Chapter 5

Small Aquaria

D. Ford

Animal Studies Centre, Melton Mowbray, England

I. INTRODUCTION

Much research is performed with small species of fish kept in self-contained aquarium tanks in general laboratories. Many different fish are suitable and available, some of them reared for generations in tanks or under laboratory conditions. Such fish can often be kept at high densities without expensive equipment and are to the fish biologist, what the common rat is to the mammalian biologist. This chapter describes the small-scale aquarium, whether a single temporary tank on the laboratory bench, or a complete aquarium laboratory with tanks containing many different species.

II. SITING THE TANKS

Though the small aquarium may range from a single tank, established for a particular experiment, to the much larger installation, the problems of siting are essentially the same. The tanks should be placed on a firm and substantial base, in a position where the fish will not be stimulated by extraneous noises or other physical disturbances. They should be away from doors or equipment such as vacuum pumps or typewriters, which may vibrate the bench or floor. Ideally, the fish should be maintained under a controlled regime of lighting and temperature, which is best obtained by keeping them in a room set aside for the purpose. Where fish must be kept in an ordinary room, it is best to place the tank on a separate plinth or stand away from the window, preferably in a corner. Extraneous stimuli can be reduced by enclosing the corner of the room with a plywood screen.

If the laboratory is a complete fish house, serving no other function, the tanks can be mounted on stands around the periphery with a central island filled with the normal laboratory benches, drawers, cupboards and services. Any office facilities or electronic equipment are best kept separate, or partitioned-off from the part of the room containing the fish. Commonly, the fish are kept for a specific purpose, for example to monitor water quality for a factory, and in this case it is often sensible to remove the fish from the main building and place them in a shed or annex where they will not be disturbed. Basic services which should be included in the unit are a clean water supply, drainage, an electricity supply and bench and cupboard space.

III. EQUIPPING THE AQUARIUM

Each item of aquarium equipment is available in many forms, and choice must depend on purpose and budget.

A. The Tank

The traditional aquarium that has existed for many years has a rectangular iron frame with glass sides embedded in putty. This design is heavy even when empty, readily corrodes and tends to leak if moved or if the water level is changed. The putty dries out with age resulting in minor leaks that are difficult to seal without emptying the tank. However, many of these older tanks are available second-hand. If the laboratory is on a tight budget, banks of these tanks may be installed at low cost. Local newspapers often advertize complete aquaria at very low prices when some houseowner wishes to dispose of an ageing set-up.

The leaking problem can be overcome by sealing the internal corners with a silicone sealer. Any bare metal must be primed with a non-toxic paint and given several coats of a good quality polyurethane paint. Such metal framed tanks are not really suitable for sea water but may be pressed into service if the painting and silicone sealing is meticulously carried out. There must be no physical contact between sea water and any bare metal or putty. High quality stainless steel frames are excellent for all types of aquaria. However, if putty is used, the inside corners must be silicone-sealed for sea water usage.

Some modern tanks have metal frames sealed with a nylon or polyurethane coating prior to glazing. These tanks are suitable for all uses, but again if putty is used, the inside corners must be silicone sealed for sea water. Nylon coatings on frames and stands generally outlast polyurethane, the latter tending to crack after a year or so. With the introduction of aquaria made from glass sheet, bonded with silicone sealer, decorative frames made from lightweight alloy, aluminium or plastic have been marketed. All are suitable for laboratory use, but the usual precautions are necessary to ensure that sea water does not directly contact metallic frames.

All-plastic tanks have been popular in recent years because they are non-toxic, light and require no maintenance. The rising cost of plastics, however, has made these tanks expensive and some manufacturers have changed back to glass. Small plastic tanks (2–60 litres) manufactured from a single mould, are useful for handling fry and for quarantine and treatment purposes. A problem with plastic tanks is that the surface can be easily scratched making the sides opaque, so abrasive cleaning materials must be avoided.

Other non-glass aquaria can be virtually any container that is stable and non-toxic. In emergencies, a wooden or strong cardboard box can be lined with a large polythene bag. Polystyrene boxes, plastic baby-baths, even plastic dustbins can be used. Partly glazed aquaria can be made from asbestos, concrete or wood. Marine ply sheets can be pinned and screwed into large aquaria at much lower cost than the all-glass aquaria. These wooden tanks need a liberal coating of glass-fibre reinforced resin internally, to render them water-tight and non-toxic, especially for sea water. Such tanks should have a cutaway section at the front for glazing with a suitable thickness of glass. In all cases, the glazing can be done with silicone sealer.

The ideal tank is probably the all-glass silicone-sealed unit. This is simply a glass box and can range in size from 10 to 2000 litres. Small tanks of up to 100 litres can be made from glass of 4 mm thickness, but 6 mm glass is preferable. The front, back and base can be 6 mm thick with the side 4 mm. For tanks of more than 100 litres capacity, 6 mm glass should be used throughout, while for tanks of more than 200 litres, 10 mm glass is necessary. Large aquaria of 1000 litres need 20 mm glass which must usually be specifically ordered. Small tanks can be made from clear glass sheet, but for larger tanks with thicker glass, polished or floated plate glass is better for distortion-free viewing. In older tanks, the base may be slate and the rear may be the cheaper pebble or reinforced glass, mounted in a steel frame. These materials are not suitable for silicone-sealing since the strength of the join is achieved by using very clean, polished, flush-fitting joints. The reverse face of a pebble glass may sometimes be smooth enough to serve, however.

