A REVIEW OF BASIC AQUARIUM TECHNIQUES WITH COMMENTS ON MARINE AQUARIA AND PUBLIC AQUARIUM DISPLAY TECHNIQUES

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Bachelor of Science

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Stillwater, Oklahoma

1977

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1980

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Report Approved:

Report Adviser

Dean of Graduate College

PREFACE

My interest in aquariums began at the age of four when my mother set up a ten gallon tank with some guppies and swordtails. At about the same time, I remember going to a very small aquarium shop in Bartlesville and seeing a male Betta splendens busily replacing newly hatched fry in his bubble nest. I was immediately hooked. Over the years my interest grew to the point that now we have nine aquaria set up ranging from ten to fifty-five gallon capacity and a total capacity of 240 gallons. In recent years, friends and acquaintances have asked me to help them start their own aquaria or have come to me with their problems. Because my own experience has been mostly trial and error, I could not always help them. This report was originally conceived with the idea of learning more myself so as to be better able to help these friends. I learned a great deal and confirmed some opinions that I had previously formulated.

Because of the increased public interest in fishes and other wildlife in recent years, I felt that a section dealing with public displays was relevant to this report. I am pleased to say that some of these techniques have been utilized with great success at the Tulsa zoo as well as other zoos and public aquaria in recent years.

I wish to express my thanks to Dr. L. Herbert Bruneau for serving as chairman of my graduate committee as well as Dr. Bryan P. Glass and Dr. Milton R. Curd for serving as members of that same committee. Special thanks also to Stephen D. Walker, Aquarium Supervisor for the Tulsa Zoological Park, for providing materials on display techniques as well as giving general help and advice. Thanks also to my parents, Arch and Vivian Little, for all of their support and indulgence of my hobby interests as well as their encouragement toward my completion of this report. In addition, I thank my mother for typing the rough draft and Judi Metz for typing the finished product.

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CHAPTER I

INTRODUCTION

Fishes and other aquatic life have long played an important role in the lives of men. Since the invention of the first wooden spear, fish has been an important food source. Fish bones have been fashioned into fish hooks, needles for sewing, and ornamentation. Fish parts have been used to heal the sick, to fertilize crops, and to make any of a number of "magic" potions. Even in this day and age there are societies including the Eskimoes and the Polynesians which depend on fish as their main food source.

Today, the fishing industry provides a major source of the world's protein. Improvements in fisheries techniques have led to increased yields, especially in salmon fishing. In addition, stocking of lakes and streams by fisheries have led to increased interest in sports fishing. Fishing enthusiasts have accounted for millions of dollars in tourisim throughout the world.

In the past, people for the most part have restricted their interest to game or food fish. However, the idea of keeping live fish species for study and pleasure is far from a new one. There is considerable archeological evidence to indicate that the ancient Egyptians kept live fishes in large vessels or basins for the sole pleasure of looking at them. The Romans are known to have kept live fishes in pools called <u>piscinae</u> much as we keep goldfish in ponds today (Hoedeman, (1974). In the New World, the Aztecs apparently had extensive pools, both fresh and marine, in which fishes were kept for breeding and study. In the Far East, the Chinese kept extensive records on the keeping and breeding of goldfish as early as 1369. The art of fish breeding was introduced in the fifteenth century to Japan, where the many different varieties of goldfish were subsequently developed.

The aquarium hobby as we know it today, probably had its beginnings in the mid-nineteenth century. The first aquarium fish to be kept was the goldfish. In 1869 the paradise fish (Macropodus opercularis) was imported into France from China. This species is considered by many to be responsible for the tremendous growth of the hobby since that time (Innes, 1966; Hoedeman, 1974). Other species which have contributed greatly to interest in the hobby include the Siamese fighting fish (Betta splendens, introduced in 1874), the guppy (Poecilia reticulata, introduced in 1908) and the freshwater angelfish (Pterophyllum scalare, introduced in 1911).

While there are no compiled statistics concerning worldwide trade in the aquarium industry, 1973 estimates indicate a four billion dollar per year worldwide trade including live fish, aquatic plants, invertebrates and aquarium supplies and accessories. In the United States, an estimated 600 million dollars was spent for live fish and accessories as opposed to 520 million dollars for dogs and eighty-five million dollars for cats (Conroy, 1975). Conroy quotes Axelrod (1973) as estimating as many as twenty-two million aquarium enthusiasts in the United States by 1973. In 1971, the number of aquarium enthusiasts was estimated to be growing at a rate of fifteen percent per year, making the aquarium hobby the third largest hobby behind stamp collecting and photography (Kendrick, 1971). However, by 1978 the estimated increase had fallen to 4.8 percent per year (Tuthill, 1979).

In addition to the hobby and economic values of game, food and ornamental fishes, there has developed in recent years a good deal of interest in various fish species as subjects of many types of research. Research in such areas as disease control, feeding and propagation has been and is still being done in hatcheries, laboratories and public aquaria all over the country. At Marineland of Florida, research runs the gamut from shark control to the olfactory sense in the salt water drum (Carrl, 1977). C. L. Hubbs, considered by many to be the father of Ichthyology, spent his life investigating the process of speciation in shiners as well as other species while a professor at the University of Michigan and later at the Scripp's Institute of Oceanography (Miller, 1977). R. J. Miller (1977) has investigated speciation in several genera of Anabantids at Oklahoma State University based on anatomical, physiological and behavioral characteristics.

At one time, fisheries research and the research being conducted using aquarium fish were, for the most part, done separately. With the tremendous increase of public interest in all types of fishes, public aquaria and zoos are getting more involved in keeping extensive fish collections. These facilities are investigating areas in fishkeeping and propagation which can benefit the commercial fishery operator and the hobbyist alike.

Studies of various aspects of animal care in a closed aquatic system are of special interest to hobbyists, including advances in filtration, feeding and water chemistry. Studies in chemical toxicity have been done at the Shedd Aquarium in Chicago (Zumwalt, 1972) and at the Muddy Run Fish Behavior Laboratory in Lancaster County, Pennsylvania (Schutsky and Peterson, 1977), as well as sutdies concerning the effects of water temperature on various fish species. New methods of feeding have been devised such as the feeding of whole blood to invertebrates at Sea World of Ohio (Murru, 1979) or the gelatin diet developed for marine fishes at the Mystic Marinelife Aquarium in Mystic, Connecticut (Sciarra, 1977). Observations of breeding success in difficult to breed species have been reported for such animals as the giant octopus (Octopus dofleini) at the Vancouver Public Aquarium (Gabe, 1974) and the freshwater stingray (Potamotrygon motoro) at the Belle Isle Aquarium complex of the Detroit Zoological Park (Langhummer, 1979). Walker (1978) explains the use of a system for rearing larval marine fishes developed at the San Antonio Zoological Gardens and Aquarium.

The area in which public aquaria and zoos are showing the most progress in fishkeeping is in the area of disease control. Because of their ability to maintain large tanks (in excess of 10,000 gallons) public facilities are able to import many species not seen in the aquarium trade. Along with these imports have come parasites and diseases endemic only to certain areas of the world. Parasite identification and treatment within public facilities such as the work done on protozoan infestations at the Gulf Coast Research Laboratory in Ocean Springs, Mississippi (Lawler, 1977) or the Miami Seaquarium (Herner, 1979) or the work done in the treatment of all types of parasites at the Shedd Aquarium (Zumwalt, 1972) provides invaluable information for aquarium hobbyists.

Perhaps the most important function of the zoological garden or the public aquarium is the entertain the public, hopefully educating

CHAPTER II

LIGHT

In nature, light is probably the single most important environmental component of any complex ecosystem. Radiant energy from the sun is the catalyst for the photosynthetic processes of plants, which are not only the basis for most food chains, but also provide most of the earth's oxygen. Light produces heat energy which cold-blooded animals can utilize. Fishes get this heat energy indirectly through the water in which they live. In a natural system, water warms up very slowly due to its high specific heat. It takes a relatively intense and prolonged amount of sunlight to heat a body of water only a few degrees. Most naturally occurring bodies of water are large enough so that heat energy is dissipated through evaporation. In a closed system such as an aquarium, heat builds up faster than it can dissipate. For this reason, the amount of light must be regulated.

Light also affects the growth of aquarium plants. Too little light can cause many aquarium plants to literally fall apart. Gravel algae, incorrectly known as brown algae by most aquarists, forms as a brown film on the glass and rocks. This is not harmful, but undesirable (Vogt, 1963). On the other hand, too much light can lead to the uncontrolled growth of green algae. Green algae, if left uncontrolled, can completely cover glass, gravel and plants. Plants can be attacked by floating algae and eventually die.

Direct sunlight promotes algal growth and also tends to overheat small aquaria (Innes, 1966). For these reasons as well as others, the use of artificial light is desirable.

The use of artificial light gives the aquarist control over heat, plant growth and algal growth. However, there are limitations as to how electric lighting can be used. Basic room lighting, for example, may illuminate an aquarium, but is too weak to promote plant health. In order to be effective, electric lighting should be directly overhead and should be very close to the tank (Innes, 1966).

There are two basic types of electric lighting, incandescent and fluorescent. Incandescent lighting is much less expensive to install, costing one-half to one-third as much as a fluorescent fixture (Ostrow, 1979). Incandescent bulbs produce considerable heat which can be useful. In using incandescent lighting this must be kept in consideration because of the possibility of overheating. Also, because incandescent lights are so hot, they can burn the aquarist.

