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The Design of an Education Aquarium

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Abstract

The original concepts of the Natural History Centre and Aquarium at Towneley Hall was to provide an education facility for schools, colleges and the local community. In June 1986 it was decided to upgrade the aquarium within the confines of the Zoo Licensing Act 1981 and improve the educational potential. This paper details the technical design of the new aquarium, and summarises its educational advantages.

Introduction

Interest in studying living material in aquaria originally developed in the mid-nineteenth century and the modern sciences of marine and freshwater biology arose from these early discoveries. The word aquarium - derived from the latin (a place for watering cattle) - was used to describe various glass receptacles designed by Phillip Henry Gosse and used for housing various species of aquatic life. In 1855 Gosse was successful in formulating a recipe for artificial seawater which enhanced the situation for land locked biologists.

Around this period public institutions, notably museums, began to display living material. Liverpool Museum was so successful in this venture that visitor figures increased by twenty per cent in the year 1857. Evidence for this popularity can be seen from the 5th Annual Report (Liverpool Museum, 1858) which states that:

"During the year several aquaria both salt and freshwater have been established in the museum and have proved objects of very great interest to visitors; indeed, there is good reason to suppose that it is mainly owing to these new additions that the number of visitors has been so much in advance of previous years".

When present, live animal exhibitions have consistently proven to be the most popular attraction in museums.

The Natural History Centre at Towneley Hall

The Natural History Centre was erected in Towneley Park in 1983 on the site of two old greenhouses in the old walled garden. The original greenhouses were used by the Parks Department to exhibit various plants and animals on a very informal basis to the general public on request. The Natural History

Centre was financed from the proceeds of a Municipal Lottery and was officially opened in 1984. The new aquarium was fully operational by 1989.

The Brief for the New Aquarium

In drawing up the brief for the aquarium the original concept of the Natural History Centre was followed, *i.e.* to provide an educational facility for schools and colleges. It was decided to make the exhibits relevant to the local area by displaying fauna and flora found in and around Lancashire. Various education bodies were consulted, notably the Curriculum Development Centre in Burnley (part of the Local Education Authority), and STEEL (Science and Technology Education in East Lancashire). Both these organisations are concerned with the development of science teaching up to 'A' level and provided useful information on the objectives, content and assessment patterns standardized in the Biology Syllabus for 1989.

In biology the educational purposes of following a course for the GCSE examination are described as:

1. To develop an interest in and enjoyment of the study of living organisms.
2. To encourage an attitude of curiosity and scientific enquiry.
3. To promote an appreciation of the importance of experimental and investigative work in the study of biology.
4. To promote respect for all forms of life.
5. To develop knowledge and understanding of fundamental biological concepts and principles.
6. To develop awareness of the relationships between living organisms, between living organisms and their environment, and the effect of human activities on these relationships.

The aquarium is the ideal vehicle to demonstrate an understanding of living things. The content of the nationally agreed syllabus is divided into four themes:

1. Diversity of Organisms
2. Relationships between organisms and the environment
3. Organization and maintenance of the individual
4. Development of organisms and the continuity of life

The Natural History Centre fulfils most of these criteria using living displays, graphics and audio visual presentations. It was apparent from these aims and objectives that a large proportion of the curriculum required a practical input. One of the purposes of the examination is to assess the candidates' ability to make accurate observations and measurements; conduct simple experiments; record observations, data and other information in a concise, logical form; analyse, interpret and draw conclusions from experimental data and other biological information.

In order to display as many diverse organisms as possible and demonstrate relationships between these organisms it was decided that the display should contain seven ecosystems:

1. Stream
2. Canal
3. Predator Tank
4. Lake
5. Estuary and River
6. Tidal Rock Pool
7. Sub-Littoral Area of a Rocky Sea Shore

It was felt that within these ecological niches it would be possible to show how physical and biotic factors influence the relationships between various organisms, and the effect of the organisms on their environment. The aim was to demonstrate aspects of ecology such as competition, dependence and interdependence, food chains and food webs.

The formulation of this brief was discussed at all stages and comments were received from various organisations. A fairly large aquarium was set up in the Natural History Centre prior to the building of the main displays, in order to monitor the reaction from schools and the general public by means of a questionnaire based survey. The test display showed animals and plants found in a tidal rock pool and allowed the staff to experiment with various types of lighting and filtration. It proved to be a resounding educational success and we were able to demonstrate various behavioral phenomena such as symbiosis. We also used the display to gain support from councillors during our annual committee inspection.

During the construction of the aquarium, work packages were designed to include practical studies related to local ponds and streams and to the River Calder. The 'Pond Life Package' includes lectures, worksheets and equipment for experimental work, including measuring physical factors, e.g. temperature, light and pH. Equipment provided includes nets, trays, specimen containers for collecting organisms and a range of microscopes, magnifiers, keys, etc. for studying the material.

Experiments include estimating population densities using nets and counters; sampling the plant community and the mud; studying adaptations for breathing, e.g. looking at secondary adaptations of aquatic insects and classifying these structural modifications under the functions they fulfil, e.g. movement, reproduction and life in running water.

The work packages are closely related to the displays in the aquarium and many of the species caught during the sessions can be viewed in great detail in the aquaria. Therefore in order to exhibit these species to their best advantage the design of the infrastructure required careful consideration.

Design of the Aquarium

The project needed to be phased, so that the finances could be spread over a longer period of time and alternative sources of revenue could be investigated, e.g. grant aid and sponsorship, to give a reasonable financial base. The initial stages consisted of a new roof, the installation of the main display tanks and associated plant; and the construction of a quarantine section to house reserve tanks and food preparation area.

There was a fairly flexible timescale; construction began in 1987 and finished in 1988. Once the aquarium was functioning there was a two month period before fish and invertebrates could be introduced, to allow the filter beds to establish their bacterial faunas for biological filtration.

