Fish keeping : the design and operation of research aquaria

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INTRODUCTION

The overall size of an aquarium laboratory must depend on the type of research and the number of aquaria to be housed. If only part of the laboratory is to house experimental tanks they must be situated away from entrances, where traffic may give rise to stress. Noise should also be avoided, such as vacuum pumps, generators and similar pieces of equipment, particularly those giving rise to vibrations.

If the laboratory is a complete fish-house, the most practical design is to mount the tanks on stands around the peripheral area of the room, with a central working area fitted with the normal laboratory benches, drawers, cupboards and services.

If the laboratory is designed for ancillary functions, such as water-monitoring, the unit may be built as an annex, but services that must always be included are drainage, benching and cupboard space.

Specific examples of three major types of aquarium laboratories are described later to illustrate these points.

1. EQUIPMENT

Each item of aquarium equipment is available in many forms and choice must depend on purpose and budget. Considering each major item in turn:

(a) *The tank*

The traditional aquarium that has existed for many years is the rectangular metal frame with glass sides embedded in putty. The problems with this design are the weight, even when empty, and leaks. The putty tends to dry-out with age giving minor leaks that are difficult to seal without emptying the tank. There are large numbers of these older type of tanks available second-hand. If the laboratory is on a tight budget banks of these tanks may

Pedigree Petfoods Ltd, Animal Studies Centre, Freeby Lane, Waltham-on-the-Wolds, Melton Mowbray, Leicestershire LE14 4RT.

be installed at low cost. Local newspapers often advertise complete aquaria at very low prices when some houseowner wishes to dispose of an ageing set-up. The leaking problems can be overcome by sealing the internal corners with a Silicone Sealer*. Any bare metal must be primed, preferably with an aluminium-based primer, and given several coats of a good quality polyurethane paint. These tanks are not really suitable for saltwater, but may be pressed into service if the painting and silicone sealing is meticulously carried out. There must be no physical contact between saltwater and any bare metal or putty because both will pollute the aqueous phase. All-plastic tanks were popular in recent years because they are non-toxic, low in weight and require no maintenance. The rising cost of plastic materials, however, has made the plastic tanks too expensive and manufacturers have changed back to glass. Small tanks (2 to 60 litres) are manufactured from a single mould and these are useful additions to the laboratory for handling fry, quarantine, treatment etc. One problem with plastic tanks is that the surface can be easily scratched making the sides opaque, so abrasive cleaning materials must be avoided.

The ideal tank is the all-glass, silicone-sealed unit. These are simply glass boxes ranging in size from 10 to 2,000 litres. The smaller tanks of up to about 100 litres (100 cm long × 30 cm high × 30 cm wide) can be made from glass of 4 mm thickness, but 6 mm is preferable. The front, back and base could be 6 mm with the sides 4 mm, but over 100 litres 6 mm should be used throughout. Over 200 litres, 10 mm glass is required. For large aquaria of 1,000 litres, 20 mm glass is necessary, but these will need special ordering because glass merchants usually stock only up to 10 mm thickness.

Water pressure is a function of height and any tank of 1 metre depth or more, needs a supporting frame. Small tanks can be made from clear glass sheet, but from 6 mm upwards polished or floated plate glass is better for distortion-free viewing. Base or rear sides were often slate and the cheaper pebble or reinforced glass in framed tanks. Such types of glass or slate are not suitable for Silicone-sealing since the strength of the join is achieved by using very clean, polished smooth, flush-fitting joints. The reverse face of a pebble glass may be smooth enough to be used however.

Silicone Sealer can be obtained in small tubes or large cartridges, the latter requiring a specially designed gun (available from the Silicone Sealer manufacturer). Glass should be bought cut and polished and the edges cleaned with acetone or carbon tetrachloride prior to sealing. Some manufacturers of the Silicone Sealer supply details of tank construction with their products. The hobby press also have articles on all-glass tank manufacture (Harrison, 1977). An internal bead of Silicone Sealer adds to the strength of the joints, but the Silicone rubber is easily cut by sharp objects, therefore cleaners such as razor blades or metal scrapers should not be used.

Silicone Sealer will only work with glass; plastic sheet will not form water-tight seals with this adhesive. Special shape tanks for studies of water-flow etc. can be made from perspex or similar materials using solvent adhesives.

Tank sizes should be carefully considered prior to installation:—

1. *Weight*

If only one technician is available, the largest empty tank he can comfortably handle is 80 × 35 × 30 cm or 30 × 15 × 12 ins.

2. *Maintenance*

The larger the tank the easier is the maintenance since larger volumes of water take longer to become polluted.

3. *Measurements*

Tanks of equal size make measurements easier since aquarium posology can be standardised. Another advantage is that all the accessories are interchangeable.

4. *Imperial v. Metric*

If second-hand tanks are used they will probably be based on Imperial units in the U.K. and U.S.A. European tanks and contemporary tanks are metric and the smaller metric units (centimetres) gives a greater variety of tank sizes. Traditional sizes are listed in Table 1.

Table 1. Traditional Aquarium Sizes

Imperial		Metric	
Inches	Gallons	cm	litres
7×5×5	½	30×20×20	10
12×6×10	1½	60×35×37	60
18×10×10	6	80×35×41	90
20×10×12	9	100×40×41	120
24×12×12	12	100×42×50	150
30×15×12	16	135×42×53	200
36×15×12	20	140×42×53	220
48×15×12	43	150×42×53	250

The absolute volumes can be calculated for the Imperial tanks by multiplying length, breadth and width in feet, by 6¼ to give gallons; the capacity in cubic centimetres of the metric tanks by simple multiplication of the cm dimensions. The quoted volumes in Table 1 are for furnished tanks where the water volumes are 20 to 30% less than the absolute values, due to the presence of gravel, rocks, plants and accessories.

5. *Tank support*

A full aquarium is very heavy and adequate support is essential, not only the aquarium stand, but the floor area as well. The average hobbyist's tank of 24 × 12 × 12 ins. (about 60 × 30 × 30 cm) with accessories and water weighs almost 90 kg (200 lbs). The traditional angle-iron stand is adequate for vertical banks of 1, 2 or 3 tanks and are available from aquaria manufacturers. Custom built stands can be based on timber (of sufficient strength) shelving or Dexion-style fittings. To take-up inequalities in such stands, especially where all-glass tanks are used, a buffer of expanded polystyrene is necessary. The type used for kitchen ceiling tiles is ideal.