Fluorescent light, on the other hand, burns cool. This decreases the danger of overheating the aquarium. Fluorescent light is also much less expensive to operate. For example, a twenty watt fluorescent bulb produces about as much light as a sixty to one hundred watt incandescent light, therefore costing anywhere from three to five times less to operate (Ostrow, 1979). Also, because of their coolness, fluorescent fixtures and bulbs last much longer than comparable incandescent equipment. The one major disadvantage of using fluorescent lighting is that it does not effectively penetrate the water column the way incandescent lighting does. Because of this, fluorescent lighting has little or no effect on rooted plants. On large, deep aquaria, Ostrow (1979) suggests that both types of lighting be used to assure that all plants get the light they need.

Not only the amount of light, but also the quality of light is important. Plants need light from the red end of the spectrum as well as blue rays (Vogt, 1963; Innes, 1966). According to Innes (1966), ultra-violet lights have no special effectiveness on an aquarium although other authors disagree (Janze, 1964; Vogt, 1963).

There is also disagreement over the amount of light needed. Janze (1964) suggests that sixty watts per square foot be provided. A figure of one watt for every one-half inch of depth is advocated by Vogt (1963). Innes (1966) calculates for a ten-gallon tank the use of forty watts for eight hours or seventy-five watts for four hours; for a fifteen to twenty-five gallon tank, sixty watts for six to eight hours; for a twenty-five to fifty gallon tank, seventy-five watts for eight to ten hours. All figures are indicated as incandescent wattage.

All light and other electrical fixtures should be waterproof. Evaporation can lead to corrosion of fixtures which can decrease their life expectancy. Corroded metal from light fixtures can fall into the aquarium leading to metal poisoning of fishes. Wiring should be insulated with plastic rather than rubber. Rubber corrodes readily, leading to exposure of electrical wiring to water or to the aquarium frame. The use of plastic insulation serves to avoid the risk of electrocuting either the fishes or the aquarist (Janze, 1963; Ostrow, 1979).

CHAPTER III

SUBSTRATE

There is wide disagreement as to the type of substrate that should be used in the aquarium. Innes (1966), McInerny and Gerard (1966), and Brymer (1967) suggest the use of coarse sand and/or aquarium gravel in preference to fine sand. Fine sand packs too hard, restricting adequate circulation of water through it. Innes (1966) and Vogt (1963) discourage the use of soil or fertilizers of any kind. Other authors suggest the addition of organic substances such as leaf mould and peat (Janze, 1964; Hoedeman, 1974). This mixture should contain one part leaf mould, one part boiled peat and one part coarse sand or aquarium gravel. This mixture should be placed in the aquarium so that the surface of the substrate slopes upward from front to back. This substrate should then be covered with a layer of plain gravel.

Rocks can be used to achieve a natural effect in aquarium decoration. They can be used to build terraces in the substrate to accomodate different plant species (McInerny and Gerard, 1966; Hoedeman, 1974). Many fish species utilize rock overhangs or caves for resting and spawning sites.

The materials used in the substrate should be free of minerals which go into solution such as lime or zinc.

CHAPTER IV

PLANTS

The use of live plants is nearly always advantageous in an aquarium. Live plants are used to decorate the aquarium to enhance the natural appearance. In addition, plants have several practical functions. First, plants can be used to test water chemistry. Most plants will not survive in overly hard or acid water. By competing for light and nutrients in the water, plants serve as inhibitors to algae growth. At the same time, plants contribute to water filtration (Vogt, 1963). Many fish species incorporate plants into their diets. The leaves and roots of aquatic plants serve as shelter and/or egg-laying sites for many species (Will, 1971). Perhaps the most important benefit derived by the use of aquatic plants is their contribution of oxygen to the water as a bi-product of photosynthesis.

There are hundreds of species of aquatic plants, most of which have not been seen in the aquarium trade. Several new species are being introduced to aquarists each year. Stodola (1967) classifies aquatic plants into ten categories based on growth habits ranging from small floating plants with some parts (roots, leaves) reduced to large shore plants requiring water in the growing medium. For aquarium use it is easier to categorize aquatic plants into three general groups (Will, 1971). Group one consists of the tall bushy plants which grow in bunches. These are used mostly as background plants. Examples of these would include several species of _Cabomba_, _Elodea_, _Ludwigia_ and _Myriophyllum_. The second group comprises all floating plants. These plants provide shade as well as hiding places for timid fishes and fry. These plants also aid in diminishing evaporation to some extent. These range from duckweeds (_Riccia_, _Lemna_) and waterferns (_Salvinia_) to the water lettuces (_Pistia_) and banana plants (_Nymphoides_). Plants which are rooted in the substrate comprose the third group. These include the genera _Vallisneria_, _Sagittaria_, _Cryptocoryne_ and _Synemma_. Some species such as water sprite (_Ceratopteris_, _Thalictroides_) grow as both rooted and floating forms.

Maintenance of healthy aquarium plants requires the same knowledge of temperature tolerances as does the maintenance of healthy fishes. Different plant species have different ranges of temperature tolerance. With this in mind, different plants can be placed in aquaria with fish having similar temperature tolerances. In addition, different plant species have different lighting requirements both in intensity and duration. Some plants require the application of fertilizers in addition to the nutrients provided by natural processes. To know the requirements of various aquatic plants the aquarist's library should include at least one of the several good books currently on the market which deal with this subject.

Most aquarium plants propagate vegetatively either by budding or by sending out runners along the substrate. The offshoots can be separated from the parent plant and replanted. Some plants can be separated at the crown into two or more parts, each part being replanted.

Several methods of planting have been used with success in the aquarium. Most rooted aquarium plants have evolved a system of taking nutrients from the water through the leaves. The roots of these plants serve mainly to anchor the plants in the substrate. When setting these plants in the aquarium, care should be taken to avoid damaging the roots. Root damage can be avoided by winding the roots around a finger. After making a hole in the substrate, the roots should be pressed deeply in and covered. The plant then should be lifted slightly to allow the roots to begin to spread (Hoedeman, 1971). Innes (1966) suggests the use of a notched stick to press the plant into the substrate.

One technique which has proved advantageous is the setting of aquarium plants in removable trays. This facilitates cleaning and netting hard-to-reach fish while minimizing damage to the plants (Innes, 1966). Earthenware or glass trays are the best to use, but non-toxic plastic trays will serve the purpose just as well.

CHAPTER V

WATER CHEMISTRY AND CONDITIONING

Most fresh water fish are highly adaptable to a fairly wide range of water conditions. In nature the interactions of plants and animals with their environment tend to maintain the proper physical and chemical balance for the survival of all species involved. Therefore, only drastic changes in temperature or climate or man-made chemical changes can drastically alter the biological makeup of any given area.

In the closed aquarium, extreme environmental changes can occur quickly. While it is true that most freshwater species can adapt to a variety of conditions, they cannot be expected to survive in the exaggerated environmental extremes to be found in many aquaria. With some basic knowledge of water chemistry, the proper equipment and proper routine maintenance, even the most delicate fish species can be successfully maintained.

Water Chemistry

Water chemistry is a subject which some even otherwise experienced aquarists avoid. Yet the concepts of acidity and water hardness, the two basics in water chemistry, are not difficult to understand. Water has the ability to carry differing amounts of dissolved gasses and solids depending on the water temperature and pressure. The amount of solids that can go into solution increases as the water temperature increases. At the same time, gasses in solution decrease with increases in water temperature. Gasses and solids both show increased solubility when the pressure of water is increased. Because of these properties, water can show both differing acidities and dissolved solids depending on the temperature and pressure of the water being tested. This is one important reason for regulating the temperature of the aquarium.

pH

The acidity of a solution is measured on a pH scale first developed by the Danish chemist S. P. L. Sorensen (Capon, 1980) and refers to concentration of positive (H+) ions or negative (OH-) ions in the solution. The solution is said to be acidic if the concentration of positive ions exceeds the concentration of negative ions, or basic if the concentration of negative ions is greater. The pH scale ranges from zero to fourteen. A pH reading of seven is said to be neutral; that is, the concentrations of positive and negative ions are equal. As the pH readings increase from zero to fourteen, the acidity decreases and the alkalinity increases (Axelrod, 1955).

There are two methods used for determining the pH of a solution. The first is the colorimetric method. This uses test paper saturated with a dye that changes colors at different pH levels. Most pH test kits sold in aquarium shops use this method. The second and more accurate method uses an electeic meter attached to two electrodes. The electrodes are placed in the solution to be tested, and an electric current is passed through them. The current is offset by any excess positive or negative ions and the pH is read from the meter.

In nature, most freshwater fish species are found in areas with pH readings between six and eight. There are, however, some notable exceptions including the lake cichlids of the African rift valley, where pH readings in excess of 9.2 are not uncommon (Axelrod, 1975). In the aquarium, pH can change drastically in the course of an hour. Several factors contribute to the overall pH in the tank; the source of the aquarium water, the respiratory rates of the plants and animals, and the temperature of the water, to name a few. If uneaten food is left in the tank, the resulting bacterial decomposition can send the pH plunging. The best prevention for this problem is siphoning off excess food and frequent water changes. For maintenance purposes or if setting up a special tank with pH levels other than normal, several easily obtainable chemicals may be used safely. To raise the pH, or decrease acidity, sodium bicarbonate is recommended. To lower the pH or increase acidity, sodium acid phosphate or tannic acid may be added to the water, or the water may be filtered through peat moss (Axelrod, 1955). If peat moss is used, the special peat plates sold in most aquarium shops are best. Nursery grade peat may be used if it is free of the toxic chemicals used by some processors. If nursery grade peat is used, it should be boiled in a Pyrex or a stainless steel vessel for four or five hours to remove excess humic acids which can cause short-term pH problems (Ostrow, 1978).

Daily fluctuations in pH are not at all unusual in the aquarium, especially if live plants are used as part of the decor. The photosynthetic process utilizes much of the carbon dioxide given off as respiratory waste by both plants and animals. Carbon dioxide in solution contributes to an increase in the acidity of water. As photosynthesis removes CO_2 from the water during the day, the pH steadily increases. At night photosynthesis ceases and respiratory CO_2 is allowed to build up, resulting in a decrease in pH (Capon, 1980).