It is much easier to maintain large aquaria with efficient filtration systems rather than maintain a larger number of smaller tanks with less efficient back-up facilities. There was little chance of increasing the current establishment of two natural history staff so the staff time available for maintenance was an important factor to be considered. Therefore the scope of the project was limited to seven large tanks with associated filters to display seven basic habitats. This also maximised the educational impact and provided the optimum conditions for the welfare of the inmates. Plans and specification were drawn up and passed to the Borough Surveyors Department in January 1987.

Maintaining a Closed System

In order to maintain each habitat and imitate the conditions found in the animal's natural state in an aquarium, environmental factors such as temperature, light levels and water chemistry needed to be carefully controlled. It might be possible to maintain the conditions in a closed system within tolerable limits and the animals may stay healthy and survive for long periods. However, there is little scope for the animal to show any other activity, or withstand further environmental change.

The very act of confining an animal and restricting its sensory experiences, mobility and choice of diet limits its ability to regulate its internal state. If confined for long periods in unsuitable conditions an animal may be able to show morphological and physiological adaptations, e.g. a fish may increase the number of red blood cells in oxygen poor water or may exhibit some reorganisation of its metabolism and enzymes when exposed to a different temperature. However, these long term changes are not reactive to environmental conditions seen in exposure to seasonal fluctuations. Therefore, if conditions could not be maintained to keep the animals acclimatised and living well within a range over which they can regularise their physiology and behaviour (preferably close to some optimum where the costs of regulation are minimal) then the educational potential cannot be exploited fully.

For the project to be a success, the infrastructure, i.e. lighting, filtration, temperature control, etc., and the quarantine back-up facilities needed to be designed to very high standards within a facility for additional technology as and when it became available.

Artificial Light

The special composition of artificial light is very important for the well-being of fish, invertebrates and plants. The main point is to supply the wavelengths which stimulate photosynthesis and simulate natural lighting conditions in fresh and salt water. With these requirements in mind, high pressure mercury lamps supplemented with actinic blue lamps were chosen. 'Flora Set P and F' offered an range of benefits:

1. Compact design; as we were limited for space above the tanks.
2. Simple installation by means of a mounting bracket; most of the lamps were fitted in-house.
3. Built-in terminal for easy connection; again this simplified in-house installation.
4. Very long lamp life; this was an excellent economy measure and reduced running costs.
5. Low heat generation; a very important benefit, although some of the tanks would be individually cooled, it was hoped that the ambient temperature would be kept at about 13°-15°C.
6. Uniform light distribution; high illumination is very important especially for invertebrates. However certain areas of some of the tanks were to be shaded to create low light levels to provide quiet secure places.
7. Spectrum effective for plant growth; it was hoped that living plants would eventually be grown.

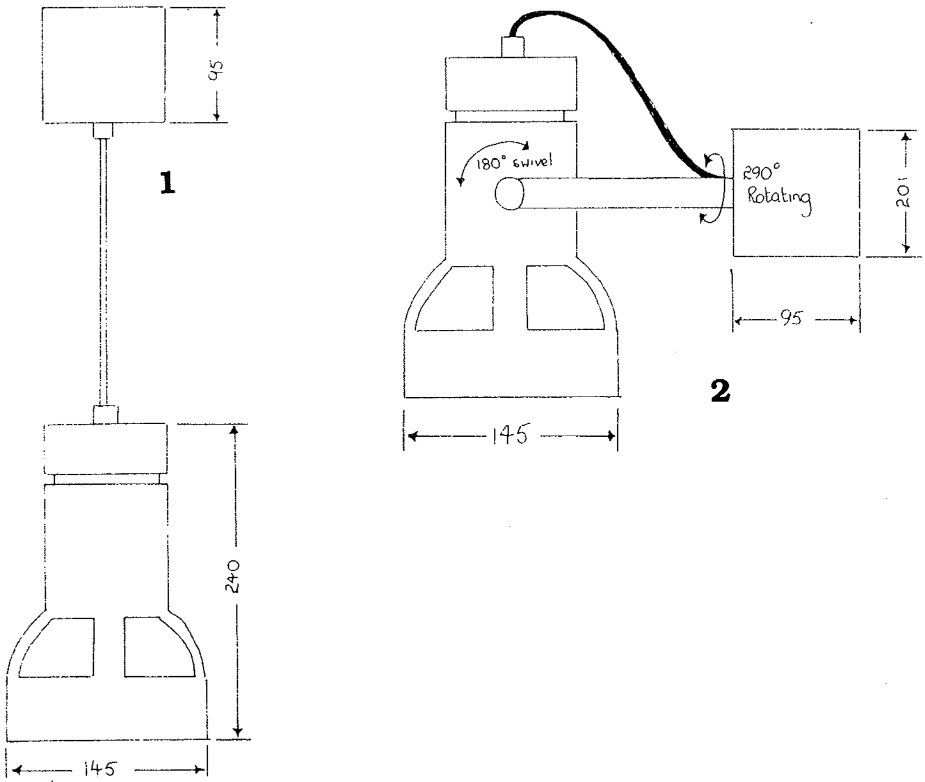


Fig. 1 Flora-Set lights, measurements in mm. 1. pendant; 2. wall-mounted.

8. Economical with high luminous efficacy; the HQL-R 80W De Luxe lamp was used in the FLORA-SET and used only 80 watt (plus 9 watt for ballast) and it generated approximately the same luminous flux as 2 incandescent reflector lamps of 150 watts each.

Each tank will have 3 pendant fittings, with an additional three wall-mounted fittings above the rock pool tank, giving a total of 24, 80 watt lamps (see figs 1 and 2). The lighting would be controlled on a timeswitch which allowed a variation of day length on a seasonal basis. Each set of lights above the tanks would be individually controlled by a cord switch. A particular advantage of this type of lighting is the slow increase in luminous flux after switching on the lamp. The full luminous flux is reached approximately 3 minutes after switch on. This prevented any undue stress to the fish and they are acclimatised slowly to an increase in light levels.