All tanks must be emptied prior to being moved. Even a low level of water can start to slop within a tank and build-up a twisting torque that can crack the glass.

6. *Cover*

Every tank must have a top cover, otherwise dust affects the surface, the fish may leap out, and evaporation losses will be excessive. 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 is to drill and screw the centre line to a suitable length of timber. The glass may be cut into overlapping halves and mounted in cupboard door plastic runners supported within the tank. This gives 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.

7. *Base*

The bottom of the tank should always be covered to give opacity so fish can orientate properly. Hobbyists have evolved a tradition of covering the base with a gravel of split pea size (5 mm), usually spread over a plastic under-gravel, air-lift operated, filter. For reasons detailed under the section on filtration, undergravel filters are best avoided. Without such filtration, a smaller sized gravel may be employed — this is better for the plant roots and individual stones are less likely to block the mouths of sucking feeders such as goldfish. A type called Birds Eye gravel (about 2 mm) is ideal. Sand is a possible medium for the base, but this can be too fine allowing compaction to occur. Compacted sand gives anaerobic conditions and possible pollution problems.

(b) *Heaters and Thermostats*

The average laboratory temperature is too low for tropical fresh-water and marine specimens, so additional heating is necessary. The standard 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. It is preferable however, to have individual heater and thermostat units for each tank because any equipment failure will restrict the consequences to one tank. 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 has the advantage of accessibility. Wattages for heating tanks are not critical but Table 2 is a guide.

Table 2. **Heater Wattages**

Imperial (ins)	**Metric (cm)**	**Wattage Required**
18 × 10 × 10	45 × 25 × 25	25 to 50
24 × 12 × 12	60 × 30 × 30	75
36 × 15 × 18	90 × 40 × 45	100 or 2 × 60
48 × 15 × 18	120 × 40 × 45	150 or 2 × 100
72 × 18 × 24	180 × 45 × 60	2 × 150 or 3 × 100

Duplicate (or multiple) heaters have the advantage of spreading the heating effect throughout a large tank. The heaters should be wired in parallel with electrical connections outside the tank and well insulated against condensation or accidental spillages of water. The author uses ceramic or plastic block connectors sealed with a smear of Silicone Sealer and wrapped in a P.V.C. insulating tape. It should be stressed however, that electrical insulation is extremely important in a fish-house and the advice of a qualified electrician should be sought. This is particularly important with marine tanks where salt crusts develop with age — these creep away from the tank on any surface and work into the electrical connections giving rapid corrosion and electrical shorts. On the marine tanks lighting circuit, the author runs the cable through polythene tubing, sealed at the connection to a fluorescent tube and at a point several metres away with Silicone Sealer.

Some fish-breeding establishments avoid the high cost of electrical heating by controlling heating to an ambient temperature of about 25°C via steam pipes. The tanks can be placed directly over the steam pipes to give adequate heat transfers. Other techniques include space heating with paraffin heaters or electric fan heaters. Such methods have lower running costs than individual tank electrical heating, but the high ambient temperature is not suitable for laboratory conditions.

(c) *Temperature*

Each tank needs a thermometer to monitor the water temperature. The cheap hobbyist thermometer is notoriously inaccurate, so a mercury-in-glass chemical thermometer is preferable. Tanks housing aggressive species of fish that may break such thermometers, can be monitored with liquid-crystal digital thermometers. These will adhere to the outside of the glass and although the reading may be a degree or so low, the error is consistent.

All water changes or fish transfers must be checked with a thermometer because rapid temperature changes will severely stress the fish.

(d) *Aeration*

Although not an absolute necessity continuous aeration is very good husbandry. To supply the air, many cheap pumps are available in the hobby trade. However, they are noisy and of limited power. If only one or two tanks are required, these small vibratory pumps are acceptable. They should be mounted above the tank water 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 of at least 8 cm (3 ins) 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 can be used, or preferably a compressor. The best type of compressor is the oil-free type and a motor of $^1/_{12}$th horsepower in adequate for 20 × 100 litre tanks. 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. This system is described in the section on the Aquarian laboratory.

(e) *Filtration*

The underground filter used by the hobbyist is best avoided because it retains detritus within the tank and adversely affects aquatic plants where required. Gross material can be removed by operating one or more corners or box filters containing polyester filterwool. Glasswool must not be used because glass splinters can be released into the main tank and then lodge in the fish's gills; nor cottonwool because this will rot and pollute the water. Several models of the box filters are available in the aquatic trade; all are air operated. To polish the water, a diatomaceous-earth filter can be used on a routine basis. The Diatom or Novita are suitable filters (the models and suppliers are advertised in the aquatic trade press). One such model can routinely treat 20 or 30 tanks weekly. Fresh charges of diatomaceous-earth are usually required for each tank.

Marine fish require biological filtration and again the tradition is to rely on undergravel filters. A better system is to use a power-filter of the type made by Eheim (as advertised in the aquatic trade press), with carbon and wool filter mediums. The carbon is not included for its absorption properties (which are quickly saturated), but for its large surface area. The biological filtration relies on surface-active nitrifying bacteria so any filter medium should maximise the surface area. The carbon granules should be packed loosely in a mesh (nylon) bag and to prevent the carbon becoming clogged with detritus the bag should be sandwiched between nylon wool to prefilter gross material and give a final mechanical filter before the water flows back into the tank. Table 3 is a guide to pump sizes that have been shown in practice to keep saltwater nitrite levels at zero.

Table 3. **Powerfilter Sizes**

Tank Size Litres	**Flow Rates Litres/hour**	**Examples of Filters**
Up to 50	Over 100	Eheim No. 388 Martin No. 300
Up to 200	Over 150	Eheim No. 386 Martin No. 400 Nuova Turbo Filter
Up to 500	Over 300	Eheim No. 486
About 1000	1000	Eheim No. No. 587 or No. 588

Although a proprietary brand of filter is listed (see aquatic trade press for suppliers), any type of pump and container can be used provided it is non-toxic. Zoo aquaria have evolved some ingenious methods of biological filtration and it is well worth contacting the curator of any local establishment that show marine specimens for a behind-the-scenes tour. An example is Marineland in Skegness, Lincolnshire, England. This public aquarium uses real seawater filtered by a unique (and patented) subsand collection system and any laboratories on the coastline could use this system. The advantage is that such a throughflow system eliminiates the need for biological filtration or preparation of artificial seawater. The chemistry of biological filtration is explained by Spotte (1970).