Water Hardness

The other major chemical property which should be of particular concern to aquarists is water hardness. Water hardness refers to the quantity of dissolved mineral salts in the water and is divided into two categories. The first category is made up of those salts which dissolve readily in water and remain in solution permanently. This permanent hardness is made up mostly, but not exclusively, of magnesium salts (Cust and Bird, 1971) and sulfates (Ostrow, 1978). In addition to these compounds, other compounds including calcium carbonate and bicarbonate contribute to temporary hardness. It is changes in the concentration of these compounds that determine any changes in the observed hardness.

The most common method for determining water hardness is the soap test (Axelrod, 1955; Cust and Bird, 1971). Soap forms suds more readily in soft water than in hard mineral-laden water. For this determination, a standard soap solution (B and B Soap Testing Solution) is added one drop at a time to a known volume of water. After each drop is added, the solution is shaken. This procedure is repeated until suds form. The number of drops of soap used is then converted to parts per million of calcium carbonate dissolved in the water being tested. In addition to the soap test, there are colorimetric DH test kits on the market which can be obtained from most aquarium shops.

Water hardness may be expressed in three ways. The first, which has already been mentioned, is expressed as parts per million of calcium carbonate (ppm $CaCO_3$). The second is expressed as grains of calcium carbonate per one gallon of water and is referred to as Clark degrees. The third and most common designation found in aquarium literature is the German degree of hardness (DH), expressed as parts of $CaCO_3$ per 100,000. Any one of these scales may be found in different books so it is useful to remember that one Clark degree equals 14 ppm or 4/5 DH (Cust and Bird, 1971).

It is useful to remember that, although not equivalent, pH and DH are related. Alkalinity is determined by the $CaCO_3$ and bicarbonate content; these chemical compounds, as stated earlier, are also responsible for water hardness. Although pH and DH are separate factors in nature, hard water is nearly always alkaline. Acid water is usually due to the presence of peat or decaying vegatation in the water, which tends to soften the water as well.

There are several methods one can use to adjust the hardness of aquarium water. To harden water, sodium bicarbonate may be added or dolomite used as the gravel substrate. Another alternative is to add a chunk of hardened pure plaster of Paris to the filter (Ostrow, 1978). This has the advantage of hardening the water gradually. All of these methods tend to increase the pH as well (Capon, 1980). Water may be softened through the gradual addition of distilled or rain water (Axelrod, 1955) or by filtering through peatmoss containing no chemical additives. This last method can also drastically increase the acidity, as previously mentioned.

As stated earlier, most fish species can adapt themselves to pH and DH values which are different than those found in their home ranges.

Even very delicate species can be successfully maintained as long as careful attention is paid to their other requirements. However, if fish can be maintained in water with pH and DH values similar to those found in their natural habitats, they will obviously do better. In fact, if breeding is desired, most fish species have very limited breeding ranges (Vogt and Warmuth, 1963).

Conditioning

Before fish are ever placed in a tank, the water should be conditioned. Depending on the source, there are different methods used in conditioning. According to Axelrod (1955), if tapwater is used, it should be allowed to stand at least one week. This allows any chlorine gas, used by many cities for purfication, and lethal to most fish, to escape. It also allows time for the oxygen concentration in the tank to stabilize (Axelrod, 1955). However, there are artificial water conditioners on the market which chemically remove chlorine as well as other harmful substances. Rainwater may be used, but it should be collected only after it has rained steadily for a sufficient length of time to wash down any industrial pollutants in the air (Dutta, 1972). Because of man-made atmospheric pollutants, Montadore (1976) discourages the use of rainwater altogether. If rainwater is used, it should be collected in clean, non-toxic containers. Run off from tin roofs should never be used because of their high zinc content (Hoedeman, 1974). In addition, since pure rain water contains no chemicals, pH and DH adjustments will surely need to be made (Cust and Bird, 1971). Axelrod (1955) suggests conditioning of rainwater for forty-eight hours for aeration. The same thing applies to the use of distilled water. If, for some reason, lake or stream water is the source, it should be allowed to stand two weeks to allow any fish parasites time to die off without finding a host. This also allows all of the suspended organic matter to settle out.

If the water becomes cloudy after the tank is established, it generally indicates a bacterial build-up in response to a build-up of uneaten food (Axelrod, 1955). To avoid this condition, any uneaten food should be siphoned off or a sufficient number of scavenger species should be provided to utilize the uneaten food. To rid a tank of this condition, any uneaten food should be siphoned off and feeding should cease until the water clears up. Clearing should occur within forty-eight hours (Innes, 1966).

Green water is another problem which occurs in many tanks. This condition is actually an algal bloom in response to the nutrients from fish waste in combination with bright light. Proper filtration will help to avoid this condition, but if it should occur, the light should be removed. The tank should be covered if possible. This interferes with the photosynthetic process of the algae and the algae dies off within a few days. One word of caution; since the photosynthetic process is interrupted, no oxygen is released into the water. A carbon dioxide build-up will occur due to the respiratory processes of both plants and animals in the tank. To avoid this CO_2 build-up, an airstone should be placed in the tank. In some cases, green water is useful. It is rich in food for new fry and, if thick enough, can prevent new fry from being eaten by the parents. Daphnia cultures are also easily propagated in green water.

CHAPTER VI

AERATION AND FILTRATION

Fishes, like all animals, require oxygen to live. While some fish species have the ability to utilize atmospheric oxygen, most species are limited to extracting dissolved oxygen from the water in which they live. Water is eight hundred times more dense than air (Marshall, 1966), but the oxygen content is much lower. In addition, oxygen and carbon dioxide diffuse much more slowly in water than in the atmosphere. Fishes live in natural habitats in which the exchange of gasses is facilitated either by large surface areas, as in lakes, by movement as in streams, or a combination of both. These same processes occur in the aquarium, but to a much lesser degree, because of the limited surface area of an aquarium in relation to its depth coupled with the severe restrictions of water flow (Ostrow, 1978). For these reasons, as well as others, most authors recommend the use of mechanical aeration.

Aeration

The simplest aeration system used in most aquariums consists of an electric air pump, a length of rubber or plastic tubing and a porous airstone. There are two types of air pumps on the market, the piston pump and the diaphragm pump. The diaphragm pump works by means of an electromagnet set beneath a rubber diaphragm. As the electromagnet vibrates, it causes the diaphragm to vibrate, setting up a current of air which is funneled through the rubber tubing. While most pumps of the diaphragm type are inexpensive and quiet, they have the disadvantage of seldom being very powerful (Hoedeman, 1974). The piston pump is much more powerful and also much more expensive (Cust and Bird, 1971). It delivers the air in bursts rather than in a steady stream as the diaphragm does. The worst problem with the piston pump, however, is that it has to be periodically rested to prevent overheating. Continuous running can cause this type of pump to burn out (Dutta, 1972).

There is some disagreement as to exactly how the air pump aerates the aquarium. The principle means in nature and in the aquarium by which oxygen is taken into water for use by fishes and other aquatic organisms is by mixing of air and water molecules at the water surface (Ostrow, 1978). Most authors (Vogt and Wermuth, 1963; Innes, 1966; Dutta, 1972) agree that an aerator's main use is in causing surface agitation thereby allowing more efficient exchange of carbon dioxide and oxygen (Cust and Bird, 1971). Vogt and Wermuth (1963) indicate that an aerator introduces oxygen into the water directly, but most authors consider this insignificant. According to Hoedeman (1974), the aerator does not give off oxygen directly but rather promotes circulation of bottom water to the surface. This not only increases gas exchange at the surface, but it also causes oxygen to be more evenly distributed throughout the tank.

The most common error made by aquarists regarding aeration is in the location of the air pump in relation to the tank. The pump should be placed above the tank to keep water from entering the pump through the rubber tubing by siphon action (Hoedeman, 1974). If the pump has to be placed below the level of the water surface, the tubing should be long enough to place several coils above the tank. The coils should be three or four inches in diameter and may be bound together with the twist ties used to secure trash can liners. The coils may then be concealed on the tank cover behind the light fixture or taped to the wall above and behind the tank (Gilbert, 1977).

Filtration

In addition to proper gas exchange, there is another major problem that occurs in the aquarium. In nature toxins are produced by bacterial decomposition and metabolic wastes as well as being introduced in the form of pollutants. In a stream environment these toxic compounds are constantly washed away while in lakes these compounds break down into less harmful substances. These cleaning processes do not occur in the aquarium without mechanical assistance. The various types of aquarium filters currently on the market are made to provide this assistance.

There are three components of filtration needed in the aquarium (Terciera, 1977). These are mechanical, biological and chemical filtration. Mechanical filtration is the removal of particulate matter from the water such as bits of food, decaying vegetation or solid animal wastes. There are several types of filtering material which may be used. The most popular filtering material is made of synthetic polyester fibers resembling glass wool, another popular filtering material. Other materials used include sand, the aquarium gravel, and diatomaceous earth (Wolf, 1975). As water passes through these materials, any particulate matter is trapped. Any of these materials are acceptable for aquarium use as long as water can pass through them. If the filtering material is not porous enough or becomes clogged with debris so as to interfere with water flow, the filtering action will cease and the filtering material can actually be more harmful than if no filter were used at all.

Biological filtration is probably the least understood area of aquarium filtration and yet may be the most important (Terciera, 1977; Ostrow, 1979). The biological filter is made up of certain types of bacteria in the aquarium. These bacteria break down many toxic compounds given off as waste products by the fishes and produced by the decomposition of organic matter. These compounds are broken down into harmless substances, some of which are then utilized by aquarium plants.

