CAROLINA™
Teamed with Teachers

Carolina Marine Aquaria

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Contents

A marine aquarium creates tremendous interest and enthusiasm in the classroom and greatly enhances lectures and laboratories by providing living organisms to supplement slides and preserved materials. A marine aquarium works equally well as a demonstration tank containing an assortment of genera or as a holding tank for living animals for use in the laboratory. With our carefully designed aquarium system, you will be able to maintain organisms with little more work than is required of a standard freshwater aquarium. However, it must be emphasized that a marine system cannot be neglected and the instructions covering setup, maintenance, and care of a marine aquarium should be carefully followed.

Marine Aquarium Science

Tanks

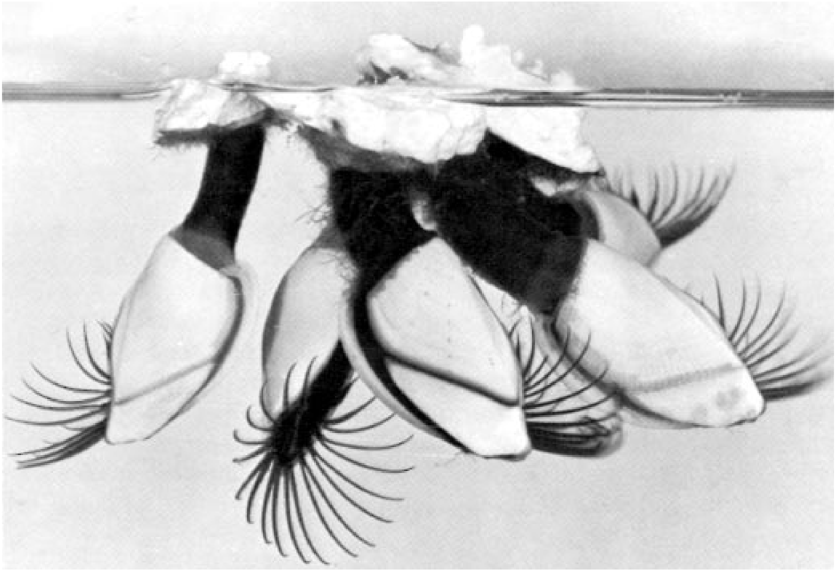
Salt water is very corrosive. For this reason, it is generally not practical to use an aquarium where any metal would come in contact with the salt solution. A stainless-steel framed aquarium is no exception, because it will begin to show signs of rust, often within a month, when used as a marine aquarium. Marine invertebrates and fish are all sensitive to heavy-metal ions, and even very minute amounts of these ions prove to be lethal.

All-glass aquaria ranging in capacity from 1 to more than 100 gallons are now available for setting up marine systems. These aquaria are sufficiently sturdy and usually sell for less than metal-bound aquaria. Plexiglas and other plastic aquaria are also available, but are generally more expensive than all-glass.

Filtration

The filtration system is one of the most important factors in the successful operation of a marine aquarium. In a freshwater system, it is possible to keep a 10-gallon aquarium in operation with little filtration or aeration. In a marine system, a high rate of filtration and aeration is essential. The entire volume of water in a marine system should pass through the filters at least once every 15 minutes, so that a filter in a 20-gallon aquarium should turn over about 80 gallons of water per hour.

There are three major types of filtration systems: biological, mechanical, and chemical. At this time, only the biological and mechanical are practical for marine aquaria.



Gooseneck Barnacles

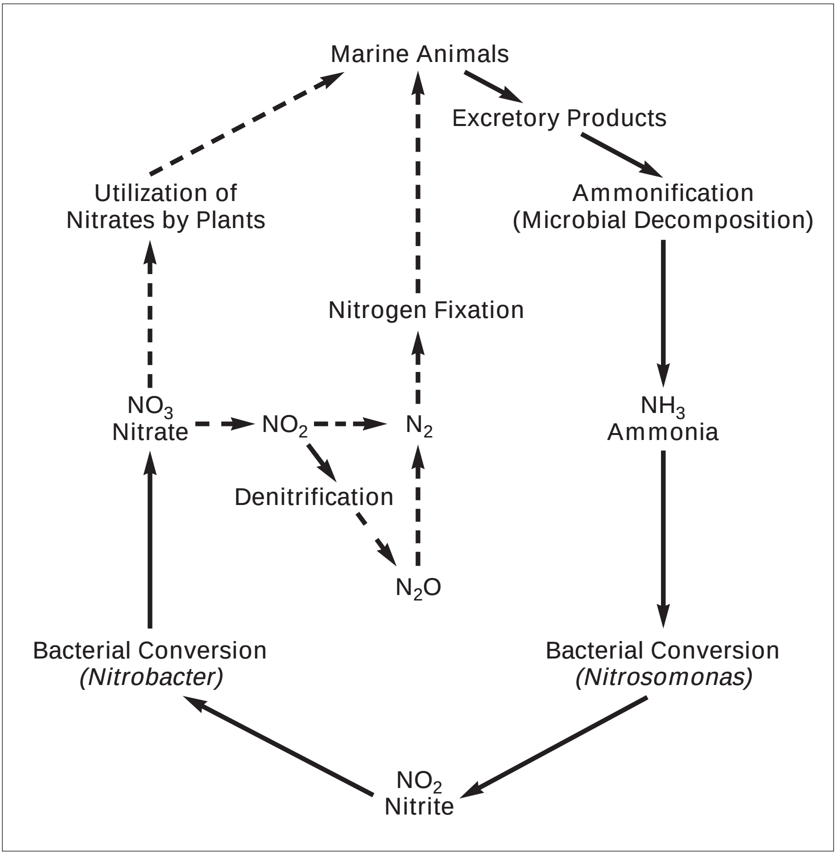
Biological Filtration

Biological filtration is nearly mandatory for a successful marine aquarium. The animals in the aquarium give off waste products which are principally urea and ammonia, both of which are toxic in very low concentrations to marine animals.