(f) *Decoration*

Apart from aesthetic considerations a tank should be decorated to emulate the typical aquascape of the fish's natural habitat. This includes tank-bred specimens since generations of line-breeding has produced fish where petrified logs or pot mermaids have been imprinted as a natural environment. A bare tank will stress the fish. Any rocks, pebbles or ornaments must be non-toxic and sterilised prior to use. Rocks must be lime-free to prevent dissolving salts increasing the water hardness. Granite, river-washed boulders or glass are ideal. Aggessive species like many *Cichlidae* need caves built from these rocks to give territorial areas and safe retreats. Coral-fish need pieces of coral to weave through, and these are usually bleached white for sterility. Sensitive species such as Discus need dense plants (real or plastic) to hide in. Burrowing fish like Wrasse (*Labridae*) need coral sand of reasonable depth. Even a treatment tank should at least have a gravel base and a plastic plant.

To give a better view of the fish, the back glass should be made opaque. An effective method is to cover the outside rear glass with a liberal coating of a white emulsion paint while the tank is laid face down, prior to installation.

(g) *Lighting*

Fish prefer dull conditions so the permanent bright lighting of display tanks are not necessary unless plants are present or Algal growth is required. However, the diurnal rhythms of the fish possibly require a light/dark cycle and daily inspection by laboratory staff is essential, so overhead lighting should be installed. Table 4 is a guide for an 8 hour period of lighting per day.

Larger tanks than those listed in Table 4 can be lit by Dichroic spotlights mounted over the tanks. The only cover required is then a top-glass. A 2 metre long tank can be lit by two 150W spotlights such as Phillips Cool-lite. The ordinary filament bulbs are cheaper to buy than the fluorescents and the heavy starter-units are avoided, but the usual sideways mounting of these bulbs in a standard cover gives a short life due to sagging of the tungsten filament. Lifting the cover whilst the lamps are lit often breaks the

Table 4. Lighting

Length of Tank	Wattage of Filament Bulb	Wattage of Fluorescent Tube
Up to 18 in (45cm)	40	8
24 in (61cm)	2 x 40	15
30 in (76cm)	2 x 60	20
36 in (91cm)	3 x 40	2 x 20
48 in (122 cm)	3 x 60	2 x 30

filament by vibration. The bulbs also burn hot raising the surface temperature to unacceptably high levels for many fish, such as coldwater species or the *Anabantidae*. The heat can also give condensation problems, but this, and the surface heating, can be overcome by using a glass sheet between the lamps and water, mounted either in the cover or the tank's top. The bayonet or screw fitting of the bulb can be protected from condensation by a few inches of tubing cut from a bicycle innertube.

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 because their heavy weight gives the danger of the whole lid falling into the water when dislodged. Springclips will hold the tubes in the lids but these must be highgrade stainless steel or nylon-coated. 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 ring main or all the tanks may be lit from a single circuit with a masterswitch that could be controlled by a timer. In the latter case, override switches should also be fitted so individual tanks can be switched off.

(h) *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 with surges a rating of 1 Amp should be used in calculations. Hence a 30 Amp, 240 Volt circuit will maintain 30 standard aquaria. The wiring to each tank can be 3 Amp, 3 core domestic cable via a suitable socket outlet for each unit of 1, 2 or 3 tanks. This will allow one tank, or unit, to be easily electrically isolated before any handling. The socket and plug can take a lead to a junction box and the hobby-trade sell such units under the name 'Cable-Tidy'. This junction box in turn feeds the thermostat, heater, lights, pump and power filter as required. External units can be earthed including the frame of the tank, if metal, and the stand. The water itself should not have an earth connection because of the danger of metal pollution. The Electrical Appliances (Safety) Regulations 1975 of the United Kingdom require all electrical accessories to be double insulated and this level of safety in design is being adopted by European and American manufacturers.

2. SETTING UP THE TANK

(a) *Installation*

Wash the tank with water and disinfectant. Soap or detergents should not be used because any trace left in the aquarium will kill the fish. Install the tank and add any gravel or sand. This must 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 can be used to fix the suckers permanently in position.

Fill with water and use a dish to spread the water flow and prevent it disturbing the aquascape. If a plastic garden hose is used for this purpose the hose must be flushed through before use to prevent any plasticiser concenbright and others need dull 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, the surplus light will encourage algal growth which can spread on to the plants, stunting growth or even killing them. So if real plants are required, plant sufficient. 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 and packed in shredded paper or polystyrene to maintain temperature. These packs must be opened in dull light to reduce panic and stress. The plastic bag should be cut open (not burst open) again to reduce panic, and left floating in the receiving tank to equilibrate temperatures. The bag needs to be opened because when floating the normal porosity of the plastic ceases and carbon dioxide build-up can affect the fish. The fish should not be transferred directly into the aquarium because of temperature differences. There is usually a difference in water chemistry so partial water changes to acclimatize the fishes over half an hour of so is recommended. This is particularly important with marine fish.

Fish bought from a local dealer must be chosen carefully. The fish's eye must be bright and fins erect and other specimens in the dealer's tank must be free of any obvious disease or parasite. Marine fish particularly must be fully quarantined since all are wild stock imported with all the endemic diseases and parasites. Once a stable tank of fish has been established a separate quarantine tank is essential to check any additions for at least a few days.