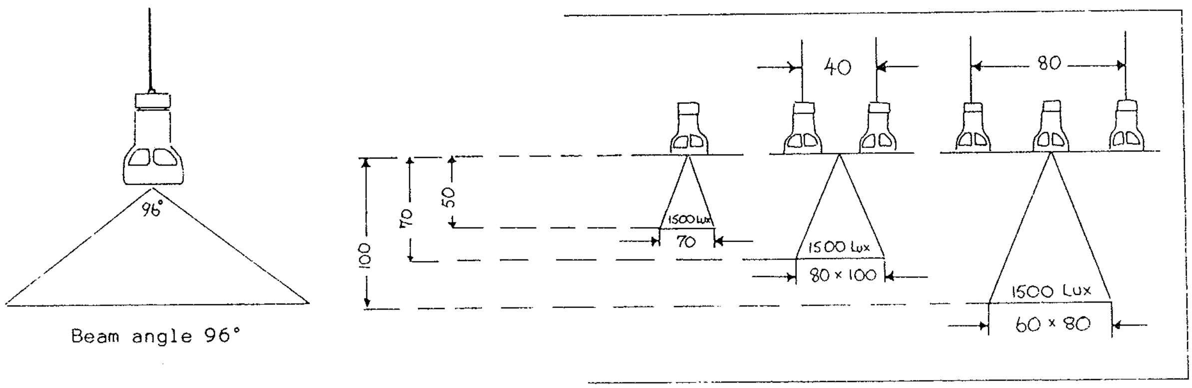


Fig. 2 Flora-Set lights, diagrammatic representation of beam angles and light intensity (measurements in cm.).

Spectral Analysis - The biochemistry of the plants and animals is very complex, e.g. in plants photosynthesis takes place in light of 435/450 and 650/700 nanometres (see figure 3). Photomorphogenesis (plant patterns - leafshape) are determined in the range 600-750 nm and phototropism (the direction a plant will face) requires light at the blue end of the spectrum (350-500 nm). The Flora-Set HQL-R80W de luxe light is manufactured to a CIE specification under the abbreviated title of Full Spectrum Lighting. This provides the correct balance of ultra violet, which research is now showing to be necessary for the health of plants and fish.

Actinic Tubes - Although the Flora-Set provided a good spectral power distribution with peaks at the appropriate wavelengths, it was decided to increase the light at the lower end of the spectrum by having actinic blue lamps over certain of the tanks (specifically the rock pool display). The actinic florescent lamps were used as long-wave UV sources. They peak at about 420-430 nm (see figure 4). Because salt water rapidly absorbs red light many marine fish and invertebrates have evolved adaptations to blue light. These animals will benefit from the use of actinic blue lamps.

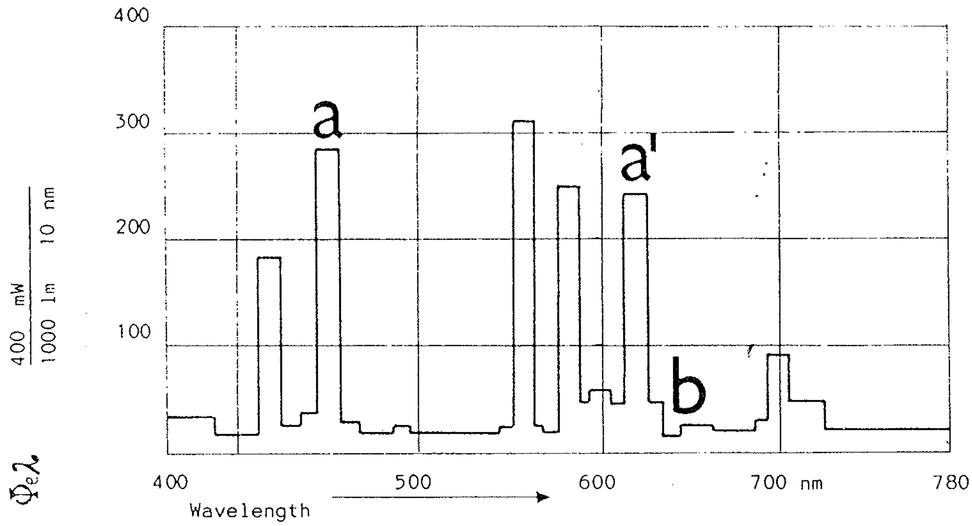


Fig. 3 Spectral analysis of Flora-Set lights. a. and a1. photosynthesis; b. photomorphogenesis.

Light Penetration into Water - The water surface reflects back part of the light rays and this reflection increases with the angle of incident. Obviously, the illumination decreases with distance from the source of light. For geometrical reasons the illumination of a given object or surface is inversely proportional to the square of the distance from the light source. This meant that the lamps would have to be positioned as close to the surface of the water as possible; the manufacturers recommend a minimum distance of 40 cms for safety.

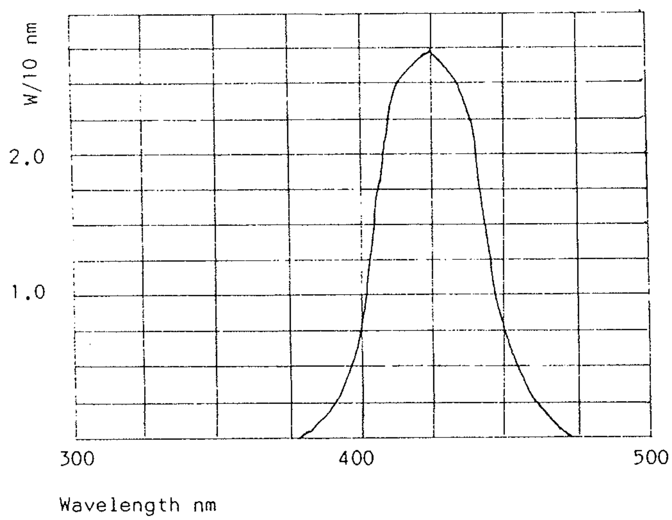


Fig. 4 Spectral analysis of actinic blue lamps.

In addition to distance the penetrating qualities of light depend upon the optical properties of the water, and in particular its transparency. The main effect of turbidity on light is extinction or attenuation. Consequently a very efficient filtration system was designed to provide crystal clear water and optimum conditions for the well being of the fish.