These bacteria literally cling to every surface within the aquarium and filter including each grain of gravel, rocks, plants and even live fish. For this reason, the gravel layer can provide a very efficient biological filtering system. For the biological filtration system to maintain its efficiency, the mechanical filter must be efficient enough to prevent solids from becoming imbedded in the gravel and impeding the water flow to the bacteria. Restricted water flow results in insufficient oxygen and nourishment. Without the biological filter, nitrogenous wastes build up in the water and eventually poison the fish. In addition, anaerobic bacteria may proliferate and produce poisonous gases such as hydrogen sulfide, which not only gives the tank the smell of rotten eggs, but also eventually kills fishes (Terceira, 1977).

It takes two to four weeks for the bacteria to become established in newly set-up fresh water aquaria and about twice that long for marine tanks. In a freshwater tank a few fish can be introduced before biological filtration is totally established.

Chemical filtration is the third component of filtration of concern to aquarists. This component removes chemicals which cannot be removed by the biological or mechanical filters, including such chemical compounds as cigarette smoke and cooking fumes, as well as chemicals introduced in other ways. Wood charcoal and activated carbon serve as both a mechanical and chemical filter (Montadore, 1976). The intricate surfaces in these filter materials are able to extract a wide variety of toxic substances through the process of absorption. The positively-charged surfaces of activated carbon and charcoal remove negatively-charged organic compounds as well as certain ions including copper, zinc, iodine, odor molecules, gas molecules and taste molecules. It should be noted, however, that activated carbon cannot extract urea, which can only be eliminated through biological breakdown.

Filter Types

There are three basic types of filters on the market; the underground, the inside box type, and the outside power filter, each of which incorporates all three components of filtration. The oldest type is the undergravel filter. This system consists either of a gridded platform placed beneath the gravel or a system of perforated tubing running through the gravel (Wolf, 1975). Attached to the platform or tubing grid is a piece of plastic pipe known as an output pipe. Depending on the size of the aquarium, there may be one or several of these. An air pump is then attached with a piece of rubber hose to the base of the output pipe. When submerged and started, the air pump forces the air to bubble up through the output pipe. This creates a vacuum effect causing the water to circulate down through the aquarium gravel. In addition, the bubbling action agitates the surface of the water, promoting gas exchange (Hoedeman, 1974). The gravel serves as a mechanical filter and a medium for the biological filter as well. After the water passes through the gravel it flows to the output pipe and the cycle is repeated. Most filters of this type come with cartridges of activated carbon which, when attached to the ends of the output pipes, serve as chemical filters.

For this type of filter system to work at its maximum efficiency, the gravel layer should be of uniform thickness throughout the tank to ensure even water flow. Uneven flow can lead to a rapid build-up of anaerobic bacteria (Wolf, 1975). It is because of this that an undergravel filter is not recommended for tanks containing species which dig such as the larger South American cichlids or most African cichlid species (Goldstein, 1973; Axelrod, 1975).

The undergravel filter is an inexpensive and efficient filtration system if properly maintained. If set up properly, this type of filter has the added advantage of being fairly unobtrusive (Wolf, 1975). The biggest disadvantage of an undergravel filter involves the necessity to completely break down the tank in order to clean the filter (Wolf, 1973; Montadore, 1976).

The inside box filter works in a similar manner to the undergravel filter. The output pump is attached to the bottom of a plastic box containing a layer of charcoal under a layer of filter floss. The water flows in a current along the gravel surface and is drawn into the filter through the slotted top. Bacteria colonize the filter floss as well as the gravel bottom so that all three filtration components are taken care of by this type of filter as well. The inside box filter is especially good for use in tanks containing small fry. When the filter is started, the vacuum effect keeps the filter floss in place so that the top of the box may be removed. With the filter set up in this manner, small fry can pick food particles from the floss without getting trapped in the filter (Manners, 1977). The inside box filter has the added advantage of being easy to remove and clean. It is not very efficient, however, in that much of the particulate matter never makes it to the filter and may build up in the gravel. A variation of this system consists of a box which hangs outside the tank and is fed water through a siphon (Wolf, 1975).

The outside power filter is the newest and most efficient type of filter currently on the market. This type of filter utilizes an electric motor to turn a rotating magnet. The motor housing is attached to a plastic box which hangs outside the tank. This box contains a tube, the return tube, which has a free rotating magnet at its base. This magnet, which is attached to a propellor apparatus, is turned by the magnetic force of the electrically controlled magnet. The propellor pushes water up through the return tube and into the aquarium. This system also is known as a centrifugal pump (Montadore, 1976). The filter is fed by a siphon tube. The plastic box contains a layer of activated carbon topped by a layer of filter floss. Water is drawn up into the filter box by the siphon tube and flows over the floss, through the carbon and then is returned to the aquarium via the return tube. This type of filter comes in several sizes with circulating capacities from twenty to two hundred gallons per hour (Wolf, 1975;

Dutta, 1972). This provides a strong enough current in the tank to keep any particulate matter in suspension long enough to be filtered out eventually. The power filter is especially useful in cichlid tanks previously mentioned. The high circulation rate promotes maximum gas exchange at the surface, and ensures continuous mixing of the water (Montadore, 1976). There are several variations of this type filter currently on the market, some of which are fairly inexpensive. They are easy to clean and if properly maintained, remain efficient. Maintenance includes keeping the tank's water level high enough to permit proper siphon action.

Montadore (1976) suggests the use of some additional materials in the outside power filter. Pumice chips can be mixed with the activated carbon to release trace elements which may, in turn, be utilized by plants. In addition, marble chips may be added to act as a pH buffer. For fishes requiring water of high acidity, peat moss may be used as the filtering material in the place of filter floss (Ostrow, 1980).

One interesting variation of the outside power filter is the diatomaceous earth filter. This system utilizes the siliceous shells of diatoms as the filtering medium and is capable of straining microscopic particles from the water (Ostrow, 1979). This type of filter should not be used in the place of the other filter types but should be used only to augment the effectiveness of the other filtration systems. The diatomaceous earth filter should only be used a few hours per week and only on tanks containing fishes that are large enough and strong enough to withstand the strong current produced by it.

No matter what kind of filter is used, it should be remembered that no filter is totally efficient. Periodic partial water changes are essential to keep various chemical and organic toxins from eventually building up and interfering with the health of the tank's inhabitants.

CHAPTER VII

TEMPERATURE CONTROL

The most common error made by the majority of aquarists, especially those just starting out, is the failure to properly control the water temperature in the tank. Fishes, being cold-blooded animals, have no mechanism for controlling their body temperature. This means that their body temperature as well as their metabolic rate is directly affected by the temperature of their environment (Hopkins, 1971). In other words, as the water temperature decreases, so does the metabolic rate of the fish. The result is that fishes seem to have evolved into environments having a narrow range of temperatures (Wolf, 1977). Fishes kept at temperatures below their tolerance can develop gastro-intestinal distress, constipation or swim bladder disease (van Duijn, 1973). They are also more susceptible to parasitic infestations such as white spot because of the fishes' reduced resistance coupled with the increased vigor of the parasite (Ichthyophthirius) in lower temperatures (Innes, 1966). Excessive heat, on the other hand, lowers the concentration of dissolved oxygen in the water while raising the metabolic rate of the fishes, thus increasing their oxygen requirements. In extreme cases, the fishes can die of starvation due to the failure of the food supply to match the increased metabolic rate. They also might die of suffocation (Wolf, 1977).

There are several factors which influence changes in water temperature. Obviously, air temperature is the major influence over aquarium temperature. Bacterial, plant and animal respiratory and metabolic activity could contribute to minor increases in temperature. These are usually counteracted by the cooling effects of evaporation and the circulating action of the air pump and filtration system.

As stated earlier, fish have evolved into environments having rather narrow ranges of temperature. Different species have different optimum temperatures. For this reason the aquarist should be aware of a particular species' temperature range and optimum temperature before attempting to keep it. Most "tropical" fish species come from areas in which there is very little fluctuation in temperature. For these fishes, control of the aquarium temperature is crucial. Temperature control is not as important for temperate zone fishes because of the greater fluctuation of both daily and seasonal temperatures which naturally occur. With most fishes the amount of temperature change is not nearly as critical as the speed with which the change occurs (Innes, 1967; Wolf, 1977).

The first step in controlling aquarium temperature is knowing the temperature. Each aquarium should have its own thermometer. There are several types on the market including those that float, those that hang on the aquarium rim and those that sink. If an aquarium heater is employed, the thermometer should be placed in the tank as far away from the heater as possible.

There are also several different types of heaters currently on the market ranging from undergravel "hot-plate" types to the glass tube type which clamps to the rim of the tank. Generally speaking, heaters should be checked frequently to be sure that the thermostat is working properly. For most standard sized aquaria a semi-submersible heater is sufficient if there is adequate water circulation. For deep aquaria, Vogt (1963) suggests the use of a fully submersible heater with an airstone placed beneath it to faciliate circulation.

There is one peculiar problem with thermostatically controlled heaters which went unrecognized until 1976. A connected heater which is shut off only by a thermostat will sometimes generate a harmful electrical field in the water. This electric field has a more detrimental effect on some fish species than others. An electrical device called a multi-tester is needed to check for the presence of such a field. If the presence of an electrical field is verified, the solution is simply to rotate the heater's plug 180° in its socket (Wolf, 1977).

While most authors tend to agree on the use of electric heaters in aquaria, there is some disagreement as to the size and heating capacity needed to control temperature. Since small tanks generally lose heat faster than larger tanks, the heaters need to be proportionally more powerful. A heater's output can be estimated if the wattage rating is known. According to Brymer (1967), approximately one watt is needed to raise the temperature of one gallon of water by four degrees fahrenheit. Vogt (1963) suggests that for aquaria in heated rooms, heaters should be used at a ratio of one watt to four pints of water; aquarium heaters in unheated rooms should be used at a ratio of one watt to two pints. Other authors tend to use the rule-of-thumb figure of five watts per gallon (Wolf, 1977). Ostrow (1978a) suggests 2.5 to five watts per gallon for aquaria with capacities of twenty gallons or less. Proportionally less wattage is needed for larger tanks.