Silicone sealer can be obtained in small tubes or cartridges, the latter requiring a specially designed caulking gun. Glass should be bought in a cut and polished state and the edges cleaned with acetone or a degreasing agent prior to sealing. Some manufacturers of silicone sealer supply details of tank construction with their products. The hobby press often publishes articles on all-glass tank manufacture. An internal bead of silicone sealer adds to the strength of joints, but the silicone rubber is easily cut by sharp objects and tank cleaners such as razor blades or metal scrapers should not be used. The sealer sets in one hour but full strength is not achieved for 48 h. During the setting stage, the sealer produces acetic acid and any residue must be flushed away with water. Silicone sealer will not work with plastic sheet since it will not form a water-tight seal. Specially shaped tanks can be made from Perspex, Lucite, Darvic or similar materials. Perspex needs a solvent adhesive but the thermosetting plastics may be welded.

The size of the tanks should be carefully considered prior to installation. If only one technician is available, the largest tank he can comfortably handle is 80 × 35 × 30 cm (30 × 15 × 12 in). On the other hand, the larger the tank, the easier is the maintenance. Uniformity of size will make measurements easier since aquarium posology (dosage levels) can be standardized. Another advantage is that all the accessories are interchangeable. If second-hand tanks are used, they will probably be based on Imperial linear units in the UK or USA. European and contemporary tanks are measured in metric units (aquaria sizes are usually quoted in centimetres) which gives a greater variety of tanks sizes. Traditional sizes are listed in Table I.

Table I. Traditional aquarium sizes. The water volumes are for furnished tanks in the presence of gravel, rocks, plants, etc.

	Imperial		Metric	
Inches	U.K. Gallons	U.S.A. Gallons	cm	Litres
7 × 5 × 5	½	½	30 × 20 × 20	10
12 × 6 × 10	1½	1¼	60 × 35 × 37	60
18 × 10 × 10	6	5	80 × 35 × 41	90
20 × 10 × 12	9	7½	100 × 40 × 41	120
24 × 12 × 12	12	10	100 × 42 × 50	150
30 × 15 × 12	16	13	135 × 42 × 53	200
36 × 15 × 12	20	17	140 × 42 × 53	220
48 × 15 × 12	43	36	150 × 42 × 53	250

A full aquarium is very heavy and adequate support is essential, not only the aquarium stand, but also the floor beneath it must be strong. The water pressure within the tank is a function of height, and a tank one metre or more deep needs a supporting frame, which adds to the overall weight. The average hobbyist's aquarium of 24 × 12 × 12 in (about 60 × 30 × 30 cm) with accessories and full of water weighs almost 90 kg (200 lb). The traditional angle-iron stand is adequate for vertical banks of 1, 2 or 3 tanks and is available from most domestic aquarium suppliers. Custom-built stands can be made from strong timber or Dexion-style fittings. To compensate for inequalities in such stands, especially with all-glass tanks, a buffer of expanded polystyrene is necessary. Kitchen ceiling tiles are ideal. With sea water aquaria, iron or galvanized stands will corrode (see Chapter 6). Painting or coating with epoxy resin is rarely satisfactory. Plastic coating is expensive and may crack in time. Nylon coating is effective if correctly applied by the hot-dip process. The most suitable cheaper alternative is to use timber frames that can be replaced when the wood rots.

All tanks must be emptied before being moved. Even a little water can slop about within a tank and build up a twisting torque that can crack the glass or cause a leak.

Every tank must have a top cover otherwise dust can get in, the fish may leap out and heavy evaporation losses will be suffered. A simple sheet of glass or plastic is sufficient. The glass may be 3 or 4 mm (window glass) but rigid plastic of this thickness will sag with age and some support is necessary, one method being to drill and screw the centre line to a suitable length of timber. The cover may rest on the top of the aquarium, but a better system is to arrange flush fitting within the tank. This ensures condensation returns to the tank rather than running down the outside. With framed tanks, stainless steel or plastic clips designed to hold coverglasses within the tank can be bought from most pet shops. With all-glass tanks, supporting strips of glass or vitrolite can be silicone-sealed into place inside the tanks. These can support plastic runners for cupboard doors. The coverglass can then be cut into overlapping halves that slide within the runners to give easy access for feeding and maintenance. Manufactured covers are available for most standard sized tanks and these will accept overhead lights and are close fitting.

The bottom of the tank should always be covered so that the fish can orientate properly. Hobbyists cover the base with a gravel of split pea size (5 mm), usually spread over a plastic undergravel, air-lift operated, filter. For reasons detailed later, undergravel filters are best avoided. Without such filtration, a smaller sized gravel may be employed; this is better for plant roots and individual stones are less likely to block the mouths of sucking feeders such as goldfish. A type called bird's-eye gravel (about 2 mm) is ideal. Sand is a possible medium but can be too fine and compaction may occur. Compact sand can give rise to anaerobic conditions and may therefore pose pollution problems.

B. Heaters, Thermostats and Thermometers

The average laboratory temperature is too low for most tropical freshwater and marine specimens, so additional heating is necessary. The standard glass-sheathed equipment produced for the hobby trade is ideal. It is possible to have a master thermostat controlling a series of heaters in a bank of tanks. However, it is preferable for each tank to have its own heater and thermostat since this will minimize losses in the event of failure. The simplest form is a combined heater and thermostat wired for direct mains supply. Separate thermostats can be purchased and of these the outside fitting variety is more accessible for adjustment. Wattages for heating tanks are not critical but Table II is a guide.

comfortably handle is 80 × 35 × 30 cm (30 × 15 × 12 in). On the other hand, the larger the tank, the easier is the maintenance. Uniformity of size will make measurements easier since aquarium posology (dosage levels) can be standardized. Another advantage is that all the accessories are interchangeable. If second-hand tanks are used, they will probably be based on Imperial linear units in the UK or USA. European and contemporary tanks are measured in metric units (aquaria sizes are usually quoted in centimetres) which gives a greater variety of tanks sizes. Traditional sizes are listed in Table I.

Table I. Traditional aquarium sizes. The water volumes are for furnished tanks in the presence of gravel, rocks, plants, etc.

