

**A STUDY OF THE
DISTRIBUTION OF ALGAE**

**IN THE
TWO OCEANS AQUARIUM,**

**KELP TANK,
CAPE TOWN**

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RBRDEB001
Botany Honors Project
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2000**

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ABSTRACT

Five years have passed since the Two Oceans Aquarium, Cape Town, opened its doors for the first time in November, 1995. Since then, a seaweed community has established itself in the Kelp tank. The seaweeds were brought in as either epiphytes on mature macro algae or as epiphytes on boulders that were placed on the floor of the tank. Thus, the community in the tank can be assumed to have established itself naturally. This study looked at the extent of the species diversity, zonation patterns in the tank (with particular reference to wall orientation), depth substrate type, plane (i.e. vertical or horizontal surfaces) and species distribution with depth. This was done by placing quadrats in transects down each wall and noting the percentage cover of each species. Quadrat depth, substrate type, wall orientation, and plane were noted. The percentage cover values as well as the environmental data were entered into CANOCO, an ordination programme for windows. Ordination showed that the tank was essentially a homogeneous environment with no difference in species distribution with regard to wall orientation, depth, substrate type, or plane. It was noted that self-seeded *Ecklonia maxima* were very unhealthy, small, deformed and had many epiphytes, with the exception of three plants that were growing under the plunger. From this it was concluded that water motion, and not light or nutrients, was limiting in the tank. *Schimmelmannia elegans* was found growing in the kelp tank. It had never been described as growing in South Africa previously. One theory was that the increased daylight length in the tank, caused by the fact that lights over the tank were often left on for extended periods, triggered a photoperiodic reproductive cue from the crustose phase (which was assumed to be growing unrecorded on the Cape Peninsular) for the sporophyte to grow. However, daylight length in the Kelp tank and Tristan Da Cunha (where it was first recorded as growing) were the same so that theory was discarded. Another theory was that the algae was introduced into the tank in some way. This, however requires further investigation. Environmental conditions in the tank were investigated using aquarium records. Light intensity and duration, water temperature, pH, salinity, dissolved oxygen concentration were all found to be optimal for photosynthesis and growth to occur. Water motion was seen as the only limiting factor for photosynthesis and growth as it also has an effect on nutrient uptake. Grazer intensity was also examined. It was found that grazing by fish was stable; however, grazing by invertebrates and particularly meso-herbivores could be increased, by adding more of them into the tank. It was found that with light being left on for functions there was no real seasonal change in light duration and this may be a problem for seaweeds that experience seasonal growth as they are missing seasonal cues. A management option of having a strictly controlled 11 hours of daylight during a winter month was proposed as a solution. This study is a good reference point for future work to be done on seaweed succession in the Kelp tank.

INTRODUCTION

In November 1995 the Two Oceans Aquarium (TOA) in the Victoria and Alfred (V & A) Waterfront, Cape Town, opened its doors to the public. The main themes of the aquarium are marine and fresh water ecosystems of South Africa. One of the main aims of the aquarium was to establish a west coast kelp forest display. This display was intended to be a self-sustaining exhibit encompassing both a fish display and an algal community. However, very little information is available on the successful establishment of algae in marine aquaria. Aquarists grow seaweeds in aquaria for display purposes, scientists grow seaweeds in tanks in order to understand the physiological processes that promote or demote growth. Aquarists and scientists ultimately want seaweeds to grow optimally, but an aquarist is more interested in what is required to maintain a static display, which consists of mature plants, while a scientist is more interested in the dynamics of interactions that occur between the alga and its environment. In other words, a scientist is more willing to sacrifice beauty in order to understand function and an aquarist wants and needs a beautiful product in order to satisfy public demands and economic requirements. In South Africa, there is very little information available on the procedures for maintenance and manipulation of optimum growth conditions for algae in the west coast ecosystem. This has meant that the curators of the display have essentially been working in the dark as to what algal species would form part of a thriving community, how they would survive and grow in an aquarium environment.

Before the aquarium opened its doors, the aquarium commissioned a study by J. Bolton and R. Anderson, (1995). The study dealt with recommendations for the growth of South African West coast kelps and understorey seaweeds in an aquarium system. The study realized that there is a large amount of literature dealing with factors affecting growth of seaweeds in both nature and laboratory culture. However, as far as aquaria were concerned there was very little. The study summarized most of the former literature with particular relevance to local kelps as far as it was relevant to the aquarium. The study dealt with environmental factors such as light, nutrient concentrations, temperature, pH and carbon uptake, water movement, salinity and dissolved oxygen. They study gave recommendations for optimum conditions required for growth of seaweeds in a tank and listed possible problem areas. The study also gave recommendations as to the long-term maintenance of seaweeds, methods for measuring their growth, and likely species to be placed in the tank, as well as potential problems relating to seaweed growth and interactions with grazers.

In addition, in 1995, an honours project by S. van Rensburg was conducted on the suitability of ten South African seaweeds for establishment in marine aquaria. She looked at the viability of these ten species in a range of light conditions, their re-attachment ability, and their sporeling recruitment in an indoor tank environment. The study was not done in the actual kelp tank, but was done in a concrete tank painted with enamel paint. She recommended that seaweeds with robust forms with spreading holdfasts be included as part of the understorey algae in the tank.

In 1997, C. J. Maddams, conducted an honours project on the problems faced by macro algae in the TOA kelp display. He dealt primarily with two species of macro algae in the tank, namely *Ecklonia maxima* ((Osbeck) Papenfuss) and *Macrocystis angustifloia* (Bory). He found that the growth of these two seaweeds was limited by grazing from herbivorous fish and by lack of light and the supply rate of nutrients. He also constructed a species list of what types of algae were found in the tank. He constructed the list by collecting samples off rocks and walls and later identifying them at the University of Cape Town (UCT).

Five years have passed since the aquariums grand opening in November 1995 and an algal community has developed in the tank. What is unknown is the extent of the species diversity and if there are zonation patterns occurring in the tank, with particular reference to north and south facing walls, depth substrate type and plane (i.e. vertical of horizontal surfaces). The reason for wall orientation having a factor in the zonation of algae is that in the southern hemisphere, a wall that is north facing will receive more light than a south facing wall. Since, light intensity decreases with depth will this difference be reflected throughout the walls that receive more sun compared to walls that receive less sun? If there is any difference in species distribution with depth, are there more algae occurring on the walls or are there more algae occurring on the rocks? Does the fact that the rock is vertical or horizontal mean that there are any changes in the number of species that occur? These are some of the questions that this study will attempt to answer.

To do this the study will attempt to identify those algal species that have established themselves naturally in the tank and will attempt to see whether there are zonation patterns with regard to species diversity and what the possible reasons for zonation are.

The kelp tank environment

The kelp tank holds approximately 800 000 l of water. This water is drawn from two intake pipes in Cape Town harbour, next to the Penny Ferry in the Waterfront basin. These intakes are situated in about 4.5 m of water and are approximately 1.5 m above the sea floor. Each pipe draws in about 20 000 l³.h⁻¹. The water is pumped by centrifugal pumps through dual media filters. Ferric chloride (FeCl₃), which is added to the water before passing through the filters. FeCl₃ acts as a primary coagulant and causes flocculation. The water is then passed through the filters, which remove particles to reduce turbidity. The dual media filters are manufactured from glass reinforced polyester (GRP) resin to eliminate corrosion. The filters are filled with a layer of silica sand (diameter ± 0.7 mm) and then topped with a layer of anthracite (diameter 1 – 1.8 mm). Due to the depth of the filter some bio-filtration activity occurs, (see Figure 1). Due to the size of the silica sand there are large spaces between adjacent sand grains and particles of up to 200 μm can pass through the filter without being trapped. This is particularly true of the larvae of a species of tubular hydra, *Tubularia warreni* and the strawberry anemone *Corynactis annulata*, which are present in most displays after having passed through this filter.

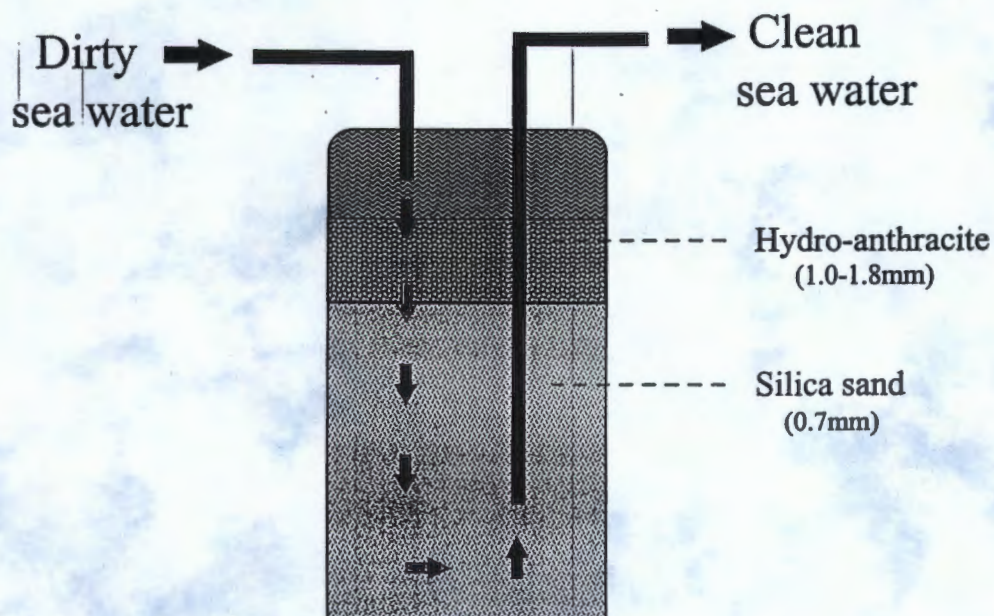


FIGURE 1: Mechanical filtration.

After passing through the first series of mechanical sand filters, caustic soda (NaOH) is added to the water to create and maintain a pH of 8.

The water is then passed through a heat exchanger, which is sensoried to the water temperature and adjusts it to about 15 °C automatically. The heat exchangers are made up of a number of titanium plates through which the heating and cooling takes place. The seawater to be heated/cooled flows through a series of thin pipes in the opposite direction to the piped heating or

cooling medium, i.e. counter current circulation, (see figure 2). The cooling medium (freshwater) is chilled by a large chiller situated on the first floor of the plant room. The heating medium (fresh water) is obtained from heat produced by an air conditioning system. The kelp display and the riverine display can both be heated or cooled. The heating and cooling of the displays is regulated, depending on the incoming water temperature, by a computerized system in the control room next to the workshop on the ground floor.

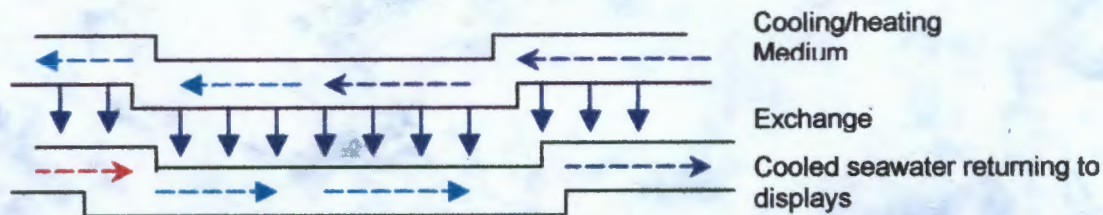


FIGURE 2: Counter current temperature exchange system

After the water has passed through the mechanical sand filters it is introduced to the tank at a rate of $5\,000\text{ l.h}^{-1}$. There are six large air lifts in the tank which draw water down through a bio filter at a flow rate of $200\,000\text{ l.h}^{-1}$, thereby recycling the entire volume of water in the tank in four hours, (see figure 7). The bio-filtration takes place through a bed of 15 – 20 mm stone approximately 1 m deep on the floor of the tank. Here harmful dissolved waste products (e.g. fish waste and ammonia) are converted into nitrates by bacteria in the stone bed. A down flow filtration system is used and the velocity is such that the entire volume of the filter bed remains aerobic at all times. The airlifts are sized to provide an additional turnover of water volume equal to that of the pumped dual media filters. The airlifts provide two functions: one, a measure of protein skimming and two, circulation of water from under the bio-filter stone and discharge of well-aerated water back to the surface of the tank. Protein skimming is done by means of a counter current dispersed air column that agitates the water until foam starts to form. The foam and other dissolved materials (e.g. kelp and fish mucus) are then separated and removed from the water. The protein skimmer and bio-filtration remove nitrites. However nitrates are not removed by either of these processes and continue to build up in the system. It is for this reason that 10 % of the water is replaced every day with filtered seawater. This helps to dilute nitrates and other waste products.

The depth from the surface of the water in the Kelp tank to the floor is approximately 6 m. The floor of the tank is covered by gravel, loose rocks and artificial reefs made up of artificial rocks. These rocks are made up of fiberglass sheeting, which was sandblasted before the fiberglass set, so as to appear natural. A surge generator, consisting of a large diameter (1 m) fibreglass cylinder and a drum shaped piston is located in one corner of the tank (See Figure 13). The drum-like piston is constructed from fiberglass, which is filled with closed cell foam. It is attached to an oval shaped rotating wheel and looks similar to the oil well pumps seen in Texas, America. This provides the main water movement in the tank, along with a slight anti-clockwise current, which is caused by the filtration outlets. Light is mostly natural as this is the only tank that is open to the sky. However, when temperatures in the tank get too high,

the tank can be shaded with 80 % shade cloth. There are six 1000-Watt metal halide lamps set along the top of the tank wall, above the windows, horizontal to the water surface. The distance between the lamps and the water surface is about 60 cm. This is so that on dim days and at dusk the guests in the aquarium can see into the tank. They are also left on until 11 'o clock at night when the aquarium has functions such as sleepovers or evening talks or concerts. The walls of the tank project about a meter above the water level in the tank, this means that direct sunlight only reaches the bottom of the tank at midday. Otherwise, the organisms in the tank are subjected to the natural fluctuations in ambient light intensity. The lamps in the metal halides are supposed to be replaced every 6 000 hours of use, as the manufacturers state that the photo spectrum of these lights changes after this time period. This has not happened in the kelp tank and the lamps are only replaced if they blow.

