CHAPTER 1

Caring for an Aquarium

Before you even decide for certain that you want a saltwater aquarium in your living room, you need a clear understanding of the time, effort, and expense involved in maintaining it properly. Although this book emphasizes design over technique, once the design is executed, maintenance becomes all-important.

Coral reefs shelter their diverse inhabitants in one of the most stable environments on Earth. In fact, environmental stability may well explain a substantial portion of that diversity. When you can count on tomorrow being pretty much like today for thousands of years at a stretch, adaptations necessary for coping with, or preparing for, environmental change can be redirected into specialization of lifestyle. In turn, most coral reef organisms have, as a result of that specialization, sacrificed adaptability to change.

To provide the stability necessary for your organisms to thrive in your saltwater aquarium, you need to:

- Regularly monitor and maintain proper water conditions
- Feed the fish
- Keep records
- Perform water changes
- Be alert to potential problems

That said, caring for an aquarium need not be a terrible chore, and anyone can learn how an aquarium works. Even if you consider yourself a rank amateur, you should have a good grasp of the basics by the end of this chapter.

Sources of Saltwater Specimens

Saltwater aquarium enthusiasts have a plethora of choices for purchasing both supplies and livestock, from local specialty dealers to big-box pet retail chains to mail-order suppliers. Finding the right combination of these for your aquarium needs will facilitate the creation of the tank you want at a cost you can afford.

Choosing a Dealer

Look for a store with a large saltwater dry goods section and a varied inventory of healthy marine fishes and invertebrates living in well-maintained holding tanks. A dirty, unkempt, poorly lighted store should be an immediate signal to look elsewhere. If you live in or near a reasonably large city, look for a store that sells only saltwater aquariums. It is likely to have a better selection, more knowledgeable personnel, and better prices than a store where saltwater is a sideline.

Never buy fish on your first visit to any store. First, investigate the range of offerings, quality, and prices in your region before making any decisions, especially if there are several competitors. Make at least two visits a week or more apart. The idea is to find out how the store operates on a continuous basis. Be critical but fair in your evaluations. We all have our good days and bad ones. Ask questions. Do not expect everyone to be an infallible expert, but you should hear correct answers at least to basic questions about water quality, the particular needs (feeding behavior, for example) of any fish in the shop, and steps to prevent or cure common problems. One good sign to watch for: when someone does not know the answer to your question, they take the time to look it up in a book. Good shops always have several well-used reference books behind the counter.

Dealers *are* in business to make money, but a sales pitch should not be the sole communication you have with them. Professional dealers know that the key to their business success is for their customers to be successful hobbyists. It is in the dealer's best interest, for example, to steer you away from fishes that would be inappropriate for your tank because of size or compatibility problems. Remember, though, that most dealers will sell you anything you want if you insist.

The next step is to evaluate the specimens themselves, and there are several factors that you should consider.

Purchasing Fish Based on Collecting Practices

Care in purchasing may be the most important aspect of managing your aquarium. Here are some suggestions for making wise decisions in this regard.

Collecting from Wild Populations

Bear in mind that most saltwater fish have been collected from wild populations. The time between being collected and arriving at your local shop typically ranges from two to three weeks. During this time, the fish may or may not have been maintained under optimum conditions. Unfortunately, it is seldom possible for you to know much about this chain of custody.

Against the practice of wild collecting, two primary arguments are raised:

- Overfishing
- Generalized damage to the reef itself

In favor of wild collecting, the response concerns the importance of this source of income to local fishermen lacking other options for feeding their families. Establishing hatcheries in the source country, rather than collecting from its waters, maintains the income stream while reducing the toll on the reef. Fishing for food already removes substantial numbers of reef fishes, though not usually the same species as those collected for the aquarium. Stresses induced by turbidity from shore development, increased water temperature due to global warming, and the influx of human-created pollutants contribute far more to the decline of reef health than does aquarium collecting. Nevertheless, most saltwater enthusiasts would prefer that their aquarium not contribute to the decline of the coral reefs it is intended to depict!

For thirty years or more, the problem of using poisons to collect reef fish has been a subject of controversy within both the aquarium industry and the conservation community. Despite a huge investment of expertise and millions of dollars, a satisfactory resolution of the issue has yet to emerge. Anyone who owns a saltwater aquarium must be aware that at some point they may purchase a fish that was collected by poisoning. No certain method exists to determine, after the fact, if chemical exposure has taken place. Little agreement seems to have been reached regarding the effects of chemical collecting on the survivability of fish subsequent to being collected. Trying to account for the effects of holding and handling methods, shipping circumstances, and the capabilities of aquarists themselves on survival presents significant challenges.

Collecting from Good Sources

One way to avoid unhealthy fish is to choose species that routinely come from good sources. Several popular aquarium fishes come largely or exclusively from Hawaii, for example. Fish-collecting in that state is well regulated. Shipping to the mainland is relatively inexpensive and does not involve red tape, since it is interstate commerce. Therefore, travel time is minimized. Good Hawaiian fishes include the yellow tang (*Zebrasoma flavescens*), Potter's angelfish (*Centropyge potteri*), Vanderbilt's chromis (*Chromis vanderbilti*), and several desirable butterflyfishes, such as the raccoon (*Chaetodon lunula*), threadfin (*C. auriga*) and longnosed (*Forcipiger flavissimus*).

The tropical west Atlantic and Caribbean regions also supply many good aquarium fishes, such as the French angelfish (*Pomacanthus paru*), the royal gramma (*Gramma loreto*) and the yellowhead jawfish (*Opisthognathus aurifrons*). I have noted remarkably few problems with Florida or Caribbean specimens over the years. Shipping time from Florida, of course, is minimal to most locations in the country, with specimens sometimes arriving the same day.

If you want to be completely sure of chemical-free fish, avoid purchasing fish from areas known for a chemical collecting problem. This can be tricky. Many popular aquarium species may come from any of several source countries. Only the importer knows where a particular batch originated. On the other hand, even in the Philippines, where chemical use has historically been widespread, some collectors use only nets to harvest specimens.

Catching Fish, Killing Coral

Coral reefs can be directly affected by collecting activities associated with the aquarium trade. In some regions of the world, divers use poisons to make fish easier to catch. The chemicals can kill coral polyps, which take a long time to regrow. Like so many other places on the planet, coral reefs face even greater dangers from pollution and global warming. Unlike freshwater aquarium fish, the majority of saltwater fish are taken from their natural habitats rather than produced in hatcheries. Aquarists must recognize that they have a responsibility to avoid contributing to the degradation of coral reefs by their purchasing decisions.

For more than twenty years I have involved myself in efforts to keep saltwater aquarium-keeping a sustainable hobby and industry. Home saltwater aquariums can do an enormous amount of good by bringing ordinary folks up close and personal with some of the sea's most remarkable denizens. A broader awareness of the fragile beauty embodied by coral reefs can only increase the desire to protect them for future generations. Biology imposes constraints upon the potential for captive propagation of many saltwater fishes. This has seldom been the case with freshwater species. Less than 10 percent of saltwater fish and a still smaller fraction of invertebrates come from captive propagation. Despite many efforts to learn how to spawn and rear them, some of the most desirable (from the aquarist's point of view) saltwater species will come from wild stocks for a long time to come. That being the case, we should choose wisely and avoid species that have little or no chance of adapting to captivity. The obligately coral-feeding butterflyfishes, such as *C. ornatissimus* mentioned above, provide a perfect example. On the other hand, home aquarists should encourage the efforts to breed saltwater fish and invertebrates commercially by seeking out captive-propagated specimens whenever possible. I am proud to serve on the scientific advisory board of Reef Protection International (www.reefprotect.org). This organization has produced *the Reef Fish Guide* listing both recommended species and those that hobbyists should think twice about. You can download a copy from the Web site, and I will be referring to this guide in the chapters that follow.

Your saltwater aquarium dealer will likely become a major source of advice regarding your aquarium. No one has more control over the health of the fish you will place in your aquarium than the retail dealer. Saltwater fish endure a difficult journey before eventually arriving in your town. How the dealer selects fish and how he treats them while in his possession can make all the difference to your success. Fish can experience delayed mortality, meaning that their circumstances today can produce effects that may not manifest themselves for weeks, long after you've brought the fish home. In 1995, I founded the American Marinelife Dealers Association (www.amdareef.com) to enlist like-minded saltwater aquarium dealers in combating negative environmental impacts resulting from the aquarium trade. Check the Web site for an AMDA dealer in your area, and when you visit, be sure to tell them I sent you.

Captive-propagated fish are among the best possible choices for the saltwater aquarium. Many species of anemonefishes are available from hatcheries, along with several kinds of gobies and dottybacks. Dealers usually advertise that they have captive-propagated stock, but always inquire. Captive-bred specimens may be smaller than wild caught counterparts but will of course grow to the size typical for their species. In all cases, captive-bred fish acclimate better to aquarium conditions and have fewer problems than do similar specimens harvested from the wild. Captive propagation takes some of the pressure off natural populations.

Widespread development of hatcheries for the production of both fish and invertebrates may provide the key to solving some of the thorniest problems related to the collecting of wild specimens for aquariums.

Selecting Healthy Fish

Here are some characteristics of healthy fish:

- Their colors are bright.
- They search actively for food.
- Their fins are held erect.

Follow these tips to avoid taking home unhealthy fish:

- Watch out for rapid movement of the gill covers ("panting" or "gasping"). This could indicate that the fish is infested with parasites.
- Beware of ragged fins and the presence of lesions, open wounds, or similar abnormalities. Fish can lose a bit of fin tissue or a scale or two without serious consequences, but any damage should appear to be healing.
- No bloodiness or cottony fungal growth should be apparent.
- Unless the behavior is characteristic for the species, a fish that hides excessively is in some kind of distress.
- Look for signs of poor nourishment, such as a hollow belly or a thinning of the musculature behind the head.
- When viewed head on, the fish should be convex in outline, not concave.

Ideally, the dealer will quarantine all new arrivals for at least a week before releasing them; two weeks would be better. If this is not the routine at the store you select, the dealer should at least be willing to hold a fish for you if you agree to buy the fish after the holding period is up. Saltwater fish have a harrowing journey from the reef to the dealer. They require a period of rest and adjustment before yet another move. A few days, or just until the fish has had its first meal, is not enough time for recovery. If the dealer cannot, or will not, provide this kind of quarantine period, you should make plans well in advance to quarantine all specimens at home yourself. I suggest a minimum quarantine of two weeks.

