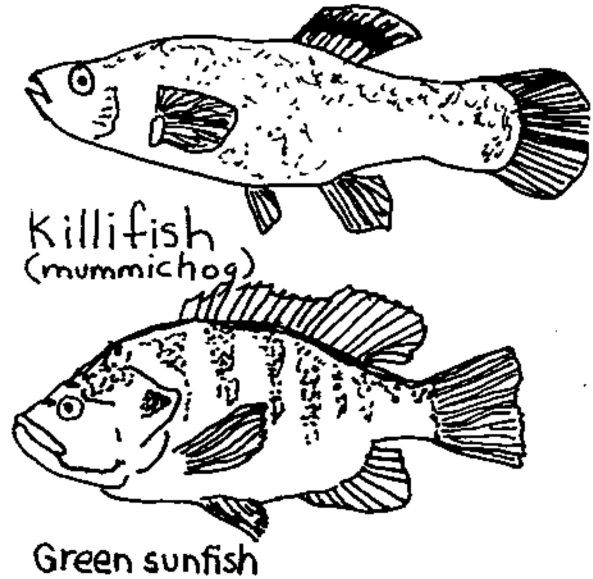
[1]adapted from Andrews, 1972.

Fish and the Aquarium Ecosystem

Fish represent the largest tertiary consumer in aquatic systems. They are the end product of most freshwater aquaculture endeavors. Naturally-occurring species are always used in culturing. For a classroom aquarium, common hardy species that may be easily collected or bought are the killifish (*Fundulus*), various species of dace (*Chrosomus*), smaller sunfish (*Mesogonistius*), or the carp relative, the common goldfish (*Crassius*). Two fish per gallon of aquarium space is recommended to avoid overcrowding. Mixing species of fish is not recommended, as most will exhibit interspecific competition that will affect maximum production.(Figure 5).



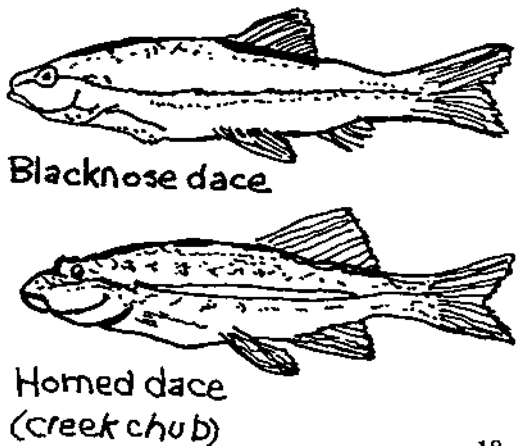


Figure 5. Recommended Aquarium Fish (not drawn to scale).[1]

[1]adapted from Needham and Needham, 1970.

Aquarium Maintenance

Now that the aquarium is in operation, general maintenance should require very little class time. Yet, as with any successful aquaculture operation, there are some basic maintenance needs which must be met if plants and animals are to thrive.

THESE MAINTENANCE ROUTINES SHOULD BE FAITHFULLY FOLLOWED:

1. **Daily inspection by a class member** who understands how the system should be operating. Plants and animals should be alive and actively feeding and appear in good health. Dead animals should be removed immediately. Water temperature should be checked and the filter system should be inspected to see that it is operating. A daily log of the date, water temperature, observed activities of animals, propagation, deaths, and other interesting observations should be kept (see student worksheet in Chapter 4). The log will yield interesting information and insight into problems which may occur. Reference to the log will help students understand basic aquaculture principles related to food, growth, and cost/benefits of the system.

2. **Evaporation of water from the tank will be apparent,** especially after weekends and school vacations. Be sure to mark the original level of the water when you set up the tank and add de-chlorinated water to maintain that level.

3. Aquatic animals will stay healthier and live longer if partial water changes are made periodically. Aquatic animals produce waste products which are toxic. By **partially changing the water in the system,** these products will be diluted and will not build to a toxic level. One fourth of the water should be changed each month.

4. To make the most of the nutrient-rich water you remove from the tank each month, use the water to **irrigate terrestrial plants** growing in pots or flats in the classroom. In fact, if you can start a small garden of lettuce plants in a tray in the classroon, you can snip leaves from the plants throughout the entire year, dry them, and feed them to the fish in your aquaculture system.

4. Classroom Activities & Sample Student Worksheets

Physical Science and Engineering

In the beginning stage of putting together a working aquarium/aquaculture system, the class can address several physical science and engineering concepts.

Tanks must be constructed of appropriate materials that can withstand fluid pressure. They must not be made of potentially-toxic materials that could leech into the water, and they must provide adequate volume for growth. If you do not have aquaria available, they can easily be constructed from scrap glass and silicone rubber cement. If you have tanks that leak or need repair, they provide an excellent classroom opportunity to introduce some of the technological concerns related to aquaria and aquaculture operations.

When you select gravel for the aquaculture system, use the opportunity to present a geological overview of rocks and minerals and how they can help regulate the acidity of the tank. It is important to include calcium carbonate in the gravel (possibly in the form of broken clam shells) to help neutralize the build-up of acids from waste production.