Chemical conditions in the tank, such as pH, temperature, NH₃ concentration, % oxygen and salinity are monitored daily. These measurements are taken and recorded, as optimum conditions are vital to the good health of the fish. They also affect the algal community in the tank. Figures 3, 4, and 5, show the % Oxygen, pH and temperature of the kelp tank from August 1999 to January 2000. Temperature in the tank generally remains around 15 °C. It can reach a maximum of 23.5 °C or a minimum of 11 °C. The high temperatures in November and December 1999 resulted in another chiller is being placed into the cooling system for the tank. The pH remains constant at around 8.2. The oxygen concentration remains high at around 94 %. The importance of environmental conditions for algal growth will be discussed later in this report.

The water that is drawn off the tank i.e. 10 % of the total tank volume, is fed into the riverine ecosystem and from there is passes unfiltered through either the seal pool or into the normal freshwater drainage system in the aquarium. The water run-off from the seal pool goes directly into the Victoria basin of the Cape Town harbor from an over flow system that is about 2 m higher than the spring high water mark.

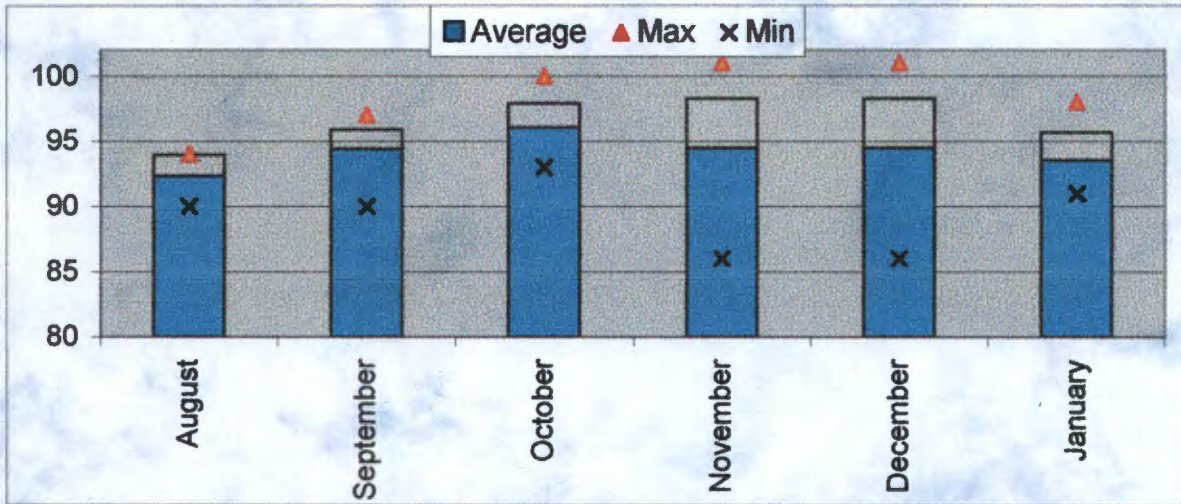


FIGURE 3: This graph shows the average monthly % oxygen in the tank from August 1999 – January 2000. It shows maximum and minimum value for each month as well as the standard deviation for each month as shown by the blank area on top of the columns (TOA records).

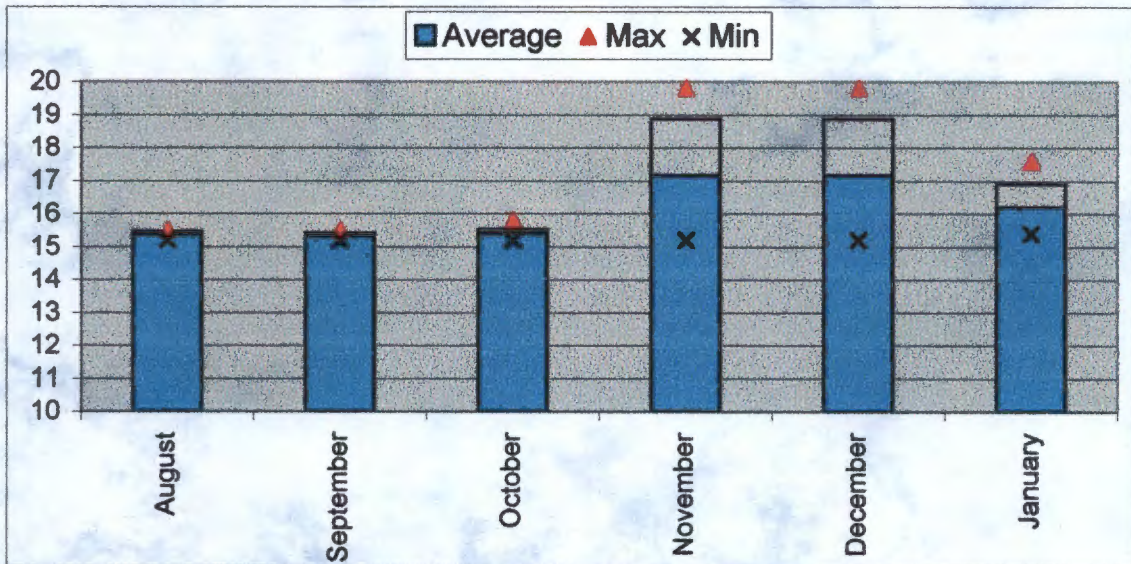


FIGURE 4: This graph shows the average monthly Temperature (°C) in the tank from August 1999 – January 2000. It shows maximum and minimum value for each month as well as the standard deviation for each month as shown by the blank area on top of the columns (TOA records).

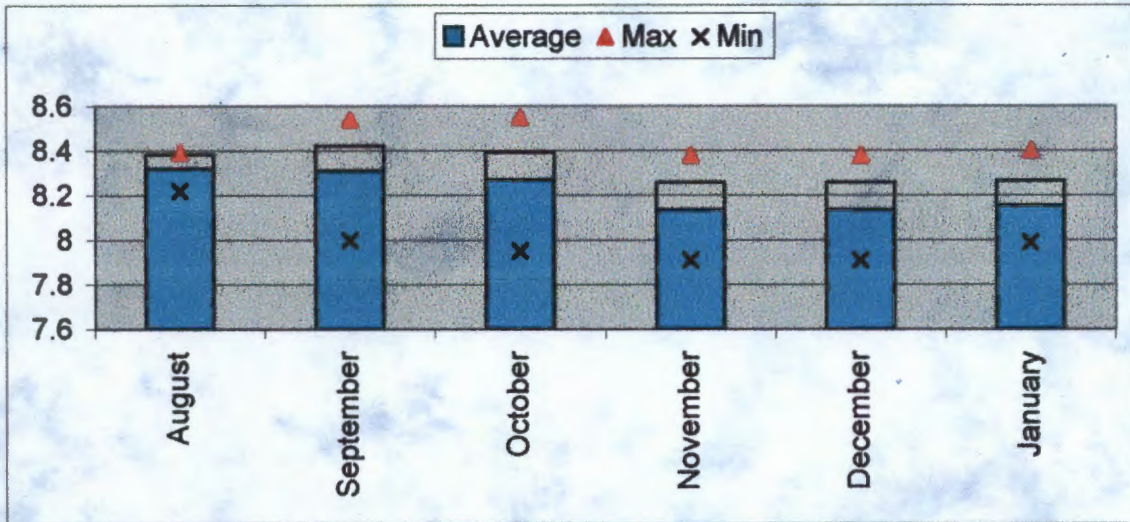


FIGURE 5: This graph shows the average monthly pH in the tank from August 1999 – January 2000. It shows maximum and minimum value for each month as well as the standard deviation for each month as shown by the blank area on top of the columns (TOA records).

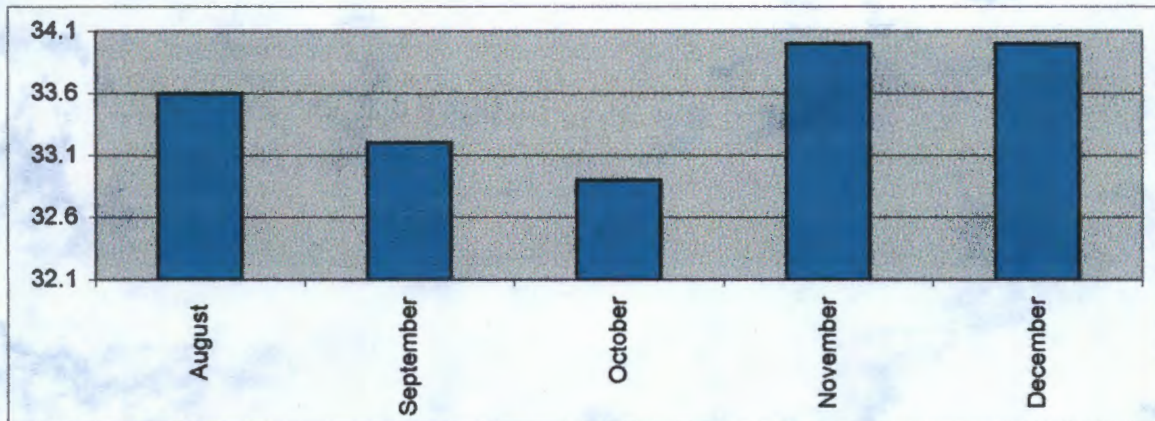


FIGURE 6: This graph shows the monthly salinity in the tank from August 1999 – January 2000 (TOA records).

The Riverine Tank Environment

The Riverine display is a display that depicts the course of a river from the highland source, through to low lands and eventually to the sea. There are fresh water tanks that form the upper reaches of the river display, there is an estuarine type tank where the river meets the sea, and there is a pure marine tank. The marine tank, which is part of this study, has a wave generator and can form a wave that rushes up a small beach area. The tank is about 1 m deep and is on a tidal system, which changes the tidal level by about 25 cm. The tank has a boulder floor and artificial rocks provide the main features in the tank, (See Figure 7A & B).

This tank is treated similarly to the rest of the system by means of dual media filtration at the rate of 40 000 l.h^{-1} . A small amount of bio-filtration occurs. This tank has a tide control device that is linked to the external tide in the harbour allowing a "Small Rise and Fall" of the main wave generating section of the system, (See Figure 9).

There are a number of metal halide lamps in the riverine ecosystem. These lamps have their bulbs replaced every 6 000 hours to keep the photo spectrum constant for photosynthesis for plants. A strictly controlled cycle of 12 hours of light followed by 12 hours of darkness is maintained. A long window runs along the length of the marine part of the ecosystem. However, as it is south facing, no direct sunlight enters the display area.

Excess water (unfiltered) that is taken off the tank goes either to the seal pool or to the natural drainage of the Aquarium.



FIGURE 7A: A picture facing east showing the beach section in the front and the rock formation which hides the surge generator and tidal mechanism of the Marine section of the Riverine ecosystem



FIGURE 7B: A picture facing south, showing the tidal level and the long south facing window of the Marine section of the Riverine ecosystem

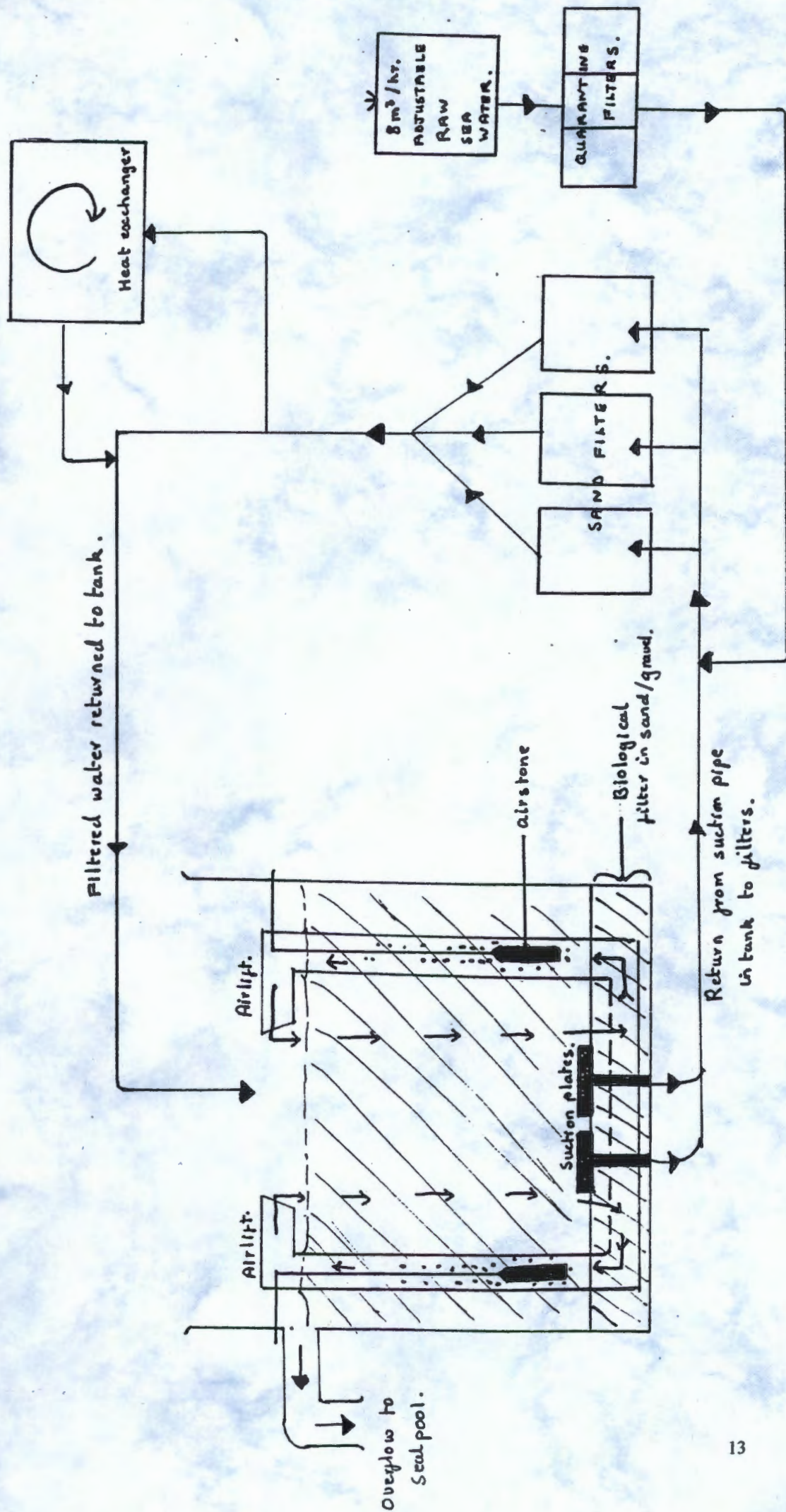


FIGURE 8: Water circulation and filtration in the help tank (TOA, 1996)