Imperial			Metric	
Inches	U.K. Gallons	U.S.A. Gallons	cm	Litres
7 × 5 × 5	½	½	30 × 20 × 20	10
12 × 6 × 10	1½	1¼	60 × 35 × 37	60
18 × 10 × 10	6	5	80 × 35 × 41	90
20 × 10 × 12	9	7½	100 × 40 × 41	120
24 × 12 × 12	12	10	100 × 42 × 50	150
30 × 15 × 12	16	13	135 × 42 × 53	200
36 × 15 × 12	20	17	140 × 42 × 53	220
48 × 15 × 12	43	36	150 × 42 × 53	250

A full aquarium is very heavy and adequate support is essential, not only the aquarium stand, but also the floor beneath it must be strong. The water pressure within the tank is a function of height, and a tank one metre or more deep needs a supporting frame, which adds to the overall weight. The average hobbyist's aquarium of 24 × 12 × 12 in (about 60 × 30 × 30 cm) with accessories and full of water weighs almost 90 kg (200 lb). The traditional angle-iron stand is adequate for vertical banks of 1, 2 or 3 tanks and is available from most domestic aquarium suppliers. Custom-built stands can be made from strong timber or Dexion-style fittings. To compensate for inequalities in such stands, especially with all-glass tanks, a buffer of expanded polystyrene is necessary. Kitchen ceiling tiles are ideal. With sea water aquaria, iron or galvanized stands will corrode (see Chapter 6). Painting or coating with epoxy resin is rarely satisfactory. Plastic coating is expensive and may crack in time. Nylon coating is effective if correctly applied by the hot-dip process. The most suitable cheaper alternative is to use timber frames that can be replaced when the wood rots.

heaters. Such methods may have low running costs but a high ambient temperature is unpleasant for staff to work in.

Each tank needs a thermometer to monitor the water temperature. The cheap hobbyist thermometer is notoriously inaccurate and a mercury-in-glass chemical thermometer is preferable. Some aggressive species of fish may break such thermometers and the temperature in this case can be monitored with a liquid-crystal digital thermometer. The latter will adhere to the outside of the glass and though the reading may be a degree or so low, the error is consistent. The temperature of the water involved in water changes or fish transfers should always be checked with a thermometer because rapid temperature changes will severely stress the fish.

C. Aeration

Continuous aeration is very good husbandry since it mixes the water, supplies oxygen for the fish, and removes carbon dioxide. It is only unnecessary where stocking levels are very low; on the other hand, it should not be relied upon to support high stocking levels because of the danger in even temporary failure. Many cheap airpumps are available in the hobby trade, though they are often noisy, are of limited power and may frequently fail. If only one or two tanks are required, such small vibratory diaphragm pumps are acceptable, but a spare pump and several replacement diaphragms should be stocked. The pump should be mounted above the tank level or the air-line fitted with a non-return valve to prevent back-siphoning when the pump is stopped or fails. A loop in the air-line 8 cm (3 in) vertically above the tank's water level will also prevent back-siphoning by absorbing the oscillations when the air-flow stops. With banks of aquaria, one or more large air-pumps or preferably a compressor can be used. To give a uniform rate of airflow, the pump should operate a pressure line in a closed circuit system with individual airlines to each tank.

D. Filtration

The undergravel filter used by the hobbyist is best avoided because it retains waste materials within the tank and the water flow through the gravel adversely affects aquatic plants. Gross material can be removed by operating one or more corner or box filters containing polyester filterwool. Glasswool must not be used because irritant glass splinters can be released into the tank; cottonwool is also to be avoided because this will quickly rot and pollute the water. Several models of box filter are available; all are operated by air lifts. To clarify the water, a diatomaceous-earth filter can be used.

These filters consist of a motorized pump that draws water through a glass jar containing a nylon mesh bag. Diatomaceous-earth powder is added to the jar and the water flow coats the nylon bag with the powder. The water then has to pass through the powder which within an hour or two will "polish" the water to a high clarity. One filter can routinely treat 20 or 30 tanks weekly. A fresh change of diatomaceous-earth is usually required for each tank.

Marine fish require their water to be biologically filtered and on a small scale, this filtration is normally done by means of undergravel filters. A better system is to use an external power filter. The power filter is more efficient than an undergravel one, gives a better water flow within the tank, and can easily be cleaned without disturbing the fish. Any filter medium with a large surface area is suitable, including silica sand, coral sand, gravel, glass beads and various resins. The author favours carbon and polyester wool. The carbon is not included for its adsorptive properties (which are quickly saturated), but for its large surface area. Since biological filtration relies on surface-active nitrifying bacteria the filter medium with the highest surface area will be the most effective. The carbon granules should be packed loosely in a mesh nylon bag, and to prevent them becoming clogged with solids, the bag should be sandwiched between polyester wool which removes gross material and gives a final mechanical filtration before the water flows back into the tank. Table III is a guide to pump sizes that have been shown in practice to keep saltwater nitrite levels near zero.

Table III. Powerfilter sizes for saltwater tanks.

Tank Size	Flow Rates	Examples of filters
Up to 50 l	Over 100 l/h	Eheim No. 2016 Martin No. 300
Up to 200 l	Over 150 l/h	Eheim No. 2018 Martin No. 400 Nuova Turbo Filter
Up to 500 l	Over 300 l/h	Eheim No. 2026 Interpet No. 200
About 1000 l	1000 l/h	Eheim No. 2030 or No. 2034

E. Decoration

Most fish seem to prefer a tank decorated to resemble their natural environment. Even generations of tank-bred fish need some cover, and a bare tank may stress them. Any rocks, pebbles or ornaments placed in the tank must be non-toxic and sterilized with boiling water. Rocks must be lime-free to avoid increasing the water hardness, and should not have sharp edges. Granite, river-washed boulders or rounded lumps of glass are ideal. Aggressive species like many Cichlidae need caves built from rocks to give territories and safe retreats. Many coral-fish need pieces of coral to weave through (these are usually bleached white when sterilized). Sensitive fish such as the Discus need dense plants (real or plastic) to hide in, while burrowing fish like certain wrasses (Labridae) need coral sand of at least 3 cm depth. Even a tank used to house a fish temporarily should have a gravel base and a plastic plant.