The urea, ammonia, and certain other organic wastes must be quickly converted into non-toxic substances; this conversion takes place on the bed of the filter. Various bacteria attach to the substrate of the filter bed and convert the toxic ammonia and urea to nitrite and the nitrite to nitrate, a non-toxic end product in the marine aquarium.

In nature and in freshwater aquaria, the nitrate is usually assimilated by plants and moves back through the nitrogen cycle (see diagram on next page).

In the marine aquarium, the potential for plant assimilation of nitrate is much less, being limited to a few marine algae. The buildup of nitrate in the aquarium system is controlled by dilution. That is, about once a month one-fourth of the aquarium water volume is drawn off and replaced with a fresh salt solution. This method of dilution effectively holds the nitrate at a nonlethal concentration.



Nitrogen Cycle

Mechanical Filtration

A mechanical filter removes particulate matter from the aquarium system, assists in keeping the dissolved oxygen high, and helps keep the water clear.

There are a number of inexpensive filters which have power units constructed so that no metal comes in contact with the salt water. These are usually set up with fibrous filtering material and charcoal (activated carbon). The fibrous material filters out particles, microorganisms, and organic colloids, while the charcoal adsorbs organic particles. The efficiency of the charcoal is very limited. As the potential sites for adsorption become loaded, the ability of the charcoal to remove organic matter decreases. The charcoal does play a dual role, as it also increases the surface area for bacterial attachment, thus functioning as a biological filter. If the aquarium water becomes cloudy, the addition of fresh charcoal to the filter will often clear the water quickly.

Chemical Filtration

A chemical filter functions by removing certain ions from solution. Several chemical filters (ion exchange resins) are available for marine aquaria, but so far none is capable of selectively removing specific compounds and leaving the others in the water. While it is desirable to remove excess nitrates and organic molecules, problems will result if trace metals and other necessary salts are removed as well.

Substrate and pH

The oceans are such vast bodies of water that they tend to be a tremendously stable environment for the animals which inhabit them. Unlike the smaller bodies of fresh water, the pH and chemical equilibrium of the oceans do not change appreciably even under the stresses produced by man. For this reason, most marine animals are not adapted to tolerate rapid fluctuations in pH and chemical composition of their environment.

In a marine aquarium, changes in pH can occur very quickly, so a system of buffering the water is necessary. The easiest method of buffering is to use a calcium carbonate substrate for the biological filter. This will provide surfaces for bacterial attachment, and also act as a buffer. Crushed limestone rock, oyster shell, coral sand, and dolomite are substrates commonly used as pH buffers in a marine aquarium. We use exploded shell which supplies the necessary calcium carbonate for buffering, and also gives increased surface area because of the porous nature of the highly expanded shell.

Gorgonian Colony

Water

Natural seawater can be used successfully in a marine aquarium, but it does pose certain difficulties. Natural seawater is expensive to ship, which prohibits extensive inland use. Depending on the site and time of collection, the salinity of the seawater varies. Also, if water is collected close to shore, there is a chance of encountering organic pollutants.

The advent of a number of good, inexpensive synthetic salt mixtures for use in place of natural seawater has greatly improved the success of marine aquaria. These salt mixtures, while not duplicating seawater, provide the salt and trace element ratios in proportion to that of natural seawater. A mixture should always be selected that contains trace elements and does not have salts in abnormal proportions.

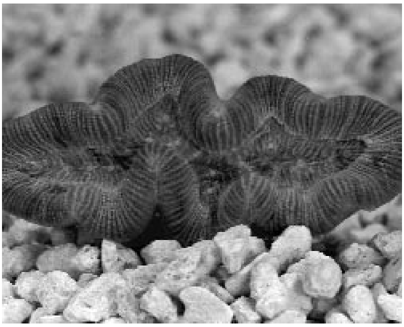
Any water source may be used for mixing the synthetic salts, but hard water will often cause minor precipitation and temporary cloudiness. Tap water which is rusty or which flows through copper or leaded pipes should not be used in an aquarium. Water containing chlorine will have no effect on the water quality if the water is aged at least three days. The salt solution should be mixed in plastic, glass, or other nonmetal containers, or in the aquarium.

Biomass

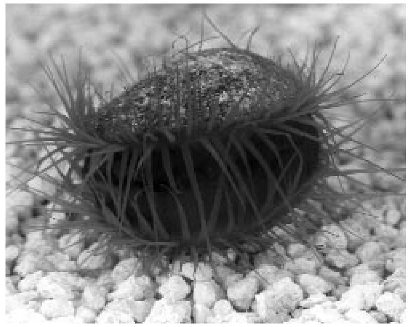
Much has been written about the biomass capacity of an aquarium system, and there are many generalized rules as to the allowable number of animals per gallon of water. The actual ability of the system to sustain animals is dependent upon the kind, size, and metabolism of the specific animals; the efficiency of the filter system in both aeration and conversion of waste products; and length of time the animals are to be kept in the system.