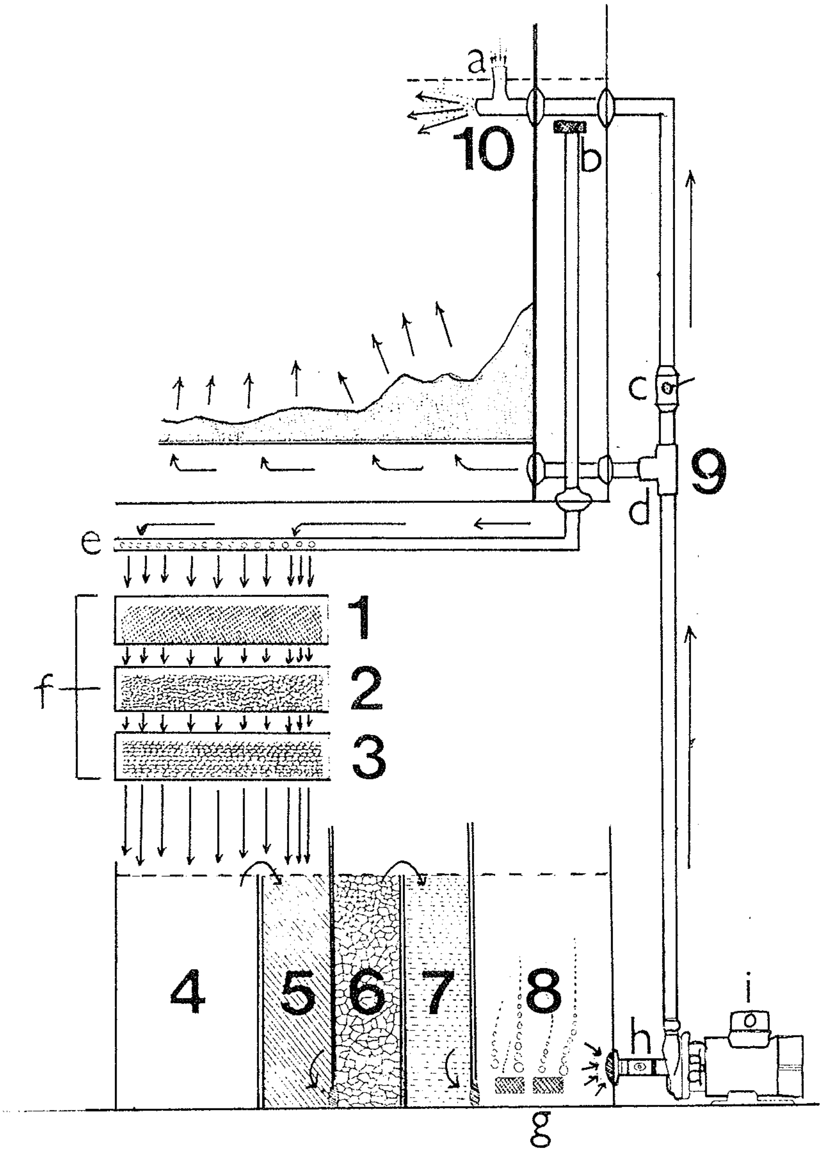


Fig. 5 The ten stages in filtration (see text) a. 'Venturi' device; b. one inch diameter over flow pipe with coarse filter' c/d/ adjustable valve and T-piece on 3/4 inch pipe balancing reverse flow between 'venturi' and under-gravel return; e. spray bar to spread water flow; f. filter trays stacked two inches apart; g. airstones to aid re-oxygenation; h. non-return valve to prevent siphoning if pump fails; i. Stuart Turner pump.

The Filtration System

Amino acids, proteins, phenols, polyphenols and many other organic compounds are excreted by fish and invertebrates into the surrounding water. In the wild these compounds form part of the nitrogen cycle and are converted by bacteria to atmospheric nitrogen, but in a closed system such as an aquarium the build-up of these compounds and their derivatives are highly toxic to fish and invertebrates.

To prevent the accumulation of wastes, a filtration system was required. To provide the most effective filtration system it was decided that a wet and dry mechanical and biological filter, with an optional capacity for chemical filtration, should be designed with the following prerequisites:

1. Effective but cheap to build
2. Easily maintained with minimum man-hours
3. Sufficient capacity for the proposed stocking levels

To keep costs down, the 10 stage filter was designed to be constructed 'in-house' using commercially available materials adapted for the purpose.

Physical Filtration

Trickle Filter (Stage 1) - This part of the system comprises a trickle filter through a 2" thick fitted foam pad which has 45 ppi (pores per inch) and filters out large pieces of detritus and waste. The pad requires periodic cleaning and maintenance. One of the main advantages of this stage in the filtration is the prevention of waste reaching the filter beds beneath, where it would decay and acidify the bacteria faunal beds and eventually destroy them.

Aerobic Filter (Stages 2/3) - The water trickles slowly through the foam prefilter into the first gravel bed which consists of 'Litag Granules'. Aerobic bacterial faunas build up on the granules which are damp rather than submerged. Consequently the bacteria are able to work more efficiently removing harmful toxins like ammonia. This process of removal is known as biological nitrification. It requires high levels of oxygen and nitrifying bacteria like nitrosomonas. Biological nitrification can be summarised by the equation:

$$55NH_4+ + 5CO_2 + 760_2 \text{ nitrosomonas } C_5H_7O_2N - 5NO_2 - 52H_20 + 109H+$$

One of the products of this oxidation are nitrites which in large quantities are extremely harmful to fish and must be removed. The second filter bed in the dry filter system contains fine gravel which again provides a large surface area for denitrifying bacteria.

These filter beds are prone to the development of anaerobic conditions when circulation fails or when dead spaces occur due to blockage with sloughed bacterial film or detritus. The risk is reduced if the filter bed is raked and disturbed periodically and the prefoam mechanical filter is kept clean and functioning.

Settlement Chamber (Stage 4) - The water passes from the biological dry filter into the settlement chamber. If any detritus or small particulate matter remains it falls to the bottom of the reservoir. This sediment is easily removed using a syphon.