To give a better view of the fish, the back glass may be made opaque. An effective method is to cover the outside rear glass with a liberal coating of a white emulsion paint (best applied with the tank lying face down, prior to installation).

F. Lighting

Most fish prefer dim lighting conditions. The bright lighting of the aquarist's display tank is not necessary unless plants are present. Many fish are diurnal in habit, requiring a regular light/dark cycle. For many species, maturation is triggered by changes in the day length. Table IV is a guide to the Wattage for an 8 h period of lighting where plants are present.

Table IV. Light intensity for planted aquaria.

Length of Tank	Wattage of filament bulb	Wattage of fluorescent tube
Up to 50 cm (approximately 18 in.)	40	8
60 cm (approximately 24 in.)	2 × 40	15
75 cm (approximately 30 in.)	2 × 60	20
90 cm (approximately 36 in.)	3 × 40	2 × 20
120 cm (approximately 48 in.)	3 × 60	2 × 30

Larger tanks than those listed in Table IV can be lit by dichroic spotlights mounted over the tanks. The only cover required is then a top-glass. A 2 m long tank can be lit by two 150 W cold running spotlights. Ordinary tungsten filament bulbs are cheaper to buy than fluorescent tubes and heavy starter units are avoided, but the usual sideways mounting of these bulbs in a standard cover gives a short life due to sagging filaments. Lifting the cover while the lamps are lit often breaks the filament. The bulbs also heat the surface of the water to unacceptably high levels for many fish, such as coldwater species or the Anabantidae. The heat can also create condensation problems, but this and the surface heating, can be overcome by placing a glass sheet between the lamps and water, mounted either in the cover or the tank top. The bayonet or screw fitting of the bulb can be protected from condensation by a few inches of tubing cut from a bicycle inner-tube.

Fluorescent tubes have the advantage of being cool and are cheaper to run. The starter unit is best housed on a wall behind the tank rather than on or in the cover. This is is because its heavy weight creates a danger of the whole lid falling into the water if dislodged. Spring clips will hold the tubes in the lids but these must be of stainless steel or nylon-coated steel. Electrical connections can be smeared with silicone sealer.

Domestic wiring is sufficient for all normal aquaria and hence a wide range of readily available accessories can be used. Each tank may be lit from a universal ring main or all the tanks may be lit from a single circuit with a masterswitch that can be controlled by a timer. With the latter, overide switches should be fitted to allow individual tanks to be switched off. The lighting of individual tanks can, of course, be controlled by a separate timer if required.

G. Electricity Supply

A ring main of sufficient amperage should be available to operate the banks of aquaria. The average tank described earlier has a rating of 0.5 amp, but to allow for surges, a rating of 1 amp should be used in calculations. The wiring from the ring main should be via a suitable socket outlet for each unit of 1, 2 or 3 tanks. This will allow one tank, or unit, to be electrically isolated before any handling. A lead of 3 amp, 3 core, domestic cable can be taken from the socket and plug to a junction box near the tanks. The hobby trade sell junction boxes under the name "cable-tidy". This junction box in turn feeds the thermostat, heater, lights, pump and power filter as required. External parts can be earthed, including the frame of the tank and the stand, if these are made from metal. The water itself should preferably not have an earth connection because of the danger of corrosion of the metal and subsequent pollution.

Where it is necessary to earth the water (perhaps to eliminate mains hum from any electronic monitoring equipment in the tank), then highly toxic metals such as copper and brass must be avoided. Steel may be used in freshwater though any rusting is unsightly. An ideal earth for all aquaria is a carbon rod (e.g. taken from a dry cell). Electrical safety regulations of most countries will soon require all electrical accessories to be double insulated. An ideal arrangement for a tropical fresh water tank is shown in Fig. 1.

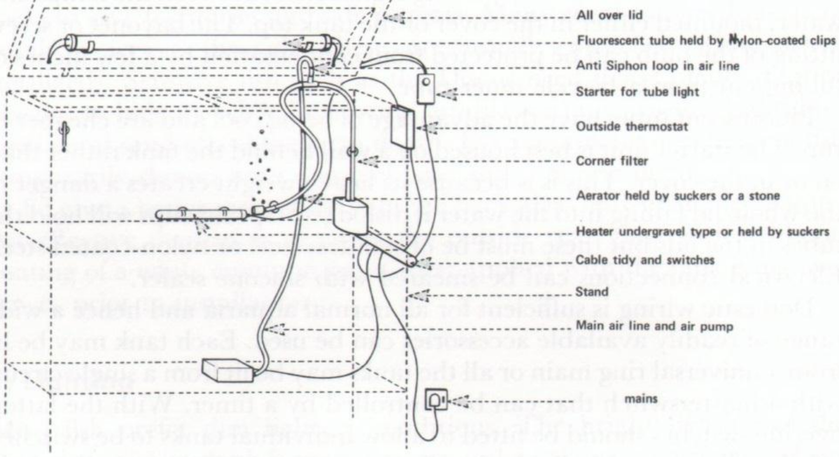

Fig. 1. The well-appointed tropical fish tank.

IV. SETTING UP THE TANK

A. Installation

Wash the tank with water and a disinfectant that does not contain detergent (e.g. sodium hypochlorite or potassium permanganate solutions). Strong soap or detergents are highly toxic to fish and should not be used in case traces are left in the aquarium. Place the tank in position and add any gravel or sand. This must previously be thoroughly washed to prevent fine material clouding the water. The best method is to half fill a bucket with the gravel or sand, push a hosepipe to the bottom and flush with running water until the overflow is clear.