LOW TIDE

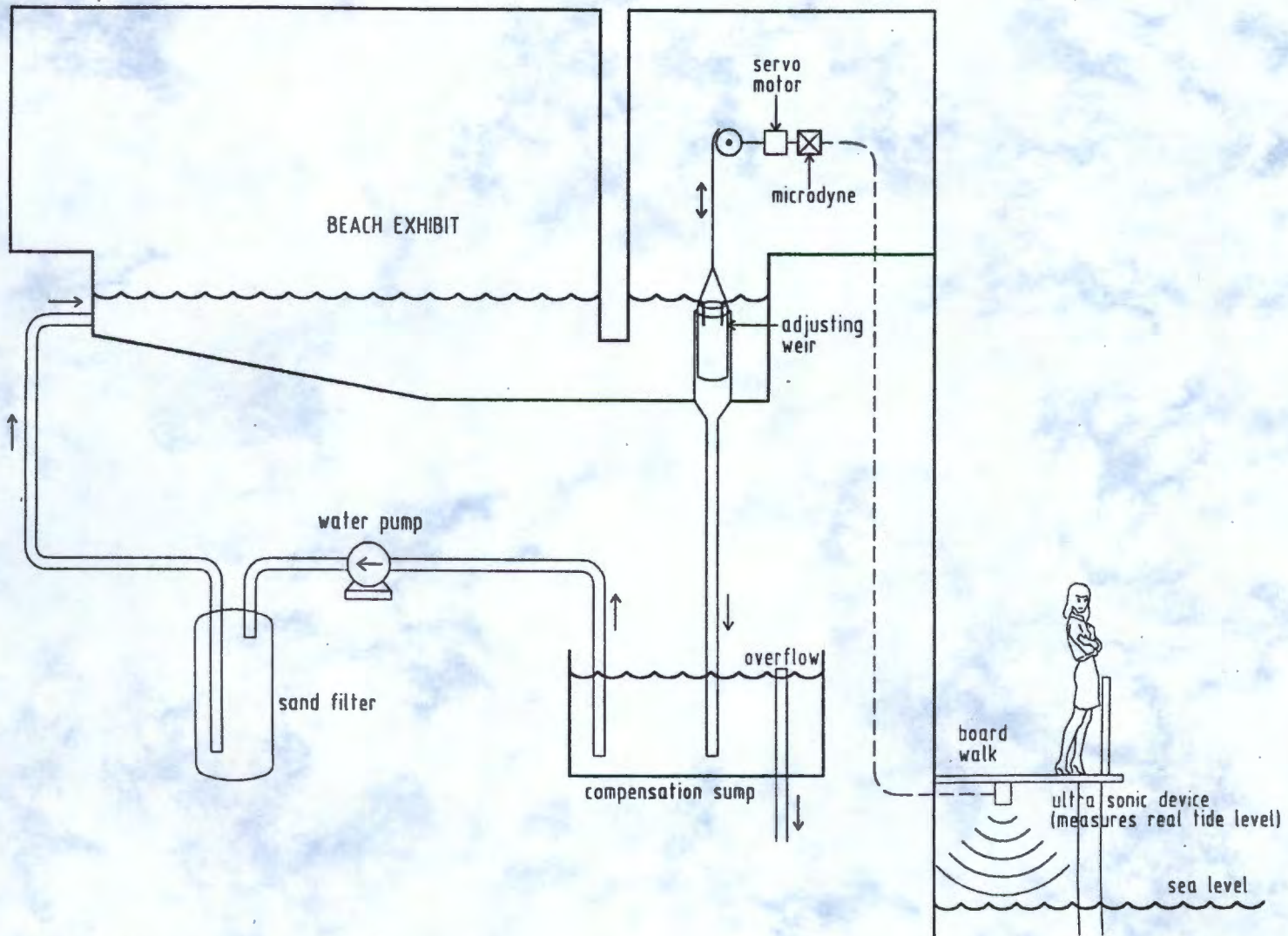


FIGURE 9: Ecosystem tide level control system (TOA, 1996)

The algal growth history of the kelp tank

After the tank was filled with water, the surfaces below water level rapidly became covered with a layer of biofilm, which consisted of micro-organisms such as bacteria and diatoms and their cellular products (micro-fouling), (van Rensberg, 1995). This is the first step in a type of ecological succession that occurs on any surface submerged in water. Following this biofilm and in the absence of suitable control measures, filamentous algae, animal larvae and other larger algae and animals (macro-fouling) then coat the surfaces (Evans, 1988). By the 22nd of October 1995, 3 months after the kelp tank was filled, the artificial rock surfaces were covered with a very fine film of *Enteromorpha* sp., with occasional small plants of *Ectocarpus* sp. These are both common macro-algal colonisers, (J. J. Bolton, pers. Comm.). Unfortunately, in the TOA, no data was collected on the algal covering from this point until 1997. So, to understand what occurred in the kelp tank, the data obtained from the kelp display tank in the Monterey Bay Aquarium in California is used. The surfaces covered with the semi rigid/micro algal slime provided a natural substrate for the settlement of macro algal spores (such as *Ulva*). This then germinated and intermixed with the biofilm and coated the walls and kelp fronds. In both the Monterey Bay Aquarium and the TOA, large macro algal species were introduced into the tank in the adult form complete with epiphytes. The *Ulva* sp. in the Monterey Bay aquarium was removed physically and after five months the cover also decreased through undetermined causes. This allowed Californian understory perennial species to become dominant (Watanabe & Philips, 1988). This did not occur in the TOA kelp display. The Monterey tank has the advantage of having raw unfiltered water (which contains the spores and larvae of many organisms) pumped into the tank, through very large diameter pipes. Whereas, the TOA does not do this because of invertebrate settlement clogging the intake pipes, and because it was too expensive to install the large pipes as used in the Monterey Aquarium. Thus, the only algal species occurring in the tank are those, which have been specifically introduced (such as the large macro-algae), or have come in as epiphytes on the kelp or on rocks that have also been brought into the tank from various collecting sites on the west coast and in False Bay. One of the main sites for macro-algal collection is near Robben Island. This is because it is a relatively sheltered area and the kelps that grow here would be better able to cope with the low water motion in the kelp tank. This lack of propagules has probably been a barrier to a secondary succession occurring in the tank. What the aquarists at the TOA have noticed was that when there were strepies (*Sarpa salpa*) in the tank there was an intensive amount of grazing occurring and therefore little or no understory alga. After the strepies were removed (in late 1997), there was a rapid growth of *Cladophora radiosa* ((Suhr) Kuetzing)). However this cover has decreased and there is now what seems to be an understory succession occurring. There are also visible recruits of both *Ecklonia maxima* and *Laminaria pallida* (Greville ex. J. Agardh) and it is hoped that these recruits will survive and form part of a self-sustaining canopy in the tank.

MATERIALS AND METHODS

A series of preliminary dives were done in early April 2000 (to identify algal species occurring in the TOA kelp tank). Samples were taken, and later identified at UCT.

Sampling continued from April to early October 2000, by diving in the tank and measuring a 25 cm X 25 cm quadrat, which had been further divided at 5 cm intervals to allow for easier percentage calculations. Species in the quadrat were identified and the number of squares that they occupied was counted to get a percentage cover estimate. Following that a diver would chose a 10 cm by 10 cm square in the quadrat that had a good cover of algae (often there were bare areas in the quadrats). The chosen square was destructively sampled for four minutes, with the diver removing every thing occurring in the square by means of scraping, with a paint scraper or by plucking with hands and tweezers. This was to ensure that species were correctly identified and that no new species were missed. The material removed was placed in a bottle that had a mesh on the bottom which allowed water to flow through while the sample remained in the bottle. To facilitate easy collection of small materials a mesh size of 265 μm was used (See Figure 10).



FIGURE 10: The collecting bottle used

Each wall was given a particular colour to facilitate easy recognition of where samples came from (See Figure 11). Quadrats were placed at roughly 3 m intervals along the walls and every meter vertically to obtain vertical transects in the tank. The distance from the top left hand side of the quadrat was measured to the left wall, to provide a reference co-ordinate to be used in mapping. The depth from the top left hand side of the quadrat to the bottom of the tank was also noted as a reference point. Quadrats were not placed on kelp holdfasts

that were not seeded naturally in the tank. The unnatural seeders were easy to identify as they had string attaching them to the rock surfaces. This was to ensure that the quadrats measured only those plants that were growing naturally in the tank.

When the quadrats were placed it was also noted if they occurred on the vertical artificial rock, the wall of the tank or flat rock. Some quadrats were taken where boulders made up the floor of the tank. However, for most of the tank this was ignored as quartz pebbles were mainly on the floor of the tank and these were cleaned and aerated about once a week so it was assumed that nothing would seed itself in these areas. The windows of the tank were also ignored from the quadrats as divers clean the windows with a cloth every two to three days and wipe the windows free of any diatoms that attach.

The plunger that creates the water movement in the tank contained a number of species. However, the excessive water motion in the plunger prevents the entry of fish. This area, as well as one other man-made exclusion zone against large herbivores, were also sampled to see if there was any difference in seaweed species. It must be noted however, that the plunger is not a true grazer exclusion zone. Due to its tubular shape, the light penetration is limited, while the excessive water movement may prevent the growth of some species.

A grazer exclusion cage is present in the tank, and is made from aluminium and plastic mesh. The cage extends 15 cm above the surface. The cage is 35 cm long by 15 cm wide and screws attach it to the wall in the tank. The sides of the cage are held in place by means of cable ties. The grazer exclusion cage was not placed in the tank when the tank was initially filled with water but was placed in some months later. However, as it has been four years since it has been in place, one can assume that it is representative of an ungrazed environment that exists in the tank.

As the water from the kelp tank flows into the riverine tank and then into the seal pool without undergoing any form of filtration, the overflow at the seal pool was also measured with quadrats to see what species occurred there. These species were then assumed to have been seeded from the kelp tank. The same is true of the riverine ecosystem tank.

The species diversity in the riverine ecosystem was investigated by removing samples from various areas in the tank. This was to compile a species list for the tank.

Environmental conditions in the tank were also investigated. Irradiance was determined through the use of a Li-cor meter (LI - 1000) with a spherical radiation sensor. These readings were compiled into a light profile for the tank. Readings were taken at each wall and in the middle of the tank at specific depths (1 m, 3 m, and 6 m below the surface). The readings were taken in roughly the same place as the vertical transects that were taken with the quadrats (i.e. at 3 m intervals). They were taken at 13h30 on a sunny spring day in October.

Using data obtained from the TOA records, the average daylight length per month for the year August 1999 to August 2000 was calculated for the kelp tank.

The average monthly temperatures from August 1999 to January 2000 were also calculated as well as noting maximum and minimum temperatures that occurred in the kelp tank.

Grazing activity by fish and invertebrate grazers was noted although the results were not analysed statistically.

In performing the statistical analysis all species that were identified from the first initial sampling dives and subsequent data sampling were used to construct a species list, (See Table 2). The total number of 5 cm X 5 cm squares occupied by each species was calculated and converted to a total area occupied by the species. The total area sampled by the quadrats was calculated by multiplying the number of quadrats by 25. This figure was then used to calculate the percentage area occupied by each species in the tank (See Table 1). Only species which occupied an area greater than 0 % of the total area were used in the analysis. The reason for this is that some of the preliminary species identified in the tank on the first dives were not in any of the quadrats. But, because the species were positively identified, they are included in the species list.

All quadrat data was entered into an EXCEL 2000 spreadsheet, and then sorted according to which wall they occurred on, the left side distance of the quadrat position and depth.

Data analysis Methods

Ordination

The sorted data, except for the exclusions mentioned above, was then transferred to CANOCO for Windows (version 4.0, Micro-computer Power, Ithaca, NY, USA) where it was ordinated. By using this multivariate computer analysis, such as gradient analysis, it is possible to determine: 1) how the algal community varies in terms of species composition in the tank, and 2) which components of the algal community relate best to the physical data.

Ter Braak and Prentice (1988) reviewed data analysis techniques for the interpretation of community composition in terms of species responses to environmental gradients. In this study, the environmental data to be included in the analysis of the algal community in the tank were various measures of quadrat position and placement: i.e. Depth, plane, substrate type, wall and left length (See Appendix 4 for environmental variables and their values).

A correspondence analysis was used to extract the dominant patterns of variation in community composition from the algal data, even though a Detrended Correspondence Analysis (DCA) would have been preferred, due to the large number of zero values. A correspondence analysis (CA) sometimes has interpretation problems due to the arch effect created by large numbers of zero values (ter Braak & Verdonschot, 1995). In order to relate the algal

community composition to environmental variables a canonical correspondence analysis was used. This is a direct gradient analysis technique in which a series of species data is related directly to a set of environmental variables.

The ordination diagrams produced by the CA's show a scatter plot. The species and/or sites are represented by points and environmental variables by arrows. The eigen vector scores used to produce a sample environmental variable biplot are linear combinations of the structural variables with the regression coefficients (ter Braak & Similauer, 1998). In other words, the score sites are derived from both the environmental variables and the species data. In this study there are 184 sites and the environmental variables are the position of the sites. The distribution of the sites along each of the environmental gradients is shown in one of the ordination diagrams.

Three ordinations were performed, the first two using the species data and the final one using species data and environmental data. The data was not transformed, and the sites corresponding to walls of the same colour were grouped together. The first CA that was run included all the data. The second and third had exclusions.