The biomass carrying capacity of any particular system depends on the rate of conversion of toxic products (urea, ammonia) to nontoxic products. If the number of animals is such that the bacteria in the filter cannot convert the wastes fast enough, toxins will accumulate and kill the animals.

Fish and active invertebrates produce greater quantities of ammonia and urea than do starfish, snails, and less active invertebrates, so the biomass concentration should be reduced if fish are kept in the aquarium. About 18 to 20 medium-sized invertebrates can be handled safely in a well-filtered 20-gallon aquarium. This is about one-fourth to one-half pound of animal per 10 gallons of water.



Rose Coral



File Shell

Temperature

Animals from the Pacific coast or northern Atlantic coast must have lower temperatures than those from the southern Atlantic coast or the Gulf of Mexico. Animals from northern waters require fairly constant temperatures in the range of 10° to 20° C (50° to 68° F), while southern animals need temperatures in the range of 21° to 29° C (70° to 85° F). For the average classroom aquarium, it is best to use southern animals and thereby escape the problems and expense of refrigeration.

Light

The aquarium should be placed so that it receives standard, diffuse light. Areas of direct sunlight and unusually bright artificial light should be avoided. Unless the area selected is exceptionally dark, it is not necessary to use an aquarium hood with lights.

Conditioning

A marine aquarium needs a period of conditioning to establish the bacterial population in the filter system before it is ready to accept a full load of animals. The best method for conditioning is to allow the salt water to age for about three days and then add one animal. After seven more days, the aquarium is ready to receive all the animals. If it is a problem to obtain a single animal for the conditioning period, the aquarium can be run without animals for at least 14 days, after which the animals can be added.

Marine Aquarium Operation

Upon receipt of a Marine Aquarium Kit, unpack all of the items and become familiar with all the components. Read the information and instructions in this manual completely before beginning the assembly steps. The aquarium tank will need a break-in period of complete operation for about 14 days prior to adding the organisms. Only when the kit is completely assembled and in operation is it advisable to order the marine animals. Delivery of the living animals will take about 14 days (the time necessary for your unit to complete its break-in period and be ready to receive the animals).

Setting Up the Aquarium

Placement

When choosing the site for an aquarium, it is best to find a room where the temperature is fairly constant between 70° and 80° F. The aquarium needs standard, diffuse light and should not be placed in direct sunlight or unusually bright artificial light. An aquarium receiving direct sunlight through a window may have a water temperature as much as 10° above the temperature in the room. High temperatures can be lethal to the animals in the aquarium.

As with any aquarium, it is best not to place it in an area where large amounts of volatile chemicals are stored or used, or in a room where the air becomes heavily smoke-filled. Pollution of this sort can quickly leave you with unhealthy, dying animals and an unsuccessful experience with marine animals.

When a metal aquarium stand is to be used or when the aquarium is placed in an area where saltwater mist or spilled saltwater will be corrosive, it is best to spray the stand or materials with a plastic sealer and place the aquarium on a sheet of plywood or Formica.

Once the aquarium is in position and filled with water, it should not be moved. The water in a full aquarium is exerting pressure on the glass sides and bottom and moving or carrying the aquarium can cause it to leak or actually crack. If the aquarium must be moved, it is best to siphon as much of the water as possible into plastic buckets and move the nearly empty aquarium.

Assembly

Step 1. The new aquarium tank and lid should be wiped with a wet paper towel to remove any accumulated dust. *Do not* use glass cleaner or detergents to clean the aquarium.

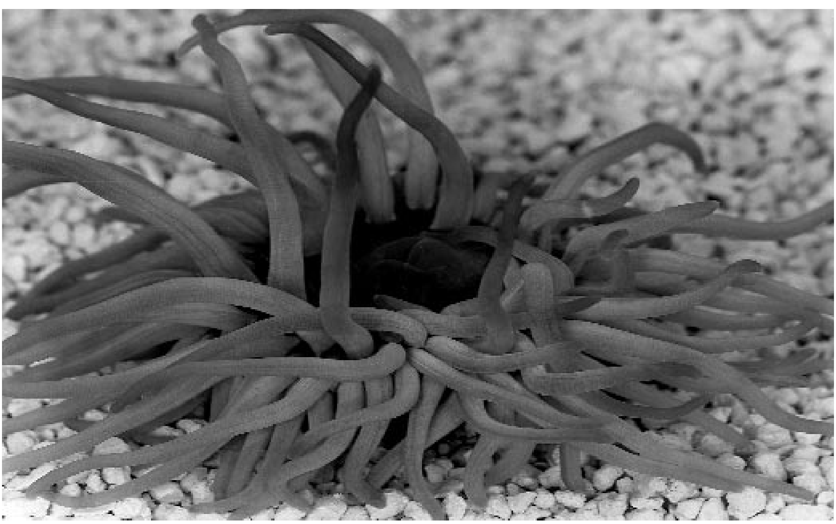
Using the tube of aquarium sealant supplied with the tank, reseal all tank seams with a fine bead of sealer. Allow 48 hours to dry. Now fill the tank with clean water and carefully inspect for leaks. When you are sure no leaks exist, siphon (do not pour) the water from the tank and proceed with Assembly Step 2.