Add the ornaments, accessories, cables and tubing. Plastic suckers are available to aid mounting, but the suction tends to fail with time, so an acrylic resin or silicone sealer can be used to fix the suckers permanently in position. Fill with water using a dish to spread the water flow and prevent it disturbing the substrate. If a plastic garden hose is used, it must be flushed to waste for a short while to prevent any of the toxic plasticizer contained within the coils entering the tank.

B. Water

Water quality must be tested and adjusted to optimal values for the chosen species of fish. Tapwater is for drinking, not for keeping fish. It is sterile, chlorinated, sometimes fluoridated and often very hard and alkaline. Most tropical species require soft, slightly acid, biologically active water. Chlorine may be removed from tapwater by adding a few drops of 1% sodium or potassium thiosulphate solution or by leaving the water to mature for a day or two, especially with strong aeration. Hardness can be reduced by adding de-ionized or preferably distilled water.

The pH can be lowered by adding sodium dihydrogen orthophosphate (NaH_2PO_4) and acidic water can be neutralized with sodium bicarbonate ($NaHCO_3$). An ideal water source is rainwater, provided that industrial air-pollution is not present. The collecting area must also be non-toxic and the water stored in the dark and kept covered to prevent infestation. Pond and river waters may introduce parasites and disease.

Some fish require hard, alkaline waters (e.g. some Cichlidae) and crushed cockleshell, dolomite or marble chips may be added to the substrate to help maintain these conditions. Other fish need some sodium chloride (e.g. many *Poecilia sp.*). Seasalt, rocksalt or even A.R. sodium chloride can be used, but not table salt because iodine (as an iodide) and/or flow agents such as magnesium carbonate have often been added.

Once the ideal chemical balance has been achieved, it must be monitored and maintained, particularly during routine water changes. Sudden changes in the chemical equilibrium will stress the fish. The water can be biologically matured by seeding with water from an established tank or pond or rainwater tub, providing disease or parasites are not present. Proprietary water conditioners are available for new aquarium water. These contain buffers and chelating agents and may reduce any inflammation of the fish's gills resulting from dissolved substances such as metallic ions.

Fish should be introduced over several days, or even weeks. The tank is then well understocked during the critical period of maturation. The fish's excreta (ammonia, urea and faecal matter) will encourage bacteria to develop, which in turn "softens" the water and makes it more suitable for the fish. Eventually a balance is set up between fish and water that can be maintained by frequent but partial water changes. Twenty per cent weekly has proved to be the optimum in the author's laboratory. Since each aquarium is practically a closed system, this partial water change is important to dilute the steady build-up of dissolved solids.

Various alternative sources of sea water are described in Chapter 2, but remember that synthetic sea water has to mature. This process is easily monitored by testing the nitrite (NO_2^-) concentration. Colorimetric equipment is available from laboratory suppliers, and kits are available from pet shops.

The ammonia and consequent nitrite are converted to the much less toxic nitrate (NO_3^-) ion by denitrifying bacteria that develop in the filter system, so to establish the bacterial colony, nitrogenous material must be made available. This can be by the addition of a material such as shrimp flesh, left to decay in the water, or by adding a marine fish that can tolerate the nitrite crisis e.g. the lionfish *Pterois volitans* (but note that this species is venomous). A cheap freshwater fish that will tolerate both saltwater and nitrite is the black molly (*Poecilia sphenops* var.).

C. Stocking Levels

The limiting factor to stocking level in the small aquarium tank is the oxygen content of the water. This is often dependent on gaseous solution (and exchange with carbon dioxide) at the air–water interface. Hence, the stocking levels are dependent on the surface area, not the volume, of the aquarium. The size of the fish is also important.

To calculate maximum stocking levels in freshwater aquaria, measure the water surface area in square centimetres. Measure the fish's length excluding the tail and group into small (up to 3 cm), medium (3 to 5 cm) and large (5 to 10 cm). Divide the surface area by 70 to give the maximum number of small fish, by 120 to give the maximum number of medium fish and by 140 to give the maximum number of large fish. Very large fish need swimming room as well as adequate oxygen levels, so allow at least 20 litres of water per fish. Table V shows the average number of fish that can be housed in five sizes of typical aquaria.

Marine fish must be stocked at about half the freshwater fish level, because of the lower solubility of oxygen in sea water. At 20°C, saturated sea water contains about 20% less oxygen than saturated freshwater. Table V refers to adult fish. If fry or young fish are installed, the initial density may be higher but the fish must be culled, or some fish moved, as they grow. If a permanent fish population is required, allowance must be made for growth. The species to be kept will of course depend on the research work, but a general rule is to house at least a trio of a given species. To prevent stress by bullying, the preferred ratio is usually one male to two females.

Table V. Stocking levels.

Surface area (cm^2)	Tropical fish	5–8 cm goldfish
700	10 (small)	3
1800	15 (medium)	5
2800	24 (medium)	7
4600	40 (medium)	12
8400	70 (medium)	20

D. Plants

Real plants can prove beneficial in the aquaria since when illuminated, they oxygenate the water and help remove nitrates from solution. In marine aquaria, few higher plants can be cultivated (the author has had some success with *Caulerpa sp.*). However, the common algae can be encouraged to grow with bright lighting. The disadvantage of real plants is that unless conditions are ideal, they rot and pollute the tank. When conditions are good, growth can be vigorous necessitating constant attention e.g. pruning and thinning.

If plants are required, a suitable rooting medium is necessary. This can be provided by small plastic pots filled with peat and Innes potting compound topped with gravel, each container housing individual or groups of plants. To grow directly from the gravel or sand base, a layer of peat 2 or 3 cm thick should be laid before the gravel or sand is placed in the tank as a top covering. The best peat is the commercial variety available for gardening but it must be free of added fertilizers. Pre-soak the peat for several days and squeeze dry before layering. This removes much of the humic acid and colour which otherwise would alter the pH and stain the aquarium water.