3. MAINTENANCE OF THE AQUARIA

(a) *Foods and feeding*

If the trials do not involve nutritional studies the best basic diet for aquarium fish is a commercial flake food. The advantage of flake is that it will float for top feeders, sink slowly for middle feeders and lay discretely on the bottom for bottom feeders. Fish have a higher requirement for protein and vitamins per body weight than mammals so the usual mammalian foods (eg. kitchen scraps) are nutritionally deficient. The ideal diet would be a natural one such as daphnia, tubifex, larvae etc. but such a diet would inevitably lead to the introduction of some disease or parasite. Hence the sterile prepared foods are preferable. Most flake foods are made from meals such as fish meal, meat meal, oatmeal and so on. These raw materials are necessary in commercial fish farms where feeding costs need to be as low as possible, but in the confines of an aquarium such raw materials can

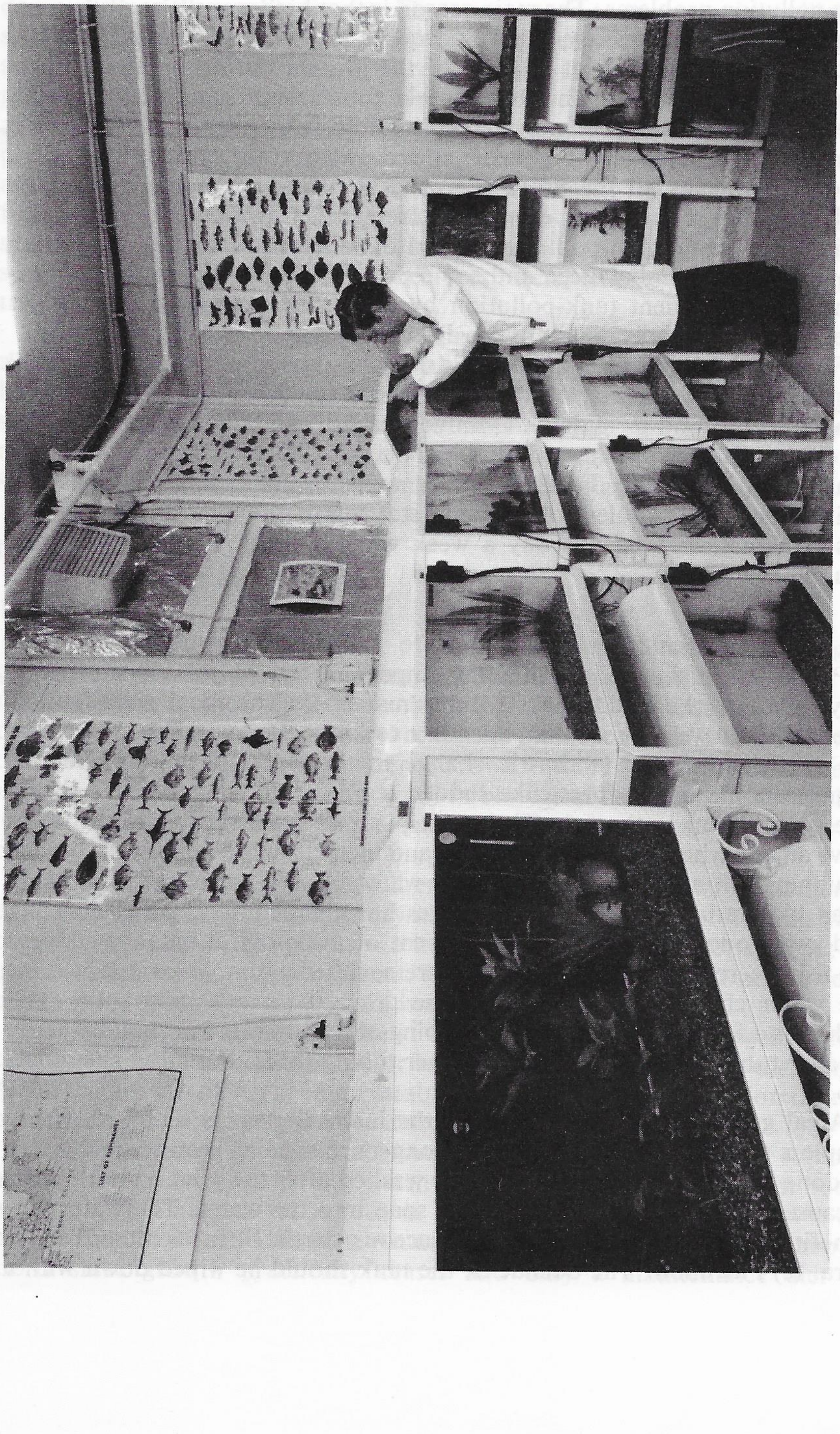

FIGURE 1

give pollution problems. The main reason is that high quantities of the protein material are necessary to give adequate levels of the essential amino-acids, due to possible heat damage of the protein during the drying to a meal. A recent innovation has been a flake food called Aquarian that is unique in being flaked from wet mixes of whole fish and meats. This overcomes the problems of using meals and allows a lower protein level to be used. This means all the protein is used in body-building processes and carbohydrates are used for energy requirements. Carbohydrates are metabolised to give the non-polluting carbon dioxide and water residues. High protein diets are unbalanced and some protein is used for energy production with consequent tank-pollution by the residues urea and ammonia. The author can supply details of the diet on request.

Fry need feeding as frequently as is necessary to maintain a constant full stomach. This is easily checked with a hand magnifying glass. Carnivorous fish need one good meal daily. Omnivorous fish can be fed twice daily and vegetarian fish several times. Individual needs of the actual species must be considered, of course. Feeding can be weekdays only (except small fry) which means the problem of weekend staffing of the laboratory does not arise. In fact, at least one day a week without food is beneficial to the aquaria.

(b) *Routine cleaning*

Partial water changes are the most important routine job. This is necessary to dilute the build-up of soluble materials. The ideal level is 20% weekly. This level is more than adequate to dilute the aquarium solutes but not sufficient to give a drastic change in the water chemistry. Sudden changes in pH or hardness, like sudden temperature changes, give rise to stress conditions in the fish. The worst possible situation for the fish is to leave an aquarium until it is very dirty and then clean the tank by emptying, scrubbing out and refilling with fresh water. A well-established tank kept clean by routine, partial water changes has characteristic gin-clear water and sweet odour due to the development of a biological balance between the fish, excreta and bacteria. Solid excreta, called 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 and larger tubing tends to remove the gravel too.

Algal growth or mulm settling on the internal glass is removed with a soapless scouring pad as a daily (or longer) routine as required. This 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 water also benefits from a polish with diatomaceous earth filter as described in para. (e) *Filtration*. The outside of the tank should be wiped down with a damp cloth or disposable tissues. Floor areas tend to get wet with spillages so a mop and pail is useful. A bucket of water with added disinfectant should be conveniently placed to receive used fishing nets. Sufficient of these nets in a range of sizes should be made 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. The nets need to be made from synthetic fibre to withstand this treatment. They should also be a very small mesh size. Large mesh nets are available, but the barbles, hooks and gills of many species of fish easily hook into open mesh nets, leading to wounds when trying to disentangle the fish.