Step 2. Assemble the first undergravel filter by threading one end of the air-line tubing through the hole in the top slotted portion of the back air-lift plate. Attach an air stone and make sure it reaches the bottom of the aquarium. Now slide the air-lift plate into the bottom plate and place the assembled filter tightly against one corner of the tank. Do the same for the second undergravel filter.

Care must be taken to see that the back air-lift plate fits tightly against the aquarium glass. An opening between the back plate and the aquarium wall will greatly decrease the efficiency of the filter. If necessary, a thin strip of aquarium sealer can be applied to seal the air-lift plate to the aquarium walls. If this is done, the sealer should be allowed to dry for 48 hours before proceeding with the assembly.

Step 3. Carefully wash the marine gravel under running water until all fine particles are removed and the water runs clear. An excellent basket for washing filter gravel and charcoal can be easily constructed by bending a sheet of screen wire into the form of a box. Wash the material under running water to allow the particles and dust to flow through the screen. When the marine gravel is clean, add it to the aquarium and completely cover the undergravel filters.

Step 4. Add about 18 gallons of tap water, deionized water, or water from any pure source to the aquarium. The less mineral content the water contains, the better it is. Plug in the air pump (which activates the undergravel filters) and check to see that the filter system is operating. With the filter system running, carefully add six bags of the sea salts to the 18 gallons of water



Sea Anemone

in the aquarium. Let the aquarium operate for 24 hours to assure that all of the salts go into solution.

Step 5. When the system has operated for 24 hours after the addition of the salts, shut off the filters and check the specific gravity by floating the hydrometer in the salt solution. Reading the hydrometer at the water line, the specific gravity should be between 1.020 and 1.025. If the specific gravity is less than 1.020, you should add more sea salts to the water. If the specific gravity is more than 1.025, you must remove some of the salt solution and replace it with fresh water. After adjusting the salt concentration, the filter system should be activated and allowed to run for several hours before checking the specific gravity again.

Step 6. When the specific gravity is between 1.020 and 1.025, the aquarium is ready for the break-in period. Wash the bag of charcoal to remove dust and small particles, and add the clean charcoal to the compartment in the power filter. Cover the charcoal with the filter floss and connect the filter to the aquarium. Turn on both the power filter and the undergravel filters, and place the aquarium cover on the tank. With a wax pencil or other marker, inscribe a line on the outside of the tank at the water level. This will allow you to replace water which evaporates without changing the specific gravity of the seawater.

Step 7. With the complete marine system in operation, you may now order the animals either by returning the Notice to Ship Card, or by placing a standard order. The aquarium should be allowed to run for about 14 days before adding the animals. By waiting until the beginning of the break-in period to order the living material, your aquarium is ready to accept the animals when they are delivered.

Selecting the Animals

Many of the marine invertebrates are natural predators and when hungry will attempt to eat other animals in the aquarium. With healthy, well fed animals there will be very little trouble with predation; it will be limited to weak and dying animals. To keep predation at a minimum, follow the feeding instructions in this manual and see that each predator has an opportunity to eat.

Starfish

Hermit Crab

Sea urchins, hermit crabs, spider crabs, and lobsters are especially aggressive animals and should *not* be kept in aquaria with marine fish and delicate filter feeders. When possible, it is best to have a separate tank for these interesting animals.

Maintaining the Aquarium

Now that your marine aquarium is set up and operating, general maintenance will require very little of your time. However, for a successful marine aquarium, the following maintenance procedures should be faithfully followed.

Daily Inspection

Each day a person familiar with the aquarium and its operation should make an inspection of the systems and the animals. Dead animals should be removed immediately, all animals should be inspected for their general health, the water temperature should be checked, and the filter systems should be inspected to see that they are operating. A daily log of water temperature, observed activities of animals, propagation, deaths, and other interesting information should be kept for the aquarium. This log will provide interesting information and yield insight into problems which may occur. Reference to the log can be helpful in handling new arrivals for the aquarium and in heading off problems in operation. The logging of aquarium operations can be handled by an interested student or group of students as a project.

Evaporation Control

As water evaporates from the aquarium, the salts remain, resulting in a higher salt concentration and an increase of the specific gravity. To keep the animals healthy, it is wise to add fresh tap water to reestablish the original level in the tank. By adding a small amount of fresh tap water every few days, the specific gravity will remain fairly constant.

About once each week, filtration should be stopped and the specific gravity of the water checked with a hydrometer. If the specific gravity needs adjusting by the addition of salts, it is best to add them in the form of a concentrated solution, or to put them in the power filter, rather than dumping them directly into the aquarium.

Periodic Water Changes

While the marine salts do not wear out in an aquarium, the animals will stay healthier and will live longer if partial water changes are made periodically. Marine 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.

About two weeks after the addition of animals to the aquarium and again at one month, a volume of artificial seawater equal to one-fourth of the tank's volume should be mixed and allowed to stand for at least 24 hours. Aeration will assist in dissolving the salts during this period. The specific gravity of the solution should be checked and matched to that of the aquarium. One-fourth of the water should be siphoned from the aquarium and an equal amount of fresh seawater added. After the first two changes, partial water changes should be made once each month. For aquaria carrying a heavier than normal load of animals, the water changes should be made more often and a greater quantity changed each time.

During water changes it is best to unhook the power filter and wash the charcoal and filter floss well under running tap water. When the filter floss becomes heavily clogged with materials, it should be replaced. The charcoal should be replaced every three months.