The requirements of the chosen plants need to be studied just as much as the needs of the fish. Some plants require soft water and others hard, some need bright and others dim conditions. For photosynthesis, the lighting must be of sufficient brightness per unit area, hence the same intensity of lighting is necessary whether the aquarium contains one or one hundred plants. If only a few plants are present, small algae will proliferate and these may spread on to the plants, stunting growth or even killing them. Therefore, if plants are required, plant a sufficient number. There should be at least one plant per litre.

E. Adding the Fish

Fish imported from the tropics arrive in plastic bags blown up with oxygen. The bags are packed in shredded paper or polystyrene to maintain the high water temperature. These packs must be opened in dim light to reduce panic and stress. The plastic bag should be cut open, not burst and left floating in the receiving tank for the temperature to equilibrate. The bag must be opened because gas diffusion through the plastic from the water is poor. Slow, partial water changes are not recommended. Excreted ammonium ions (NH_4^+) can be converted to toxic ammonia (NH_3) during this procedure. Direct transfer is better.

Fish bought from a local dealer must be chosen carefully. The fish should be active and alert, with erect fins and no superficial blemishes. Other fish in the dealer's tank must be free of any obvious disease or parasite. New marine fish particularly must be fully quarantined before placing in a tank with established fish since all are wild stock, imported with endemic diseases and parasites. The new animals should remain in the quarantine tank for at least several days.

V. MAINTAINING THE AQUARIUM

A. Foods and Feeding

If the trials do not involve nutritional studies, the best basic diet for the small aquarium fish is a commercial flake food. The advantage of flake is that it will at first float for top feeders, sink slowly for middle feeders and lay discretely on the bottom for bottom feeders. Carnivorous fish have a higher requirement for protein and vitamins per body weight than omnivorous mammals and the usual mammalian foods (e.g. kitchen scraps) are nutritionally deficient. The ideal diet would be a live one such as Daphnia, Tubifex, etc. but such a diet is sometimes difficult to provide and can lead to the introduction of diseases or parasites. Sterile prepared foods are preferable. Most flake foods are made from the dried meals of fish, meat, cereals, etc. Because processing to a meal tends to heat damage amino acids, the total protein content of these foods is high to bring the limiting essential amino acids up to the levels required by the fish. A better balanced diet is achieved with lower levels of a higher quality protein source, as in flakes made directly from wet mixes of whole fish and meats.

Fry need feeding frequently to maintain a full stomach. This is easily checked with a hand magnifying glass. Carnivorous fish need one good

E. Adding the Fish

Fish imported from the tropics arrive in plastic bags blown up with oxygen. The bags are packed in shredded paper or polystyrene to maintain the high water temperature. These packs must be opened in dim light to reduce panic and stress. The plastic bag should be cut open, not burst and left floating in the receiving tank for the temperature to equilibrate. The bag must be opened because gas diffusion through the plastic from the water is poor. Slow, partial water changes are not recommended. Excreted ammonium ions (NH_4^+) can be converted to toxic ammonia (NH_3) during this procedure. Direct transfer is better.

Fish bought from a local dealer must be chosen carefully. The fish should be active and alert, with erect fins and no superficial blemishes. Other fish in the dealer's tank must be free of any obvious disease or parasite. New marine fish particularly must be fully quarantined before placing in a tank with established fish since all are wild stock, imported with endemic diseases and parasites. The new animals should remain in the quarantine tank for at least several days.

V. MAINTAINING THE AQUARIUM

A. Foods and Feeding

If the trials do not involve nutritional studies, the best basic diet for the small aquarium fish is a commercial flake food. The advantage of flake is that it will at first float for top feeders, sink slowly for middle feeders and lay discretely on the bottom for bottom feeders. Carnivorous fish have a higher requirement for protein and vitamins per body weight than omnivorous mammals and the usual mammalian foods (e.g. kitchen scraps) are nutritionally deficient. The ideal diet would be a live one such as Daphnia, Tubifex, etc. but such a diet is sometimes difficult to provide and can lead to the introduction of diseases or parasites. Sterile prepared foods are preferable. Most flake foods are made from the dried meals of fish, meat, cereals, etc. Because processing to a meal tends to heat damage amino acids, the total protein content of these foods is high to bring the limiting essential amino acids up to the levels required by the fish. A better balanced diet is achieved with lower levels of a higher quality protein source, as in flakes made directly from wet mixes of whole fish and meats.

Fry need feeding frequently to maintain a full stomach. This is easily checked with a hand magnifying glass. Carnivorous fish need one good