WARNING The usual advice is to look for obvious signs of disease when shopping for saltwater fish. This is a good suggestion, but only a very foolish, or very busy, dealer will leave a sick fish in the display tanks. The problems you may encounter will be of a more subtle nature. How was the fish collected? What has happened to it since that time? How has the dealer cared for the fish after its arrival? Neither you nor the dealer will have reliable information on any but the third question. Quarantine, either by the dealer or by you, offers the best option for avoiding trouble once the fish enters your display aquarium. Another recommendation often given is to ask to see the fish eat before you purchase it. Of course, a prospective fish should be willing to eat, but this is no guarantee of its health. A mishandled fish can experience delayed mortality even though it may feed normally. Quarantine will help to assure any latent problems develop away from the main tank.

Making Rational Purchasing Decisions

Why, I am often asked, are saltwater fish so expensive? Fish and invertebrates are commodities to the aquarium shop. Every dealer has to make a living. But can a fish really be worth $300?

Many factors affect the retail price of saltwater aquarium fish. These include the species, source, size of the store, geographic location of the store, nature of the store's competition, and operating costs. My only advice is this: do not shop for price alone. Common sense must play a role in your evaluation of the "worth" of a particular specimen. For example, if an individual animal is being offered at a price that is "too good to be true," I urge extreme caution. A cheap fish is no bargain if it only lives a week or two after you take it home. Once you find a dealer that consistently provides you with good-quality fish, your best bet is to support that dealer with your business, even if a particular specimen is a few dollars less across town.

Here are some guidelines:

- Check out the dealer's reputation with experienced aquarists. You can find them at your local club or in online chat rooms.
- Ask the dealer about the collecting and shipping of his or her livestock. A good dealer should be willing to share this information.
- If your dealer has a separate, behind-the-scenes holding facility, ask for a tour. Seeing how the tanks are maintained out of the customer's view should reveal a lot.
- Ask yourself if the shop appears to be prospering. A struggling enterprise is more likely than a thriving one to cut corners on livestock sourcing and care.

Trans-Shipping

Trans-shipping is a cost-saving method. An exporter in, say, Indonesia, ships an entire air cargo container of fish to a trans-shipper in Los Angeles. The trans-shipper meets the plane with a sheaf of orders from retail dealers throughout the country. At the airport terminal the trans-shipper opens the cargo container and sorts out the plastic bags of fish and invertebrates into boxes, each corresponding to a dealer's order. When the sorting is done, the boxes are sealed, labeled, and handed back to the airline. Eventually, the boxes arrive at the dealer's airport. The fish may have been in the plastic bag for as long as seventy-two hours. Trans-shipped specimens may not recover completely for several weeks, and may suffer delayed mortality. But they are cheap.

Five Rules for Buying Saltwater Fish

1. Know your dealer.
2. Know which fish come from what area of the world.
3. Be aware of problems with fish from certain areas.
4. Learn to recognize the signs of poor health.
5. Don't shop only for price.

Ordering Fish by Mail

A good mail-order supplier can be better than many local shops. Otherwise, how would the supplier have managed to stay in business when customers must pay freight costs and have no opportunity to see the fish that they are buying? Shop owners often complain about mail-order livestock suppliers, but the fact is that the customers would not buy live specimens by mail order if they were not frustrated with their local dealer. I can recommend this avenue to anyone for whom the local merchants fall short, but with a cautionary note. You might save a lot of money by ordering. You might find rare and unusual livestock. On the other hand, fish can arrive in poor condition, even dead. Getting a replacement or refund may be problematic.

Don't buy fish on impulse. Aquarium shops sell fish that grow much too large for the home aquarium. They sell fish that cannot be enticed to eat in captivity. They sell fish that will devour everything else in your tank. They sell fish that may bite or sting you. So, always do some research on any fish or invertebrate you consider purchasing. This can save a lot of headaches in the long-run.

The best way to zero in on good dealers, local or otherwise, is by talking to their other customers. Get to know the other aquarists in your local shop. Join an aquarium club, or chat online. When you travel, visit shops and compare them to the ones in your hometown. Finally, remember that the ultimate responsibility for your aquarium lies with you. If you purchase foolishly, suffering the consequences later is your fault, not the dealer's.

The Chemistry You Need

I warned you already that you would have to understand some basic chemistry in order to understand your saltwater aquarium. If you desire more in-depth information, it is readily available in books or online.

"Most people realize the sea covers two-thirds of the planet, but few take the time to understand even a gallon of it," says Miles O'Malley, the protagonist of Jim Lynch's novel, *The Highest Tide*. We may know the sea is salty, but the basic composition of seawater remains a mystery to most people. When you take on the responsibility of a saltwater aquarium, the properties of seawater become highly relevant.

The range of optimum water conditions for a saltwater aquarium is much narrower than for a freshwater tank. In order to keep conditions in the aquarium within that narrow range, the aquarist must engage in a regular process of what I like to call “test and tweak.” You periodically perform some key chemical tests. If water conditions are found to be out of line, you tweak them back into place. Often, the tweak involves a partial water change; at other times the addition of a supplement may be necessary. Making a judgment about what to do with a saltwater tank requires a somewhat broader background than that required for freshwater aquarium-keeping.

Salinity

The planet is composed of chemical elements, all of which can be found at some level in seawater. When dissolved in water, an element assumes a chemical form known as an ion. Ions bear either a positive or a negative electrical charge and can participate in reactions with other ions. These facts bear heavily on the interactions between seawater and the life forms swimming in it. *Salinity* is the total amount of dissolved ions in seawater. Seawater contains eleven major ions at a concentration of one part per million (ppm) or more, comprising 99.9 percent of the dissolved components. They are: chloride, sulfate, bicarbonate, bromide, borate, fluoride, sodium, magnesium, calcium, potassium, and strontium. The major ions are said to be conserved, meaning that the total amount of these ions can vary locally, but their relative proportions remain constant.

Besides the major components, two other groups of ions contribute to salinity. Minor ions are those that are present at a level less than 1 ppm, but greater than 1 part per billion (ppb). Trace ions are those that are present in concentrations lower than 1 ppb. An important distinction between the major ions and the minor and trace ions is that major ions are largely unaffected by local conditions, but the concentrations of minor and trace ions may be altered substantially by chemical and/or biological processes. Changing the concentrations of certain ions has definite biological effects. Adding iodide can result in accelerated growth of certain organisms, for example. Adding phosphate often results in an algae bloom.

Copper provides an example of a trace ion with significant concentration-dependent effects. At 0.2 ppm, copper produces little noticeable effect on fish. On the other hand, any amount of copper detectable with a hobbyist test kit is lethal to echinoderms (starfish and their kin). Copper is an essential element for many life forms; the requirement, however, is extraordinarily minute. The presence or absence of other trace ions, such as vanadium, may be of no consequence, as they play no important biological role, at least so far as we know.

Because of their known concentration-dependent effects, minor and trace ions must be tracked by the aquarium keeper under certain circumstances. See the sections “Phosphate” and “Copper” discussed below for more information on these trace ions.

The salinity can be different in different locations, but the gross chemical composition of seawater is constant everywhere in the sea. Around coral reefs, salinities of 35–36 parts per thousand (ppt) prevail. This means the seawater bathing the reef contains 35–36 grams of dissolved salts per kilogram of water. Since weighing out a kilo of seawater, evaporating it, and reweighing the remaining salts is impractical, salinity is seldom measured directly. Salinity is determined by various methods, with hydrometers, refractometers, and conductivity meters being the major ones.

Hydrometers

Hydrometers may be of two types. A floating hydrometer consists of a weighted glass tube that floats higher or lower in water samples of different salinities. A scale on the tube allows a direct reading of the specific gravity. A dip-and-read hydrometer, the most common type in the aquarium trade, consists of a sample cup in which an indicator points to the specific gravity on a scale engraved into the cup. Specific gravity is the ratio of the weight of the sample to that of an equal volume of pure water. Thus, the specific gravity of pure water is 1.0000. Dissolved substances add weight, resulting in a specific gravity greater than 1.0000. After determining the specific gravity, the salinity can be estimated from a set of conversion tables if the temperature is also known.

First, measure the specific gravity of your aquarium and write down the observed reading. Next, find the temperature column in Table 1 that is closest to the temperature of your tank.

Table 1: Conversion of Specific Gravity to Density by Temperature Correction

Observed hydrometer reading	Temperature					
	68	70	72	73	75	77
1.0170	10	12	15	17	20	22
1.0180	10	12	15	17	20	23
1.0190	10	12	15	18	20	23
1.0200	10	13	15	18	20	23
1.0210	10	13	15	18	21	23
1.0220	11	13	15	18	21	23
1.0230	11	13	16	18	21	24
1.0240	11	13	16	18	21	24
1.0250	11	13	16	18	21	24
1.0260	11	13	16	19	22	24
1.0270	11	14	16	19	22	24
1.0280	11	14	16	19	22	25
1.0290	11	14	16	19	22	25

From the temperature column in Table 1, note the conversion factor. Add this to the specific gravity reading. In the table, two leading zeroes are omitted from the conversion factors. Thus, for specific gravity reading of 1.0260 at 75°F, the density is 1.0282. (1.0260 + 0.0022). Now look up the density in Table 2 and determine the corresponding salinity.

Table 2: Conversion of Density to Salinity

Density	Salinity
1.0180	25
1.0185	25
1.0190	26
1.0195	27
1.0200	27
1.0205	28
1.0210	29
1.0215	29
1.0220	30
1.0225	30
1.0230	31
1.0235	32
1.0240	32
1.0245	33
1.0250	34
1.0255	34
1.0260	35
1.0265	36
1.0270	36
1.0275	37
1.0280	38
1.0285	38
1.0290	39
1.0295	40
1.0300	40

Refractometers

A refractometer estimates the salinity of a water sample by measuring its refractive index. You place a drop of water in the sample chamber and read the salinity directly from the scale by looking through the instrument. As with specific gravity, the refractive index varies with temperature. An individual refractometer is designed to operate at a certain temperature. Make sure the one you choose is designed for water at 75°F.

Digital Conductivity Meters

A digital conductivity meter has a probe that is placed in the water. Salinity is displayed electronically. All of the calculations take place in the meter's microprocessor. Though more expensive than either a refractometer or hydrometer, a meter provides the simplest way to get an accurate reading.