CHAPTER VIII

FOOD AND NUTRITION

The best food for most fish species is fish (Goldstein, 1973). This is, of course, an oversimplification, but it illustrates the point that live foods are, in most cases, much better than prepared foods. Hoedeman (1974) advocates the use of dry or "flake" food only as an auxiliary in cases where a good live food supply cannot be maintained. Other authors, such as Axelrod (1955) and Innes (1966), hold a more moderate view point. All authors appear to agree, however, that maintenance of healthy fish requires variety in their diet and that the diet should include a generous proportion of live foods.

In the wild, a wide variety of live foods are utilized by fish. Most of these occur with seasonal abundance and are, therefore, not practical to try to maintain. Still, there are a great many species which can be maintained in fairly large numbers, some of which make excellent fish food. Among the easiest to maintain are several species of the genus *Daphnia*. These small crustaceans thrive in old water with a great deal of algal growth and other biological action. They do best in cool water (65 - 70^{o}F.); supplemental aeration is desirable but not absolutely essential. When fed a diet of brewer's yeast, fairly large *Daphnia* cultures can be maintained in fairly small quarters. A twenty-gallon long aquarium can support a large enough culture for most hobbyists. Commercial breeders and public aquaria can maintain larger cultures just as easily. Newly hatched Daphnia are small enough to be taken by the fry of most fish species, while full-grown Daphnia can be used to feed even fairly large species of fish such as adult angelfish (Pterophyllum scalare). Livebearers seem to do particularly well on a diet of these crustaceans. However, Innes (1966) discourages the exclusive use of Daphnia saying that they may be constipating.

Brine shrimp of the genus Artemia also make excellent food for tropical fishes. The eggs of these small crustaceans are practically indestructable and are shipped all over the world. The method of hatching is simple. Six tablespoons of non-iodized salt to one gallon of water is the proper mixture for hatching. The water should be well aerated so that there is a fairly vigorous stirring action. Just enough eggs should be added bo barely cover the surface of the water. After hatching the new shrimp can be collected by shining a light in one corner of the container; the shrimp will congregate in the light and may then be siphoned off through a very fine net. The shrimp can be raised in much the same manner as Daphnia. Most authors agree that newly hatched brine shrimp are the best food for newborn fish. Both newly hatched and adult brine shrimp can be bought in frozen form. While there is some evidence that the freezing process negates some of the nutritive value of brine shrimp (Alexrod, 1955), most smaller fish species seem to thrive on a diet with this as the main component. If either the live or frozen forms are used, frequent partial water changes should be made so as to eliminate the problem of salt buildup in the aquarium.

Another good food species for smaller fish which is fairly easy to maintain is the fruit fly, Drosophila melanogaster. A flightless strain of this species has been developed which can be obtained commercially. These may be raised either on rotting fruit or on an artificial agar medium such as that described by Boucher, (1978). Most top-feeding fish species will accept these eagerly.

Boucher (1977) proposes the culturing of mosquito larvae of the species Culex pipiens which, although they are excellent food, require a blood feeding by the female before reproduction. This blood requirement can be fulfilled by squeezing raw liver into a recessed microscope slide. The adults can be maintained in a fine screened bottomless cage built over an aquarium. The larvae should be provided with a culture of protozoans to feed on. If the aquarium is provided with a two inch layer of river mud or some similar medium, tubifex worms can be raised simultaneously with the mosquito larvae. These worms also make an excellent supplemental live food.

Other good live food species which can be cultured fairly easily include the larvae of certain chironomids, commonly called "bloodworms" (Boucher, 1976). One of the highest protein foods is the species Enchytraeus albidus or white worm (Stansbury and Nordheim, 1976). These as well as the common earthworm may be cultured in a fifty-fifty mixture of garden soil and peat moss on a diet of white bread. One word of caution should be added concerning these; their protein and fat levels are too high for many fish if fed as a steady diet.

For larger fish such as the larger South American cichlids, earthworms are an excellent food. Perhaps the best food for larger fish species is live fish. Livebearers, such as guppies or mollies, can be raised easily for this purpose. Goldfish can be obtained as a fairly cheap food source as well.

If, for some reason, live foods are difficult to obtain or maintain, small fish can be fed shaved beef heart along with any good commercially prepared food. Larger fish can take strips of beef heart. If beef heart is used, all fat should be trimmed away beforehand. Griffiths (1971) suggests a blend of ground earthworms, beef heart and brine shrimp, all good protein sources, mixed with lettuce or spinach for roughage. It is important to include these vegetable materials even for exclusively carnivorous species. In nature, these carnivores feed on herbivorous species including any undigested vegetable materials in the herbivore's gut.

A common error in feeding display fish is ignoring the various methods of feeding. There are four general feeding categories found in fishes (Griffiths, 1971). The first and largest group consists of the grazers and nibblers. Most grazers are either herbivorous or omnivorous, feeding on such things as algae, benthic and pelagic crustaceans and plankton. These species do best on foods such as Daphnia, mosquito wigglers or white worms. They also are the species which adapt best to commercially prepared flake food. The second feeding group consists of the suckers. Because of their tendency to be scavengers, these species require foods which sink to the bottom of the tank. Benthic organisms make excellent foods for these sucker species. The third major feeding group is the active predators. These species are characterized by sharp teeth and shorter intestines. Some are built for bursts of speed while others hunt by stealth. The key word here is "hunt". All predatory species are considered active hunters as opposed to those grazers which feed on animal materials. The fourth feeding group consists of those species which are parasitic, such as lampreys. Because of the need to provide a host for the parasite, these species are rarely, if ever, seen in captivity.

Nutritional requirements vary from species to species (Griffiths, 1971); however, as long as the diet is varied and care is taken to remove any uneaten food, most captive species can be kept and propagated successfully. Uneaten food can be removed either with a net, a good filtration system, or by scavenger species.

CHAPTER IX

DISEASE CONTROL

There are three main aspects to be considered under the heading of disease control; prevention, symptom recognition and eradication. Disease prevention involves the practice of good aquarium maintenance techniques. Maintenance of a proper aquatic environment includes reliable temperature control, proper water chemistry, the right amount and type of light and a reliable filtration system. All of these are discussed in previous sections. Another important point is that of overcrowding. Animals that are in overcrowded conditions are more prone to communicable diseases. This is especially true for aquatic animals. Aquatic organisms have more direct contact with the toxins and pathogens in their environment. Overcrowding contributes to the build-up of toxins in the aquarium as well as increasing the rate at which disease can be transmitted throughout the population.

The third point in the discussion of disease prevention is the idea of isolating incoming specimens. Many aquarists have lost whole tanks of fish by introducing a diseased animal into the aquarium. All incoming animals should be quarantined in a separate tank set up exclusively for that purpose, for at least two weeks, preferably longer. Most diseases should become apparent within a month of arrival. The quarantine tank should be set up so that its environment resembles the environmental conditions into which the organism will ultimately be placed. This serves to eliminate environmental stress factors which could lead to disease or decline in the organism. In most cases, the organism can be placed in the permanent tank at the end of the quarantine period with little danger of exposing the previous residents to any disease.

There are times, despite all efforts to prevent it, when disease will find its way into any aquarium. It is, therefore, most important for the aquarist to be able to recognize and look for any signs of distress or disease. There are several easily recognizable symptoms of distress. However, any one symptom by itself might not be diagnostic. Sometimes a disease manifests itself by a series or combination of symptoms. In some cases a fish might show no diagnostic symptoms. These cases might require sacrificing an individual organism in order to dissect it. Therefore the aquarist needs some dissecting skills as well as the ability to recognize diseases to internal organs.

Some of the most common and easily recognized signs of stress or disease include the following. Any change in coloration can be a sign of stress, although this is not always the case. Some fish show temporary discoloration in reaction to the introduction of strong light. Sometimes fish temporarily lose their colors when they are frightened. Only when discoloration occurs for a long period of time should the aquarist become concerned. Abnormal growths or excretions of the skin are almost always signs of parasitic or bacterial infestation. Most bacterial skin diseases cause red spots on the skin and in the muscles in advanced stages. Other skin diseases can be recognized by observing abnormal swimming behavior such as rubbing up against rocks, plants or other materials. This behavior also occurs as a reaction to larger parasites such as the fish louse.

With many diseases, a fish will linger in one position, either near the surface or near the bottom of the tank, with its fins folded. Folded fins are not always a sign of disease; it may be due to nothing more than too low water temperature. Breathing difficulties may be a sign of gill disease or thermal shock. Pale gills are always a sign of disease.

Diseases of the internal organs are generally recognized by abnormal swelling or emaciation of the belly accompanied by loss of appetite. However, swelling may be due to nothing more than constipation which can be avoided by feeding a varied diet and not overfeeding. If a fish shows blood flecked excrement, an intestinal inflamation is almost always the cause.

The loss of swimming equilibrium is a sure sign of some swim bladder disorder. Sometimes with constipation, the swim bladder may be squeezed by the swollen intestine causing loss of equilibrium. In this case, the loss is temporary. In other cases, the swim bladder may itself be infested with bacterial disease. There is little that can be done to save a fish with swim bladder disease.