RESULTS

SPECIES IN THE KELP TANK

The general tank walls were covered with a low turf of *Sphacelaria* sp., *Derbesia marina* ((Lyngbye) Solier), *Polysiphonia scopulorum* (Harvey) and *P. namibiensis* (Stegenga & Engledowse) and a wide variety of filamentous diatoms. In the region of the north wall at the bottom, filamentous diatoms were the most dominant element. The species present in the tank tended to be found naturally in the warmer waters around the coast. Many occur in False Bay, while a few have distributions that extend to the Atlantic side of the Cape Peninsular (Stegenga et al, 1997)

The exception to this statement was the collection and identification of *Schimmelmannia elegans* (Family, Rhodophyta, Baardseth) (See Figure 12). The algae was identified by Dr. O. De Clerck (pers. comm.). This species was described on Tristan Da Cunha in a high energy wave zone in depths ranging from 5 – 10 m depth (Baardseth, 1941). This alga has not been described as occurring in South Africa, or any where else. It has a red crust phase from which the sporophyte grows. The alga was only found growing on three air lift outlet pipes on the surface of the tank in the splash zone on the Blue wall (See Figure 13) and on an airlift outlet pipe on the green wall 30 cm below the surface (See Figure 11 for a plan of the tank), as well as on the top of the plunger, which was submerged occasionally, and on the plunger walls (See Figure 14). It was not found deeper than a meter in the sporophyte phase although red crusts were found all the way from a meter below the surface to the bottom of the tank. It was not possible to identify if these crusts were *Schimmelmannia* or other red algal species, even though the crust of *Schimmelmannia* is very loose. It must be noted that the areas where the sporophyte was found growing are all very high water motion areas in the tank.

The rocks in the tank tended to be covered by *Cladophora radiosa* with *Rhodophysema* or crustose corallines growing beneath this layer. On the walls the *Cladophora radiosa* rarely grew to the surface and the top two meters of the walls of the tank tended to be dominated by *Polysiphonia* or *Derbesia* species. Flat areas in the tank, especially on the rocks, tended to have articulate corallines growing on them.

Enteromorpha and *Blidingia* species were only found growing at the top of the splash zone and only on walls that had either more direct sunlight or higher water motion. The splash zone in the tank varied from 45 cm at the plunger and outlet pipes (opposite ends of the tank) to 5 cm at positions midway between these two points. Other points around the tank had splash zone widths of 10 – 20 cm.

In areas of low light and low water motion and also at depth *Hildenbrandia* tended to dominate.



FIGURE 12: A picture of pressed *Schimmelmannia elegans* collected from the outlet pipes in the Kelp tank



FIGURE 13: A picture of the three outlet pipes on the Blue wall of the Kelp tank taken when the surge is at its lowest in this corner. Note *Schimmelmannia elegans* and *Pachymenia carnosa* growing around the edge of the pipes



FIGURE 14: A picture of the top of the plunger, note *Schimmelmannia* on the edge of the drum.

Table 1 is a species list of all species that were identified in the tank and the percentage area that they occupied in the tank. Species that have a 0 % value were identified on the preliminary dives and were not found again in any of the sampled quadrats taken at later stages. The crustose corallines covered the largest area in the tank occupying 21.3 % of the total area sampled. *Cladophora radiosa* covered 17.9 % of the tank. It must be noted that these measurement were taken on a two dimensional plane with the quadrat squashing algae that were under it, when in actual fact, the algae could be covering a much larger area due to its three dimensional shape. The group that were identified as young reds were small red algae that had formed tufts and it was impossible to identify them down to the species level. Dives done in the tank in October after all sampling was complete showed that some of the algae identified as young reds, which had grown, were identifiable as *Grateloupia*. If *Grateloupia* is a seasonal algae, this would explain why it was found during the preliminary dives and end dives but not during the sampling phase and thus would account for the 0 % value in the table. If one looks at the area in the tank covered by epiphytic algae (this is algae that was growing on other algae in the quadrats, mostly the self seeded *Ecklonia*, but also on *Cladophora sp.*) in total it is over 21 % of the total area of the tank. This is very large amount of epiphytic algae in the tank. In total crust forming species occupied over 33 % of the tank area.

TABLE 1: This table shows the percentage cover in the quadrates of all the species found in the tank, for the total area sampled in the tank, ranked from lowest to highest.

NOTE: Names that are highlighted in red were not used in statistical analysis (see Appendix 10.5, for Species Authorities).

rank via %	Species
0	<i>Anthophycus longifolius</i>
0	<i>Champia compressa</i>
0	<i>Gelidium capense</i>
0	<i>Grateloupia doryphora</i>
0	<i>Grateloupia filicina</i>
0	Kelps (microscopic)
0	<i>Petalonia fascia</i>
0	<i>Plocamium suhrii</i>
0	<i>Ralfsia verrucosa</i>
0	<i>Sphacelaria</i> sp.
0.045	<i>Codium papenfussii</i>
0.091	<i>Bangia atropurpurea</i>
0.114	<i>Delesseria papenfussii</i>
0.136	Filamentous diatoms
0.25	<i>Stypocaulon funiculare</i>
0.591	<i>Porphyra capensis</i>
0.636	Colonial diatoms
0.636	<i>Ulva rigida</i>
0.682	Diatoms
0.773	<i>Kallymenia schizophylla</i>
0.841	<i>Chaetomorpha robusta</i>
0.886	<i>Pachymenia carnosa</i>
0.932	Bare Rock
1.341	<i>Schizymenia obovata</i>
1.432	Blue Green Algae Filament
1.5	<i>Enteromorpha</i> sp.
1.659	<i>Epymenia obtuse</i>
1.977	Bare wall
2.023	<i>Blidingia minima</i>
2.045	<i>Ectocarpus</i> sp.
2.455	<i>Schimmelmannia elegans</i>
2.841	<i>Pugetia harveyana</i>
2.977	<i>Carpoblepharis flaccida</i>
3.318	<i>Arthrocardia</i> sp.
3.341	Red crusts
3.977	<i>Cladophora capensis</i>
4.250	<i>Rhodymenia natalensis</i>
4.705	Young reds
5	<i>Epymenia capensis</i>
5.682	<i>Ecklonia maxima</i>
6.091	<i>Derbesia hollenbergii</i>

6.659	Derbesia marina
8.045	Polysiphonia namibiensis
8.227	Polysiphonia scopulorum
10.997	Rhodophysema
11.614	Hildenbrandia sp
17.977	Cladophora radiosa
21.364	Crustose corallines

Ordination results

Ordination of the data using CANOCO v4 showed a group of outliers made up of samples from the upper outlet pipes. These samples differ from others in that they have *Schimmelmannia* and *Pachymenia carmosa*, whereas the other samples do not. For further cluster analysis, these samples were excluded, along with samples from the plunger and the seal pool that grouped out together, because of the presence of *Schimmelmannia* (See Figure 15).

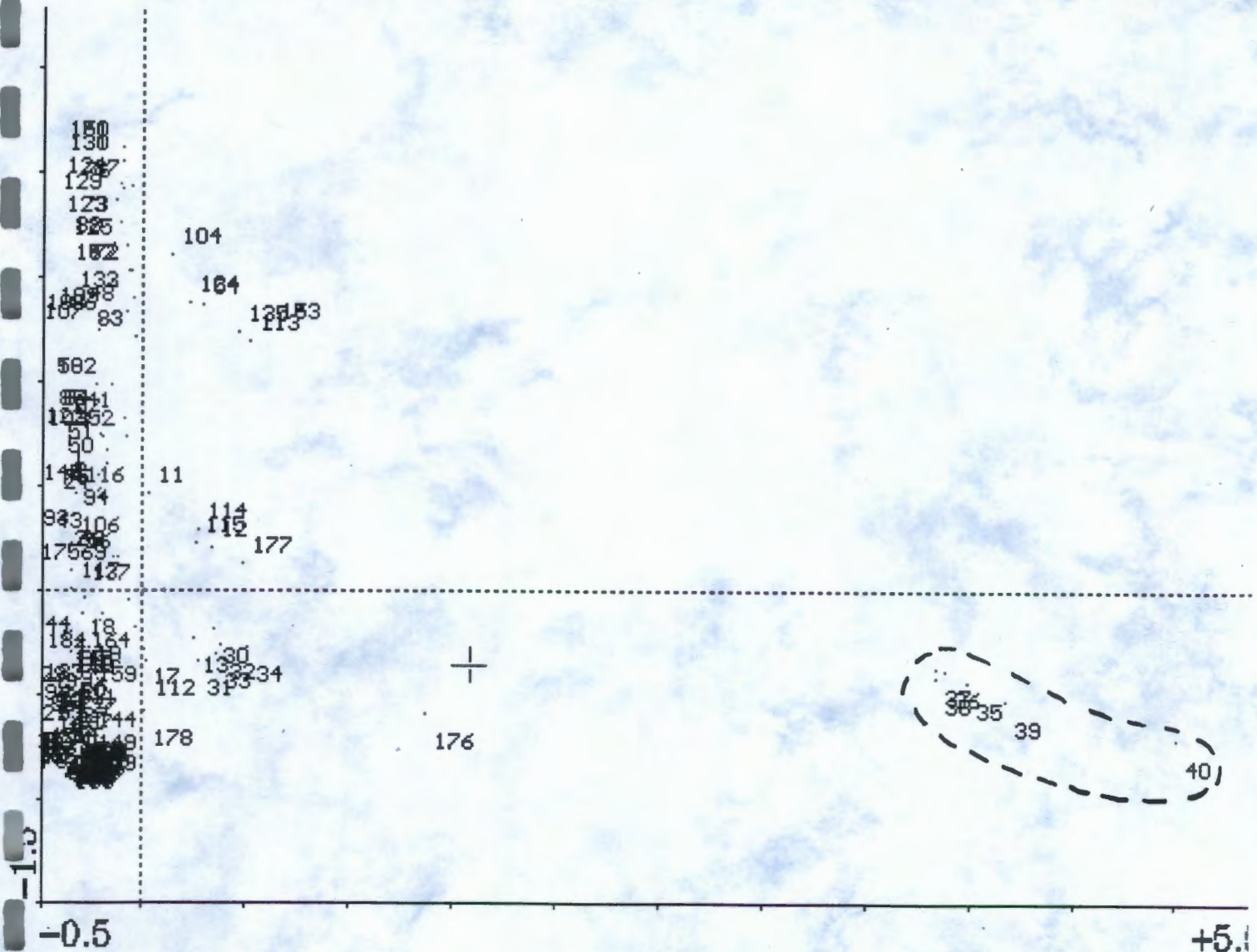


FIGURE 15: Ordination of the all the samples from all 184 sites sampled. Note grouping of samples 35 – 40 which are the upper outlet pipes

In Figure 15, the Eigen values for the horizontal and vertical axis are 0.612 and 0.416 respectively. These are relatively high eigen values, indicating that the observed patterns are well supported. The first two ordination axes together explain 22.4 % of the cumulative variance. The total inertia value is 4.577. This long gradient length suggests that Detrended Correspondence Analysis should have been tried. However, only a correspondence analysis was carried out.

In Figure 16, the seal pool and plunger as well as the outlet pipes were excluded. The Eigen values for the horizontal and vertical axis are 0.731 and 0.606 respectively. Together these two axes explain 26 % of the cumulative variance. These are relatively high eigen values, indicating that the observed patterns are well supported. The total inertia value is 5.152. The samples that were on the same walls were grouped together. What can be seen from this is that there is no difference in species composition between different walls, as samples from the same wall do not form a separate cluster. This implies that there is no real difference in species distribution between different walls and that the tank is a homogeneous environment.

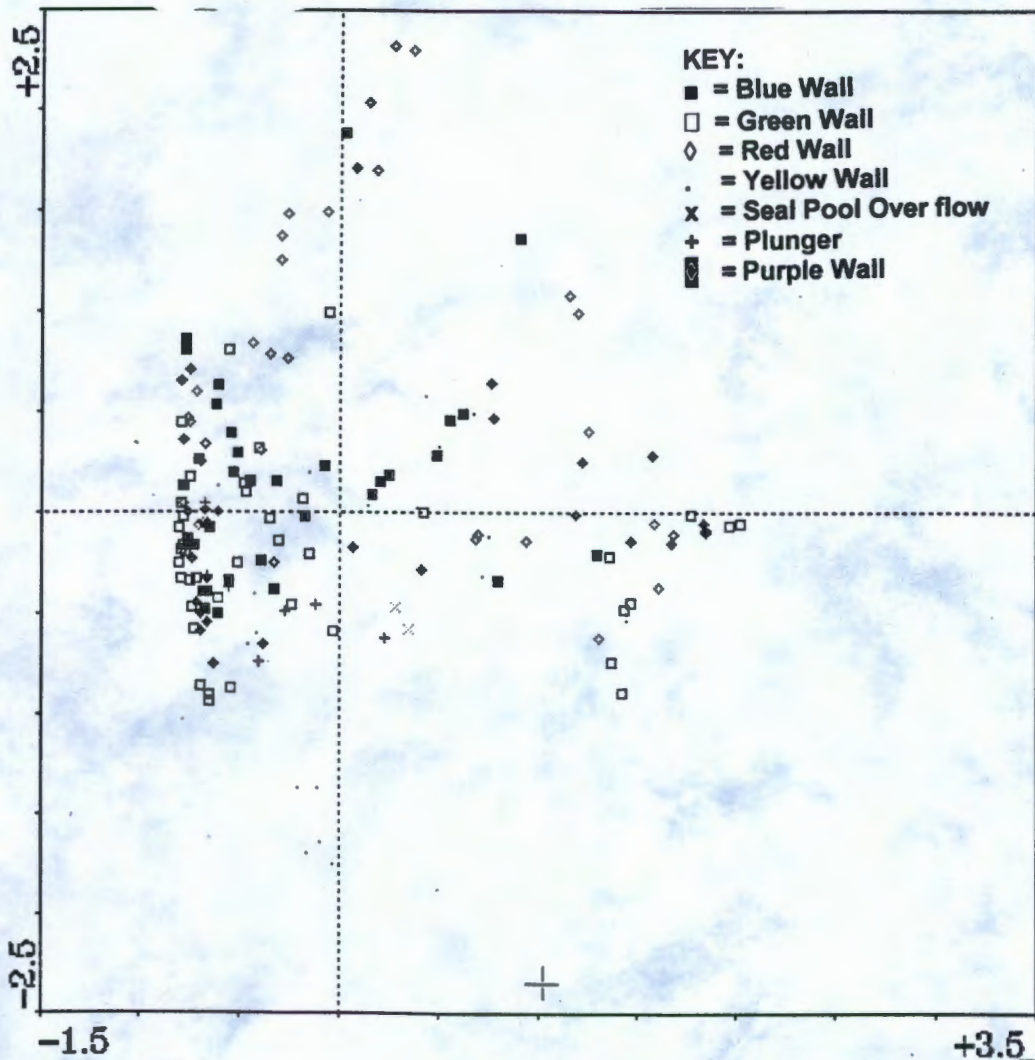


FIGURE 16: Ordination of the all the samples with the seal pool, plunger and the outlet pipes excluded.