Strive to keep the aquarium at a constant salinity near that of natural seawater. This often entails adding water to compensate for evaporation. Use distilled or tap water for this purpose, not seawater. Adding seawater will cause a gradual increase in salinity that will ultimately reach harmful levels. I suggest checking and adjusting salinity weekly. When carrying out a partial water change, make sure the salinity of the replacement water matches that of the aquarium.

pH Measurement

The degree of acidity or alkalinity of a solution is expressed as pH. It affects everything from the respiration of fish to skeleton construction in corals. Natural seawater has a pH of 8.3. The pH of pure water is 7.0. Acidic solutions are lower than 7.0 on the pH scale, while anything above 7.0 is alkaline. Aquarium pH is easily measured in much the same way as it is for a swimming pool or hot tub, with either a chemical kit, a dip-and-read test strip, or a digital meter. Digital pH meters can be costly. They also need repeated calibration to give accurate readings. The pH probe requires a lot of care to avoid frequent replacement, which can represent half the cost of the instrument. Meters do provide great accuracy, however. On the other end of the spectrum, dip-and-read tests are simple and cheap but may not offer enough precision; a tenth of a pH unit is needed. For a home aquarium, the best choice is a pH test that involves placing a water sample in a vial and adding a chemical that changes color in response to the pH. The color of the sample is compared with a printed chart to determine the corresponding pH.

The pH of any saltwater aquarium can vary due to a number of factors, including the time of day. Photosynthesis by algae is responsible for the daily fluctuation. When light is available, algae remove carbon dioxide from the water. This tends to drive up the pH. During darkness, photosynthesis ceases and carbon dioxide accumulates, lowering the pH. In an improperly maintained aquarium, this fluctuation can be so dramatic as to cause a wholesale loss of fish overnight. Most of the carbon dioxide in aquarium water comes from respiration by fish and invertebrates. Overcrowding will lead to carbon dioxide buildup that cannot be effectively countered.

Carbon dioxide exits the aquarium not only by photosynthetic conversion, but also by chemical conversion and diffusion into the atmosphere. Vigorous water movement facilitates diffusion to the atmosphere. Chemical conversion depends upon a complex relationship in which various ions participate, taking the carbon dioxide out of the solution through the formation of insoluble carbonates. Because of these interwoven processes, aquarists should monitor alkalinity as well as pH.

Alkalinity Measurement

Alkalinity refers to the ability of seawater to maintain a constant pH as acid is added. The higher the alkalinity, the greater the amount of acid needed to change the pH. The alkalinity of seawater is about 7 milliequivalents

Alkalinity Conversion Factors

Alkalinity is expressed in milliequivalents per liter (Meq/L). Other terms you may encounter are:

Carbonate hardness expressed in parts per million (ppm) 50 ppm = 1 Meq/L

Alkalai reserve expressed in grains per gallon (gr/gal) 2.92 gr/gal = 1 Meq/L

German hardness (KH) expressed in degrees (dKH) 2.8 dKH = 1 Meq/L

Depending upon the brand of test kit you purchase, you may need to convert your readings to alkalinity, using the conversion factors above.

per liter (Meq/L). Saltwater aquariums should maintain this level of alkalinity, or be slightly higher. The most useful alkalinity test for home aquariums involves mixing the water sample with a small amount of pH indicator, then adding a standard acid solution until the pH changes abruptly, evidenced by the color change of the indicator. Each drop of acid corresponds to a unit of alkalinity. Alkalinity is expressed in different ways, so you may need conversion factors to derive milliequivalents per liter from the kit you select.

Calcium

For invertebrates that manufacture integuments of calcium carbonate, the amount of calcium dissolved in the water is crucial to their survival. Calcium is one of the major ions of seawater and occurs at about 400 ppm. If you choose a design featuring corals or giant clams, among other invertebrates, you should monitor the calcium concentration and take steps to adjust it appropriately.

The test for calcium is similar to the alkalinity test. Reagent is added drop by drop to a water sample that has been mixed with an indicator solution. A color change indicates the endpoint of the test, with the number of drops corresponding to the calcium concentration in parts per million.

Studies have shown that calcium is depleted from saltwater aquariums by corals and other organisms, and thus requires regular replenishment. Typically, calcium is added in a concentrated form after the amount needed has been determined by testing. This can be accomplished in several ways.

Limewater, a solution of calcium hydroxide, is a popular calcium supplement. Prepared from dry calcium oxide, it can be dosed in large amounts without adverse effects. Slightly more than one teaspoon of the dry powder makes a gallon of finished product. Limewater, sometimes known by the German term under which it was first introduced, *Kalkwasser*, has a short shelf life because it absorbs carbon dioxide from the atmosphere. This results in the formation of calcium carbonate, which precipitates out, rendering the calcium once more unavailable. Aquarists have therefore sought other methods for replacing calcium.

The *calcium reactor* is merely a piece of pipe in which calcium carbonate in solid form is allowed to react with distilled water. Water passing through the pipe leaches calcium from the solid material, producing a rich supplement of calcium ions for the aquarium.

Reef aquariums featuring many specimens that require calcium may respond best to constant small doses of calcium supplements. Some designs call for a pump and timer to add supplements automatically. Others simply add the supplement to replace evaporated water, either constantly with a drip system or when the water level drops below a certain point, as determined by a float switch. Smaller tanks can be managed effectively without elaborate systems such as these, but large systems should have automated equipment installed.

Dissolved Oxygen

Dissolved oxygen is measured in milligrams per liter (mg/L) and should always be at 100 percent saturation in the saltwater aquarium. (This means that the water holds all the oxygen it theoretically can.) The amount of oxygen necessary to achieve saturation varies with salinity and temperature. For a salinity of 35 ppt at 75°F, 100 percent saturation corresponds to 6.9 mg/L. While the concentrations of both oxygen and carbon dioxide are discussed below in the section on gas exchange, neither parameter is often measured. Carbon dioxide concentration can be calculated from other parameters. Oxygen concentration can only be determined practically with a digital meter, as wet chemical tests are quite cumbersome. Most aquarists do not invest in an oxygen meter, and instead rely on high flow rates to ensure oxygen saturation.

Phosphate

Phosphate, the ionic form of dissolved phosphorus, plays a role in the biology of all organisms. In the aquarium, however, we are primarily concerned with the effect of abnormal phosphate levels on the growth of algae. Phosphate is usually present in great excess in the aquarium, compared to its concentration in the ocean. The phosphate ion (PO_4^{3-}), known as orthophosphate, is the form measured by aquarium test kits. Particulate organic phosphate (POP) is partially degraded organic matter with a high phosphorus content. POP is also present in the aquarium and can serve as a reservoir because it releases orthophosphate as it decomposes. Synthetic seawater mix, tap water, activated carbon, water conditioners, and food may all be sources of phosphate.

Phosphate Test Kits

A phosphate test kit is likely to be one of the most expensive kits you purchase. Make certain that the one you choose uses the ascorbic acid method. This analytical procedure is the only one that works well in seawater. Some commercially available phosphate tests are intended for use in freshwater only and use an alternate procedure. Such tests will give erroneous results in seawater.

When you buy the test, also purchase a supply of disposable plastic vials. Use a fresh vial for each test. When the same test vial is used again and again, phosphate residues from water samples can build up, resulting in spurious test results.

Phosphate is not considered harmful to marine organisms at the concentrations likely to be achieved in the aquarium under normal circumstances, but it does appear that it acts as a fertilizer for undesirable algae growth. In the ocean, the scarcity of dissolved phosphorus in a form that can be utilized by living organisms tends to be a factor limiting algae growth. Herbivores crop algae from the reef almost continuously, too. In the aquarium, where phosphate is abundant and herbivores may be few in number, too much algae may grow. Excess algae may pose a threat to sessile invertebrates because it can smother them, or even poison them by exuding toxic substances. Limiting phosphate seems to be an effective way to avoid this unsightly problem. Ideally, there should never be any phosphate in a coral reef aquarium that is measurable with a test kit that is accurate to 0.05 mg/L. If a test shows any measurable level of phosphate, start looking for ways to reduce the phosphate concentration.

Iodide

Aquarium literature contains numerous references to the benefits of iodide supplementation. Iodide (I^-) is found in seawater at a concentration of 0.06 mg/L. It is removed by protein skimming and by activated carbon filtration, techniques that will be discussed later in the book. It is essential to many invertebrates and fishes. For example, certain soft corals that exhibit rhythmic pulsing movements may fall motionless if they lack this ion. Test kits for iodide are available in aquarium shops, along with additives for replenishing it. Exercise caution not to overdose.

Copper

The importance of copper to saltwater aquarium-keeping derives from its use as a therapeutic agent in treating the most common parasitic infestations of marine fish. I will have more to say about copper in chapter 6, “Troubleshooting.”

Nitrogen Compounds

Tests for ammonia, nitrite, and nitrate enable the aquarist to monitor the crucial process of biological filtration. Ammonia or nitrite in the water is a sign of trouble. Nitrate accumulation can be used as a rough indicator of the overall biological state of the aquarium. The concentration and form of nitrogen present in aquarium water changes in response to a complex cycle of biological activity. Proper operation of this important chemical cycle is fundamental to the success of your aquarium.

Physical and Chemical Cycles

The most important physical and chemical cycles operating within the saltwater aquarium are biological filtration, gas exchange, and the day/night cycle. Without biological filtration, an aquarium requires water changes so frequently as to be impractical. Life in an aquarium cannot exist without the exchange of oxygen and carbon dioxide at the surface. Photosynthetic organisms require both light and darkness for their survival, and the alternation of light and dark regulates the metabolism of both fish and invertebrates. Good aquarium design and regular maintenance take care of all these requirements.

Water Quality Parameters

The chemistry of the surrounding seawater varies little from one coral reef to the next. Therefore, only one set of parameters is needed for all saltwater aquariums that display reef fishes and invertebrates. Some authors recommend maintaining the temperature at a slightly higher range than recommended here. Otherwise, broad agreement exists regarding the numbers presented here.