Evaporation losses should be replaced by distilled water in fresh-water aquaria. Tapwater is adequate for saltwater aquaria. In laboratories with banks of aquaria, the volume of distilled water required can be quite large, so 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 to 40 tanks of 100 litres capacity each.

(c) *Problems*

1. Algae

The most common problems of the inexperienced aquarist is algal growth in the tank. There are many species of Algae that can flourish in the aquarium so the problem can be green water, sometimes as thick as pea soup, or filamentous growth that chokes plants, or a blanket form over the gravel and rocks. There are green, brown and red varieties. All of these algae indicate that the aquarium is not in biological balance i.e. excess biological material is present. Three factors are involved, and each must be examined and corrected.

(a) Lighting. Excess lighting will encourage Algae to grow, particularly daylight or direct sunlight. Photosynthesis is dependant upon illumination per unit area, so if real plants are included, the same level of lighting is necessary for many or a few plants, (see para. 2 (d) *Plants*). If only a few plants are present, the surplus light is available to the Algae.

(b) Balance. The water must be in biological balance by the ageing process and continuous dilution described in para. 3 (b) *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 this 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% since growth practically 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, attempting to feed to satiation is simply polluting the aquarium with excess food, via the fish. Growing fish should be fed for 2 or 3 minutes 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 one month.

2. Infestation

Parasitic diseases are the second major problem in aquaria because the small confines of the tank favour explosive growth in common parasites such as White Spot (Ichthyophthiriasis), Fungus (Dermatomycosis) and in saltwater, Oodinium (Oodiniasis). All of these parasites are present in any body of water but healthy fish can resist the parasites. It is unhealthy fish from poor husbandry, stress, or damage from fighting or handling, that fall prey to the parasites. Treatment for these infestations is described elsewhere, but once an outbreak has been contained the underlying fault in the husbandry should be sought and corrected.

3. Marine Fish

The maintenance of marine fish aquaria is very important because the fish are much more sensitive to their aquatic environment than freshwater species. The body fluids of marine fish are lower than the surrounding seawater and hence osmosis continuously dehydrates the fish. Hence, a marine fish must drink seawater and extract the salts, to compensate for the water loss. Freshwater fish, on the other hand, show reverse osmosis and are continuously absorbing water that is copiously excreted. A freshwater fish does not therefore, drink the aquarium water, but a marine fish must drink continuously and hence is much more susceptible to pollutants. The pH, nitrite and S.G. levels should be monitored routinely and swiftly corrected if necessary. Most marine species require a pH over 8.0, but biological filtration systems tend to produce acidic byproducts which slowly reduce the pH from its ideal value of 8.2. Alkaline materials can be added to the tank such as crushed shells or dolomite granules, but in the laboratory where control facilities are available, additions of sodium carbonate (Na_2CO_3) can be made. Nitrite levels should be zero after the initial crisis has been passed, a few days into the maturing period. A value over 0.1 ppm NO_2^- should be taken as an indication of some problem in the system. This could be blocked or dirty filter beds, a dead fish or an invertebrate decaying somewhere, overcrowding or inadequate water-changing. It is advisable to keep a supply of made-up artificial seawater available for partial water changes immediately a nitrite reading is obtained. The saltwater may be kept at normal or double strength (to reduce bulk storage) and should be housed in a plastic dustbin with a lid. The black or grey plastic is advisable since coloured plastics may contain dyestuffs toxic to marine fish. An airline and aerator will keep the water moving and prevent any precipitation especially if double strength solution is stored.

4. SPECIMENS

The type of fish housed in the laboratory will depend on the subject of the experiments. If typical petfish are required, the top ten most popular Tropical species are as follows:—

(a) Angel Fish, *Pterophyllum scalare*
The Queen of Tropical fish and two or three specimens will be found in every community tank. They have been bred into a variety of colour-forms.

(b) Guppy, *Poecilia reticulata.*
A livebearer with high fecundity. The male carries the colour and varied fin shape. There are local and national societies devoted to this one species in most European countries and the U.S.A.

(c) Swordtail, *Xiphophorus helleri*
Another popular livebearer notable for the male possessing an elongated caudal fin shaped like a sword.

(d) Black Molly, *Molliensia sphenops*
Also a livebearer. The fish's popularity is due to the intense black colour which gives contrast to the other colourful species.

(e) Neon Tetra, *Paracheirodon innesi*
This fish and the similar Cardinal Tetra, *Cheirodon axelrodi,* are the most vividly coloured of all tropical fish.

(f) Zebrafish, *Brachydanio rerio*
This small fish is very active and several specimens will shoal. The Zebra stripes give a distinctive appearance.

(g) Platy, *Xiphophorus maculatus*
A livebearer that is easy to keep and breed and has a variety of colour forms.

(h) White Cloud Mountain Minnow, *Tinachthys albonubes*

Similar in shape to the Zebrafish, this small active fish has a distinctive colour pattern.

(i) Dwarf Gourami, *Colisa lalia*

The Gouramies are popular fish of unusual shape and they possess feelers. Many Gouramies grow too large for the community tank, hence the popularity of the Dwarf variety.

(j) Catfish, *Corydoras sp.*

A Catfish is a useful addition to an aquarium because it is a bottom-feeder and will scavenge food overlooked by the pelagic species.

The listed fish are all community species i.e. they are compatible when mixed in one tank. Pecking orders usually evolve and any one specimen can become boss of the tank. This is acceptable if any aggression is by display or short chasing, but if actual fighting occurs, the aggressor, or victim, should be removed.

Many species of Tropical fish need to be isolated as a group or even individually. Each interesting type of fish has its own adherents in the hobby eg. Killifish, Cichlidae, Discus, Guppies, and each of these species is studied by a national society in the U.S.A. and most European countries.