In Figure 17, the environmental variables were added to the data. The variables included which wall the sample was on, if the sample was on a horizontal or vertical surface, if the sample was on the wall, rocks, bottom of the tank, plunger or pipes. The Eigen values for the horizontal and vertical axis are 0.626 and 0.424 respectively, together these two axes explain 13.7 % of the cumulative species-environmental variance. These are lower eigen values than found in figure 15, indicating that the observed patterns and the environmental data shown do not have a direct or close relationship. The total inertia value is 4.735. The samples that were on the same walls were grouped together. There is a cluster of samples from the yellow wall that grouped out to wards the bottom of the ordination and affected left length vector. These samples are all from the overflow above the tank and are characterized by having articulate corallines. The data for depth was entered in as 15 cm, as this was the depth of the overflow tank. However, the samples were taken out side the tank and thus their left length value is different. This would explain why left length appears to be working against depth even though left length is completely random and should not affect species distribution at all.

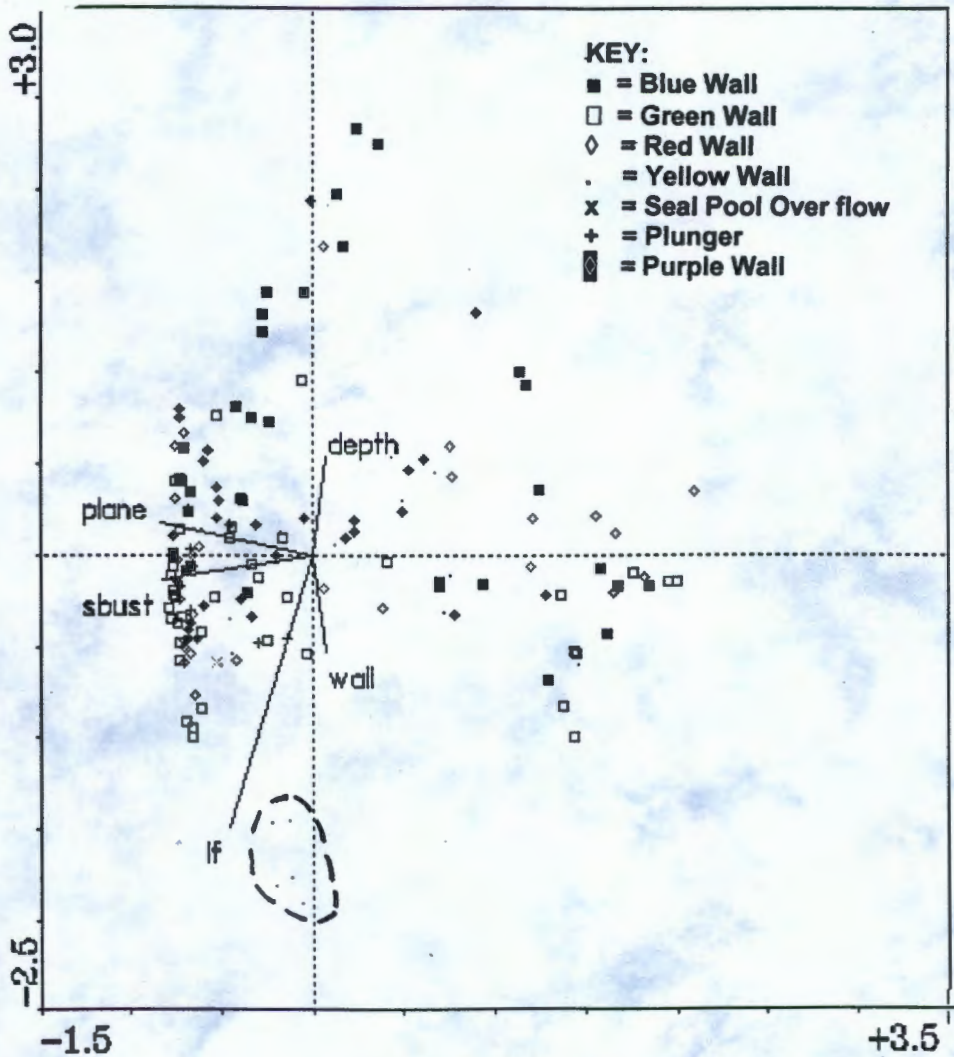


FIGURE 17: Ordination of the samples with exclusion missing and environmental data added. Note yellow wall cluster.

SPECIES IN THE RIVERINE TANK

The riverine tank is dominated by red algae, particularly *Epymenia obtuse*. There are very few green algae which occur in this tank. The author only found three *Cladophora radiosa* plants in the riverine tank, these were small in comparison to those found in the kelp tank and they were covered in epiphytes. There was also a large occurrence of *Gelidium capense* and *Gigartina polycarpa* (ex *radular*). *Schimmelmannia* was only found in one section of the tank. There was also a very high water motion in this area, due to the fact that it was in the direct path of the wave created by the surge generator in the tank. *Ecklonia maxima* was found in three areas in the tank all sub tidally and all in relatively high water motion areas. The upper intertidal zone was dominated by green diatoms. The beach areas that were in the tank were dominated by *Polysiphonia* and *Derbesia*. There was very little crustose coralline in the tank and there were no articulate corallines in the tank even though there were large flat areas for them to potentially occur.

SPECIES IN THE SEAL POOL

The overflow was the only area in the seal pool that was sampled as the author wanted to see if there was any *Schimmelmannia* occurring outside the aquarium. *Schimmelmannia* was growing on a shale rock face in an area, which was at the bottom of a two meter waterfall. There were also crustose corallines, articulate corallines and large amounts of red algae, particularly *Ahnfeltiopsis glomerata*. There was no *Cladophora* around the overflow. Species of blade algae were generally larger than those found in the kelp tank.

TABLE 2: Full species list for the kelp tank, the riverine tank and the seal pool over flow (see Appendix 10.5, for Species Authorities)

Species	KELP	RIVERINE	SEAL
Ahnfeltiopsis glomerata	Yes	Yes	Yes
Anthophycus longifolius	Yes		
Arthrocardia sp.	Yes		Yes
Arthrocardia flabellata	Yes		Yes
Arthrocardia corymbosa	Yes		Yes
Bangia atropurpurea	Yes		
Blidinga minima	Yes		
Blue Green Algae	Yes	Yes	
Carpoblepharis flaccida	Yes		
Champia compressa	Yes		
Cladophora capensis	Yes		
Chaetomorpha robusta	Yes		
Cladophora radiosa	Yes	Yes	
Codium papenfussii	Yes		
Colonial diatoms	Yes	Yes	
Crustose corallines	Yes	Yes	Yes
Delesseria papenfussii	Yes		
Derbesia hollenbergii	Yes	Yes	Yes
Derbesia marina	Yes	Yes	Yes
Diatoms	Yes	Yes	Yes
Ecklonia maxima	Yes	Yes	
Ectocarpus sp.	Yes		Yes
Enteromorpha sp.	Yes		Yes
Epymenia capensis	Yes	Yes	Yes
Epymenia obtusa	Yes	Yes	Yes
Filamentous diatoms	Yes	Yes	Yes
Gelidium capense	Yes	Yes	Yes
Gigartina polycarpa (ex. radular)		Yes	
Grateloupia doryphora	Yes	Yes	
Grateloupia filicina	Yes	Yes	
Hildenbrandia	Yes	Yes	Yes
Kallymenia schizophylla	Yes	Yes	Yes
Kelps (microscopic)	Yes	Yes	Yes
Nothogenia erinacea		Yes	
Pachymenia carnosa	Yes	Yes	Yes
Petalonia fascia	Yes		
Plocamium suhrii	Yes		
Polysiphonia namibiensis	Yes	Yes	Yes
Polysiphonia scopulorum	Yes	Yes	Yes
Porphyra capensis	Yes		Yes
Ralfsia verrucosa	Yes		
Rhodophysema	Yes	Yes	Yes
Rhodymenia natalensis	Yes	Yes	Yes
Schimmelmannia elegans	Yes	Yes	Yes

Sphacelaria spp.	Yes		
Schizymania obovata	Yes		
Stypocaulon funiculare	Yes		
Young reds	Yes	Yes	Yes
Ulva rigida	Yes		Yes

GRAZERS

Very high numbers of fish are maintained in the kelp tank as it is an exhibit and large numbers of fish would make it aesthetically pleasing to the public. A negative effect of the high fish numbers is that a large proportion of the fish in the tank are herbivorous (TOA, 1996). Maddams (1997), noted that the streepies (*Sarpa salpa*) were very intense grazers and that seaweeds that were introduced into the tank without protection rarely survived longer than a week before succumbing to grazing pressure. Following his request 30 streepies were removed from the tank and as a result he noted an increase in the thickness of the algal turf on the walls and rocks as well as an increase in the length and amount of *Cladophora radiosa*. There are still a large number of vertebrate grazers in the tank and evidence of their grazing activity in the form of scratches can be seen very clearly in *Polysiphonia* turfs on the walls of the tank. The following is a list of vertebrate grazers that occur in the tank. The fishes names are common names and the data is from personal observations as well as from Branch et al, (1994) and van der Elst, (1993).

Jan Bruin / John Brown	<i>Gymnocrotaphus curvidens</i> (Günther)
Galjoen	<i>Coracinus capensis</i> (Cuvier)
Fransmadam	<i>Boopsoidea inornata</i> (Castelnau)
Hottentot juveniles	<i>Pachymetopon blochii</i> (Valenciennes)
White Stumpnose juveniles	<i>Rhabdosargus globiceps</i> (Cuvier)
Blue Hottentot	<i>Pachymetopon aeneum</i> (Gilchrist & Thompson)
Southern Mullet	<i>Liza richardsonii</i> (Smith)
Pilchard	<i>Sardinops ocellatus</i> (Pappe)
<i>Southern Mullet and Pilchard eat mainly diatoms and phytoplankton</i>	

During the placement of quadrats occasionally limpets and other invertebrate grazers would be under the quadrat. In these cases, the quadrats were moved to adjacent areas. However, the species of invertebrate grazer was noted. These species included:

Perlemoen / abalone	<i>Haliotis midae</i>
Alikreukel	<i>Turbo sarmaticus</i>
Periwinkles	<i>Littorina</i> spp.
Limpits	<i>Patella longicosta</i>
	<i>Patella cochlear</i>
	<i>Dendrofissurella scutellum</i>
	<i>Fissurella mutabilis</i>

It must be noted that the perlemoen were only added to the tank in July 2000. Although they had been in the tank previously they rarely survived longer than a week. These perlemoen tended to be placed on the fiberglass rocks in front of the windows for aesthetic reasons. It was noted that when young perlemoen were placed on the rocks they would curl up the foot and fall off the rocks. They would land on the bottom and be eaten by fish in a matter of minutes. Older perlemoen tended to survive for a couple of days before the same thing happened (Pat Garratt, pers. comm.). It is postulated that perlemoen are very sensitive to certain chemicals. If, for example, the fish in the tank suffer from an outbreak of white spot disease (a fungal infection of the skin) the tanks are treated with high copper concentrations. No perlemoen survive the initial treatment stage, and a test to see if there is residual copper in the tank is to place perlemoen on the walls. If they fall off, the walls and bottom of the tank need to be scrubbed and the water flushed to remove the copper (Pat Garratt, pers. comm.). The theory is that the resin or the catalyst MEKP used in the construction of the rocks, is still leaching out and the perlemoen are sensitive to this. Personal observation showed that limpets and perlemoen were only found on the walls of the tank and not on fiberglass rocks. The effects of limpet grazing were generally confined to small areas such as the size of the quadrates and the species being grazed were usually turf species such as *Polysiphonia*. Perlemoen grazed the *Cladophora radiosa* and the effects were visible for about a square meter.

When the collecting bottles were brought to the lab, they sometimes contained a number of isopods and amphipods. These were identified in the lab at UCT using Griffiths, (1976) and Kensley, (1978). The total number collected from 184 samples was 25 meso-herbivores from 7 samples. Species included the following:

Kelp isopods	<i>Paridotea rubra</i>
	<i>Paridotea reticulata</i>
Tube tail isopod	<i>Cymodocella magna</i>
Variiegated spherical isopods	<i>Exospaeroma varicolor</i>
Pocket amphipod	<i>Amaryllis macrophthalma</i>
Big-eye amphipod	<i>Paramoera capensis</i>
Seaweed amphipod	<i>Hyale grandicornis</i>

SELF SEEDED ECKLONIA

When diving in the tank it was noted that the average length of self seeded *Ecklonia* rarely exceeded 45 cm. Also these self seeded *Ecklonia* plants were covered in epiphytic growth. The self seeded *Ecklonia* had a long primary blade and very rarely had secondary blades forming. Christie et al, (1988) & Levitt et al, (2000) noted that epiphytic growth was an indication of the age of *Ecklonia* and the general health of the algae. This means that generally older *Ecklonia* had more epiphytic growth than young plants. However, in the tank the young self seeded plants had as much epiphytic growth in the form of *Derbesia* and *Polysiphonia* as the older and larger plants that were introduced into the tank. This was true all over the tank except for three self seeded *Ecklonia* that were

growing under the plunger. These *Ecklonia* had fully developed primary and secondary blades and were completely free of epiphytes as well as being over 1.5 m in length. Of particular note is that the plants growing right under the plunger never receive direct sunlight and were in shade for most of the day. However, they were subject to the most violent water motion in the tank.