First Anaerobic Filter (Stage 5) - The water passes over a weir into a chamber filled with coarse gravel. This provides a large surface area for an anaerobic bacterial fauna. Here the nitrites are further oxidised to nitrates and can be summarised by the equation:

$$400NO_{2-} + 5CO_2\ NH_{4+} + 195O_2 + 2H_2O$$

nitrobacter

$$C_5H_7O_2N + 400NO_3 + H^+$$

This process is known as nitrification, some of the nitrates produced are used up by the anaerobic bacteria living in the oxygen depleted wet filter. This is known as dissimilation, several species of anaerobic bacteria are capable of converting the nitrates into nitrogen or nitrous oxide (see nitrogen cycle). Complete removal of the nitrate constitutes denitrification. Because denitrification is primarily an anaerobic process conditions in the wet filter are ideal.

Chemical Filter (Stage 6) - The water now passes through the mesh filter at the bottom of the coarse gravel chamber into another chamber containing 'Zeolite' or Activated Carbon Granules. This forms the basis of the chemical filtration by removing ammonia by absorption. Several species of anaerobic bacteria have the capacity to convert some of the nitrates back into ammonia and nitrites. This section of the filter is a safeguard against introducing nitrites and ammonia into the tank.

Second Anaerobic Filter (Stage 7) - The water now flows over a weir into the final filter stage which is a chamber filled with fine gravel which again provides a large surface area for anaerobic bacteria.

Re-Oxygenation (Stage 8) - The water now flows into a final reservoir; because of the biological filtration, the water here has a low oxygen content, and therefore is saturated with oxygen via airstones.

Second Physical Filter (Stage 9) - The water is drawn out via a mesh filter which prevents debris from entering the impeller chamber of the pump. It is then pumped through a reverse flow under-gravel filter. Because the water flows up through the filter bed rather than being drawn through it, no debris can accumulate on the bottom of the tank. Instead debris is sucked out of the tank and strained out at Stage 1 of the filtration system.

Water Surface Cleaner (Stage 10) - A large quantity of the water is passed via a ball valve to a 'Venturi' which provides surface turbulence and the cleaning of the surface film, allowing oxygen to penetrate and the release of carbon dioxide and other harmful agents.

Although the filtration design hopefully allows for a complete nitrogen cycle, there are several factors which affect an enclosed system. Because denitrification is primarily an anaerobic process conditions in some of the tanks, e.g. the marine and salmonoid displays, are usually hostile. These displays by necessity will be rich in oxygen with high levels of turbulence and aeration, bringing oxygen to most parts of the system. Denitrifying bacteria usually only work where oxygen is greatly depleted, so few of them survive in the tank. Nitrification therefore exceeds denitrification and nitrate always accumulates. This means regular water changes are needed to remove and keep the nitrate level low.

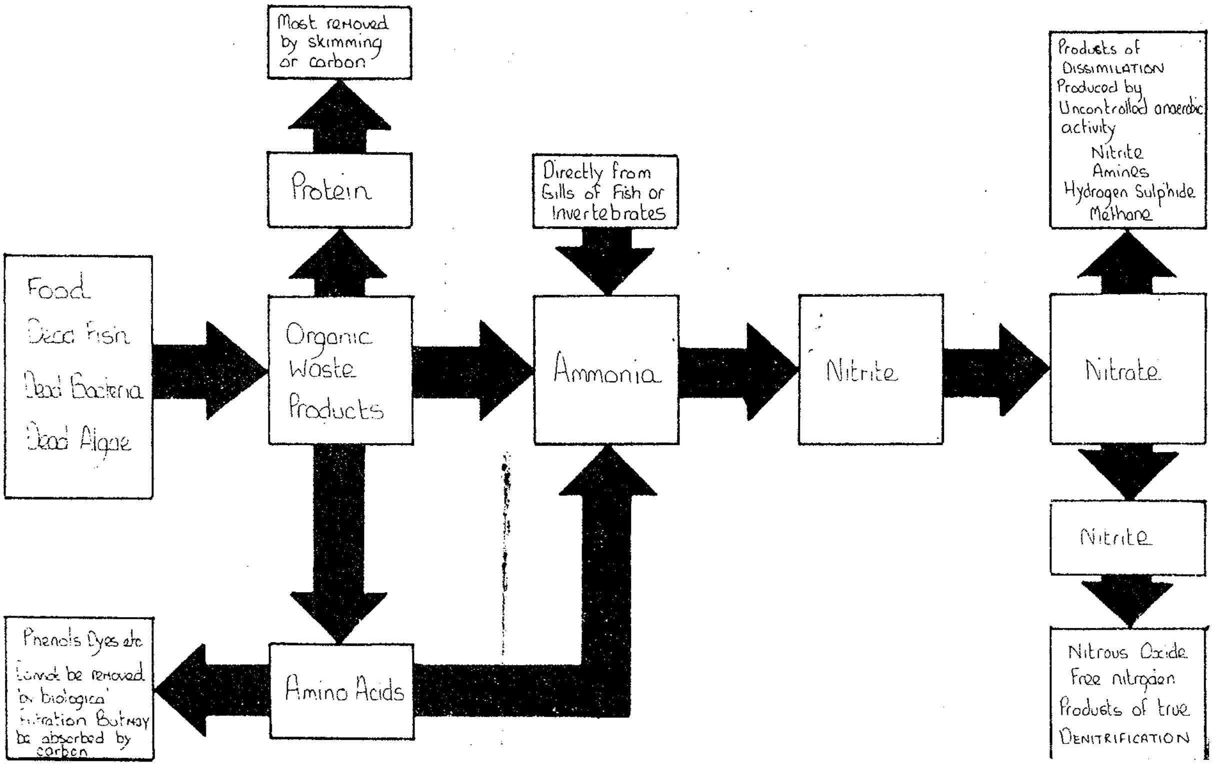


Fig. 6 Summary of the Nitrogen cycle in relation to filtration in a closed system.