Tips for a Successful Aquarium

1. Never bring metal in contact with salt water. Marine invertebrates are very susceptible to the toxic ions of metals, and even minute quantities of heavy metal ions can cause death of the animals.

2. Before you place your hands in the aquarium tank, rinse them well with water. Make sure that all hand creams, lotions, medications, soaps, and detergents have been washed off.

3. Never add solutions to the aquarium to kill algae, bacteria, or fungi as these materials are lethal to invertebrates.

4. Use high quality plastic buckets and other plastic apparatus to mix water and sea salts. Inexpensive buckets are often made of reprocessed plastic and can contain chemicals that will be lethal to the animals. If in doubt, always soak buckets in brine solution for a week or more before using. Never use a metal bucket when mixing salt water.

5. Cloudy water is usually a sign of bacterial growth. A bacterial overgrowth in your aquarium will decrease the oxygen concentration and very quickly kill most of the animals. To check bacterial growth, add one or more air stones and aerate the water vigorously. As soon as possible change about half of the aquarium water with fresh saltwater. Look carefully for the cause of the bacterial growth. It is probably a dead animal or a piece of deteriorated food. Always remove dead animals and large uneaten pieces of meat from the aquarium.

6. Algae growing in a tank should never be removed or killed. Usually a, number of the animals will use the algae as a food source. Algae also

help eliminate the excess nitrogen products in your aquarium. If you prefer, you may keep the front plate of the aquarium clean by wiping it with a plastic sponge on a plastic handle. These long-handled sponges are available as dishwashing aids in most grocery stores.

7. Usually, some yellowing of the water occurs over a period of time as organic chemicals begin to accumulate. This, in small amount, is of no concern and can easily be corrected by increased water changes.

8. If necessary, an emergency system can be used to hold the animals for a short period of time. Fill a large plastic bag in a bucket with salt water, add the animals, and aerate vigorously with several air stones.

9. All synthetic sea salts do not have the same formula and care should be taken to see that different sea salts are not mixed in the aquarium. When making periodic water changes, be sure you use the same brand of sea salts that you used in mixing the original water.

Handling Living Animals

The animals should be ordered so that they will arrive at about the time the aquarium is conditioned (see Setting Up the Aquarium, Step 7). If the animals arrive too early, they can be placed in the aquarium if it has had at least three days of full operation. If the aquarium is stocked earlier than the 14th day of operation, the system should be watched closely and an extra water change of at least one-fourth of the volume made seven days following the addition of the animals.

When the animals arrive, the package should be opened immediately and the animals inspected to see that they are healthy. Do not rush to put them into the aquarium. Each bag should be opened and floated on top of the water for 10 to 15 minutes to allow it to adjust to the aquarium temperature. Water from the aquarium may be added, a little at a time, to the bags containing the animals during this adjustment period (for Marine Fish, see special handling instructions below). The animals should be carefully added to the tank, one at a time, allowing no more of their shipping water than necessary to be added with them. During the first few days, the animals should be watched closely to see that all are alive and healthy. Dead animals should be immediately removed from the tank.

Marine Fish

Marine fish are more difficult to adjust to the aquarium water than are marine invertebrates. Fish are much more susceptible to shock when transferred from natural seawater to an artificial salt water.

The fish and the water in which they were shipped should be put in a bucket with continuous aeration. Water from the aquarium should be slowly siphoned into the bucket using a siphon tube no larger in diameter than airline tubing. When equal amounts of aquarium water and shipping water have been mixed, three-fourths of this water is siphoned back into the aquarium. The aquarium water is once again siphoned into the bucket, and the fish are allowed to adjust for 10 to 15 minutes. The fish should then be carefully netted and added to the aquarium.

Feeding the Animals

The animals in the aquarium will live for several months without being fed, but to keep them healthy, a simple, standard feeding program is necessary. Animals such as sea anemones, crabs, horseshoe crabs, and starfish eat minnows, chopped fish and shrimp, earthworms, white worms *(Enchytraeus),* and small bits of very lean beef. Filter-feeders, such as scallops, corals, hydroids, and barnacles will eat mixtures of *Daphnia,* brine shrimp, algae, protozoa, and dried fish food. Carnivorous invertebrates should be fed at least once each week and filter-feeders at least every two days. When feeding filter-feeders, it is best to turn off the power filter for 1 to 2 hours to keep the small food organisms from being filtered but of the aquarium.

Feeding Instructions

Barnacles. Feed every two days with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Brittle Stars. Feed with bits of very lean meat, chopped shrimp or fish, minnows, earthworms, or white worms. Place directly under the center of the animals.

Colonial Anthozoan. Feed every two days with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Corals. Feed every two days with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Crabs. Feed with small pieces of lean meat, shrimp, or fish placed close to or in the pincers.

File Shell. Feed every two days with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Fish. Feed twice each week with living brine shrimp or *Daphnia*. Feed each day with a dry fish food. Add directly to stank.

Florida Lobster. Feed with small pieces of lean meat, shrimp, or fish placed near or under the body.

Gorgonian Colony. Feed with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Horseshoe Crab. Feed with small bits of lean meat, shrimp, or fish. Place food under the animal.

Mantis Shrimp. Feed with small pieces of lean meat, shrimp, or fish placed in pincers or close by.