Temperature: 72–78°F

Salinity: 35 parts per thousand (ppt), 36 ppt for Red Sea

Specific Gravity (at 75°F): 1.0260

pH: 8.0–8.5, optimum 8.3

Alkalinity: 7 Meq/L

Dissolved Oxygen: 6.9 mg/L (= 100 percent saturation)

Calcium: 380–420 ppm

Iodide: 0.06 ppm

Phosphate: undetectable

Nitrate: see page 36 for a discussion of nitrate concentration and what it may mean

Nitrite: undetectable

Ammonia: undetectable

Biological Filtration

Fish excrete their wastes directly into the water. Under natural conditions, fish population density, considering the total volume of water surrounding a coral reef, is much lower than that of even the largest aquarium. Dilution, therefore, immediately counters fish waste pollution in the ocean. Additionally, in a short time natural processes degrade the wastes into simple compounds that can be taken up by algae or utilized in some other ecological process. When we establish an aquarium's artificial ecosystem, we must harness these same natural processes to promote the survival of our fish and invertebrate display. The totality of these processes as they occur in an aquarium is biological filtration. Biological filtration is the detoxification of wastes by beneficial bacteria known as nitrifiers or nitrifying bacteria. Coating every available surface that lies in contact with oxygenated water, these organisms chemically convert ammonia (the primary component of fish waste) into nitrate (a relatively harmless compound taken up by photosynthesizers). Biological filtration, or biofiltration, readily develops in the aquarium. All that is required is an ammonia source (fish) and the right kinds of bacteria. The latter are automatically transferred along with fish or any other item taken from the reef or from a previously established saltwater aquarium (the dealer's inventory system, for example). Within a month, nitrifying bacteria will colonize the aquarium system sufficiently to process a moderate amount of waste. The gradual development of biofiltration capacity prompts the widely offered recommendation always to stock the aquarium slowly, over a period of several months. Within six months to a year, the population of beneficial nitrifying bacteria will have matured completely, and biofiltration will be adequate to permit fish to be stocked at full capacity indefinitely.

Though biofiltration is a totally natural process, most aquariums are outfitted with some kind of filtration system. Designed to maximize biofiltration capacity, aquarium filtration equipment may employ a variety of techniques to increase the surface area available for colonization by nitrifiers. The bacteria refuse to carry out the desired chemical transformations when they float freely; they need to be stuck to a solid surface. Thus we have rotating "bio-wheel" devices, "wet/dry" systems, and "fluidized bed" technology. All these filtration methods provide extremely efficient biofiltration, converting all the ammonia generated within the tank to nitrate in a short period of time. Aquarium system design sometimes focuses on biofiltration to the exclusion of other important factors because the aquarist is often seen as trying to squeeze the maximum number of fish into the minimum number of gallons. Although you could buy a highly efficient filter system and have the tank teeming with fish, you would be inviting disaster, nearly guaranteeing it, because you would exceed what I like to call the true carrying capacity of the system.

Carrying Capacity

We can debate all day about carrying capacity; that is, how many fish of what size a particular aquarium can support. If by *support* we simply mean "adequately detoxifying the ammonia waste produced," we can bump up the number of fish to high population densities indeed. Consider how many fish might be packed into a dealer's inventory system, for a case in point. Ten saltwater fish in a fifty-gallon tank would not be considered unusual. For the home aquarium display, biofiltration is not the whole story. We must think about the long-term success of an aquarium whose residents will be there for the rest of their lives. Fish and other organisms need what I like to call ecological space. A given species may need swimming room, a minimum number of companions of its own species, or a certain amount of water movement to really thrive. The ability of the aquarium to provide for these needs as well as for basic waste removal is a measure of the true carrying capacity. Taking into account not only waste removal, but also the need for ample oxygen, swimming room, and benign social interactions, ecological space must be allotted in the process of designing the aquarium. Care must be taken not to exceed the true carrying capacity of the system.

Water Changes

Regardless of its design, every aquarium needs regular partial water changes. I suggest removing 10 percent of the water weekly and replacing it with freshly prepared synthetic seawater. Depending upon your schedule, you might elect to change 20 percent every two weeks or 40 percent monthly, but the aquarium will look better and its inhabitants will appear more vibrant with more frequent, smaller changes. Partial water changes not only dilute nitrate that accumulates as a result of biological filtration, but also removes other forms of pollution that can harm fish and invertebrates.

Gas Exchange

Gas exchange is crucial. The water must continuously contain sufficient oxygen and must be continuously rid of carbon dioxide. While photosynthetic organisms, algae, and some invertebrates absorb carbon dioxide during daylight periods, at night this may not be enough to prevent the accumulation of CO_2. Carbon dioxide dissolves in water to produce carbonic acid, which drives down the pH and can inhibit critical respiratory processes in the fish. In sufficient concentration, CO_2 is lethal. Merely agitating the water at the surface facilitates most, if not all, needed gas exchange. All saltwater filtration systems require water movement, and this usually creates plenty of surface action. Problems sometimes do occur when accumulated debris clogs the filter and causes it to slow down, and the resulting change in flow rate goes unnoticed. Many aquarists add immersible water pumps, known as powerheads, to increase both surface agitation and movement deeper in the water.

Gas exchange may be inhibited, regardless of the degree of water movement, when too little surface area exists for the volume of water in the tank. A tall, narrow tank has considerably less surface area per gallon than a shallow, broad one. Consider the following comparison between two commercially available sizes of tanks:

A fifty-gallon breeder tank (36 x 18 x 18 inches) has 4.5 square feet of surface, or a ratio of 0.09 square feet per gallon. A seventy-seven-gallon show tank (48 x 12 x 24) has only 4.0 square feet of surface, or 0.05 square feet per gallon. That is roughly half as much surface for 1.5 times as much water volume. To maintain the oxygen content of the water in the larger tank, plenty of water movement is required.

Gas exchange must be taken into account in developing an aquarium design. A tall tank may be dramatic in appearance, but it needs to be correspondingly broad (most aquarium shop owners would say deep) to provide adequate surface area.

Oxygen enters the aquarium and carbon dioxide escapes it via the water surface, but water must circulate within the tank so that oxygen remains constantly available to the inhabitants. Similarly, carbon dioxide must not accumulate. Photosynthesis can account for significant oxygen production and carbon dioxide removal during the daylight hours. At night, photosynthesis ceases, and organisms that were formerly adding oxygen and removing carbon dioxide are now doing the opposite. In the dark, surface exchange must be relied upon. Even if the filter turnover rate meets the 500 gallons per hour standard suggested above, you may need to provide additional water movement via powerheads in order to facilitate adequate gas exchange.

Filter Numbers

Filter throughput for a saltwater aquarium should be at least five times the total tank capacity per hour. For example, a 100-gallon tank needs 500 gallons per hour of turnover or more. Pumps capable of delivering such flow rates necessarily create water currents.

With a pH test kit, you can determine if you have enough water movement. Without sufficient exchange, carbon dioxide accumulates in your aquarium, reducing the pH. Remove a gallon of water to a bucket and aerate it vigorously overnight. The next morning, test the pH of both the tank and the bucket. If the pH of the bucket is 0.2 or more pH units higher than that of the tank, you need more water movement.

Lighting

You must decide if your saltwater aquarium is to house any organisms that depend upon photosynthesis for their survival. This includes seaweeds and a host of invertebrate animals that harbor photosynthetic symbiotic partners. Make the critical decisions about lighting early in the design process. Aquarium lighting should show off the underwater scene to its best advantage and, if necessary, provide energy for photosynthesis. If the design relies solely on plastic reproductions or coral skeletons, then a single fluorescent lamp positioned over the tank may be enough. Even in an all-plastic ecosystem, more light always makes the tank appear inviting and fosters the growth of filamentous algae upon which many fish feed. Sometimes, unconventional lighting (by which I mean anything in addition to, or other than, the standard fluorescent strip across the top of the tank) can be used to produce striking effects. For example, a spotlight shining in can direct the eye toward a particular underwater feature, in much the same way that stage lighting directs the attention of the audience.

In the tropics, corals of all types reach their greatest abundance and diversity in clear, shallow waters, such as the shallows off the Florida Keys. Under such conditions, sunlight penetrates well. Even under the most favorable circumstances, however, the amount of available light underwater is only a fraction of that shining on the surface. Reflection, absorption with increasing depth, and turbidity all limit light availability in the reef environment. Even so, enough light for photosynthesis can reach the bottom to support dense growth because sunlight is quite intense. Few home aquariums rely on sunlight as the main light source and must make do with artificial lighting. Choosing an artificial-lighting system for a particular aquarium design requires knowledge of the available types of lighting equipment and their respective capabilities. In order to make comparisons, we must first define the terms used to describe light sources and light intensity.

The amount of light energy emanating from a source is measured in units known as lumens. The light intensity, or irradiance, over a given area is measured in *lux*, or lumens per square meter. Over a cornfield in Iowa in the middle of summer, the midday sun may provide irradiance of 100,000 lux or more. You'd be lucky to find an aquarium lighting system that can deliver 10 percent of this amount to the tank underneath it.

Several factors conspire to limit the efficiency of aquarium lighting. For example, the reflector housing the lamps cannot be 100-percent perfect, and therefore not all light emitted will reach the water surface. Reflection from the water surface itself reduces light penetration, too. Further, as the tank becomes taller, the amount of light reaching the bottom decreases dramatically due to the inverse square law of optics. Light intensity decreases in proportion to the square of the distance between the source and the object illuminated. In practical terms this means that the same light fixture over a tank twelve inches in height delivers only one-fourth as much light to the bottom if the height of the tank is increased to twenty-four inches. Double the distance, and illumination decreases fourfold. Further, the greater height of the water column means more absorption by water itself. This again reduces the effective light intensity.

The implications for aquarium lighting design are straightforward:

- For aquariums up to about twelve inches in height, two fluorescent lamps of the maximum length that can be accommodated across the length of the tank should be used.

- For deeper tanks up to four feet long, use four fluorescent lamps of the maximum possible length.
- For larger tanks, use one to several metal halide lamps to provide extremely bright light.

Although I suggest here choosing lamps by length, in actual practice it is the wattage that matters; the higher the wattage, the brighter the lamp. For example, a lamp four feet long consumes 40 watts of electricity and produces about 3000 lumens. Data on the lumen output of various types of lamps can be found on lighting manufacturer's Web sites. Appendix C, "Tank Specifications," provides lumen requirements for all the standard types of aquarium tanks.

For saltwater applications, several types of special lighting exist. For example, as one descends to greater depths, sunlight becomes selectively attenuated, with mostly blue wavelengths reaching the organisms. Many aquarists use actinic lighting to mimic these conditions. Where appropriate, I have included special lighting recommendations for some of the model designs given later.