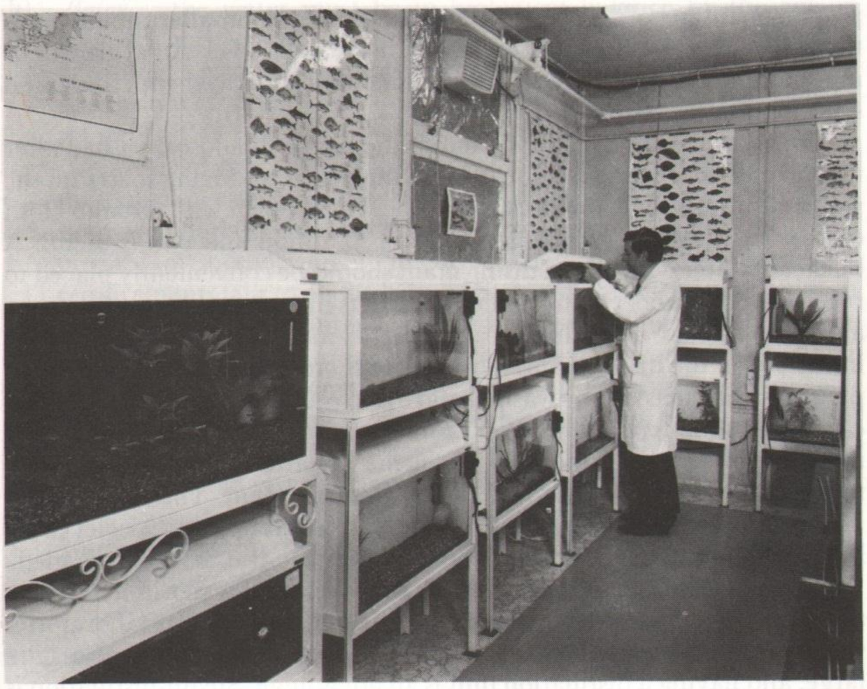

Fig. 2. The Aquarian Laboratory, where nutritional trials are performed for Aquarian products. The aquaria are housed on the periphery of a laboratory of 80 m^2. Some 30 tanks, each 80 × 35 × 30 cm are used in banks of two, each tank being a self-contained unit. The air supply is via a polythene tube, silicone sealed into a hose hung from the ceiling.

meal daily. Omnivorous fish can be fed twice daily and herbivorous fish several times. Individual needs of the actual species must be considered, of course. Feeding can be weekdays only (except small fry) and weekend working by laboratory staff is usually unnecessary.

B. Routine Cleaning

Routine partial changes of the water are most important. The changes are necessary to dilute the build-up of soluble materials. The ideal is to replace 20% of the tank volume weekly. Too great a dilution will change the water chemistry and thereby stress the fish. The aquarium should not be left until it is very dirty and then cleaned by emptying, scrubbing out and refilling with fresh water. A well-established tank kept clean by routine, partial water changes has gin-clear water and a sweet odour. Solid excreta or mulm, is removed during the water changes by "hoovering" the gravel with a siphon tube. This siphon is a few metres of polythene tubing of 8 or 10 mm internal diameter. Smaller tubing tends to block, while larger tubing tends to remove the gravel. Algal growth or mulm settling on the internal face of the glass is removed with a soapless scouring pad as required.

The cleaning can be done by hand; the hands should be washed after the job and not before because of the danger of introducing soap into the water. The outside of the tank should be wiped down with a damp cloth or paper tissue. Floor areas get wet and so a mop and pail is useful. A bucket of water with added disinfectant should be conveniently placed to receive used fish nets. Sufficient of these nets in a range of sizes should be available so that immediately after use in any one tank, they can be immersed in the disinfectant. This prevents cross-infection of diseases or parasites. The nets can be washed and dried routinely as required. In this case, most commercial brands of disinfectant may be used, but all traces must be rinsed away before re-use in the aquarium. The nets must be made from synthetic fibre to withstand this treatment. The mesh should also be very fine. The barbels, spines and gill covers of many species catch in large open meshes, causing wounds when the fish are disentangled.

Evaporation losses should be replaced by distilled water in freshwater aquaria. Tapwater is adequate for salt-water aquaria. In laboratories with banks of aquaria, the volume of distilled water required can be quite large, and having a distillation unit is an advantage. Steam-distillation is the preferred method and automatic models for chemical laboratories are available. A 4-litre still can cope with 30 or 40 × 100 l tanks.

VI. AQUARIUM PROBLEMS

A. Algal Growth

The most common problem for the inexperienced aquarist is excessive algal growth. There are many species of algae that can flourish in the aquarium and the problem can be green water, sometimes as thick as pea soup, filamentous growth that chokes plants, or a blanket forming over the gravel and rocks. There are green, brown and red varieties. Three factors contribute to this problem and each must be examined and corrected:

(a) *Lighting:* excess lighting will encourage algal growth, particularly daylight or direct sunlight. Photosynthesis is dependent upon illumination per unit area, and if plants are included, the same level of lighting is necessary for many or a few plants (see section IV D, Plants). If only a few plants are present, the remaining area can be utilized by algae.

(b) *Balance:* the water must be in biological balance by the ageing process and continuous dilution described under "Routine Cleaning". A sudden growth of algae in an established tank is a sure indication of imbalance due to excess nitrogenous material in solution.

(c) *Overfeeding:* the most common reason for an excess of soluble material is overfeeding. Freshly hatched fry can eat almost their own body weight daily in natural foods such as *Artemia salina*, but only 3 or 4% of body weight in dried foodstuffs. An adult fish's requirements falls to about 1.5% of body weight since growth almost ceases and only a maintenance diet is required. Furthermore, some fish have the ability to ingest continuously, but only absorb their nutritional requirements, simply excreting the surplus. With such fish, to feed to satiation is to pollute the aquarium with excess food. Growing fish should be fed for 2 or 3 min at each feeding and any excess siphoned or netted away. Adult fish can be fed similarly but the frequency reduced to once or twice daily according to species. A 20-g pack of Aquarian flake food should last 100 adult community tropical fish about one month.

B. Diseases and Parasites

Parasites and diseases are the second major problem in small aquaria. The confines of the tank favour explosive growth of the more common parasites, such as white spot (*Ichthyopthiriasis*), various fungi (*Dermatomycosis*) and in saltwater, *Oodinium* (*Oodiniasis*). These parasites are present in any body of water but healthy fish can resist them. Poor husbandry, stress or damage from fighting or handling, leads to unhealthy fish that may then be troubled by parasites. Treatment for various parasites and diseases is described in chapter 10. Once an outbreak has been contained, the underlying fault in husbandry should be sought and corrected.

VII. MARINE SPECIES

Many of the marine fish kept in aquaria are more sensitive to their aquatic environment than the majority of freshwater species. In the marine aquarium, the pH, nitrite and specific gravity levels in the marine aquarium should be monitored routinely and swiftly corrected if necessary.