Because of the nature of tap water and its constituent contaminants, e.g. copper, chlorine, ammonia and nitrates, some treatment of tap water is necessary before water changes. The water for the aquarium is stored in two four hundred gallon header tanks situated above the main display tanks. The header tanks are filled with tap water via a float switch and vigorously aerated to remove the chlorine. Each tank is insulated and in the future might be connected to a cooling system. Provision has been made for a deioniser to be installed which will remove any dissolved metals.

Special Filtration Items

Special items are needed for filtering the two marine tanks, such as protein skimmers, ultra violet sterilisers, ozonizers, and ion exchange filters.

Protein skimmers - . A very large proportion of the organic waste excreted into the water by fish and invertebrates consists of polarised molecules. This means that one end of the molecule is attached to water and the other end to air. Hence protein accumulates at the surface of the water. The protein skimmers designed for the marine tanks work by producing thousands of air bubbles. Because the molecules of organic waste are polarised they accumulate around the air/water interface of the bubble. One end of the fish waste molecule is hydrophobic and the other end is hydrophillic; the bubble's air-water interface allows both requirements to be satisfied (see figure 7).

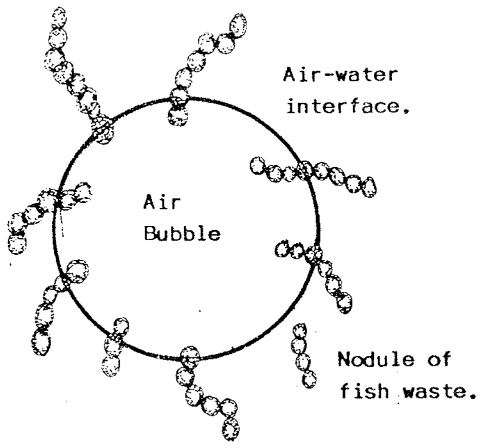


Fig. 7 Diagram showing how fish waste attaches to an airbubble (see text for explanation.

In the simple air-driven skimmer used in the aquarium, bubbles are driven up the perspex cylinder and burst at the surface of the water. The protein is released and forms an oily film on the top of the column. As air cannot pass easily through this film, protein is pushed to the top of the skimmer where the dirty froth is collected in the removable top cup.

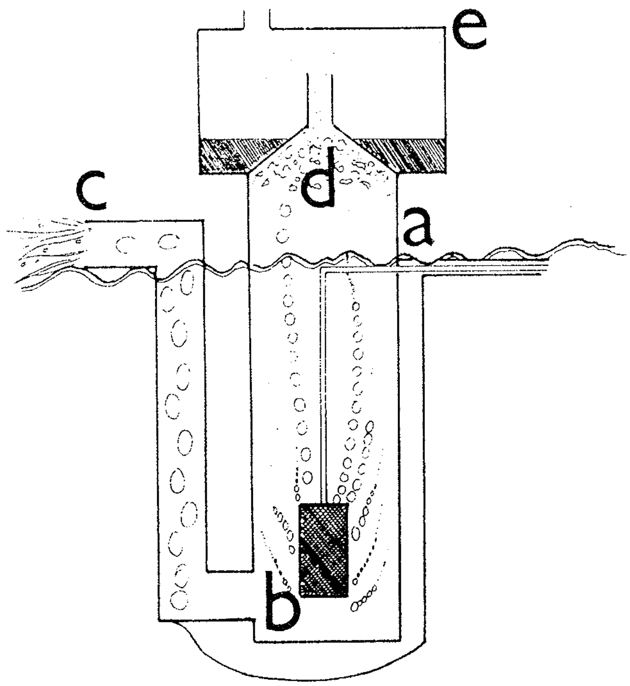


Fig. 8 Protein Skimmer. a. water from the aquarium enters the cylinder; b. diffuser; c. outlet back into the aquarium; d. protein froth; e. removable top.

The protein skimmers are only capable of removing polarised molecules and other products bound up to them. There is still a proportion of non-polarised products which cannot be removed by this process; these include a certain number of complex chemicals which cause the water to yellow. These may be removed only by water changes or chemical filtration, i.e. filtering through activated carbon in the biological wet filter.

There is one other major disadvantage of protein skimmers, they can remove a proportion of trace elements if they become chemically bound to the polarised molecules. Therefore, it is necessary to introduce a trace element solution to the rock pool tank for the filter feeders and algae.

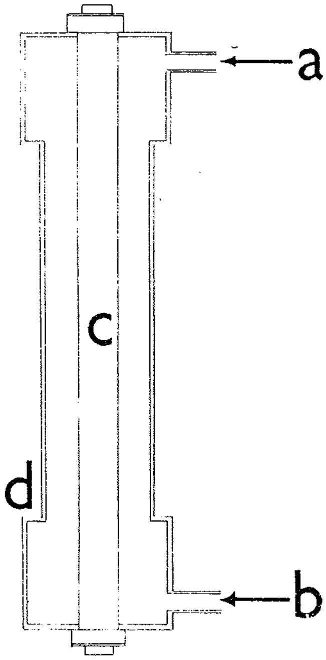


Fig. 9 Protein Skimmer. a. water from the aquarium enters the cylinder; b. diffuser; c. outlet back into the aquarium; d. protein froth; e. removable top.