Natural lighting varies as the sun first climbs and then descends across the sky. Cloud cover, reflection due to water movement at the surface, and turbidity, not to mention water depth, all affect the amount of light actually reaching marine organisms. If you obtain captive-propagated coral specimens, you may be able to learn the lighting conditions under which they were grown. Seldom do you have this information from a collected specimen. Therefore, some experimentation may be needed to optimally light any given item you obtain. As a rule of thumb, provide illumination that averages around 5000 lux over the course of a day. Thus, a forty-gallon long-style tank has 0.4 square meters and requires about 2000 lumens to achieve an irradiance of 5000 lux. You can check lumen output data for various lamps on the manufacturers' Web site. Use the average lumen value, if it is given. Reduce this number by 30 percent to allow for losses due to reflector inefficiency, reflection from the water surface, etc. Then total up the number of individual lamps you require to achieve the proper level of irradiance.

The length of the day is an important factor in regulating the growth of many species, and coral reef denizens are no exception. Reef fish and invertebrates usually do best with twelve hours of light daily. Use a timer to control the lighting system and provide a consistent day-night cycle. Large installations with complex lighting systems can mimic not only dawn-to-dusk fluctuations but also incorporate night illumination corresponding to the phases of the moon. While it is certainly not necessary to go to such lengths to have a successful reef tank, the lunar cycle definitely influences the reproductive cycle of many corals in their natural habitat.

Lighting a Living Reef Tank

You cannot grow corals and their relatives, or giant clams, or seaweeds without sufficient light, but unless the water conditions are also correct, you will end up growing only filamentous algae, even if you have the best lighting system on the market. Besides light, seaweeds and invertebrates need pollution-free seawater with the correct chemical and physical parameters. If you aspire to owning a living reef tank, you should be aware that invertebrates are less tolerant than fish.

Foods and Feeding

Choosing foods appropriate for your aquarium should pose little difficulty if you keep a few basic points in mind. Saltwater fish tend to be specialists when it comes to food. Quite a few vegetarians exist, for example. Some of them feed on many types of algae, others need a specific kind. Carnivores can usually be satisfied with a varied diet, but some feed only on specific classes of food, such as crustaceans. Many predatory saltwater fish need the movement of living prey to stimulate their feeding response, and only learn to eat nonliving foods as a result of the aquarist's efforts. I have already mentioned that species with strongly specialized feeding requirements, such as coral-eating butterflyfishes, should be avoided altogether. I provide feeding recommendations at various points throughout the book, usually when a given type of fish is first discussed.

Feeding Invertebrates

Fish grab food and swallow it. Feeding them is straightforward. Invertebrates, on the other hand, provide some special challenges. Invertebrates exhibit a variety of feeding methods, from hunting to straining the surrounding water for particulate food items. As a result, they require captive diets tailored to those methods. Some soft corals, for example, rely entirely on the photosynthesis carried out by their symbiotic algae, and thus need no food at all provided lighting is sufficiently intense. The majority of corals also has symbiotic algae but nevertheless consume small particles of food when it is available. Some invertebrates feed almost continuously, others only at certain times of the day. Let's consider each feeding strategy you are likely to encounter.

Filter Feeders

Filter feeders strain the surrounding water for particles of food. Usually, a particular animal specializes in particles of a certain size and has a feeding apparatus designed accordingly. Fanworms provide a good example. The worm's fan of feathery radioles entraps food particles and secretes mucus in which the food becomes embedded, preventing it from simply washing back into the sea. Along the midrib of each radiole, tiny hairs beat back and forth, creating a current that directs the mucus-coated food to the mouth, located at the center of the fan. Fanworms specialize in dust-sized particles and usually subsist quite well in a mature tank without specialized feeding. They respond well to small amounts of fish or shrimp juice, and they appear to capture brine shrimp nauplii, also.

Other types of filter-feeding invertebrates include sponges, which remove extremely small particles, such as bacterial cells, from the water. In fact, most sessile encrusting invertebrates are filter feeders. Virtually all corals and other coelenterates are capable of feeding this way to supplement photosynthesis. The nonphotosynthetic corals require feeding with brine shrimp and other products several times a day. Some species may feed only at night, others feed continuously. You can usually tell if a specimen is actively feeding, because its tentacles, radioles, or other apparatus is visible.

Scavengers

Quite a few common invertebrates can be included in this group. Hermit crabs, shrimps, and brittlestars all scour the aquarium and seldom need to be deliberately fed. They perform a valuable service by cleaning up food missed by the other inhabitants of the tank.

Tiny Foods for Invertebrates

Besides live brine shrimp, there are many options for filter feeders. Various foods are sold for the purpose. You can also add the juice that collects when you chop seafood for feeding to the fish. Seafood can be puréed in a blender and strained through a fine net. The particles that pass through the net can be used as invertebrate food. With any of these nonliving foods care must be taken not to add an excessive amount, or you risk overloading the aquarium's capacity for waste removal. For this reason, and to avoid wasting the food, I suggest you use a medicine dropper or plastic syringe to squirt little "puffs" of food in the vicinity of the invertebrate you're feeding. It doesn't take much, maybe a teaspoon at a time. After all, these critters just sit in one place all day, so they have relatively small food requirements compared to an active, mobile creature. Filter feeders have such appeal for minireef enthusiasts that a plethora of commercial products for feeding them have appeared on the market.

Grazers

This group includes critters placed into the tank primarily for algae control. Snails and small hermit crabs constitute the "lawn-care" patrol. Sea urchins also feed on algae but are not above munching a piece of shrimp unnoticed by the fish. Larger invertebrates that need a steady diet of algae will eat fresh or dried seaweed or frozen foods containing a high proportion of green matter.

Predators

A few invertebrates are active hunters, and many are capable of subduing a tank mate and killing it when no other food is available. Starfish, for example, normally feed off sessile invertebrates and bivalve mollusks. Predatory starfish can be distinguished from brittle stars because the latter have flexible, snaky arms, while the former are shaped like the stars on the American flag. The larger the starfish, the more likely it hunts for a living. Lobsters and crabs of all types, with the exception of anemone crabs, feed both by scavenging and predation. Large crustaceans of any kind are not to be trusted with small fish or delicate sessile invertebrates. Similarly, large snails are usually predatory, unless they have been sold specifically for algae control. Any of these invertebrates can be kept in an otherwise fish-only aquarium, assuming the fish won't pose a threat to them. They are not good choices for a miniature reef tank.

Photosynthesizers

As already discussed, many invertebrates manufacture their own food with the help of symbiotic algae. Nearly all of these, with the exception of giant clams and a few types of coral, also feed on brine shrimp, uneaten fish food, and even fish feces that happen to fall on them. In this way, they obtain important nutrients not supplied by their symbiotic algae. As a rule, it is not necessary to feed photosynthetic invertebrates deliberately, as long as food is being added to the tank now and then for other inhabitants. However, no photosynthetic invertebrates do well with inadequate lighting. Most anemones have symbiotic algae, but all of them do best with a weekly feeding of a small bit of fresh shrimp or fish. A piece the size of a bean is adequate for a four-inch-diameter anemone, measured when fully expanded. Increase the size of the food in proportion to the diameter of the oral disk for larger anemones.

Specialized Feeders

Many types of invertebrates have specialized food requirements that cannot be easily met by everyone. If you are considering purchasing an unfamiliar specimen, make sure you understand its feeding requirements before you commit. Some mollusks, for example, require living corals as food. The beautiful harlequin shrimp feeds only on the tube feet of living starfish! With diligence, such specialists can be accommodated, but make sure you are up to the task.

Availability of Foods

Commercial fish foods can consist either of a single ingredient, such as freeze-dried brine shrimp, or a compound of many ingredients, such as most flake foods. The trick to providing a balanced diet for your aquarium is to feed a wide variety of foods, alternating among two or three kinds during the course of a week. If your fish are primarily vegetarian, you will find products made just for them. Supplement these with small amounts of animal protein, frozen brine shrimp, for example. Conversely, if your fish are primarily carnivorous, supplement their diet with small amounts of vegetable matter, such as products containing saltwater algae.

Fish food may be supplied as flakes or as pellets, in freeze-dried form or frozen. Many dealers also stock live foods.

Feeding

Beginning aquarists usually give too much food. This results in an excessive load on the filtration system, since uneaten food simply decays on the bottom of the tank. The notion that fish will eat themselves to death is nonsense, but the pollution in an overfed aquarium can certainly wipe out its inhabitants.

A fish's stomach approximates the size of its eye. Obviously, it will not take a lot of food to fill it up. One rule of thumb is to feed only as much as will be consumed in ten minutes. You can determine the correct amount for your situation by trial and error. When in doubt, feed less. Fish can go for a surprisingly long time, weeks in many cases, without eating, so the likelihood of starving them is quite small in comparison to the likelihood of polluting the tank with uneaten food.

Most people find twice daily feedings work best with their schedule. If your schedule permits, though, feed a community of smaller fish about five times daily with just a tiny pinch of food at each feeding. Feed about an hour after the lights come on in the morning, and again about an hour before darkness falls. You will need to modify this schedule if you have, for example, large predators like groupers and lion fish. For these, the usual feeding regimen is three or four times a week. On the other hand, vegetarians feed almost continuously. These fish do best when there is plenty of algae growing in the tank to supplement the twice daily feedings.

Be careful not to feed vegetarian fish a diet rich in animal protein, even though they may eat such food greedily. The vegetarian digestive system is not designed to cope with such a diet, and problems will develop. Similarly, fish that need plenty of animal protein will not get enough to eat if kept on a diet better suited to vegetarians.

In the natural environment, of course, diets consist mostly of living foods. Some live foods can be cultured at home, provided you have the time and inclination. Ideally, one would feed only live food, but this is usually impractical at home.

Live Foods from the Aquarium Store

Virtually all aquarium dealers stock feeder goldfish. They are sold by the dozen and keep well for a week or so in a small, aerated container. Ten gallons of water accommodates about one dozen. Instead of a glass tank, you can use a plastic trash can outfitted with an airstone. Goldfish do fine in cold water and can be kept outside year round, as long as the water does not freeze. If you only purchase, let's say, a dozen a week, change the water between batches of goldfish. Unfortunately, only large, predatory tropical fish will consume them, so feeder goldfish are not for every aquarist.