In the coldwater aquaria the most popular species is the Goldfish, *Carassius auratus*. This species has been bred into many forms, Veiltail, Bubble Eye, Oranda etc., but the original common form is still the most popular of all petfish. Other coldwater fish include Silver and Golden Orfe and some game fish. For the pond the Goldfish remains a favourite, but increasing numbers of the Japanese Carp, *Cyprinus carpio*, known as Koi, are being kept as petfish.

The marine tank usually includes compatible specimens of the many Tropical Coral fish and may also include invertebrates from coral reefs. Coldwater sea specimens are not common in the hobby field because of the problem of cooling, rather than heating the seawater.

If toxicological studies are required, the common Goldfish is a suitable fish for study, being cheap, plentiful and tolerant of a wide range of temperatures. However, this very tolerance makes it an unsuitable 'early-warning' system of pollution in waters under test. A better choice would be Trout, *Salmo gairdnerii*, because these fish are very sensitive to pollutants. Their drawback is that they do not tolerate high temperatures and a cooling unit is necessary to maintain their optimal temperature of 18°C.

In Tropical waters, the Zebrafish, *Brachydanio rerio*, has been well studied by the Japanese; and the Guppy, *Poecilia reticulata*, is a popular laboratory fish because of its fecundity. For growth trials in Tropical fish, the Common Angel fish, *Pterophyllum scalare*, is a good choice because it is omnivorous, greedy and shows rapid growth, which may be monitored by measurements in both vertical and horizontal planes. Growth rates can be measured by photogrammetry as described later.

5. EXAMPLES OF THREE TYPES OF LABORATORY AQUARIA

(a) *Aquarian aqualab*

Figure 1 is a photograph of part of the laboratory where nutritional trials are carried out for the Aquarian products. The aquaria are housed in the peripheral area of a laboratory of 80 m^2. The laboratory includes an office and library, but these are partitioned from the main tanks to reduce noise levels: the bubbling or gushing of water is very noisy, especially when multiplied by a few dozen tanks. Electric convection heaters maintain a comfortable ambient temperature and an Expelair unit (visible in the photograph of Figure 1) keeps the humidity levels down. Some 30 tanks of the optimal size (80 × 35 × 30 cm) are used in banks of two. Each tank is an integral unit with its own water, air supply, box filter, heater and thermostat. Electrical supply to each tank is from a cable-tidy plugged into a ring main by an earthed plug, fitted with a 13 Amp fuse. The air supply is via a polythene tube silicone-sealed into a garden hose hung from the ceiling (also visible in Figure 1). This hose is sealed into a closed circle and pressurised from 1/12th horsepower compressors mounted in weatherproof boxes placed outside and at opposite ends of the laboratory. This system gives a uniform supply of fresh air to all tanks and with the main tube being mounted in the warm roof area, air drawn through in icy weather is prewarmed to prevent it chilling the aquaria.

The working area is a central laboratory bench with the usual services. In one corner is a sink unit with town water supply and an electric water heater for hot water supply. The floor is concrete with Vinyl covering with a central drain. A 3 kW continuous distillation unit is bolted to the wall near to the sink unit. There is a section for microscopic work on the central workbench. The drawers and cupboards hold all the paraphernalia of aquaria labelled in the group names eg. Tools, Electrical, Tubing, Pumps, Foods, Remedies, etc. This apparently minor point is quite important because items such as pump valves or triple-tube connectors are usually needed in an emergency and searching through a mass of equipment housed in one box is time wasting and possibly dangerous to the fish.

The laboratory is used for nutritional studies on Aquarian foods. Relative growth data is obtained by dividing a tank with a sheet of plastic with 2 mm holes drilled randomly. This allows water flow between the two sides, but prevents small fish swimming through. If newly hatched fry are present, an extra undrilled sheet (or glass sheet) is used to close the holes temporarily.