Sea Anemone. Feed with very small pieces of lean meat, shrimp, or fish dropped on a tentacle close to the mouth.

Sea Cucumber. Feed every two days with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Sea Horses. Feed live brine shrimp and invertebra diets.

Sea Squirt. Feed every two days with freshly hatched brine shrimp, algal flagellates, *Daphnia,* or finely powdered fish food. Add directly to the tank.

Sea Urchin. Feed with chopped fish or shrimp, lettuce leaves, or seaweeds placed directly under the animal.

Snail. Feed with bits of meat, lettuce, or seaweeds placed near the animal.

Starfish. Feed with bits of very lean meat, chopped shrimp, fish, minnows, or earthworms placed under the animal. They also enjoy very small freshwater mussels.

Culturing Food Organisms

Many of the food organisms needed for feeding marine animals can be easily cultured.

Brine Shrimp

To culture brine shrimp, fill a pint jar to within 2 inches of the top with a 2% solution of noniodized table salt or artificial seawater. Put about ½ teaspoonful of eggs into the jar and keep at room temperature.

Aeration will increase the proportion of hatching eggs. Hatching occurs within 36 to 48 hours. The freshly hatched brine shrimp may be separated from the egg shells and unhatched eggs by directing light on one side of the jar. The young brine shrimp will swim toward the light and may be picked up with a pipette.

Daphnia

Fill a glass or plastic container (1 gal or larger) with clean pond water or spring water. Add egg yolk medium to give the water a slightly cloudy appearance. Inoculate the container heavily with *Daphnia.* Within four to five days the

Tulip Snail

Colonial Anthozoan

water should clear and more food may be added. The optimum water temperature for *Daphnia* is from 21° to 27° C (70° to 80° F). *Do not overfeed.*

Algal Flagellates and Seaweeds

These are easily cultured in the laboratory, but will seldom grow well in the tanks with the animals. Of the algal flagellates, cultures of *Dunaliella* and *Amphidinium* both grow well in the classroom. For the seaweeds, use *Cladophora* and *Percursaria.*

Alga-Gro® Seawater Medium. Pasteurize 1 liter of natural seawater by slowly heating to 73° C (163° F) on two consecutive days. When the seawater has cooled after the second pasteurization, add 20 mL (one tube) of Alga-Gro Concentrate (16-4604). Mix the solution and dispense into sterile containers. This medium supports excellent growth of most marine algae.

Illumination. Freshly transferred subcultures should be placed under cool-white fluorescent tubes for a period of 7 to 14 days. The use of incandescent bulbs or direct sunlight is discouraged because of the high amount of heat generated. If sunlight must be used, it is best to diffuse the rays by covering the window with tissue paper or with greenhouse shading paint. After the initial growth period, the cultures should be removed to an area of low illumination. Usually the amount of light in a classroom is sufficient for the storage of these cultures.

Temperature. To be successful in culturing algae, the temperature should be held somewhere between 10° and 27° C (50° and 80° F) with poor growth expected at either extreme. Most genera grow well at about 21° C (70° F).

Marine Aquarium Chemistry

Water Quality

In a closed aquarium system where there is no continuous input of fresh clean water, the biological activity of the organisms drastically affects the quality of the water. The animals produce large quantities of ammonia, urea, free amino acids, and other organic substances. The bacteria and algae utilize and change these substances. Some of the specific chemical changes which occur in an aquarium can be followed and analyzed with simple tests.

Animals can be satisfactorily maintained in an aquarium for long periods with gross control of chemical changes by a calcium carbonate substrate to buffer the pH and by periodic water changes. However, the need for these controls does not give a complete picture of what happens in the aquarium.

Simple chemical tests indicate the activity of certain chemicals and the efficiency of the filter systems, and can warn of potentially dangerous chemical increases. If these tests are made on a regular basis and carefully recorded, aquarium management is simplified and a useful teaching aid results. Students can use the recorded data to construct graphs of the chemical parameters measured. This organization of data should help students understand some of the basic factors concerning an organism's effect on its environment.

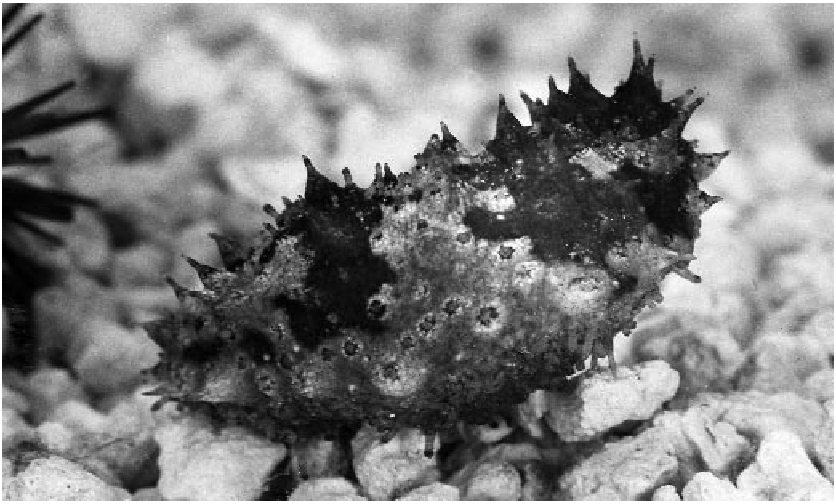
For successful maintenance of a marine aquarium system, probably the most important factors affecting water quality are the presence and quantity of ammonia, nitrite, nitrate, pH, salinity, dissolved oxygen, carbon dioxide, hardness, and copper. The tests for these factors can be found in *Standard Methods for the Examination of Water and Wastewater* and in *Fish and Invertebrate Culture.* Also available are specific kits designed to facilitate handling and testing.