You can also buy feeder guppies by the dozen at the aquarium shop. They will be eaten by any fish large enough to swallow them. Since they breed continuously, you can have many different sizes of guppies, from newborn to adult, available at all times to suit the varied sizes of fish in your aquarium. Fifty adult guppies are fine in ten gallons of water, provided it is well aerated and the water is changed between batches of feeders. They can tolerate water temperatures down to about 50°F, and so can be kept in an unheated garage or outbuilding during the winter. In warm weather, they thrive in a small outdoor pond or child's plastic wading pool located away from direct sunlight. To maintain a high population density, the aquarium or pond requires filtration or a weekly change of half the water.

Some shops stock live blackworms. These are small relatives of the earthworm that live in clean, cold water. Shops sell them in portions of a tablespoon or two. Purchase a shallow plastic food-storage container at the grocery store. The ones designed to hold a sandwich are perfect. Place the blackworms in the container and cover them with no more than a quarter inch of tap water. Store in the refrigerator. Remove a few worms every day with a spoon and feed them to your fish. Rinse the worms and change their water each day. Simply pour off as much as you can and replenish with cold water straight from the tap. Repeat a couple of times until the water rinses off clear. Treated this way, the worms will keep a week or two easily. The hard part about keeping blackworms is negotiating with the other members of the household regarding the refrigerator space.

Live adult brine shrimp can be found on the menu at many good aquarium shops, particularly those that stock saltwater fish. They are usually sold in portions amounting to about two teaspoons when the shrimp are drained in a net. Because they don't keep too well without careful attention, it is best to purchase a small quantity and feed them to the tank within a couple of days. Use a net to separate the shrimp from the strong salt solution in which they grow. Rinse under the tap before adding to the aquarium. They will die within about an hour in fresh water. Therefore, make sure to feed only the amount likely to be eaten by your fish within a short time.

With the exception of brine shrimp, the foods just mentioned should not be fed exclusively to your saltwater fish. Their nutritional needs are better met by foods derived from marine sources. Live marine feeder fish are impractical as food unless the aquarium is near the ocean. It is therefore often necessary to train predatory saltwater fish to accept nonliving foods such as frozen fish.

Culturing Live Foods

Live foods for the saltwater aquarium can be cultivated at home. You will need some extra space and equipment, but the added effort will pay off in healthier, more vibrantly colored fish and thriving invertebrates.

Brine Shrimp Nauplii

Larval brine shrimp, known as nauplii (singular, nauplius), have been used for decades as fish food. They are rich in nutrients and can be easily hatched from the resting cysts, often incorrectly referred to as brine shrimp eggs. The ability to breed and subsequently rear saltwater fish in hatcheries depends upon the use of brine shrimp nauplii, once the fry grow large enough to take them. The cysts, nearly indestructible, keep for months, even years, with proper storage. They are collected from evaporation ponds and other highly saline environments, and look like coarsely ground cinnamon. Hatching them is a cinch.

Fill an empty wide-mouth quart jar with water up to the shoulder and add two tablespoons (about an ounce, or thirty grams) of synthetic seawater mix. (Seawater mix is available wherever saltwater aquariums are sold.) Drop in an airstone and connect it to a pump. Aerate the water vigorously. You will want to locate your brine shrimp hatchery where the salt spray will do no harm, as it is impossible to keep it from splattering out of the container. The jar should be in a spot that remains around 75–80°F. Bright, indirect light will improve the yield of the hatch, but keep the jar out of direct sun, or it will get too warm. As soon as the salt mix dissolves, add 1/4 teaspoon of the cysts. They will hatch in twenty-four–fourty-eight hours, depending upon the temperature. The warmer the water, the quicker the hatch. You can see the tiny nauplii swimming jerkily in the water. When you are ready to harvest, turn off the aeration. This will allow the empty cysts to float to the top of the container. Separating the cysts from the shrimp is the main difficulty in using brine shrimp nauplii. If the cysts are added to the aquarium, they will form an unsightly ring just above water level, and they can be harmful if fish ingest them. The nauplii are attracted to light, and you can exploit this trait to collect them. Make a sleeve out of thin cardboard that will encircle the jar, cutting a one inch hole just above the bottom. When you are ready to harvest shrimp, place the sleeve around the jar and shine a flashlight into the hole. The shrimp will gather at this point, from which they can be siphoned out with a length of flexible plastic tubing. Trap the nauplii with a net, and rinse under the tap before adding them to the aquarium. They will be relished by virtually all tropical fish. Like the adults, the nauplii survive only about an hour in fresh water, so feed accordingly. Try to feed your entire hatch within forty-eight hours because the nauplii will lose much of their nutritional value during that time.

Brine Shrimp Adults

Nauplii can be grown to adulthood if you have the space. Fill a shallow container that holds at least fifty gallons, such as a child's plastic wading pool, with synthetic seawater prepared at the ratio of four ounces of dry seawater mix per gallon. The container should be located in bright light but out of direct sun. Add a pinch of soluble garden fertilizer (such as Miracle-Gro) and a quart of either natural seawater collected from the ocean or water from an established saltwater aquarium. After a couple of weeks, the water in the rearing container will be green with algae growth. Hatch the cysts as just described and add the nauplii to your rearing pond. They will feed on algae and grow to adulthood in about two weeks. You can feed them to your fish at any point. About once a week, add another batch of nauplii. In this way you will be able to grow a continuous supply of adults. When harvesting the adult shrimps, use a net with relatively open mesh, so smaller individuals can escape and grow.

Rotifers

Rotifers are nearly microscopic invertebrates that swim by means of specialized structures unique to their phylum. The saltwater rotifer, *Brachionus*, has been extensively used to rear larval saltwater fish. Cultivation of rotifers requires that you also culture the single-celled algae on which they feed and may not be practical to do at home.

Phytoplankton

Single-celled marine algae, collectively known as phytoplankton, are an important part of the diet of many filter-feeding organisms. If you have the space and equipment, phytoplankton can be cultivated, but most enthusiasts opt for commercial products. Believe it or not, bottled phytoplankton can be stored under refrigeration for several months.

Routine Maintenance

Change part of the water in your saltwater aquarium regularly. I recommend changing 10–15 percent per week, but you can do it biweekly or monthly, so long as you change roughly half the water every month. This simple procedure will do more to enhance the appearance of the tank and the health of the fish and invertebrates than anything else you do as an aquarist.

Changing Water

Aquarium shops sell various types of siphons for removing water from the tank. Purchase one with a long enough hose to reach from the bottom of the tank, over the top edge, and down to the floor. You will also need a couple of plastic five-gallon buckets. Use them only for aquarium maintenance. Don't mix garden fertilizer or paint in a bucket and then later carry water in it. You may inadvertently poison the aquarium.

Before removing water from the tank, make certain to turn off all equipment, especially the heater, which should be unplugged.

Fill the buckets and discard the used water until you have removed the correct amount. Refill the aquarium with previously prepared synthetic seawater.

WARNING If you expose the heater to the air, it will get hot enough to blister you if it should switch on. Subsequent contact with water is likely to cause the heater to crack, which may create a dangerous electrical hazard, and will certainly ruin the heater.

Carefully pour the replacement water into the tank. If the tank is a large one, you may find hoisting heavy buckets to its rim too much of a chore. In this case, purchase a small submersible pump and a suitable length of hose to take care of the work. A five-gallon bucket full of water weighs over forty pounds. Please don't hurt your back trying to lift this much weight in a controlled manner; do it only if you are physically up to the task.

The fish, of course, will freak out over the disturbance, but it is doubtful any will suffer long-term harm. Since you have to remove the light fixture to get at the tank, the darkness will help some in this regard. Once the tank is full again, switch the pumps and heater back on and check for normal operation. I suggest leaving the lights off until the next day to allow the fish to calm down. Don't feed them, either, on water-change day.

For a large built-in aquarium, the plumbing system should be designed to permit draining and filling the tank via the filter sump, as will be discussed in chapter 5, "Nuts and Bolts."

You may want to do some housecleaning as part of your water-change routine. This is a good time to clean algae from the front and sides of the tank, and to siphon out any noticeable accumulations of debris. It is likely that you will stir up fine debris in the course of maintenance. It will be removed once the filter is restarted. This is the ideal time to check and replace filter media, which may become clogged with particulate matter. I save the major work for once a month, but you may want to clean the inside of the glass weekly. Use a plain plastic scouring pad (such as Scotch-Brite) from the supermarket for this purpose if you have a glass tank. Acrylic tanks require the use of a cleaning pad made especially for them. In either case, always be careful not to get a piece of gravel or a grain of sand between the pad and the tank wall, or you will scratch it.

Before replacing the cover, clean it thoroughly on both sides with plain water and the scouring pad you use for algae removal. Water spots, dust, and algae on the cover glass can seriously reduce light penetration. If you maintain corals or other photosynthetic invertebrates, they will need all the light the fixture can provide. Also, wipe off the fluorescent lamp itself. You will be surprised how it picks up household grime due to the electrical charge it bears when in operation. Make a note when the tank is first set up, and on the anniversary date each year replace all the lamps in your fluorescent fixture. Light output decreases as the lamps age, even though you may not notice this visually. If using metal halide lighting, follow the manufacturer's directions regarding an appropriate lamp replacement schedule.

Now and then you will need to replace worn parts such as the impeller in your filter pump. Plan to do this, too, while the equipment is shut down for a water change.

Once you complete the water change and other routine maintenance, you will be amazed at how the tank sparkles. The benefits of a short time spent on maintenance will be clearly apparent.

Mixing Synthetic Seawater

If stored covered in a cool, dark place such as a garage, basement, or closet, natural or synthetic seawater keeps indefinitely. You can mix up a large batch to have available as needed. Slightly more than two cups of dry mix will make five gallons of seawater. Buy your salt mix in large quantities to save on its cost. It keeps indefinitely if stored in a tightly sealed container away from moisture. Dampness promotes caking, which makes the mix hard to measure and causes it to dissolve more slowly. Too much moisture can also cause chemical changes in the mixture, in which case it should not be used at all.

Salt mix dissolves more quickly if you add the mix to a pail of water, rather than put the mix in the bottom of the bucket and add water. Agitating the mixture also speeds solution. If you use only a five-gallon bucket for mixing, you can drop in a small air diffuser and bubble air into the bucket overnight. For larger amounts, consider making a mixing tank. You can find plans for one in hobby magazines or on the Internet.