Most marine species require a pH of about 8.2, but biological filtration systems tend to produce acidic by-products which slowly reduce the pH. Alkaline materials can be added to the tank such as crushed shells, dolomite granules, marble chips or sodium carbonate. Nitrite levels should be zero a few days into the maturing period, after an initial crisis level. A value over 0.1 mg/l should be taken as an indication of some problem in the system. This could be blocked or dirty filter beds, a dead fish or invertebrate, overcrowding or inadequate water-changing. It is advisable to keep a supply of made-up synthetic sea water for partial water changes when a high nitrite reading is obtained. The water may be kept at normal or double strength (to reduce bulk storage) and should be housed in a plastic dustbin with a lid. Black or grey plastic is better, since coloured plastics may contain toxic dyestuffs. Some aeration keeps the water moving and prevents precipitation, especially if double strength solution is stored.

VIII. SUITABLE FISH FOR THE RESEARCH LABORATORY

The species of fish to be housed in the laboratory will depend on the purpose of the research. The following are examples of fish that are commonly the subject of scientific study.

A. Toxicity Screening and Water Quality Research

The International Organisation for Standardisation has issued a document (ISO, 1976) detailing proposals for screening chemicals and commercial products for their acute toxicity to freshwater fish. The test species recommended is the zebra fish, *Brachydanio rerio*. An extensive review of the biology of this fish has been given by Laale (1977).

Other species commonly employed for assessing the effects of pollutants are as follows:

threadfin shad (*Dorosoma petenense*)
brook trout (*Salvelinus fontinalis*)
rainbow trout (*Salmo gairdneri*)
northern pike (*Esox lucius*)
emerald shiner (*Notropis atherinoides*)
fathead minnow (*Pimephales promelas*)
white sucker (*Catostomus commersoni*)
channel catfish (*Ictalurus punctatus*)
white bass (*Roccus chrysops*)
blue gill (*Lepomis chrysops*)
largemouth bass (*Micropterus salmonides*)
yellow perch (*Perca flavescens*)

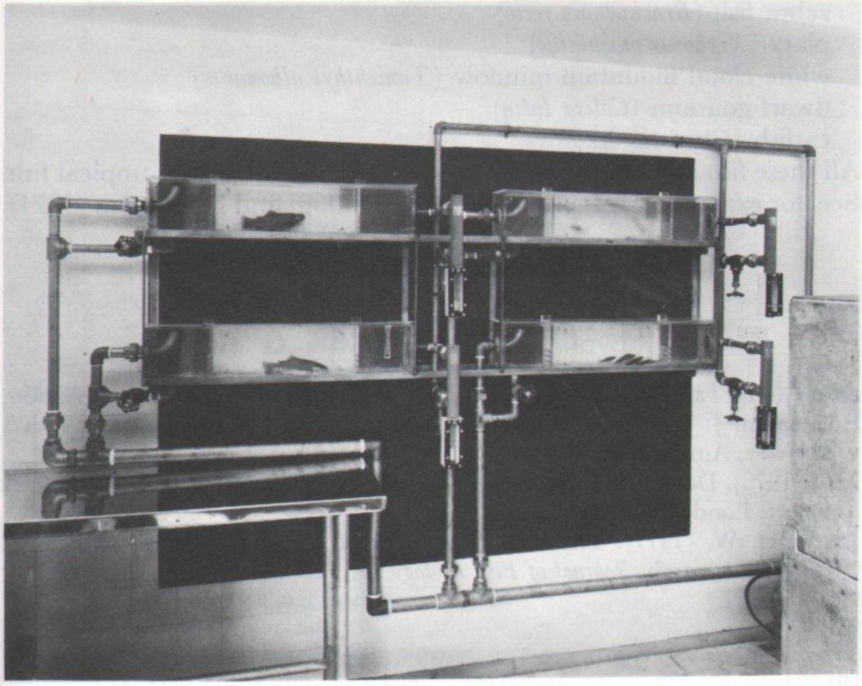

Fig. 3. A unit for monitoring water quality. Water piped to a food processing factory passes through a settlement tank. Water is drawn directly from this settlement tank to four aquarium containing rainbow trout. Each aquarium holds 20 litres of water and is fed at a flow rate of 10 l/min. The fish are viewed continuously on a TV monitor by factory security personnel.

B. General Biological Studies

The equivalent of the laboratory rat for much behavioural and physiological research is the goldfish, *Carassius auratus*. The aquarium requirements of this fish are described by Hervey and Hems (1968). The rainbow trout, *Salmo gairdneri*, is also a common laboratory species, though it requires cool, well oxygenated water. Based on sales figures, the ten most popular and readily available freshwater fishes are given below. They are compatible species, and can be mixed in a community tank. They are also the easiest fish to keep in the aquarium:

angel fish (*Pterophyllum scalare*)
guppy (*Poecilia reticulata*)
swordtail (*Xiphophorus helleri*)
black molly (*Poecilia sphenops* var.)
neon tetra (*Paracheirodon innesi*)

zebra fish (*Brachydanio rerio*)
platy (*Xiphorus maculatus*)
white cloud mountain minnow (*Tanichthys albonubes*)
dwarf gourami (*Colisa Ialia*)
catfish (*Corydoras* sp.)

All these fish are described in any good aquarist's book on tropical fish. See, for example, McInerny and Gerard (1966) and Hoedeman (1974).

IX. REFERENCES

Hervey, G. F. and Hems, J. (1968). "The goldfish", Faber and Faber, London.

Hoedeman, J. J. (1974). "Naturalists Guide to Freshwater Aquarium Fish", Elsevier, Amsterdam.

ISO (1976). Document No. 150/TC 147/SC5/WG3. 11 Nov. 1976., BS1, Park Street, London.

Laale, H. W. (1977). The biology and use of zebrafish, *Brachydanio rerio*, in fisheries research. *Journal of Fish Biology* **10**, 121–173.