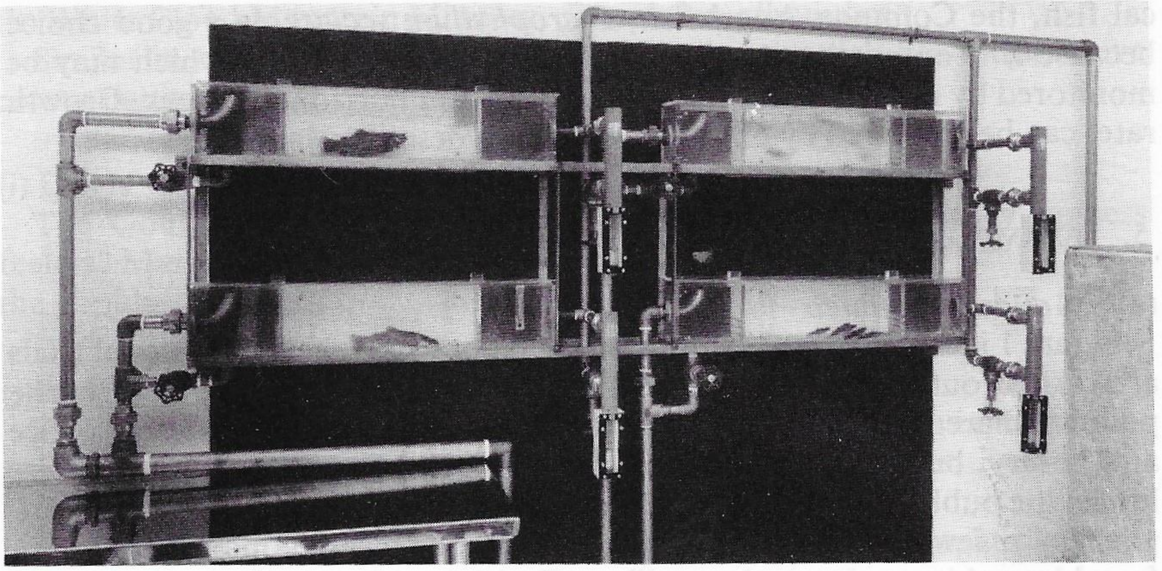

FIGURE 2

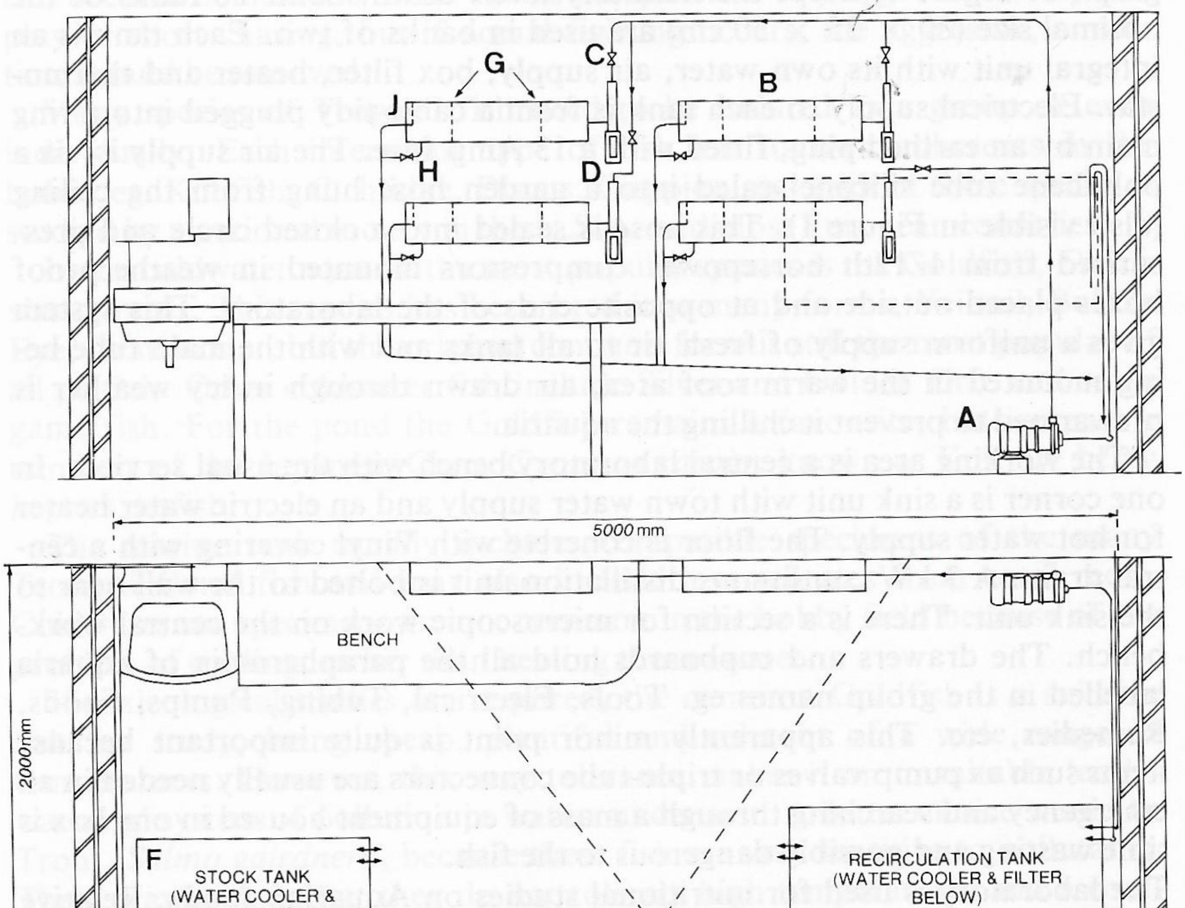

FIGURE 3

The drilled plastic is held in place with Silicone Sealer and is a few centimetres proud of the surface to prevent fish leaping over. A plastic ruler (cm and mm) is mounted against the front glass with a plastic sucker, one each side of the division. This gives a slight gap between ruler and glass, through which the fish are encouraged to swim by always feeding the preweighed foodstuffs at the apex of the ruler. The fish are photographed with a single reflex camera fitted with a magnifying lens according to the size of fish, using an automatic flash unit and colour negatives. The camera is focussed on to the ruler markings and when the fish also swim into focus the photograph is taken. The colour prints give a record of the fish's appearance and the ruler gives a factor for measuring the fish whatever the magnification or camera settings used. Photographs are taken at 1 day, 1 week, 1 month and so on for life-span studies where applicable, with the fish in side A fed one formula and side B fed the comparison formula. Since all parameters are equal, any difference in growth, colour or shape must be due to nutritional factors. The one complicating factor is that a shoal of fish develops pecking orders giving differential growth rates, and often genetic differences occur within one brood. The only solution to this problem is to measure all the fish and apply the usual statistical analysis.

(b) *Water-monitoring aquaria*

Figure 2 shows a unit housing fish to continuously monitor river water being used for processing in a factory handling food materials. Figure 3 shows the layout of this unit. Water from the main factory supply is fed to a $^1/_3$ hp, 1450 rpm, pump (A) which supplies the four aquaria (B) mounted on the wall with a flow of water controlled by valves (C) fitted with flowmeters (D). Each aquarium holds 20 litres of water and a flow-rate of 20 litres/minute is possible with fully open valves. The actual flow rate is normally about 10 litres/minute to give the fish a comfortable swimming pace. The pump draws water from the recirculation tank (E) which is fitted with an overflow pipe back to the river. All this pipework must be plastic or stainless-steel and the tank should be of similar material or other inert substance such as asbestos or fibreglass. In the unit of Figure 2, the recirculation tank is galvanised iron, but the walls are coated with fibreglass-filled resin. Copper, Iron or Galvanised pipes will lead to fish stress or deaths from metal-toxicity, which negates the whole purpose of the unit.

The most sensitive fish for this type of aquaria is the Trout. In the U.K., Rainbow Trout (*Salmo gairdnerii*), is widely farmed giving a cheap and plentiful supply of quality fish.

The fish revel in the continuous flow of water when housed in the aquaria, but they are changed periodically with fish held in a stock-tank (F) where feeding is carried out. The fish are not fed in the test tank (B) because of the water flow and possible pollution.