Water Tests

One important aspect of maintaining your saltwater aquarium is keeping water conditions within rather narrow limits. It's easier to do than it sounds. Make regular tests, then make adjustments. For example, evaporation causes a gradual increase in salinity. This happens because only water leaves the tank, and the same quantity of salt thus becomes concentrated in a diminishing volume of water. Your job is to keep the change to a minimum, which you accomplish through maintenance. Checking the salinity weekly and adding fresh water to compensate for the loss is the appropriate response to evaporation. Similarly, for other important parameters, such as pH, alkalinity, and nitrate, test the water regularly and make appropriate adjustments when conditions begin to deviate from their target values. I like to say, "test and tweak."

Neglecting maintenance to the point that you can only bring the water conditions back in line by doing a massive water change virtually guarantees problems. This, nevertheless, is a common mistake. Regular testing and small corrections are the way to go. Buy good test kits, use them on a regular basis, and keep a written record of the results. Keeping a record lets you compare your results with previous tests, in order to refine your technique. You may learn, for example, that your aquarium evaporates about ten ounces of water every week, consistently. Knowing that, you can just add ten ounces of fresh water every Friday and dispense with testing until the next water change.

How to Test

Always follow the manufacturer's instructions when using test kits or instruments. Rinse out vials thoroughly with fresh water after each use, and store them upside down to drain. Rinse the vial with the water to be tested prior to each use. Use a cup or medicine dropper to remove water from the tank for testing. Do not dip the test vials into the water. *Take care never to spill test chemicals into the aquarium.* Do not store test chemicals for more than a year, and keep them out of children's reach.

If the tank has been set up properly and maintenance carried out on schedule—and if you don't overstock or fail to feed the fish with restraint—it is unlikely that ammonia or nitrite, the two major pollutants that pose an immediate threat to fish health, will accumulate. If you do regular water changes, excess nitrate accumulation is unlikely, also.

With that in mind, it still pays to be prepared to take quick action in case the fish show signs of distress. It is always worthwhile to have a basic water chemistry lab available for troubleshooting purposes. For that I suggest purchasing test kits for the following:

- Ammonia
- Nitrite
- Nitrate

Aquarium water should never have any detectable ammonia or nitrite. The presence of either one indicates that biofiltration is not proceeding as it should. Immediate action should be taken to reduce the concentration of either of these compounds should you discover them. Change enough water to substantially reduce the level. Keep testing on a daily basis, changing water as needed, until the system returns to normal. Stop feeding during this time. The fish will not starve, and more food will only exacerbate the problem.

Nitrate

Nitrate is another matter. If you check nitrate just before doing a water change, you will note that it increases by about the same amount every month. Immediately after the water change, it will be reduced in proportion to the amount changed, that is, a 50-percent water change will reduce nitrate by 50 percent. By the next water change, more nitrate will have accumulated. The difference between the nitrate level immediately after a water change and the level immediately before next month's (or next week's) change represents the normal amount of nitrate production for your particular situation. A deviation from that norm means that something has upset the equilibrium established between ammonia production, biological filtration, and nitrate removal. Several factors can produce this deviation. Adding a fish produces a noticeable change, for example. Similarly, rotting food or a dead snail decomposing behind a rock adds ammonia, and this will eventually result in nitrate accumulation. Thus, it is important to keep a record of each nitrate test. Should an anomaly appear, try to identify an obvious explanation, e.g., new fish were added. Otherwise, you need to track down the culprit.

Ask yourself the following questions:

Did I carry out the test correctly? (It is always worth doing a confirming test before looking for other explanations.)

Have water changes been skipped?

Have fish been added?

Have I fed more than I normally do?

Is everyone present and accounted for? (Small fish or invertebrates sometimes die unnoticed.)

Have I added anything out of the ordinary? (Medications, especially, may disrupt bacterial activity and thus change the nitrogen equilibrium.)

Nitrate may be removed by natural processes, such as conversion to nitrogen gas by specialized bacteria. This process, *denitrification*, takes place in the absence of oxygen. Live rock (see page 64) harbors denitrifying bacteria beneath its surface, where oxygen cannot readily diffuse. Your partial water changes may constitute the primary way nitrate leaves the aquarium, particularly if it is a fish-only tank. Measuring nitrate accumulation allows you to spot anomalies that may be a sign of trouble.

The amount of nitrate produced per unit of time remains constant as long as conditions do not change. Conversely, changes in aquarium conditions will be reflected in changes in the nitrate concentration of the water. Each partial water change lowers the total amount of nitrate in the aquarium, creating a new point from which accumulation begins again. Note that the trend in nitrate concentration will always be upward unless 100 percent of the water was changed each month. At some point—I suggest every six months—you will need to do an extralarge water change to return the tank to a reasonable base line position with regard to nitrate. When fish are added a new, higher base line for nitrate is established, owing to the additional waste output. Adding more live rock, which increases the rate of denitrification, results in the removal of nitrate from the water. This changes the base line in the opposite direction. Invisible nitrate, therefore, can be an indicator of the overall biological activity in your aquarium. Thus, it is worth carrying out this one test on a regular basis.

How to Tweak Nitrogen Compounds

Finding ammonia or nitrite during a routine test is always cause for concern. Determine the source of the problem immediately.

Common possibilities are:

- The aquarium contains too many fish.
- Uneaten food or a dead animal is decaying in the aquarium.
- An antibiotic has been added to the aquarium, killing the nitrifying bacteria.
- There is a shortage of oxygen.

Responses to these problems are:

- Remove some fish.
- Find whatever is decaying and siphon it out.
- Remove the antibiotic with activated carbon filtration or by doing a large water change.
- Repair the pump or add additional powerheads to increase the water movement.
- Lower the temperature by installing a chiller.

The Nitrate Base Line

The best way to keep tabs on the balance between food going in and bacterial activity is by measuring nitrate accumulation weekly. Any increase in nitrate from the base line level indicates changes in the utilization of food. As fish grow, their food requirements increase. This results in a change in the nitrate budget of the whole system. Similarly, adding or removing specimens alter the slope of the accumulation line. As you add or remove specimens, regular nitrate measurements must be taken to determine the new base line. A stable system will show stable nitrate accumulation, and any sudden deviation should be taken as a warning sign. A system in nitrogen equilibrium has a nitrate base line of zero, because denitrification exactly balances nitrate production.

Not all nitrate tests are created equal. Some test total nitrate and some test nitrate nitrogen. Without going into the details, suffice it to say that you must always record the same parameter if your test results are to be of any value for comparison purposes. Don't switch brands of test kits, unless you are sure that the new kit is measuring the same thing your old one did. (Different brands that test the same parameter may give different results with the same water sample, but the difference will be slight.) If you simply cannot find, for example, a total nitrate test and are forced to rely on one for nitrate nitrogen, multiply the result by 4.4. Similarly, to convert total nitrate to nitrate nitrogen, divide by 4.4.

pH

If the pH is low because too much carbon dioxide accumulates in the water, increased water movement may be all that is needed to alleviate the problem. Keeping the aquarium at the correct pH can also be accomplished by adding a buffering agent to increase and stabilize the pH. A host of products are offered in aquarium shops for this purpose. Products that help both to buffer pH and to maintain alkalinity may be the most useful. Seawater mix brands vary in the degree to which they maintain the correct pH when mixed. Always check each new batch of seawater before using it. If you find consistent problems, try a different brand. The use of aragonite sand as part of the substrate can also aid in pH stabilization. As the sand slowly dissolves, ions are released, helping to maintain alkalinity and calcium levels. When the alkalinity of the aquarium is at natural seawater level or above, the pH tends to remain within a suitably narrow range. Test pH weekly and use one of the buffering additives if you need it. Make sure to follow the directions on the package.

Calcium and Alkalinity

You need to monitor and adjust the calcium concentration of the aquarium if you have a minireef. Corals, soft corals, clams, snails, scallops, shrimps, crabs, starfish, sea urchins, and even some algae all need calcium for their skeletons. Several techniques exist for keeping the calcium content of the aquarium close to that of natural seawater, 400 mg/L. A simple approach is to add limewater. Limewater is a saturated solution of lime in water. It is prepared by adding dry calcium oxide to distilled water, allowing the mixture to settle, and decanting. Use about two teaspoons of lime per gallon of water. Some undissolved powder should always remain at the bottom of the container. Calcium oxide is sold in supermarkets for making lime pickles, or you can purchase it at an aquarium shop. Use limewater to replace all evaporated water. Limewater is alkaline. Take care that additions do not drive the pH above 8.6 for more than a few hours at a time. An hour after adding a dose, check the pH. You can quickly determine how much to add on a routine basis after a few weeks of testing and keeping records. After that, just add the correct amount on a regular basis, and only check the calcium concentration once a month. Make up only enough limewater for a week's supply. Over time, atmospheric carbon dioxide will cause much of the lime to precipitate out of solution as insoluble calcium carbonate.

In aquariums with a thick substrate layer of aragonite sand, the pH will be very low in the anoxic regions deep in the substrate. The low pH causes aragonite to dissolve and return both calcium and carbonate ions to the water. Depending upon the makeup of the community of organisms in the aquarium, pH/alkalinity/calcium balance may be maintained through this process alone, and no limewater or other additives will be required. Other aquariums may need additional help in the form of limewater additions, as described above, or through enhancement of the aragonite dissolution process by means of a calcium reactor. This is simply a device that allows acidified distilled water to be passed over a layer of aragonite, which results in the enrichment of the water with calcium and carbonate ions. This water is then added to the aquarium to replenish evaporation. This technique avoids the drawbacks inherent in the use of limewater, but requires more work. You can purchase a calcium reactor, or make one yourself. It is basically a plastic pipe with screen at one end to keep the aragonite from falling out. Water is added at the top of the reactor, flows through the aragonite, and is collected below. Using distilled water to which a small amount of vinegar (about a tablespoon per gallon) has been added is most effective in dissolving the aragonite.

As acids are produced by the biological activity in the aquarium, alkalinity decreases. Restoring the alkalinity to normal levels is part of routine maintenance. Using a chemical additive such as limewater, adding aragonite sand to the substrate, or adding calcified water from a calcium reactor will all increase the alkalinity. The relationship between alkalinity and calcium concentration is reciprocal. Increase one, and the other decreases. In the early days in the life of your aquarium, you may have to experiment with repeated testing to determine the best way to keep pH, alkalinity, and calcium all within their proper ranges. Of greatest importance to the inhabitants of the aquarium is the pH, influencing as it does not only the respiration of fish, but the deposition of calcium carbonate by invertebrates. If the pH is correct, the specimens can get along with less than the natural amount of dissolved calcium. Therefore, focus on maintaining the correct pH. The higher the alkalinity, the easier this will be. If you do not use limewater or some other means of calcium supplementation because you have no invertebrates, there are plenty of commercial additives for maintaining the alkalinity.