SCHIMMELMANNIA ELEGANS

Schimmelmannia elegans was first discovered in the kelp tank in July 2000. In September 2000, it was found in both the Seal Pool over flow and the Riverine ecosystem. Due to this discovery in the kelp tank and the fact that the alga has never been found or described in South African waters before this study, we needed to find possible reasons for it being found in the tank. Several theories were discussed and the following were investigated.

DAY LIGHT LENGTH IN THE TANK

The author noted that the lights in the tank were often on after the sun had set. It was thought that due to the fact that Tristan Da Cunha (37° 03' S: 12° 20' W) is further south than Cape Town (33° 50' S : 18° 20' W), the average summer daylight length in Tristan Da Cunha might be longer than in Cape Town, and that the crustose sporophyte of *Schimmelmannia* might be an alga that has a reproductive cue from photoperiod length. This was based on the assumption that the crustose phase of *Schimmelmannia* may have previously existed in South Africa but the daylight length even in summer was too short to allow the gametophyte to form. Using records from the TOA, figure 18 was constructed, by taking the lights being turned on from 07:00 to whatever time was noted on the record sheet, for the months August 1999 to August 2000. The standard deviations are given for each month. The graph shows that the lights were on every month except May 2000 for a period of 12 hours or longer. In summer, Cape Town's day light length is 15 hours and in winter, it is 11 hours (Stegenga et al, 1997). In Tristan Da Cunha the summer daylight length is 15 hours and in winter it is 9 hours (Astronomical Applications, 2000).

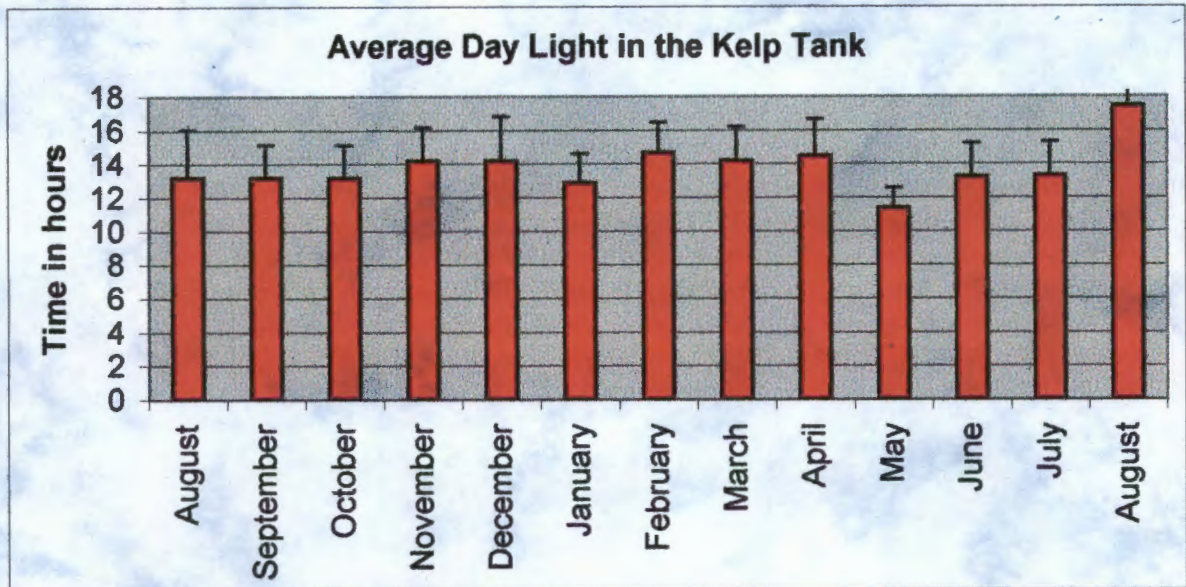


FIGURE 18: This graph shows the average daylight length of the kelp tank for the period August 1999 – August 2000 (TOA records). Standard deviations are shown on the graph.

LIGHT PROFILE IN THE KELP TANK

The light profile obtained for the tank is shown in table 3. The average light for each depth was calculated for each wall, these averages were then used in a Student's T test to see if there were any differences between walls. It was found that there were significant differences between the Blue and Green walls, $df = 2$, $p = 0.4001$ and the Blue and Yellow walls, $df = 2$, $p = 0.02538$. The only other walls that differed significantly from each other were the Purple and Yellow walls, $df = 2$, $p = 0.4156$. The Blue and Purple walls received the least light in the tank. The Blue wall has a large cave or rock over hang and as readings were taken 1 m away from the wall, the overhang considerably reduced the amount of available light. The Purple wall has two rock outcrops and these could have caused the light readings to be low. The Green and Red walls received the most light apart from the centre of the tank.

Values in red are values from areas that are in caves or overhangs in the tank and therefore would be expected to be lower than areas that had readings taken away from any such obstruction. Values in blue are readings that are lower than the down welling range for a west coast kelp forest (Anderson & Bolton, 1985)

TABLE 3: Light measurements from transects down each wall in the tank. Values are measured in $\mu\text{M}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Values in red are from areas that are under overhangs or in caves. Values in blue are lower than down welling range of 50 - 100 $\mu\text{M}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ (Anderson & Bolton, 1995).

Site and left length	1 m	3 m	6 m
Centre of tank	1275	825	325
Blue wall 2 m	200	25	11
Blue wall 4 m	250	11	7
Blue wall 6 m	250	15	9
Green wall 3 m	800	500	300
Green wall 6 m	900	600	400
Green wall 9 m	700	25	200
Red Wall 3 m	700	300	200
Red wall 6 m	800	500	300
Red wall 9 m	900	400	250
Purple wall 2 m	80	17	11
Purple wall 4 m	400	200	70
Purple wall 6 m	300	127	30
Yellow wall 2 m	75	33	15
Yellow wall 4 m	700	300	200
Yellow wall 6 m	800	500	300
Above surface	3795		

DISCUSSION

Light intensity

In the open ocean, light distribution is largely determined by properties of the surface and water column. In the tank environment this is complicated by the vertical orientation of the walls, which limit penetration of direct sunlight to the bottom of the tank to the hours when the sun is near or at its meridian. The reason for this is that reflection increases as the incident angle becomes more acute. For example, reflection is only 4 % when the light strikes the water at 90 degrees, but when light strikes the water at 10 degrees, 28 % of the light is reflected. Movement of the water surface therefore affects light penetration. White caps and bubbles cause about 50 % light loss (Bolton & Anderson, 1995). The distribution of light is important as it affects species composition, abundance and the productivity of algal assemblages (Gerard, 1984). Kelp canopies further influence this by intercepting light. Previous work done in the TOA kelp tank has concluded that there is no significant difference between the tank and the natural environment light levels (van Rensberg, 1995). This could be because light in the natural environment is reduced by scattering and absorption with depth and in the aquarium in the filtered water of the tank, there would be very little attenuation with depth.

Anderson and Bolton (1985) measured the summer irradiance levels at 6 m at Oudekraal during upwelling stage with sun and clear water (maximum of $600 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ at 6 m depth) and down-welling with overcast weather and turbid water events (maximum of $200 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ at 6 m depth, range $50 \mu\text{mol.m}^{-2}.\text{s}^{-1}$ to $100 \mu\text{mol.m}^{-2}.\text{s}^{-1}$). The light profile obtained for the tank indicates that the middle of the tank as well as the Green and Red walls of the tank receive irradiance in excess of the down-welling maximum. The parts of the tank that have irradiances below this level are of concern, as these may represent a point below which macro algal growth may be difficult to maintain. The term "macro alga" as the entire tank is covered in growth of one form or another. However, for aesthetic purposes, for public viewing in the tank, macro algal growth would be preferable over crustose species like *Rhodophysema* and *Hildenbrandia*.

The fact that morning and afternoon levels of light may be lower than those found in natural beds due to shading caused by the walls of the tank, means that not only is the tank receiving light of a decreased intensity, but that the photo period may also be limiting. This idea is very difficult to prove because by looking at figure 7 we can see that in winter in Cape Town there is more light in the tank than occurs naturally. However, in summer the average in the tank is slightly less than the Cape Town and Tristan Da Cunha summers. This light in the tank is not all natural. There is a lot of shading from the walls and light in the tank is supplemented by the metal halide lights on the walls of the tank. However, the bulbs in the lights are not changed according to the manufactures specifications and they say that the photo spectrum changes after 6 000 hours and may not supply the correct photo spectrum for optimum macro algae growth, although this point is debatable.

It has also been shown that in nature, the critical level of light for kelp to maintain itself for any length of time is about 1 % of average surface light, understory algae would need less light (Bolton & Anderson, 1995; Lünning, 1990). With the water in the tank being filtered, any light that strikes the water at the right angle would be very easily distributed in the tank. What is more important to the plant however, is the total quantity of light obtained over a period (e.g. a day or week), which is also a function of day length (Bolton & Anderson, 1995). If the photo spectrum from the metal halides is right, then the average light in the tank, resulting from the lights being on, would reflect natural seasonal light periods for Cape Town and take away some of the effect of shading from the walls. However, the positioning of the lights could affect growth as well as species distribution.

Grazer intensity

The plunger, which was treated as an exclusion zone had a large number and a wide variety of species growing on it. This is an indication of the type of flora diversity that can be expected in the tank if grazing pressure decreases.

It is only just being realized how important meso-herbivores (invertebrates that are less than 2.5 mm in length (Barnes & Hugh, 1999)) are in maintaining algal communities. They perform several important functions such as removing epiphytes on macro algae and creating gaps in perennial turfs (Brawley and Fei, 1987). Duffy and Hay, (2000) found that when fish and amphipods are present in a tank then green algae is cropped to a fine turf and space was more rapidly dominated by larger macro algae. They also found that reds dominated when there are large numbers of amphipods, whereas browns dominated when fish are present. If impacts of fish and amphipods are normalized for their aggregate biomass then the effects of amphipods grazing are greater by 1 – 2 orders of magnitude. At present, the tank is being dominated by crustose corallines and *Cladophora radiosa* (Table 1). This suggests that grazing pressure on green algae is low. Epiphytic algae on both the large macro algae and the self seeded *Ecklonia* are also very prevalent (over 21 % of total algal growth in the tank (from table 1)). This suggests that grazing by meso-herbivores is almost none existent in the tank. One way to reduce the number of epiphytic algae on both the self seeded *Ecklonia* and the introduced large macro-algae would be to increase the number of meso-herbivores. There are very few meso-herbivores in the tank at present as they were only found in 3 % of the entire sample collected.

At present, it appears that the tank is capable of sustaining present grazer levels. However, new fish that are to be introduced into the tank should be carefully screened for their herbivorous tendencies, in which case, only a few of any one species should be included in the exhibit at any one time, if any should be included. Should a certain species be identified as a problem, it must be removed and new additions should be added in small quantities i.e. less than five at a time and the effect on algal growth monitored.

With regard to invertebrate grazers, it appears that the perlemoen are trapping *Cladophora radiosa* and at present, this species covers the second largest area

in the tank about 17.9 % of the total area sampled. Therefore, the tank could sustain more perlemoen as there are only four in at present.

Schimmelmannia elegans

A few important questions needed to be asked. Initially it was difficult to identify this species as it has not been recorded on the South African coast line before. *Schimmelmannia elegans* occurs naturally on Tristan Da Cunha and thus the first question was, "How did it get into the kelp tank?" There were a number of theories that were initially considered. The first was that because there were lights above the tank, which are often left on until 22h00 for functions held at the aquarium, there are longer periods of daylight, with actual daylight being combined with artificial daylight. This means that the tank could have a longer average daylight length over the period of a year when compared to Cape Town's natural average daylight length. It was thought that with Tristan Da Cunha being further south than Cape Town it would have a longer summer daylight length than Cape Town. It was also thought that the crustose phase of this algae always existed on the west coast of South Africa. However, it had never been found in the sporophyte form as the day length was too short, as photoperiod responses are triggered by a long day and not the average length of a number of days. An example of this is *Falkenbergia* which occurs here as balls of filaments but is never found in the gametophyte form which is a erect seaweed of the genus *Asparagopsis* (Stegenga et al, 1997).

The water temperature in the tank (see figure 4), is very similar to temperatures found in False Bay (Stegenga et al, 1997). Investigation showed that it is also similar to water temperatures at Tristan Da Cunha with winter being 13.7 °C and summer being 17.5 °C (van den Hoek, 1987; Baardseth, 1941). Thus, the tank is an ideal environment for this species.

The theory was that with the longer day light length in the tank the crustose phase was reproductively triggered by photoperiod and that this was the reason for the gametophyte occurring in the kelp tank. This is because the switch from vegetative growth to reproductive growth often depends on environmental factors such as light and temperature (Lobban & Harrison, 1997). Since temperature in the kelp tank is similar to Tristan Da Cunha, photo period was thought to be the trigger. However, both Tristan Da Cunha and Cape Town have a 15 hour day in summer and the average light length in the tank over these months is slightly less than that (see figure 15). The fact that the *Schimmelmannia* was also found growing in the riverine tank which has a strict 12 hour day length meant that this theory was proved incorrect. Also the *Schimmelmannia* was found growing outside the aquarium at the seal pool, this area is south facing and is in shade for most of the day so one could assume that there is less light here. However, it is close to a boardwalk, which has fluorescent lighting that is left on all night. This could provide sufficient light for the alga to grow, as *Dictyota diemensis* has been found to have an egg production cycle that is triggered by a semi lunar cycle. Gametogenesis begins the day after a full moon and is completed with gamete release 10 days later (Lobban & Harrison, 1997). Thus, moonlight is sufficient light to trigger a photoperiodic response, so maybe the fluorescent light is as well.

The second theory was that the algae was somehow introduced into the tank. It is known that crustose forms of algae and other filamentous algae can exist on the carapaces of lobsters (Rob Anderson, pers comm.). There are also many cases of algae being transported with oysters and becoming established in new areas (van den Hoek, 1987). There have been two Tristan Da Cunha lobsters in the TOA since its inception, and it could be possible that the algae came on the carapaces of these lobsters.