Light is an important physical science parameter that must be understood in order to maintain a balanced tank. A good amount of indirect light will enable plants to photosynthesize sufficiently to produce critical amounts of organic matter for animals to eat, yet will not provide an overabundance of light that often leads to undesirable algal "blooms."

Water for the tanks must have chemical and physical characteristics that promote optimum growth and system balance. Physical science concepts such as mass, volume, density, specific gravity, pH, and dissolved oxygen can be defined in terms of water chemistry. [1]Teach your class how these are measured and explain the concepts in terms of their significance to a balanced system.

Student Worksheet

Classroom Aquarium/Aquaculture System

Draw and Label your classroom set-up. Be sure to include all mechanical and biological components of the system. Specific types and numbers of organisms should be recorded, and a schematic diagram of nutrient cycles should be included. Amount and kind of light, depth of gravel, source of water, and other physical factors should also be described.

STUDENT WORKSHEET: Biological Production

DATE	FOOD (GRAMS)	#	SNAIL MASS	#	FISH MASS

Aquaculture Economics

The top priority in any commercial aquaculture operation is to make a profit. This fact provides teachers with an excellent opportunity to integrate social and natural sciences in a multidisciplinary unit, using the establishment of an aquarium as an instructional focus. The establishment of aquaria in a classroom leads to the aquaculture simulation when the class participates in the design, operation, and maintenance of a model aquaculture operation.

The basic principles are clear. It is essential for the students to:

1. Record all costs associated with the operation. This includes cost for the aquaria set up: the tank, gravel, filters, air supply, plants, and animals.
2. Record maintenance costs such as electrical needs for filtration and aeration.
3. Record the increase in the numbers and/or mass of plants and animals produced by the classroom aquaculture operation.

The results of these measurements can be transformed into a cost/benefit ratio: the amount of cost or input, i.e., materials, supplies, time, and effort measured in dollars and cents results in a particular amount of product, i.e.,increase in the number and amount of plants and animals measured in biomass (grams). Raising small inexpensive goldfish through the course of an academic year will yield good biomass production. Goldfish tend to grow large quickly in an aquaria. **Cost/benefit ratio = $/grams produced**

Of course the value of a unit amount of biomass ($/gram) may be misleading, since a specific outcome or product, such as a large number of valuable fish that have been bred during the year, may be worth more than its mass because of a specific demand for the fish. An example might be having the class raise a very prolific fish, such as guppies, in order to supply the rest of the school with fish for their aquaria. The other classes may buy the fish for a certain price. This leads to a cost/benefit ratio, which places an emphasis on the relative worth of specific individuals raised in the aquaculture simulation and is, in fact, the way most commercial operations make a profit. **Cost/benefit = $/individual raised**

Student Worksheet

Aquarium/Aquaculture Economics

Month	Capital Investment (equipment, supplies)	Plants #	Plants mass	Animals #	Animals mass

Political and Social Aspects

The whole concept of aquaculture is embedded in the social, political, and cultural systems of the communities, states, and nations in which they exist. For example, you may find that local ordinances regulate the location of coastal development in your area. Development in a semi-enclosed bay or inlet will affect the viability of an aquaculture operation located there. Certainly, run-off from drainage will cause particulate matter to be washed into the water, while septic systems can increase nutrient and pollution levels beyond acceptable levels, and the location of moorings for residents will affect access to the water. Local communities in some areas will be able to control these variables.

In many cases, there are state or provincial regulations concerning the location and leasing of coastal, submerged leases for aquaculture. The requirements for permits to operate an aquaculture operation can be very specific and require an immense amount of preliminary work to ascertain the suitability of the area for aquaculture. These requirements can be intimidating for local entrepreneurs, thus limiting access to large scale operations which have more resources at their disposal.

Of course, this is not limited to coastal operations. Inland areas are also subject to local and state regulations which can control the operation of freshwater aquaculture businesses. For instance, in many rural areas the raising of bait for sportfishing is an important type of aquaculture operation. It is not only commercially important for the individual aquaculturist but also for the well-being of the surrounding communities. If local development impinges on the water quality or ability of the operation to succeed, then it will also affect local economies.

It is important for students to understand that aquaculture is controlled by the social and political norms of the communities in which they are being proposed. In order to teach these concepts in the context of the aquarium/aquaculture class simulation, we must ask students to look at their own communities from a coastal/aquatic management viewpoint.

Student Worksheet (Case Study of Your Community)

I. Ecological Features of the Community

What topographic features exist offshore or surrounding the wetlands?

Are there productive fishing or other natural resource areas?

What are the physical and biological parameters surrounding the area? (temperature, climate, salinity, tides, currents, drainage patterns, etc.)

II. Uses of the Coastal/Aquatic Sections of the Community

How are the area's coastline or wetlands utilized?

Are there commercial enterprises existing in this area now?

What are the recreational opportunities in the area?

III. Management of the Shoreline/Wetlands and the Marine/Resources of the Community

Does the town have any regulations concerning development of the area?

Does the town or state have any ordinances controlling the siting and operations of aquaculture operations?

IV. Planning

Does the town have any plans for the future development of the area?

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