Record Keeping

Because each aquarium is unique, there is no good substitute for a complete, conscientiously maintained record book. Buy a calendar, notebook, or three-ring binder and make notes regarding water changes, lamp replacement, and other routine maintenance. You can also jot down your observations on the behavior or growth of the fish and other inhabitants. Not only will having such a record help you remember things like when to change the filter pads, but also with time the notebook will become a history of the tank that you will enjoy looking back upon. If you find yourself wondering how old that clownfish is, you can check your records and find the date you placed it in the tank. This, for me, is part of the fun, and is also a good way to spot trends.

I like to use a loose-leaf binder to hold both aquarium records and documents like equipment manuals or instructions for test kits. I drop the binder in a large plastic bag and store it under the aquarium. The bag keeps out water damage, and the binder is there whenever I need it. Keeping everything organized and handy makes it easier to stay on top of maintenance and testing. If you have to scour the house for your notes and equipment, you are less likely to do what's required at the proper time.

Record the following information about your aquarium in the record book:

- Date
- Test(s) performed and results
- Anything added and amount
- Temperature
- Specific gravity and calculated salinity
- Amount of water changed
- Species and size of fish or invertebrates added
- Incidents of death or disease, treatments, and results
- Any comments or observations you think pertinent

Your aquarium record can be as detailed as you like. The more information you retain, the better. For example, why not use a digital camera to record the appearance of the aquarium at various times. You might want to have step-by-step pictures showing the aquarium in various stages of construction. Each time you add a new fish or invertebrate you create another photo opportunity. Don't overlook using the camera to record problems. You can even e-mail a picture of a sick fish to someone helping you with diagnosis.

Digital technology makes possible continuous monitoring and recording of some important aquarium parameters, not to mention automated control of lighting and other equipment. Temperature, salinity, and pH are relatively easy and inexpensive to monitor in this way. Some tests, such as those for ammonia and nitrite, are difficult to automate, but having other routine tests automated saves time for carrying out manual testing. Aquarium monitoring and control devices usually interface with a PC to permit display of information in various forms, such as a graph of pH versus time. You can find sources for such equipment on the Internet or in hobby magazines.

Equipment Maintenance

Everything wears out, of course, but you can prolong the life of your aquarium equipment by properly maintaining it. Doing equipment maintenance at the same time as your monthly water change makes sense.

1. Turn off the tank lights and unplug the fixture. If you use metal halide lighting, the lamps will need to cool down before you can move the fixture, or you risk damaging them. Besides, a dark tank makes the

whole operation less stressful for the fish. Check the light fixture for any signs of salt accumulation or corrosion. Remove any that you find with a cloth dampened in fresh water. If corrosion is developing, try to determine why, and take steps to prevent further damage. Aquarium lighting is designed to resist corrosion and to protect electrical connections from saltwater, so corrosion is a sign of improper installation or a break in the water barrier. Any damage you discover to the electrical parts of the lighting system should be repaired immediately by a skilled person. Such damage may pose an electrical or fire hazard. Problems such as this are rare with good-quality lighting equipment.

2. With a damp cloth, carefully clean dust and salt spray from the lamps themselves, as any accumulation will reduce the light output. You may need to remove the lamps from the fixture in order to do this effectively, depending upon the fixture design. Many fixtures also have a plastic sheet that protects the lamps. The side of the plastic nearest the water surface invariably becomes spotted from droplets of seawater. Again, carefully clean the plastic with a damp cloth, ensuring that the maximum light output reaches the aquarium.
3. Shut down the filter pump and protein skimmer.
4. Wipe clean the outer surfaces of all the plumbing fittings and hoses. You'll be surprised at how much dust they can accumulate. Also clean dust from any portion of the pump intended to ventilate the pump housing. Dust clogging the vents reduces the cooling effect, and makes the pump wear out faster. Pump designs differ from brand to brand. Follow the manufacturer's directions for cleaning and maintenance of the pump. If it's time to replace the impeller, do so now.
5. Disassemble the protein skimmer and clean it in the sink, in accordance with the manufacturer's recommendations. Usually, the skimmer collection cup and the tube through which foam rises toward the cup accumulate scum on their inner surfaces that interferes with efficient skimming. After a good cleaning to remove the scum, you'll find that foam "climbs" up the tube more readily, and you may need to adjust the skimmer to prevent overflow. Only a process of trial and error will permit you to set a schedule for skimmer maintenance, since every tank is different. Your skimmer may get thoroughly dirty in a week's time, while mine may take two weeks to lose efficiency because of accumulated gook. Try to develop a schedule that results in a relatively constant amount of foam being collected per unit of time. If you keep track of the volume each time you empty the collection cup, you will note that a sparkling clean skimmer produces mostly thick, dark green foam, while a yucky skimmer collects a lot of diluted foam and water. You want to strive for a happy medium between these two extremes during the course of a month. Because skimmer designs vary, and because the amount of organic matter in the water also varies from one aquarium to another, it is impossible to give exact guidelines for properly adjusting the skimmer. You'll get the hang of it after a month or two. Skimmers that use air diffusers may need these replaced every month or so, as they will become clogged with mineral deposits. Similarly, air-supply lines can develop mineral deposits where air and water come into contact. These deposits will eventually close off the line. They can be easily removed by soaking in a weak solution of vinegar and water, scraping with a toothpick, and rinsing in fresh water before reconnecting.
6. Always remember to unplug the heater before removing any water from the tank. Submersible heaters are usually trouble free, but it doesn't hurt to check for any damage as a regular part of your maintenance routine.

The "Hurricane Effect"

Every now and then a hurricane or typhoon strikes near a reef. Wind-driven wave surges break off tons of coral fragments. The hurricane also stirs up debris, making the water turbid. Despite the apparent devastation, a hurricane actually benefits the reef ecosystem by flushing out accumulated sediments and pruning the coral. Coral fragments that happen to land in a suitable spot often resume growth as if nothing happened, creating a potential site for a new patch reef to develop.

You probably won't want to be breaking off coral fragments in the process, but creating a "hurricane" in your saltwater aquarium now and then is not a bad idea. Sediment tends to accumulate on any horizontal surface in the aquarium, just like dust gathers on your furniture. Periodically removing it not only helps keep the aquarium looking tidy, but also exposes the area under the sediment to light, providing algae and sessile invertebrates a clean spot on which to grow.

Start by gently manipulating the top inch or two of the substrate layer with your fingers. This will stir up a lot of debris. If there are algae mats growing on the surface of the substrate, break them up with your fingers. Much of the sediment and algae will settle on the rocks and corals, but don't worry about that at this point.

Disconnect one of your powerheads. Holding it in your hand underwater, direct the outflow from the powerhead toward your live rock while someone else plugs the cord back in. Play the water jet over the surfaces of the rocks and corals, blasting debris into suspension where it can be picked up by the filter system. While the "hurricane" rages, you can also temporarily run a canister filter to "polish" the water by trapping most of the suspended sediment inside the filter. Try to sweep as much sediment as possible toward the front of the tank. With only a little practice, you will learn to operate the powerhead like a leaf blower to move piles of debris. When this step is completed to your satisfaction, turn off all pumps and allow suspended debris to settle out. Wait an hour or more. Overnight is fine. Then, use a length of hose to siphon as much of the sediment as possible off the bottom of the tank. Collect it in a bucket and discard. Top off the aquarium with freshly prepared seawater. Voilà! Hurricane complete, minireef freshly scrubbed. Doing this once or twice a year works wonders for keeping the aquarium looking healthy and sparkling.

Using a Maintenance Service

While I assume the owner of the aquarium will be the one taking care of it, the possibility does of course exist for a hands-off approach. An aquarium maintenance service makes a lot of sense if you lack the time required to give the aquarium the weekly attention it needs. Nevertheless, feeding and checking key conditions on a daily basis, especially for a reef tank, can occupy more than a few minutes. On a weekly basis, an hour or so is required to carry out testing and record keeping, and part of the water should be removed and replaced with previously prepared synthetic seawater. Seaweeds, and even some invertebrates, may require pruning, algae may grow in places where you don't want it, and equipment will need servicing. Depending upon the size of the tank, maintenance may thus involve more time than you can spare. Because conditions in even the best-designed system tend to deteriorate quickly without regular maintenance, if you don't have the time for upkeep, you will need to hire someone to carry out these chores to avoid disaster.

If you decide to go this route, choose the service with care. Make sure responsibilities, yours and theirs, are clearly understood. Confirm that the price quoted covers both labor and materials, such as synthetic seawater, that will be replaced in the course of normal care. If supplies cost extra, you should have the option of shopping for them yourself, rather than purchasing only from the maintenance company. Everything should be spelled out in a written agreement. The cost for professional maintenance can be considerable, and most companies charge a monthly minimum. However, proper care is the key to long-term enjoyment from any aquarium, but especially so in the case of saltwater. Failing to appreciate this fully has resulted in many a would-be aquarium owner's disappointment.

SUMMARY

You don't need a scientific background, or a lot of experience, to have a successful saltwater aquarium with thriving fish and invertebrates. All you need to do is use common sense and stick with my basic rules. In summary, they are as follows:

- Set up the largest aquarium that your resources can accommodate.
- Know the optimal conditions for saltwater chemistry, and maintain those conditions in your tank.
- Choose a lighting system adequate for corals and other photosynthetic organisms, if you choose to include them in your tank. There is no substitute for light. Otherwise, use plastic reproductions.
- Understand the critical process of biofiltration.
- Add fish gradually. Start with no more than 10 percent of the total number you eventually will keep in the tank. This allows biofiltration to keep pace with the fish population.
- Add hardy fish first. Save delicate species for later, when the tank is more stable.
- Always choose fish and invertebrates with care. Even if you follow a recipe from this book precisely, bringing home a sick fish will create problems.
- Understand why nitrate is an indicator of the overall condition of the aquarium.
- Feed a varied diet in small amounts.
- Carry out partial water changes on a regular schedule without fail.
- Keep a notebook of observations, such as water test results, to refer to when making changes or diagnosing a problem.

Most importantly, sit quietly near the tank for a short while each day and watch what's going on. Not only will you learn a lot about the coral reef environment, your stress level will decrease, you'll learn to relax, and, hopefully, you will live longer. Not a bad trade-off, in my view.