No aquarist should be without at least one good book dealing with diseases of aquatic organisms. Several good books concerning the classification, recognition and treatment of fish diseases are currently on the market. Another necessity is a good medicine chest. Most of the commonly occurring fish diseases are treatable with standard and easily obtainable chemicals. A thorough review of the most commonly used chemicals and drugs is given by van Duijn (1973). Tabulated information concerning observed symptoms, possible causes and methods of treatment are given in a very good book by Reichenback-Klinke and Elkan (1965).

CHAPTER X

A FEW WORDS ABOUT MARINE AQUARIA

At one time or another, almost every aquarist gets the urge to set up a marine tank. The bright colors, bizarre shapes and unusual behavior patterns exhibited by many saltwater species have tempted both novice and experienced aquarists equally. Yet many aquarists fail to pursue this ultimate goal because of the difficulties and expenses which they perceive to be involved in marine fish keeping. Many fresh water aquarists have the misconception that, in order to maintain a marine tank, one needs a degree in marine biology, a small fortune and lots of spare time (Romaine, 1979). This simply is not true. Setting up and maintaining a marine tank involves essentially the same techniques, with a few modifications and extensions, as those employed by the experienced fresh water aquarist (Vogt and Wermuth, 1963).

Setting Up the Marine Environment

Creating a suitable marine environment has been greatly simplified in the last few years with improvements in filtration, improvements in monitoring water chemistry and the introduction of quality synthetic salt mixes. Vogt and Wermuth (1963) advocate the use of natural seawater, but Montadore (1976) discourages its use because of possible pollutants combined with the fact that natural seawater can deteriorate. Synthetic salts are much more stable and allow marine tanks to be set up far away from any coast. A typical synthetic salt formula (See

Table I) can be obtained at any aquarium shop.

Unlike beginners with fresh water fish, salt water novices are encouraged to begin with a large tank (Vogt and Wermuth, 1963; Goldthorpe, 1977). Romaine (1979) suggests a forty gallon all glass tank to begin with. The tank should be rinsed with tap water or salt water to remove any dust or dirt particles. Detergents should never be used to clean either the tank or any aquarium accessory.

When setting up a marine tank, an underground filter is strongly recommended (Dutta, 1972; Goldthorpe, 1977). This type of filter, when used with the proper substrate, provides the most efficient medium for establishment of the biological filter. A two to three inch layer of dolomite is the best substrate for use in the marine tank. Dolomite acts as a pH buffer, is porous enough to promote good water flow and is inexpensive (Goldthorpe, 1977).

Once set up, the tank should be filled completely with tap water, then the salt should be added to a concentration of two to four parts per thousand (Montadore, 1976). The proper concentration of salt is measured with a hydrometer. This device measures the concentration of salt in terms of the water's specific gravity. Pure water has a specific gravity of 1.0. When salts are added, the specific gravity increases. According to Goldthorpe (1977), the water in a marine tank should have a specific gravity of 1.023 at 26°C. Dutta (1972), however, points out that sea water can show just as much variation as fresh water and recommends a specific gravity reading between 1.022 and 1.025; maybe as much as 1.028. After the salt has been added, the pump and filter should be run for twenty-four hours to be sure all the salt is dissolved. This also allows chlorine gas and other harmful chemicals to dissipate

TABLE I

A TYPICAL FORMULA FOR ARTIFICIAL SEAWATER SHOWING COMPONENTS AND PERCENTAGES BY WEIGHT*

Components	Percentage By Weight
NaCl	65.2
$MgSO_4 \cdot 7H_2O$	16.3
$MgCL_2 \cdot 6H_2O$	12.7
$CaCl_2$	3.2
KCl	1.7
$NaHCO_3$	0.49
KBr	0.07
H_3BO_3	0.06
$SrCl_2 \cdot 6H_2O$	0.04
$MnSO_4 \cdot H_2O$	0.009
LiCl	0.002
$Na_2MnO_4 \cdot 2H_2O$	0.002
$Ca(C_6H_{11}O_7)_2 \cdot H_2O$	0.001
$Al_2(SO_4)_3 \cdot 18H_2O$	0.001
RbCl	0.0004
$ZnSO_4 \cdot 7H_2O$	0.0002
KI	0.0002
EDTANaFe	0.0001
$CoSO_4 \cdot 7H_2O$	0.0001
$CuSO_4 \cdot 5H_2O$	0.00002

*Source: Montadore, Arnoldo, ed. (1976). Simon and Schuster's Complete Guide to Freshwater and Marine Aquarium Fishes. Simon and Schuster, New York

(Romaine, 1979). Then a second hydrometer reading should be taken and any needed adjustments made. Once the proper salt concentration has been established, the pH should be checked. The pH should fall within a range of 8.1 to 8.5 (Dutta, 1972) with an optional pH of 8.3 (Goldthorpe, 1977). If the reading is too low, it may be adjusted upward by adding sodium carbonate.

The next step is without doubt the most important in that it involves the establishment of the biological filter (Dutta, 1972; Goldthorpe, 1977; Romaine, 1979). The biological filter is made up of bacteria of the genera Nitrosomonas and Nitrobacter (Burgess, 1976). These bacteria break down toxic nitrogen compounds into less harmful nitrogen compounds which can be utilized by algae. The decomposition of fish feces, uneaten food and decaying matter produces ammonium hydroxide whibh breaks down in water to form ammonia and water. Ammonia is extremely toxic to fishes. Nitrosomonas changes ammonium hydroxide to nitrous acid and nitrites which are relatively safe. A good growth of algae is essential in a marine tank (Vogt and Wermuth, 1963; Dutta, 1972; Godlthorpe, 1977) in that algae are able to utilize the nitrates (Burgess, 1976; Goldthorpe, 1977). The nitrogen cycle is completed with the decomposition of dead algae, feces and dead organisms.

There are several methods advocated by various authors for the establishment of the biological filter. The easiest method is to seed the new marine tank with some of the water (Burgess, 1976) or substrate from an established tank (Goldthorpe, 1977; Romaine, 1979). After seeding, Goldthorpe (1977) suggests that commercially prepared flake food be introduced in the tank which, through decomposition, initiates the nitrogen cycle and promotes the growth of the bacterial filter. About one-half ounce of food is sufficient for a thirty gallon tank.

Romaine (1979) suggests, alternatively, the introduction of one or two hardy fish. They carry the necessary bacteria on their bodies and produce fecal material for decomposition.

A few days after seeding, the nitrite level should be checked. A nitrite test kit may be purchased at any reputable aquarium shop. The nitrite level will go from zero to fifteen parts per million or more (Goldthorpe, 1977). This rise in the nitrite level is accompanied by a characteristic cloudiness. The nitrite level should continue to be periodically monitored until it returns to a zero reading. This will be accompanied by clearing. When the nitrite level returns to zero, this means that the rate of ammonia to nitrite conversion has become equal to the rate of nitrite to nitrate conversion (Goldthorpe, 1977). In other words, the biological filter has become established and the tank's full compliment of fish may be added safely (Burgess, 1976; Goldthorpe, 1977; Romaine, 1979). It may take anywhere from two weeks (Dutta, 1972; Romaine, 1979) to twelve weeks (Dutta, 1972) for the biological filter to become established, with an average time of four to six weeks (Terciera, 1977; Goldthorpe, 1977; Romaine, 1979).

Once the biological filter has been established, the ammonia and nitrite levels should ideally remain at zero, although readings up to 0.1 ppm for ammonia and 0.25 ppm for nitrites may be considered as not very dangerous. The nitrate levels should not get beyond a value of forty parts per million (Burgess, 1976). There are nitrate kits on the market.

Decorating the Marine Tank

Decorating the marine tank presents a few problems not found in fresh water aquaria. The marine tank layout tends to be limited by the struggle to keep the inhabitants alive (Dutta, 1972). Anything which is intended for use in decorating the marine tank should be soaked in a saltwater solution of approximately three times the normal concentration. This should include all filtering materials, substrate, rock, corals and the tank itself. There are very few plants which will survive in the marine tank (Vogt and Wermuth, 1963). Therefore, stones, corals and driftwood must provide the main means of decoration. Stones should be free of sharp edges to avoid injury to the animals. Suitable pieces of coral can be purchased at any aquarium shop. This is recommended over collected coral because of possible organic contamination which could quickly foul the tank. If the aquarist insists on collecting coral, it should be treated in a solution of two gallons of water mixed with one quart of fifteen percent caustic potash. After ten to fourteen days, the coral should be tested in a container of salt water. If the water clouds up, more treatment is required; if it remains clear, then the coral is ready for placement in the tank (Vogt and Wermuth, 1963). No coral or rocks should be used that might entrap organic materials or small fishes. Shells may be used, but should be treated in the same manner as described above. Under no circumstances should anything containing exposed metal surfaces be used to decorate the aquarium. This same rule applies to aquarium accessories including metal hoods, heaters, filters, etc. (Axelrod, 1955; Dutta, 1972; Goldthorpe, 1977, Romaine, 1979).

In decorating the tank, consideration of the behavior patterns of the inhabitants should be taken into account (Burgess, 1975). For example, anemone fishes should be provided with anemones, seahorses need something for anchoring themselves and noctornal fishes need daytime hiding places. While some burrowing species are able to burrow in coarse gravel, others may require finer sand. It is most important not to over-decorate a marine tank. Since salt water holds much less oxygen than fresh water (Welch, 1952), marine species are much more subject to the detrimental effects of over-crowding. If too much volume is taken up by decoration, there is not enough water for more than a few fishes. This is another reason for using larger tanks for marine species. In addition, the tank should be decorated in such a manner as to avoid hindering the siphoning of organic accumulations such as uneaten food, fecal materials and dead animals (Dutta, 1972).

Feeding and Maintenance

Marine fishes should be fed according to the same rules as those employed by the freshwater aquarist. Variety is essential to marine fish (Dutta, 1972; Goldthorpe, 1977). Live foods are always desirable, if possible. It is better to feed small amounts several times a day. This is the best way to avoid over-feeding. The marine tank should not be given more food than can be eaten in two to five minutes. Of course, this may vary with the species kept, so knowledge of the feeding behaviors of the various inhabitants is important. A good list of foods for marine species is given by Romaine (1979).