However, these lobsters were never at any stage placed in the kelp tank (Lex Fernhead, pers. comm.). They were housed in the Diversity Hall, which is on a completely separate water system to the kelp tank. Although the waste water does enter the seal pool and might explain how the algae came into the seal pool, it does not explain how it got into the kelp tank. The lobsters were also in quarantine but this again is a completely separate system from both the Diversity Hall and the Kelp Tank.

The lobsters were donated by a lobster fishery that is based in the harbour and the boats have been catching live lobsters at Tristan Da Cunha and Vema Sea Mount for a number of years. The lobsters are housed in the bilges of the fishing vessels and are kept alive by pumping fresh seawater into the bilges. There may also have been gametophytes caught with the lobsters, but this is speculation. Once they reach the factory they are housed in porta pools before being sold. It is possible that with the crustose form attached to the lobsters carapace, and bilge water being pumped into the harbour water the *Schimmelmannia* could have been introduced this way. The reason for the *Schimmelmannia* occurring in the kelp tank then would be that the water taken into the TOA through the intake pipe for the aquarium, near the Clock Tower could have contained *Schimmelmannia* algal spores which could then be drawn in through the intake pipes. Although the water is filtered it is only filtered through silica sand. The sand is round and has a diameter of 0.7 mm. This means that spaces between sand particles are fairly large and in fact large enough to allow the larva of the tubular hydra, *Tubularia warreni* to pass through the system unaffected. The intake pipes are soon going to be fitted with UV filters which should kill all living organisms that are pumped into the TOA and thus prevent further introductions like this one.

One way to prove that the above theory is correct is to look at the outlet pipe of the lobster factory to see if the algae occurs there. If it does, then this is the most likely way it came into the aquarium.

The occurrence of *Schimmelmannia* in the tank has also raised the question of alien invasive algae. An infamous example, is the introduction of *Caulerpa taxifolia* in to the Mediterranean by the Monaco Aquarium. Dr. J. T. Carlton (per. Comm.) has mentioned that because *Schimmelmannia* is in the aquarium and is already reported growing outside the aquarium in the Victoria and Alfred (V & A) basin, it could become invasive, the nature of the V & A means that *Schimmelmannia* could be placed within the realm of lagoonal hypothesis invasion establishment. The hypothesis suggests that if invasives find themselves in a low energy cul-de-sac, they are jump started and the population can grow to become robustly established. As opposed to the new

introduction finding itself on a wave swept open coast, where it could be carried out to sea, fail to find mates, and disperse without having much of an impact. Thus, the possible establishment of this alga is enhanced by its location. Further investigation into the lagoonal hypothesis states that as lagoons and estuaries have low rates of tidal flushing (a situation that is similar in the V & A), this could be conducive to the rapid growth of a population within an estuarine area (Brock, 1960 and Carlton & Eldredge, 2001). Cohen et al, 1995 stated that lagoons might nurture new inoculations of non-indigenous species, as lagoons are typically a few degrees warmer than the surrounding bays in spring and autumn months, when they are characterized by high primary productivity. Lagoons are also retentive environments, which may be crucial to maintaining the critical densities of adult organisms needed for sexual reproduction. What is in *Schimmelmannia's* favour is that it is a nice looking alga. However, if one looks at the fact that it is occurring in the kelp tank, then has distributed itself to the riverine ecosystem through pipes and pumps and then has found its way into the seal pool over-flow this means that:

- a) Environmental conditions in Cape Town are favorable for its growth and reproduction (most of the gametophyte algae found was reproductive),
- b) It can establish itself very easily
- c) It can grow in low light conditions

The only thing in favour of it not becoming established in the V & A is the fact that the sporophyte stage seems to require very high water motion areas and there are very few of these such areas in the harbour.

Long range seaweed dispersal

Tristan Da Cunha is an island that is volcanic in origin and arose from the mid Atlantic Ridge. It is approximately 1 million years old (van den Hoek, 1987). It has approximately 125 species of algae, many of which are closely related to species that occur on the Cape Peninsular and its vicinity (van den Hoek, 1987). Of the 32 non-endemic west coast species that are found north of Cape Point, twelve have global distributions and seven of these are found on Tristan Da Cunha (Stegenga et al, 1997). The distance between these two places is some 2 500 km. However, this would be against the west wind drift. Another volcanic island Gough island is some 370 km further south than Tristan Da Cunha. Despite their proximity to one another there are very distinct differences in the algal flora. This could be attributed to the fact that sea surface temperatures at Gough are lower. The reason for this is that Gough island lies slightly further south of the Subtropical Convergence Zone and Tristan da Cunha lies just north of it, although it must be mentioned that this is an arbitrary line and its position does change. However, this line is theorized to be a barrier to species spread. There is no evidence either for or against the role of planktonic stages of seaweeds (spores, propagules, zygotes) in the long distance dispersal of seaweeds. There is however, evidence of long distance dispersal of floating plants, or as plants attached to floating objects including floating algae. Data from drift cards, which were dropped in the South Atlantic gyre to monitor current patterns showed the following: some cards followed the outside of the gyre; others went into the west wind drift; others went into smaller gyres round the center of the Atlantic gyre. The most surprising was that some

cards came out of the west wind drift and ended up near Cape Town passing through the Sub Tropical Convergence Zone (Stegenga et al, 1997). Others that were dropped near Tristan Da Cunha also ended up near Cape Town, thus showing that there is a possible transport route from Cape Town to Tristan Da Cunha and visa versa. There are a few examples where seaweeds have been artificially dispersed by being carried over long distances on ship's hulls, on oysters and in ships ballast water (van den Hoek, 1987). Although long-range dispersal of seaweeds does exist, it is the exception rather than the rule.

It is possible that conditions required for the growth of *Schimmelmannia* in Cape Town are the same as those in Tristan Da Cunha (as shown by the fact that 7 species occur both in Cape Town and Tristan Da Cunha). It is debatable whether *Schimmelmannia* has found its way to Cape Town via natural long-range dispersal or if it has been artificially dispersed by man, which appears to be more likely. This needs further investigation.

Self seeded *Ecklonia*

As a result in the decline of the health of the *Ecklonia* recruits (based on the number of epiphytes on the self seeded plants), we must conclude that water movement in the tank determines the health of the self seeded *Ecklonia*. The spores that are directly under the plunger are the healthiest in the tank. The plants that are there are also shaded as they are under the overhang of the plunger casement. We can assume therefore that light intensity is not that important as the plants are shaded the entire day. Maddam's, (1997) concluded that the decline in the health of the adult *Ecklonia* plants was due to either changes in light intensity, photoperiod or water movement. By looking at the average daylight length in the tank, we can conclude that the photoperiod in the tank resembles that of the natural environment. Light intensity could also be theorized the same as the natural environment because the self seeded *Ecklonia* are doing well in a low light environment (see table 3). As the self seeded *Ecklonia* under the plunger is the healthiest and the water motion in the tank is greatest here one can conclude that water motion in the tank is the limiting factor to kelp growth and health. The reason for the apparent decline of self seeded *Ecklonia* in the rest of the tank, could be related to the fact that the algae are nutrient limited due to problems with water circulation. Movement of water in the tank is caused by the plunger, however this mechanism generates more of a backwards – and – forwards motion of the water column (personal observation). This means that the same water is moving past the thallus of a plant the whole time, and thus once nutrients have been depleted from the water surrounding the thallus, replacement of nutrients is poor. Attempts have been made to establish a counter clockwise current in the tank. However, this has not been effective as the outlet pipes which cause the current have a limited range of movement and current flow is also disrupted by the angles of the walls in the tank and the placement of false rocks in the center of the tank.

Algae are dependant on the continual replacement of nutrients from their surrounding nutrient poor medium, to obtain their nutrient needs. Water motion limits the formation of a nutrient poor boundary layer on the algae, which can inhibit nutrient uptake (Wheeler, 1980). Anderson and Bolton, (1995), pointed

out that it is not necessarily the concentration which is important, but rather the supply rate. In the kelp tank environment where there is insufficient current this supply rate would appear to be inadequate.

Seasonality in the Kelp Tank

Looking at Figure 18, we can see that with the lights being left on late at night, for functions held at the aquarium, the average daylight length in winter is much longer in the Kelp tank than is experienced for Cape Town naturally. What does this mean for the seaweeds in the tank?

The switch from vegetative growth to reproduction (which, in most seaweeds requires very little growth) depends on environmental factors such as light and temperature (Lünning, 1990; Lobban & Harrison, 1997). In 1988, 55 seaweeds were known to have a photoperiod response (Lobban & Harrison, 1997). Many of these seaweeds had heteromorphic life histories, where the algae use the cue to switch to a different phase (which is assumed a priori to be better adapted for the conditions occurring in the next season). An isomorphic alga does not have a change in its morphology when the reproductive phase is triggered. Nevertheless, photoperiodic responses have been found in isomorphic and even haplobiontic species (Lobban & Harrison, 1997). Some seaweeds have minimum requirements for accumulated total daily irradiance or a certain irradiance intensity in order to reproduce (Lobban & Harrison, 1997).

It has been shown in a number of kelps that the number of hours of light per day (photoperiod) controls the seasonal pattern of growth and reproduction (Anderson & Bolton, 1995) e.g. *Laminaria pallida* is known to exhibit seasonal growth patterns with the majority of growth occurring in spring and early summer (Stegenga et al, 1997). It is possible that even if fairly dim artificial light is used to lengthen the daylight hours in winter (e.g. if the aquarium is open late in winter and the lights in the Kelp tank are left on late for a function) this may affect the seasonal rhythms of growth and reproduction. Since the ultimate goal of the aquarium is a self-maintaining seaweed system, reproduction and reseedling of seaweeds in the tank is essential in the achievement of this goal. Because we do not know what light is necessary for growth and reproduction of more than a few of the different life history phases of local seaweeds, or how they react to seasonality, we must assume that seaweeds occurring in the kelp tank are seasonal. Therefore, they would require a minimum of one month in the year where the daylight length is the same as that of Cape Town's winter months i.e. 11 hours of daylight. This means that the aquarium should choose a month that has very few functions in winter and during that month, the light in the Kelp tank must be turned off at 18h00 (assuming they are turned on at 07h00). At present the lights for the Kelp tank and the Predator Display are linked, since functions are held around the Predator Display at night, the lights are turned on, thus both the Kelp Tank and the Predator display are lit up for functions. Since this benefits the seaweeds in summer by extending the daylight length in the tank, the author sees no reason why this should not continue. However, in winter when there are far fewer functions one month should be chosen (from Figure 18, May is probably the best month) when the lights in the Kelp tank are switched off when there is a function on around the

predator display. To do this, the aquarium would have to separate the two light systems for the two tanks. In addition, for the remaining winter months lights could only be switched on in the mornings at 8h00 or 9h00.

The Kelp tank does appear to have some form of seasonality; for example, the occurrence of *Grateloupia* before sampling was done (late summer), the fact that it was not found during sampling (winter) and its occurrence again after sampling was complete (in spring). Also noted in dives in the tank in late October was the emergence of blue green algae in areas where it had not been recorded, this is possibly due to seasonal changes.

Ordination results

From the ordinations performed on the data, the author found that the samples taken on the outlet pipes, the plunger and the seal pool overflow all separated out from the rest of the samples. This was due to the presence of *Schimmelmannia*, which occurred in all three of these areas. All three areas had very high water motion and it can therefore be theorized that the *Schimmelmannia* sporophyte requires very high water motion in order to grow.

The plunger had the most species (28 species growing on it out of a possible 50 that were recorded in the tank, see Appendix 10.4). Although the plunger is not a true grazer exclusion cage, it had more species than the grazer exclusion cage (the grazer exclusion cage had 3 species, see Appendix 10.4), which was at the same depth and on the same wall. Thus grazing pressure cannot be seen as a limit to species diversity in the tank. As the plunger generates the water motion in the tank and therefore has the greatest current flow, one can theorize that to increase species diversity one must increase the water motion in the whole tank.

One of the main aims of the project was to see if there were any zonation patterns occurring with regards to species diversity. The author wanted to see if there was any difference between the number of species that occur on north and south facing walls. When the samples from the same walls were grouped together as in Figures 15 and 16, we can see that the walls were essentially the same in their species composition and no wall was significantly different from any other. Therefore, the conclusion that must be reached is that the tank is a homogeneous environment concerning wall orientation.

Depth also had no effect on species distribution. This could be because the tank is relatively shallow at 6 m depth and although light penetration in the open ocean decreases with depth, due to spectral changes in absorption (water absorbs most in the longer infra-red wavelengths of the light spectrum, so that light at depth appears blue) and attenuation (scattering and increases with depth) (Bolton & Anderson, 1995), the filtered water in the tank would ensure that light penetration at 6 m is better in the tank than when compared to the open ocean due to the fact that scattering from particles in the water is reduced. This could explain why there was no difference in species distribution with depth.

When the author looked at species distribution on the artificial rocks compared to the walls it was found that neither substrate was better or worse for the number of species it contained. Thus, all algae in the tank could attach equally well to both substrate types. This is to be expected as algae can colonize any object that has been submerged in water for a period. This rapid colonization of submerged objects by algae has led to a large industry for anti fouling paints, which aims to prevent algae growth on boat bottoms and other structures in the sea.

The plane (i.e. whether the quadrat was vertical or horizontal) did not appear to affect the species distribution even though, visually, when diving in the tank, it appeared that horizontal surfaces were always characterized by having articulate corallines growing on them. It must be noted that horizontal surfaces only occurred on the artificial rocks. Even though visually this looked like a difference in species composition, it was not shown in the ordinations.

Physical data and photosynthesis of kelps

In order for kelp to grow, total energy production and carbon fixed during photosynthesis must exceed the energy and fixed carbon used during respiration (which occurs at all times both in light and in darkness), (Linden & Yarish, 1992). The amount of carbon fixed depends on several factors, but is usually limited by available light. The energy fixed in the carbon is used to assimilate nutrients, for example nitrogen, which are then used to build proteins and plant tissue. The rate of photosynthesis and therefore growth, depends on a number of environmental factors such as light, nutrient availability and uptake, temperature, pH and carbon uptake, water movement, salinity and the percentage of dissolved oxygen in the water.