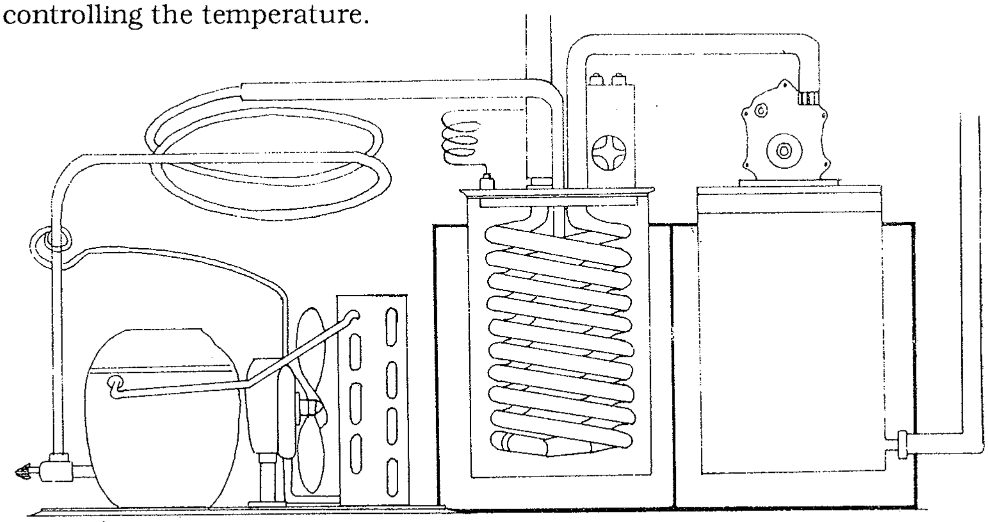
Ultra-Violet Sterilizers - These destroy free swimming disease organisms in the display tanks. This works by producing high intensity short wave ultra violet radiation, powerful enough to kill the organism by passing through the cell wall and destroy the DNA in the nucleus. Unlike other methods of sterilization, ultra violet has little or no effect on water chemistry.

Normally short wave ultra violet cannot pass through glass and can only penetrate water to a depth of 5 cm. The glass tube has to be made of a special quartz glass to allow the ultra violet through. The ultra violet sterilizer is used only to kill free-swimming organisms, it cannot kill diseased organisms attached to the fish.

Cooling Systems

Temperature profoundly affects all biological systems. It alters the properties of most biological materials and determines the rate and type of biochemical reactions. Water has a high thermal capacity compared to air, i.e. it can absorb a large amount of heat energy for a small rise in temperature. However, enclosed systems show dramatic fluctuations in temperature which can affect the metabolism of certain fish and that of the surrounding water. However, the thermal tolerances of fish and invertebrates vary greatly: the inmates of a tidal rock pool show adaptations to varying environmental conditions related to the time of day or the tidal cycle; but thermal shocks and sudden large scale variations in temperature have a dramatic affect on the cardiovascular activity and respiration of fish which live in stable environments like ponds and lakes with only seasonal variations in environmental conditions. Therefore, some form of temperature control is needed to maintain the condition at or about the optimum for the species concerned.

There are plans for three of the ecosystems to be temperature controlled, i.e. the two marine tanks and the salmonoid tank, and additional cooling systems will be installed in all the other tanks in the future. The ambient temperature of the building is subject to seasonal variations; there is some control by the use of extractor fans. The main method of temperature regulation will be by thermostatically controlled cooling units, consisting of a compressor and a temperature exchanging canister, connected to an Eheim Power Filter 2017. The unit should be capable of cooling the water to between 11-14°C. Seasonal variations can be accounted for by thermostatically controlling the temperature.



a **b** **c**

Fig. 10 Cooling system. a. compressor; b. heat exchanger; c. Eheim Power Filter.

Glass-reinforced Plastic Tanks - Specification

It was decided that the tanks should be 48" x 36" x 36" in size to provide sufficient capacity for the proposed stocking levels. Also this depth of tank ensured reasonable light penetration; any deeper and the light rays are attenuated to an unacceptable degree. Several types of tanks were reviewed, e.g. all-glass/siliconed sealed, concrete, and metal framed, each with inherent disadvantages:

All-glass aquaria

i) In order to fit the filtration system holes would have to be drilled at various points - a difficult procedure with glass.

ii) The thickness of the glass, needed to withstand the water pressures, and the strengthening needed at weak areas meant that each tank would weigh in excess of 800 lbs when filled.

iii) The costs involved were prohibitive and the durability of the silicone sealer was suspect.

Concrete aquaria

i) The tanks once constructed would need to be sealed to prevent chemicals leaking from the concrete.

ii) The construction would be a permanent fixture and a fairly lengthy and messy process.

iii) There would be problems fitting and seating the pipes for the filtration system, also sealing the glass front.

Metal-framed aquaria

i) The frame has to be reconstructed in high quality stainless steel to prevent corrosion, especially in the marine tanks.

ii) Very costly especially for the glass.

Eventually, after careful consideration, glass-reinforced plastic (fibre-glass) tanks were chosen. Initially several firms were approached for quotations and technical advice, but only two, both from outside the district were 'tooled up' to meet the requirements. Both firms were contacted enclosing a drawing of the construction of the tank with a suggested method of glazing and the various additional specifications required, e.g. an anti-splash screen.

Pumping Equipment

Stuart Turner pumps were chosen for a variety of reasons:

a) They are widely used by public aquaria throughout the country in the same sort of applications;
b) They are robust in construction with a good ability for continual running;
c) Relatively maintenance free and very reliable;
d) Spare parts are easily obtainable;
e) Wide performance range with good safety features incorporating a built in thermal overload protection;
f) A generous discount on the price.

Eight pumps were purchased, which means that we have a spare for emergencies. The five freshwater tanks will be served by a 903 pump with a stainless steel construction. This prevents the saltwater corroding the brass and contaminating the tank with copper poisoning which is extremely lethal to marine invertebrates. The 903 provides an excellent flow rate which means the water should pass through the filter at least twice an hour, i.e. 100 litres of water per minute.

Plumbing (UPVC System)

The pipes and fittings were made from unplasticised polyvinyl chloride. They have a low installation component cost with a good chemical resistance and high pressure rating. All the materials conform to the British Industrial Research Association Code of Practice for Food Usage, so they are ideal for use with livestock. The pipes and other plumbing were fitted in-house by the Natural History staff. It is a fairly easy material to work with and is designed for solvent welding.

Blower or Exhauster Unit

The blower will be used to supply air to all the main exhibition tanks and the quarantine facilities in the preparation room via a main two inch airline. At various intervals where necessary it will be drilled to take a 1/4″ valve and airlines attached.

Problems and Developments

The aquarium was opened to the public on Friday, 25th August 1990. Visitor figures increased and educational work began almost immediately. In fact the Pond Life Package, run in conjunction with indoor work in the aquarium, was over subscribed.