As far as maintenance is concerned, the marine tank requires about the same maintenance as the freshwater tank. The temperature and specific gravity should be checked daily. The temperature should not fall below 65°F (18°C) nor exceed 78°F (26°C) according to Axelrod

(1955) and Dutta (1972). Currently on the market is a combination thermometer/hydrometer which simplifies this chore greatly (Goldthorpe, 1977). Also daily checks should be made for accumulations of decomposing organic materials which should be siphoned out. The pH and nitrite levels should be tested weekly (Dutta, 1972; Burgess, 1976; Romaine, 1979). Any surface scum should be skimmed off.

According to Goldthorpe (1977), ten to twenty-five percent of the marine tank's water should be changed at least once a month. Romaine (1979) suggests a change of twenty to thirty percent. Dutta (1972) believes that water changes should be made every month, three months and six months, in increasing proportion of fifteen to thirty to fifty percent. These water changes serve to keep the nitrate level down. These changes also renew any trace elements which may have been absorbed (Montadore, 1976). New water must be of the same pH, specific gravity and temperature as the tank water to avoid shock to the fishes. For this reason, replacement water should be prepared twenty-four hours in advance (Romaine, 1979). When replacing evaporated water, tap water should be used rather than salt water to avoid building up the salinity beyond the tolerances of the fish (Vogt and Wermuth, 1963).

Finally, any injured or diseased fishes should be removed to a separate quarantine tank (Goldthorpe, 1977). Treatment should never be done in the community tank because of the danger of upsetting the balance of the biological filter. Under no circumstances should antibiotics be introduced into the marine community tank (Dutta, 1972).

If these practices are followed diligently, the marine tank can be successfully maintained with the same ease as a fresh water tank.

CHAPTER XI

DISPLAYS AND DISPLAY TECHNIQUES

The most important concept of any research facility is public support in the form of donations or admission fees. Facilities primarily concerned with research depend on good public relations to maintain this public support, whereas zoos and public aquaria depend on direct public support in the form of admission fees. For this reason, zoos, public aquaria and other public facilities of this nature depend on their ability to effectively entertain the public through their display techniques. Up until a few years ago, the main concern of the majority of zoo and public aquarium curators appeared to be the idea of displaying as many animals in as little space as possible. In the last few years, however, the zoo format has changed. In response to increased public awareness and acceptance of the principles of nature (Frieso, 1974), zoos have begun to create much more natural environmental conditions for their confined animals. The most extreme example of this principle is the approach of Lion Country Safari in Texas and California where the animals roam freely through large areas of the park which resemble the African savannah. Predator and prey species are kept separated by a system of deep ditches. Only the main sections of the park are separated by high fences. The San Diego Zoo, as well as many others across the country, has adopted the technique of naturalizing exhibits by means of decoration. If a reasonable imitation of a confined species' natural environment can be successfully created artificially, it not only results in a more attractive, educational and therefore more entertaining exhibit, but also results in the better adjustment and health of the animal. Just as with people, decor can turn a cage into a home.

However, despite the fact that zoos have slowly outgrown their early role as mere animal repositories (Friese, 1974), they have made markedly less progress in the display of aquatic animals (Schiotz, 1977). For the most part, zoo aquariums consist of poorly planned collections of totally unrelated fish species displayed haphazardly in a series of small tanks. Some zoos still judge the quality of their programs by the members of species they have on exhibit rather than by the condition in which the animals are exhibited.

In the past few years, public aquarium and zoo aquarium curators have increasingly adopted the use of thematic display techniques in the disply of aquatic animals. The concept of thematic display is a simple one. The idea is to develop a central theme and then to construct a display or a series of several related displays which emphasize the theme and deemphasize the animals, per se. The actual design of the thematic display depends primarily on the availability of the desired species as well as the availability of sufficient funds needed to carry out the design. In addition to these problems, the availability of space and location can affect not only the theme, but also the methods of display used. In some cases, themes can and should be illustrated without the utilization of living displays at all (Schiotz, 1977).

Thematic design depends a great deal on the actual facilities available. One extreme consists of a building which houses only two or three large tanks, 10,000 gallon or more capacity, or even a single 100 to 350,000 gallon tank. In this type of situation it is necessary to adopt a single dominant theme for each tank and exploit it in great detail (Herwig, 1979). For example, at Marineland of the Atlantic there are three buildings, each containing many brightly colored reef species. In addition to these large exhibits, there are numerous smaller displays in various locations around the park. The three large tanks are open system tanks; that is, the water is circulated directly from the ocean through a mechanical and chemical filtration system then through the tanks. This type of tank system is only possible near a coast from which to draw water. In addition, these exhibits contain, for the most part, rather large animals. This restricts the number of animals which can be maintained even in the very large tanks described and thereby limits the theme.

On the other hand, the small public aquarium or zoo may wish to adopt a multi-theme approach, utilizing perhaps one or two large tanks, 7,000 to 10,000 gallon capacity, supported by a large number of intermediate and smaller tanks. While it is possible to use this approach to illustrate one over-all theme, it is also possible for each tank to express a theme in itself. With enough tanks, several themes can be explored in great detail at the same time (Herwig, 1979).

Friese (1974) points out the virtually limitless range of biological topics that can be explored with a thematic approach. Even a relatively simple thematically arranged tank can lead to an explanation of fairly complicated biological concepts, especially if accompanied by other types of visual display. The implications of pollution and environmental destruction, special ways in which species are adapted to their environments, and zoo geographic distribution of fish species are just a few examples of themes which could be explored with a multi-thematic approach. The main idea is to let the theme rather than the fishes become the dominant guiding factor.

In the last few years, new facilities have been opened and old facilities have been renovated using thematic design techniques to rejuvenate their aquatic presentations. The Mystic Marinelife Aquarium of Ohio, which opened in 1973, is dedicated to the presentation of fish according to evolutionary and ecological concepts in an entertaining manner. Besides the dolphin show, held in a 400,000 gallon amphitheater, this facility maintains three main exhibit areas. The first area contains displays illustrating how, over millions of years, animals have evolved special characteristics that enable them to survive in the water. Another section contains exhibits depicting the different types of underwater communities present in North American water. There are two extensive coral reef exhibits, one depicting reef life by day and the other depicting reef life by night. One of the most exciting displays consists of a 30,000 gallon free standing tank containing open ocean species including bluefish, sharks and stingrays (The Drum and Croaker, March, 1976).

The Taronga Zoo (Friese, 1974), which has a rather modest budget, has, never the less, been able to utilize eight 60 gallon tanks to create a very effective thematic display illustrating various adaptations of fishes to their environments. Each tank contains fish showing a different adaptation and is accompanied by supportive visual displays. For example, one tank contains anabantids under the heading of air-breathing fishes. An accompanying sign explains how their ability to breath air has helped this group of fishes to adapt to even severely polluted environmental conditions. Other tanks illustrate unusual reproductive adaptations such as ovoviviparity and mouthbrooding, adaptive coloration and the production of electricity in fishes, including signs explaining the significance of these adaptations.

Nelson Herwig (1979) suggests that the most effective display contains exhibits which are attractive to the largest number of people. According to Herwig, people are most likely to be attracted to exhibits which represent the most bizarre, dangerous, strange, unusual, rare or endangered species it is possible to obtain. Along these lines, suggested themes include man-eating fish, using piranhas in the exhibit; electrical fishes, exhibiting electric eels in one tank and elephant noses or knife fishes in another; camouflage in fish; or unusual food gathering methods such as practiced by the archer fish.

A likely exhibit utilizing the feeding behavior of archer fish has been described and set up at the Steinhart Aquarium (Powell, 1977). This exhibit consists of a group of twenty archer fish in a half-filled 300 gallon tank decorated to closely resemble their natural habitat. In nature, these fish shoot water droplets at insects resting on overhanging leaves, knocking the insects into the water. At the Steinhart Aquarium, this behavior has been used to create an entertaining and at the same time informative exhibit. Pieces of food are placed on a small target which the fishes are trained to shoot. The fishes are initially trained to take small pieces of ground beef which are bounced off the target into the water. This sets up a target-food association reaction in the fishes. After this association is established, pieces of ground beef are attached to the target and raised above the water slightly. At first the fishes jump out of the water for the pieces of meat. After this behavior is firmly established, the target is raised high enough to prevent the fishes from reaching the food. At this point, the fishes should begin to shoot at the target. After a couple of weeks of consistent shooting, the target can be raised an inch or two at a time until the optimum height is reached. A five inch archer can accurately shoot up to thirty inches which is high enough for a good sized crowd to be able to see the action. This is just one type of exhibit which, while being fairly simple to construct, is nevertheless a very effective display.

Another display concept which is relatively new to aquarium curators is the idea of allowing visitors to touch and observe aquatic animals directly. These exhibits are limited to fairly hearty species and, unfortunately, are limited mostly to the use of invertebrates. Sullivan (1978) describes the "hands-on" exhibit at the Children's Museum of Hartford in West Hartford, Connecticut in which various molluscs, annelids, arthropods and echinoderms are maintained. In some cases, predator-prey relationships are maintained while some prey species are separated from their predators.

Symbiotic relationships are illustrated in displays at the "World of the Sea" Triquarium, part of Sea World of Ohio. This exhibit also includes three 10,000 gallon tanks. One tank contains marine game fishes including leopard sharks, guitarfish and giant sea bass. The second tank features freshwater fishes including red-tailed catfish and alligator gar. The third tank contains a Pacific tide pool display in which visitors are allowed to touch and observe animals including starfishes and spiny sea urchins (The Drum and Croaker, June 1974).