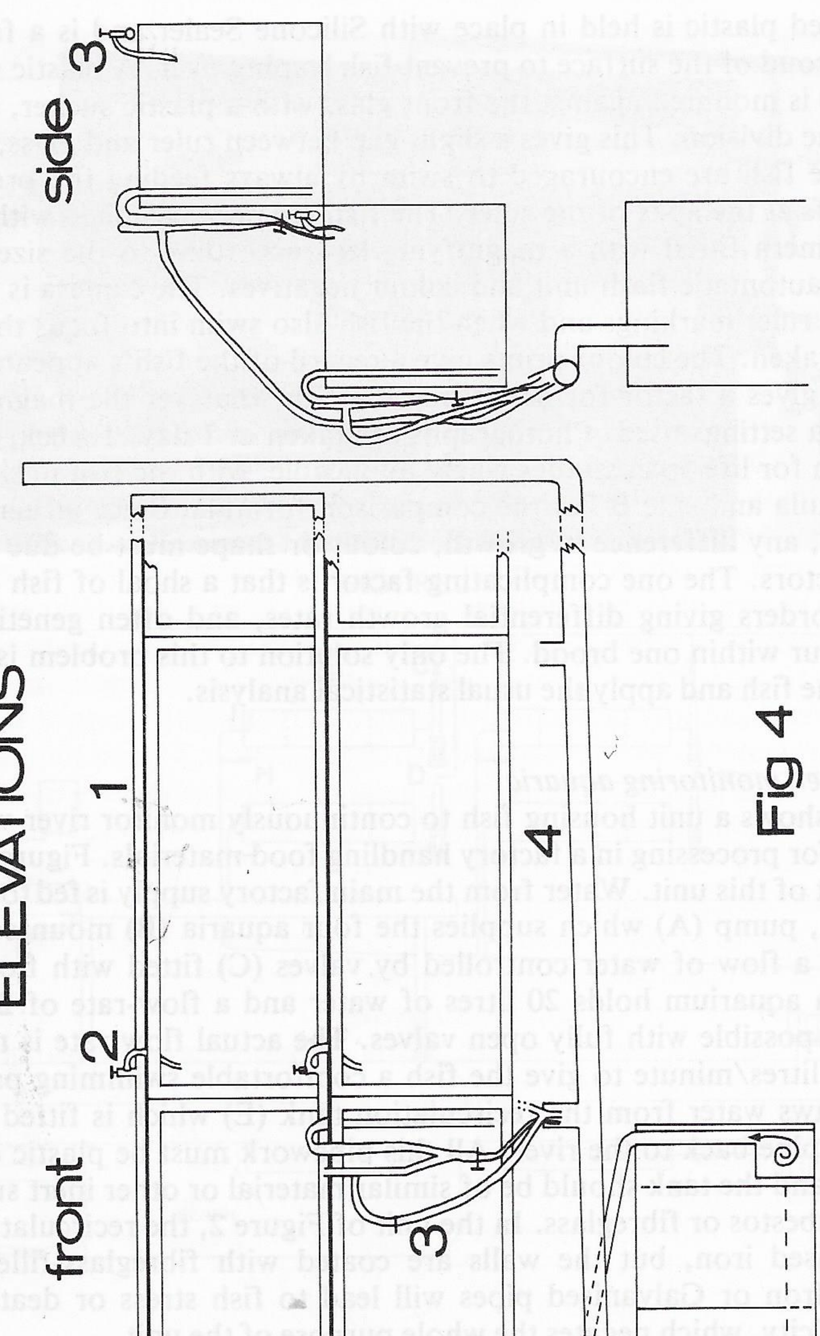

Fig 4

The aquaria (B) are made from clear Perspex and solvent adhesive, with removable dividers (G). These dividers have holes drilled to give a laminar flow to the water, but can be lifted to flush faeces and any other material down the outlet drain (H). This outlet can be closed by a valve, and the normal outlet is an overflow pipe (J), of larger diameter than the inlet pipes to prevent the aquaria over filling. A removable lid is used because Trout will readily jump out.

The fish are viewed continuously on a T.V. monitor by Security Personnel (because these staff are on duty 24 hours in a Gate Office) via a low light T.V. camera (K) and any distress is reported to the appropriate laboratory staff. Trout show distress at quite low levels of toxicity by a change in the operculum beat. Higher levels distress the fish and they stop swimming against the flow and collapse against the rear divider. The same change is seen if death occurs. The duplication of tanks is necessary to differentiate between a sick fish and response to polluted waters. If one fish is distressed, the laboratory staff is informed when on duty. If two fish are distressed, the staff are informed even outside normal duty hours. If three fish are affected, the quality control staff are notified also, to test the water supply immediately. If all four tanks are involved, the water supply to the factory is shut-off immediately.

As shown in the photograph of Figure 2, the test fish can be a single large Trout or a shoal of fingerlings. The former is easier to monitor, but the young fish are more sensitive to toxins. (Relative assessment of fish is still underway in this laboratory.)

One drawback in using Trout is that they prefer cool waters (about 10°C) and Summer heat could raise the stock tank and perhaps supply pipes to temperatures that will stress the fish (over 20°C). The stock and recirculation tanks are therefore fitted with a thermostatically controlled refrigeration unit and the aerator is housed outside the laboratory to bring in fresh air.

(c) *Integral aquaria*

A closed-circuit aquaria system using mechanical and/or biological filtration can be used for a variety of research projects. The design of such systems is limited only by the ingenuity of the research worker and the laws of physics. An example is shown in Figure 4 designed by Sellick (1977) to meet the following criteria:—

(i) water should not pass from tank to tank without being filtered mechanically and chemically;

(ii) selected tanks should be able to be linked together in pairs for certain tests on water quality;

(iii) tanks should be able to be isolated from the system in case of infection to prevent its spread;

(iv) the filtration plant should have a large volume and highly absorbent surface.

Water is pumped through a 10 mm internal diameter plastic piping (see No. 1 in Figure 4) and each aquarium fed via a plastic screw-tap and 3 mm pipe (2). This gives individual control or isolation of each tank. Outflow is via constant level syphons (3) draining to a 45 mm return-pipe (4) leading to a filter. The filter is a 60 × 30 × 37.5 cm aquarium (5) with three partitions of Perspex to provide two filter chambers for filter-wool and carbon, a sump for settling of heavy matter and a pump chamber containing a submersible, mains operated, pump.

6. BIBLIOGRAPHY

There are numerous books on Aquariology and Ichthyology, and many are repetitions or mostly coloured plates of species. The following list details practical volumes that should be on the laboratory shelf.

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**Arbosil Silicone Aquarium Sealant by Adshead Ratcliffe & Co. Ltd., Belper, Derby, DE5 1WJ, U.K. or Dow Corning Aquaria Silicone Sealant, most major aquatic stores in U.K. and U.S.A.*