Almost straight away unforseen problems became apparent, because the associated plant, e.g. pumps, cooling equipment, lights, exhaust and blower units, were working twenty-fours hours a day seven days a week, the ambient temperature within the building increased. The building by necessity is well insulated with a double skinned roof and thermal padding distributed throughout the timber structure as well as double glazing on the exhibition tanks. This meant that in trying to cool the tanks we increased the temperature in the surrounding air. It was decided to instal air conditioning for summer and an air extraction system to supplement it during cooler months. The main air-conditioning unit was installed centrally and industrial extractor fans installed in the roof space at either end of the building. We now maintain the ambient air temperature at between 55-60°C with a relative humidity of between 60-70%.

In the original plan we decided to individually cool only three tanks. Subsequently, because of various measured fluctuations, all the tanks now have a cooling plant functioning to allow greater temperature control.

Another problem which immediately manifested itself was the heating effect of the Stuart Turner pumps. These pumps have a metal casing with a plastic impeller. They run constantly and consequently there is a measurable temperature different between water entering the pump and that leaving to flow into the tank. The copper casing of the impeller chamber acts as an excellent heat exchanger. A change to a cool running version with a nylon impeller has proven very effective and this type will be eventually installed in all the systems.

We have also increased the size of the quarantine area to accommodate the larger specimens in the main exhibition tanks. Inevitably certain species rapidly outgrow their environment, e.g. some marine fish increase their size threefold within a very short space of time. Consequently some specimens are released or donated to other institutions with bigger tanks.

A recent acquisition is a large invertebrate tank to house a variety of cephalopods. The tank measures 10' x 3' designed along the same lines as the other tanks with similar filtration systems, lighting and cooling plant. This has been particularly popular with many children gathering around the display trying to spot a very introverted Common Octopus *Eleone cirrhosa.*

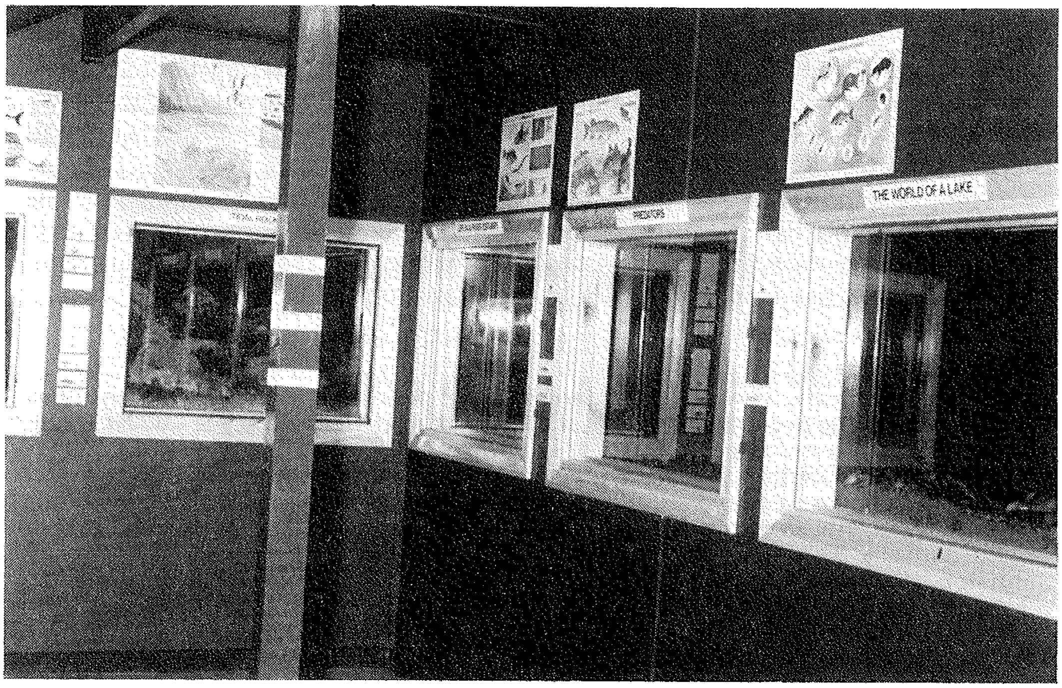


Plate 1 View of the Aquarium showing individual displays

The Educational Role of the Aquarium

The original concept of the aquarium was to provide a series of displays showing the variety of freshwater fish and invertebrates found in and around the Burnley area, and marine animals found around the coastline of Lancashire. To date we have exhibited a wide diversity of water life with associated behavioral mechanisms, e.g. schooling in salmonoids and symbiosis with shrimps and sea anemones. Feeding patterns have been used to illustrate food chains and food webs to many children during practical sessions. The 'Catch' from a day's pond dipping is usually transferred to a suitable aquarium for closer detailed examination. This has enabled the staff at the Natural History Centre to interpret many aspects and objectives of the National Curriculum and encourage and develop an interest and appreciation of all forms of life. Live displays are dynamic and provide an excellent vehicle for promoting an attitude of curiosity and scientific enquiry and are extremely useful in experimental and investigative work in the study of biology. In the Pond Life Package simple experiments have been set up to help children make and record accurate observations, and to analyse, interpret and draw conclusions from the data and other biological information.

In order to realise the full educational potential of living displays the design and maintenance has to be of a very high standard with careful consideration given to inherent problems in running a closed system.

The primary desire of the staff at the Natural History Centre is to provide a stable ecosystem in an environment that is close to that of the wild community being simulated. Improved technology and maintenance can help reduce the enormous losses of organisms through mishandling, unsuitable conditions, etc.. There is a distinct possibility that prolonged and intensive collecting at particular sites will upset and deplete the environment and the balance of natural communities. Therefore for educational purposes we cannot ethically or morally subject live animals to stressful conditions beyond their normal environmental range.

The live exhibits at the Natural History Centre have a very important role in education and can stimulate children to realise the importance of wide range of conservation problems as well as providing an insight into aspects of biology which are not normally seen in the classroom.

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