Marliave and Elderton (1979) discuss symbiosis observed in display tanks at the Vancouver Public Aquarium between rockfishes, *Sebastes* spp., or lingcod, *Ophiodon elongatus*, and large thick-tentacled anemones (*Tealia* spp. or *Anthopleura xanthogrammica*). These fish species, which are heavily infested with leaches, have been seen to glance off of the tentacles of the anemones. The leeches are either removed at once or rendered harmless by the stinging nematocysts of the anemones. If the leeches fall among the anemones' tentacles, they are consumed. In other tanks, symbiotic cleaning relationships between rockfishes and juvenile dover soles, *Microstomus pacificus*, have been repeatedly observed. In addition, coon-stripe shrimp, *Pandalus danae*, have been observed cleaning several fish species, apparently picking off protozoan ectoparasites.

Other interesting displays include a wave tank which creates the impression of waves crashing into a tidepool every twenty seconds such as that found at the New England Aquarium (Seiswerda, 1979) or fast water set-ups to show the adaptations of fishes living in fast flowing streams (Schiotz, 1977).

The planning and setting up of even a modestly attractive and successful aquarium display is not a one-man job. In addition to the obvious biological problems and aquarium maintenance techniques needed, the space utilization problems and construction problems may require architectural and engineering consultation. Friese and Strahan (1976) outline a system for the step by step planning of zoo aquarium complexes. The first step involves the formulation of an overall theme or themes. Once the theme has been established, the next step is determining the best methods to use in illustrating and explaining the theme to the general public. To do this, a board of directors should be established including an experienced aquarist or aquatic biologist, one or more competent architects and/or engineers and someone to represent public interests. In the case of a small, free-standing method of display architectural and engineering expertise may not be necessary. With the tremendous advancements made in aquarium technology in the last decade, virtually any aquarium design problems can be overcome.

The next concern is one of finance. In the case of small displays, the costs may be taken care of from zoo reserve funds, donations from private groups or even charging separate admission fees. The public has shown a great deal of interest in aquatic biological displays as evidenced by the relatively high admission fees they are willing to pay to visit the few well-funded and professionally operated aquaria around the world. Larger facilities may, in addition to collecting fees, obtain funds in the form of governmental or industrial research grants. It is recommended that no more than two-thirds of any available funds be budgeted for construction of facilities. The other one-third should be set aside to pay for any unforseen contingencies.

In the actual planning of any aquarium facility, several steps should be taken. The designs of other existing facilities should be studied including themes, floor plans, tank structures and techniques involved. In this way, past errors may be avoided and advantageous techniques may be incorporated. In addition, plans for stocking various displays should be made in advance including plans for collecting trips or plans for reciprocal animal trading programs in conjunction with other zoos or public aquaria. Finally, the public needs to be kept informed through brochures, television and other advertising media of the progress and eventual goals of the facility in order to gain and maintain public support.

The facility must be designed to provide maximum educational and entertainment effects. In addition, the visitors comfort must be considered. The facility should be designed for one-way circulation of visitors in such a manner as to encourage a steady flow. Displays should be designed in such a manner so as to avoid competition for the visitor's attention.

For maximum display effectiveness, the hallways of most public aquariums are dimly lit. This requires that the facilities be entirely enclosed. To compensate for this, an adequate ventilation system is essential. In addition, emergency exits, toilets, drinking fountains and rest areas should be provided to ensure maximum visitor comfort.

If possible, the aquarium building should be designed to provide for easy and unobtrusive access to all tanks by maintenance personnel. Filtration and heating systems should always have back-up systems to insure against failure. The facility should also contain its own system for the proper preservation and preparation of all food items needed by the aquarium inhabitants including a deep freeze and possibly kitchen appliances.

Finally, the quality of any public facility is a reflection of the management of that facility. Along with a full time manager, there should also be a fully qualified "second man" to assure that there is always someone on hand who can handle any problems (Bilodeau, 1977). With adequately trained personnel and proper maintenance, public aquaria and zoo aquaria should continue to gain in popularity across the country while at the same time providing an invaluable service of public education and scientific research to help man in his role as preservor and protector of the environment.

CHAPTER XII

SUMMARY AND CONCLUSIONS

Most people recognize the historic value of fishes and other aquatic life as a protein source, but few people realize that men have kept live aquatic organisms for study and pleasure since the time of the Egyption pharoahs. It was not until the mid-nineteenth century, however, that the modern aquarium hobby had its beginnings. Technical advances in aquarium construction, lighting, filtration and other aspects of the aquarium industry have contributed to the tremendous worldwide growth of the hobby since that time. In addition, these advances in aquarium technology have enabled hobbyists to successfully maintain and propagate many previously difficult-to-keep species. Aquatic research has also been helped by these advances, allowing research in such areas as disease control, propagation and aquatic ecology.

Advances in artificial aquarium lighting have removed the dangers of overheating and uncontrolled algal growth inherent when direct sunlight is used. Fluorescent and incandescent lighting, when used together, provide the best illumination and also provide the optimum conditions for the maintenance of healthy aquatic plants. Live plants are generally desirable in the tank. Besides inhibiting algal growth by competing for light and nutrients, plants are good test organisms for checking the acidity and hardness of the aquarium water. Aquatic plants are classified in three main groups; the tall background plants, floating plants and the rooted plants. Most aquatic plants have evolved a system of taking nutrients through the leaves, using the roots mainly to anchor them down. Planting may be accomplished using any of several methods.

Water chemistry is another area in which advances have been made. Water acidity can be determined either colorimetrically or electrometrically. The pH, or level of acidity, can be raised by introducing sodium bicarbonate into the water, or lowered by adding sodium acid phosphate or tannic acid. Filtering the water through peat moss also lowers the pH. Water hardness may be determined using the standard soap test and may be regulated by the use of several chemical compounds.

Before placing fishes in the aquarium, the water should be conditioned. This can be accomplished either by letting the water sit idle for a period of days or by adding any of several commercially available chemical conditioners.

Aerators are used on aquaria to promote water circulation and proper gas exchange at the surface. In addition, the aerator promotes uniform distribution of oxygen throughout the tank.

Mechanical, biological and chemical filtration are the three filtration components necessary to the maintenance of a healthy aquarium. There are three types of filtration systems; the undergravel, the inside box type and the outside power filter, each of which incorporates all three components of filtration. While any of these filtration systems help in aquarium maintenance, they cannot totally replace periodic partial water changes.

The most commonly ignored aspect of aquarium maintenance is that of temperature control. Because fishes are cold-blooded animals, their metabolic rates are directly corrolated to the temperature of their surroundings. In addition, since warm water holds much less oxygen than cool water, temperature regulation is doubly important. The thermostatically controlled electric heater is the best way to keep an aquarium's temperature constant. This type of heater along with a reliable thermometer will insure temperature control.

After the tank is set up and the animals are introduced, feeding becomes the next priority. Most fishes feed on other living organisms in the wild. Several of these live foods can be successfully maintained and propagated by the aquarist. In addition, all fishes can be classified in one of four feeding categories; grazers, suckers, active predators and parasites. Since nutritional requirements vary from species to species, fishes should be fed a varied diet. It is most important to remove any uneaten food to prevent fouling the water.

Fish diseases and parasites have caused more novice aquarists to quit than any other aspect in the hobby. There are three main aspects to the control of disease in the aquarium; prevention, symptom recognition and eradication. Proper maintenance will usually prevent most diseases from occurring. If diseases do occur in the aquarium, they can be eradicated with drugs for the tank or by isolating diseased fish. By isolating incoming specimens, recognizing disease symptoms and treating those diseases that do show up, the general health of the tank can be maintained.

Most aquarists eventually get the urge to maintain a marine tank. With the good synthetic sea salt mixes currently on the market, water chemistry has been greatly simplified. The correct salt content can be obtained using a hydrometer for salt content determination. Once the correct water chemistry is established, the tank should be "seeded" with substrate from an established tank in order to introduce the organisms which make up the biological filter. It should take from four to six weeks for the biological filter to become fully established. When decorating a marine tank, care should be taken to avoid introducing any organic matter or exposed metal surfaces into the water. Care should also be taken to decorate the tank in such a manner as to be compatible with the behavior of the tank's inhabitants. Over decorating must be avoided in the marine aquarium because of marine animals' need for more water space. With proper maintenance, the marine tank is almost as easy to keep as a fresh water tank.

In recent years, zoos and public aquaria have changed from simple animal repositories to displays which closely resemble natural habitats. These facilities have become involved in many types of aquatic research, making the most progress in the area of disease control. With increased emphasis on public education, the practice of thematic display techniques has become widespread. Thematic displays are based around one central theme in the case of large display tanks or several smaller displays based on one overall theme. Using thematic techniques, an effective, educational and entertaining display can be created even on a modest budget.

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VITA

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Report: A REVIEW OF BASIC AQUARIUM TECHNIQUES WITH COMMENTS ON MARINE AQUARIA AND PUBLIC AQUARIUM DISPLAY TECHNIQUES

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Pages in Report: 65   Candidate for Degree of Master of Science

Major Field: Natural Science

Scope of Report: This report consisted of a review of the techniques and equipment essential for successfully maintaining an aquarium. Subjects discussed included the use of lighting and types of lighting; substrates; aquatic plants and planting techniques; water chemistry and conditioning techniques; methods of aeration; types of filtration and filtration systems; methods and equipment needed for controlling temperature; feeding requirements and techniques for providing live foods; and methods used to control disease. Special problems involved in maintaining a marine tank were discussed. In addition, techniques involved in the display of fishes by zoos and public aquaria were reviewed with special emphasis on thematic display techniques.

ADVISER'S APPROVAL L. Herbert Bruneau