Ammonia

Ammonia, which is extremely toxic to animals, is the main nitrogen product excreted by marine animals. Aquatic animals continuously subjected to minimal concentrations of ammonia show poor health with impaired growth rate, decreased stamina, and poor disease resistance. For healthy animals, the concentration of ammonia in the aquarium should not exceed 0.1 ppm.

The toxicity of ammonia can be reduced by maintaining maximum dissolved oxygen and by lowering the pH; however, the principal method of ammonia control is efficient biological filtration. With maximum biological filtration, ammonia is quickly changed to nitrite ions by bacterial action. Nitrite ions, in turn, are transformed to the less toxic nitrate ions.

A well functioning marine aquarium should show no ammonia present when the water is tested with the Nesslerization Method. When using this method,



Sea Cucumber

the amount of stabilizer reagent should be greatly increased to prevent the precipitation of calcium and magnesium.

Nitrite

The nitrite ion is an intermediate product in nitrification (oxidation) of ammonia to nitrates. In an aquarium with a good biological filter, the nitrite is converted to nitrate very rapidly. Like ammonia, nitrite is toxic to animals in very low concentrations and should never exceed 1 or 2 ppm. If amounts greater than 1 ppm are found, steps should immediately be taken to find the malfunction in the filter system.

Tests for nitrite are usually color tests requiring a spectrophotometer. Several test kits are available which have inexpensive color standards for reading results.

Nitrate

In nature, most of the nitrates are utilized by bacteria and plants, with some nitrates undergoing denitrification (reduction) and emerging as nitrogen. In the marine aquarium, even with some algae present, nitrate production goes on at a much higher rate than nitrate removal, so that the nitrate concentration is high. By periodically changing part of the water, the nitrate concentration can be kept at the safe level of 20 ppm or less. In our development laboratories, we have allowed aquaria to accumulate concentrations of nitrate in excess of 200 ppm with no noticeable effect on the animals. Often, however, at these high nitrate levels, a bloom of algae develops which is hard to control and which can have detrimental effects on the dissolved oxygen concentration. In addition, some of these algae (especially blue-green algae and dinoflagellates) may produce toxic substances.

Several ion exchange resins are now available for the removal of nitrates and phosphates from marine systems. At this time, these resins are not totally safe for marine animals, apparently because they remove some essential salts as well.

A well-managed aquarium should yield negative results when tested for ammonia and nitrite. The opposite should be true for nitrate. Graphing the results of a series of tests for nitrates against time should produce an increasing (positive) slope. A decrease in nitrate concentration other than from water changes indicates that something is wrong with the filter system.

There are a number of assay methods for nitrate concentration, and most are satisfactory. Most kits use the zinc reduction method.

pH

The ocean is strongly buffered and slightly alkaline so that the pH is relatively stable at about 8.1. Many of the synthetic marine salts are also buffered to hold the pH of aquarium water between 8.0 and 8.4. These buffered salts along with an undergravel filter substrate of calcium carbonate should give the marine aquarium a very stable pH. A decrease in the pH of the water, especially a rapid decrease, is a sure sign of trouble. A safe pH range is from 7.5 to 8.4.

The pH can be tested either electrometrically (pH meter) or colorimetrically (visible color change). The most accurate pH test is with a pH meter, liquid titration producing a color change is somewhat less accurate, and a color change of pH paper is the least accurate method.

Salinity

Salinity is the quantity of salts in a given amount of seawater and is usually expressed as parts per thousand (0/00). Salinity may also be expressed as percent (%) salt (e.g., 32.6 0/00 = 3.26%). The normal salinity for a marine aquarium is 35 0/00. Most organisms will tolerate variations in salinity between 28 0/00 and 38 0/00.

Specific gravity is the measure of the density of a volume of seawater, while salinity is the weight of the salts in a volume of seawater. Specific gravity is temperature dependent while salinity is not. When converting specific gravity readings to salinity values, a correction must be made for temperature (Table I).

Specific gravity is measured with a hydrometer, and the value given to "standard" seawater is 1.025 at 15° C. This is equal to a salinity of about 35.0 0/00. When the temperature of the seawater increases, the specific gravity reading which corresponds to 35.0 0/00 salinity decreases (Table II).

TABLE I

Conversion of Specific Gravity to Salinity

Specific Gravity 20° C (68° F)	Salinity 0/00
1.000	.0
1.004	5.6
1.008	11.1
1.012	16.7
1.016	22.2
1.021	27.8
1.025	33.3
1.029	38.9
1.033	44.4

TABLE II

Specific Gravity Readings at Different Temperatures for a Salinity Value of 35.0 0/00

Temperature ˚C	(˚F)	Specific Gravity
10	(50)	1.026
15	(59)	1.025
20	(68)	1.024
25	(77)	1.022
30	(86)	1.021

Another test for salinity is chlorinity determination. Chlorinity is measured by the weight of pure silver (in silver nitrate) needed to precipitate the halogens in 328.523 grams of sea water. Most kits for testing salinity use the Harvey chlorinity determination and the results are converted to salinity figures. This use of the chlorinity test is acceptable because the ratio of major ionic compounds in seawater is very constant. However, the chlorinity test may not be a valid indication of salinity when using synthetic seawater or ion exchange resins.

Dissolved Oxygen

Oxygen is vital to any aquarium system. The animals in the aquarium need oxygen for respiration, and the bacteria in the biological filter require oxygen for conversion of ammonia and nitrite. For these reasons, the amount of dissolved oxygen must be monitored.

Probably one of the prime causes of loss of animals is inadequate water circulation and inadequate aeration. At least 4 ppm of dissolved oxygen should be present in the aquarium water.

TABLE III

Dissolved Oxygen (ppm) in Freshwater and Seawater at Different Temperatures

Temperature °C	(˚F)	Freshwater (ppm)	Seawater (ppm)
1°	(34)	14.24	11.15
10°	(50)	11.29	9.00
15°	(59)	10.10	8.09
20°	(68)	9.11	7.36
25°	(77)	8.27	6.75
30°	(86)	7.56	6.19

A number of factors affect the amount of oxygen dissolved in water. When either salinity or temperature of water increases, the amount of dissolved oxygen decreases (Table III).

The rate at which oxygen-depleted water is returned to the surface or brought in contact with oxygen for resaturation is also important. Oxygen starvation of the animals can occur when this rate is below maximum.

There are a number of tests for measuring dissolved oxygen in water. Accuracy of the testing depends on how the test sample is handled. Most kits employ the Winkler method, but considerably different results have been obtained by several persons performing this test on the same water at the same time. Results of 3 to 8 ppm are acceptable for an aquarium to allow for a large testing error. It is advisable to run this test in triplicate and to average the results.

Hydrogen Sulfide

Hydrogen sulfide in the aquarium usually results from anaerobic bacterial action and is very toxic. The presence of hydrogen sulfide is a sign of trouble and usually indicates that there is very poor water circulation and extremely low dissolved oxygen. The quickest way to eliminate hydrogen sulfide is to aerate the water vigorously.

When testing for hydrogen sulfide, care should be taken to keep aeration of the sample to a minimum. The presence of oxygen in the sample will quickly destroy the hydrogen sulfide test results.

Carbon Dioxide

Free carbon dioxide is soluble in water and enters both from the air and from animal respiration. High concentrations of carbon dioxide lower the affinity of the blood for oxygen and can cause stress or death of the animals.

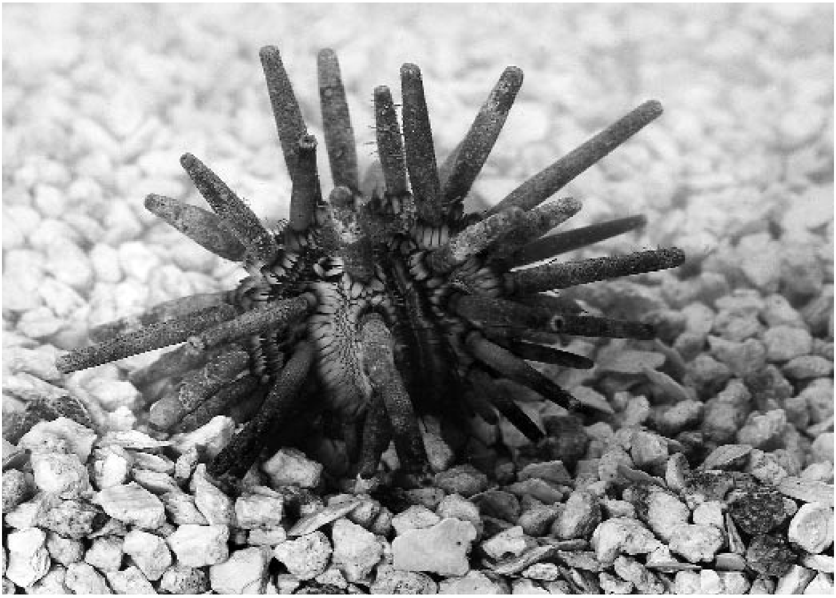
Excessive amounts of carbon dioxide also cause the aquarium water to become acid. As the pH of the aquarium water becomes more acid, carbonate ions are released by the calcium carbonate buffering system. These carbonate ions combine with free carbon dioxide to form bicarbonate ions, which then react with hydrogen ions to remove them from solution and raise the pH. Test results showing high carbon dioxide concentration and low pH indicate problems in the calcium carbonate buffering system.

Hardness

Hardness is a measure of the available calcium carbonate and magnesium carbonate in the water. These two chemicals are the principal buffers in water, and their concentration is an indication of the effectiveness of the buffering system.

Copper

The copper ion is highly toxic to marine invertebrates at concentrations as low as 0.1 ppm and can become toxic to fish at slightly higher concentrations. Before tap water is used to set up an aquarium, it should be tested for copper and discarded if results show a copper concentration of 0.05 ppm or above.



Sea Urchin

Hazards

Copper salts are used routinely for treating a number of diseases of fish, but as pointed out earlier, the copper ion is highly toxic to invertebrates. When aquarium animals are treated with antibiotics or other agents, the bacteria of the biological filter may be destroyed; the result is ammonia poisoning. For these reasons, treatment of fish or other animals should be done in a separate aquarium.

Further Reading

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