Optimal photosynthesis for *Ecklonia* occurs at a temperature 10 – 15 °C (Bolton & Anderson, 1995), which is around the average temperature in the Kelp tank. *Ecklonia* can survive in temperatures of 4 – 22 °C (Bolton & Anderson, 1995). So far, the temperature in the tank has remained within this range (See Figure 4).

pH In the tank has remained around 8.1 – 8.3 (See Figure 5), which is in the optimal range of pH (8.0 – 8.3) for photosynthesis of kelps (Lobban & Harrison, 1995; Bolton and Anderson, 1995). The normal pH of sea water is slightly alkaline, ranging from around 7.2 to 8.7 (Lobban & Harrison, 1995; Bolton & Anderson, 1995). pH is affected by the amount of dissolved carbon dioxide (CO₂) in the water. Dissolved CO₂ is removed by plants that are photosynthesizing, which increases the pH. It is added to the water during respiration of both plants and animals which reduces the pH. Sea water is well buffered with respect to the changes in pH and only if there are large amount of plant material per litre of water (as in a rock pool) is enough CO₂ removed in the day and released at night to drastically change the pH.

Dissolved oxygen concentration limits photosynthesis. As oxygen concentration rises, photosynthesis decreases (Linden & Yarish, 1992). This only becomes a problem if there is a large amount of algae in a tidal pool and the water

becomes supersaturated with oxygen. However, the aquarium rarely becomes supersaturated (see figure 3) and the dissolved oxygen concentration is optimum for photosynthesis.

Salinity in the tank ranges from 32.9 parts per thousand to 34 parts per thousand (see figure 6). There have been very few studies on the effects of salinity changes and kelp growth. Kelps are generally rather intolerant of salinity changes when compared with other seaweeds. Maximum growth of kelps took place between salinities of 25 – 32 parts per thousand and was severely reduced at salinities below 20 parts per thousand (Bolton & Anderson, 1995).

Light is known to be a limiting factor to photosynthesis. It is probable that light in the aquarium is at an optimum for photosynthesis as it is not only the amount of light which is important, but also the quantity and from Figure 18, this can be assumed to be the same as Cape Town's natural environment and therefore optimum. In addition, most of the tank receives light in excess of the downwelling range (table 3). Thus light intensity is not limiting and the duration is not limiting either.

Seaweeds derive all their metabolic requirements from the surrounding water. Concentration of nutrients is less important than the overall supply rate. A sub-optimal but constant supply is better than a high concentration that is rapidly exhausted and not replaced. Seaweeds survive in low nutrient environments only when water movement continually replaces the nutrients as soon they are used. At nutrient concentration levels which are growth limiting, a relationship can be demonstrated where increased water motion can actually promote growth (Bolton & Anderson, 1995). Thus, the self-seeded *Ecklonia* that are growing under the plunger have the advantage of being in an area in the tank that has increased water motion. Nutrients in the tank could be theorized to be non-limiting as these self seeded *Ecklonia* were the healthiest in the tank.

Since nutrient uptake is linked to water motion and the nutrients are non-limiting, water motion in the tank could be seen as the limiting factor to kelp growth.

CONCLUSION

This study has identified all those species of algae that are occurring in the kelp tank and the riverine tank. The surprise in the species list was the presence of *Schimmelmannia elegans*. The presence of this alga has raised a few important questions as to how the algae came into the tank and whether or not it is occurring elsewhere in the harbour. The answers to these questions can only be determined by further investigative work.

The study has successfully answered the questions of what is growing in the tank and where it is growing. It has also provided a basis for future research work to be done in the tank and it would be interesting to repeat this study in four years time and see if there are any changes that have occurred in species composition. Unfortunately, the only conclusions that can be reached are that *Schimmelmannia elegans* and *Pachymenia carmosa* definitely require high water motion in order to grow.

To increase species diversity in other areas, and to increase the general health of self-seeded *Ecklonia* more water motion is needed than the backward-forward motion that is currently supplied in the tank. The aquarist in charge of the Kelp tank for the duration of the research period said that it was possible to have a current flow that goes from east to west along the surface of the tank and from west to east along the bottom of the tank. The only problem that would occur with this type of current is that the rocks in the centre of the tank would disrupt any bottom current and certain corners of the tank would not feel the effects of this current. The surface current flow would definitely help the adult kelp plants in the tank by improving water motion over their thalli and could therefore lead to an improvement in their general health,

Grazing pressure in the tank by fish appears to be adequate. However, the introduction of more invertebrate grazers, particularly meso-grazers could have substantial benefits for the encouragement of secondary growth in the tank, as well as a reduction in the amount of epiphytic algae. This however, needs to be done in stages and the effects of such grazers carefully monitored. A useful tool for comparison of the effects of grazers would be the data collected from this project.

The only limiting factor for photosynthesis and growth of the seaweeds in the Kelp tank is the lack of water motion. All other factors that could be limiting in other circumstances are at optimum ranges for photosynthesis in the tank.

As some kelps require a seasonal cue for changes from vegetative growth to reproductive growth, a management option for the aquarium is to have one period in winter (possibly May) in which the day light length is very strictly controlled and limited.

The kelp tank is a homogeneous environment, and there is no difference in species distribution on different walls, substrate types, plane or depth. With the exception of areas which have high water motion, such as the plunger and the

outlet pipes which are distinguished by the fact that they have more species and the presence of *Schimmelmannia*.

The study of algal succession in the Kelp tank should be undertaken and it is suggested that the data obtained from this project be entered into a computer programme like GIS so that changes in seaweed succession over time in the tank could be monitored.

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APPENDIX

Species list of algae found in the tank in 1997 (Madams, 1997).

Anthophycus (*Sargassum*, Turner, *Fucus*, Turner) *longifolius*
Arthrocardia spp.

Bangia atropurpurea
Blue Green Algae

Champia compressa
Cladophora capensis
Cladophora radiosa

Derbesia marina

Ecklonia maxima
Ectocarpus spp.
Enteromorpha spp.

Filamentous diatoms

Gelidium capense
Grateloupia doryphora
Grateloupia filicina

Kelps (microscopic)

Pachymenia carmosa
Petalonia fasciata
Polysiphonia namibiensis
Porphyra capensis

Ralfsia verrucosa
Rhodymenia natalensis

Sphacelaria spp.

Ulvaceae

DATA TO BE COLLECTED IN THE KELP TANK WHILE DIVING

Position of quadrat

Measure distance from top left corner of quadrat to left wall and bottom/ of tank (See Figure 19).

Record the position of the quadrat in relation to the tank and the measurements
Count the percentage cover of each species in the quadrat and record under quadrat number and position

Scrape a 10 cm by 10 cm area in the quadrat and place scrapings in a bottle, note bottle number

EQUIPMENT TO BE USED

Collecting bottles

Normal bottles

Scrapers

Tweezers

Dive slates

Tape measure x 2

Formalin

Quadrats 25 cm X 25 cm divided into 5 cm X 5 cm

Map of tank

Kokie

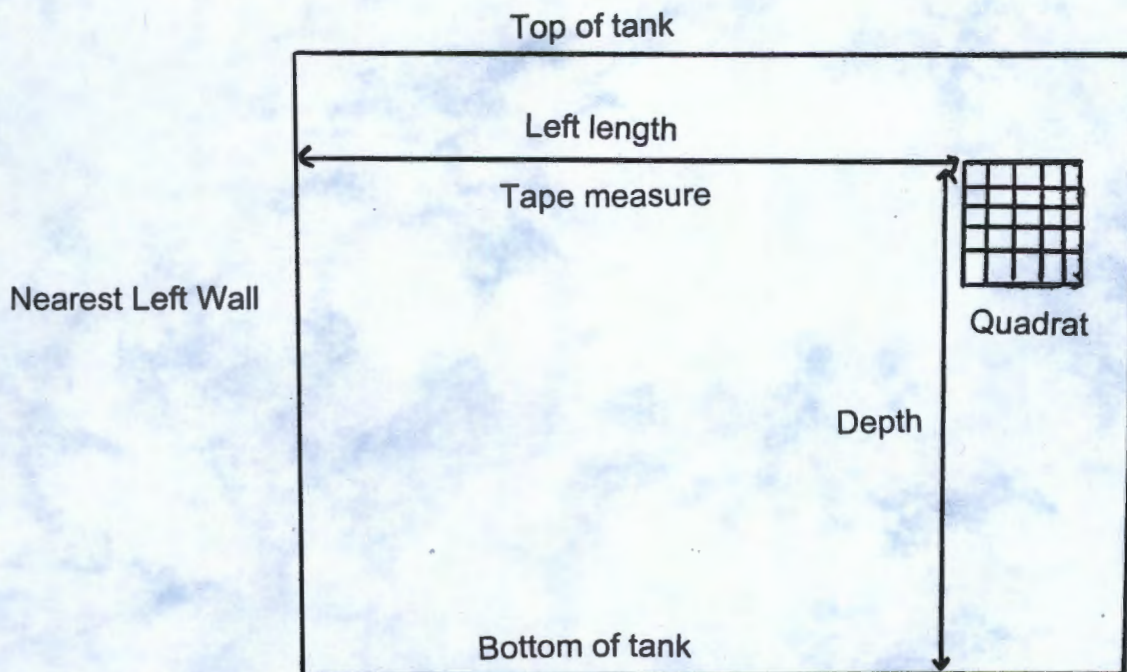
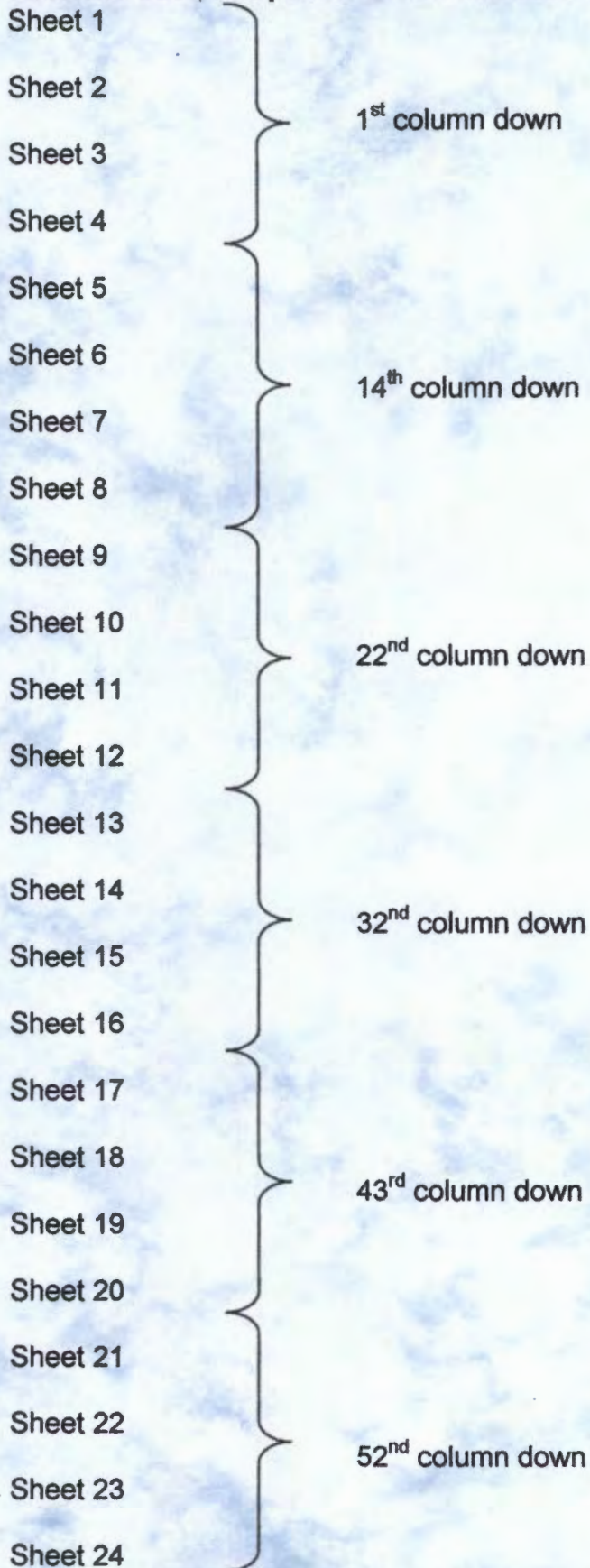


FIGURE 19: Diagram to show how the left length measurement was taken

RAW DATA

Lay out:

Note excludes all species which had zero % cover in the tank.



Sample	wall	plane	substrate	Left length	depth	Ahnfeltiopsis glomerata	Arthrocadia spp.	Bangia atropurpurea	Bare Rock	Bare wall	Blue Green Algae Filament	Blidingia minima
30	Blue	vertical	wall	3	0.25	0	0	0	0	0	0	0
31	Blue	vertical	wall	3	1	0	0	0	0	5	0	0
32	Blue	vertical	wall	3	1.9	0	0	0	0	11	0	0
33	Blue	vertical	rock	3	3.2	2	0	0	0	0	1	0
34	Blue	vertical	rock	3	4.2	1	0	0	0	0	0	0
35	Blue	flat	rock	3	4.2	1	0	0	0	0	0	0
36	Blue	flat	rock	3	4.2	1	0	0	0	0	2	0
37	Blue	vertical	rock	3	5.5	1	0	0	0	0	1	0
38	Blue	vertical	rock	3	6	0	0	0	0	0	0	0
39	Blue	vertical	rock	3	6.25	0	0	0	0	0	0	0
40	Blue	vertical	wall	3	6.5	1	0	0	0	0	0	0
41	Blue	vertical	wall	3	6.75	0	0	0	0	10	0	1
42	Blue	vertical	wall	4.39	0.25	0	0	1	0	0	5	2
43	Blue	vertical	wall	4.39	0.5	1	0	1	0	0	1	1
44	Blue	vertical	wall	4.39	0.75	0	0	1	0	0	1	1
45	Blue	vertical	wall	4.39	1	0	0	1	0	0	0	0
46	Blue	vertical	rock	4.39	1.25	0	0	0	0	0	0	0
47	Blue	vertical	rock	4.39	1.97	0	0	0	0	0	0	0
48	Blue	vertical	rock	4.4	0.25	0	0	0	9	0	0	0
49	Blue	vertical	rock	4.4	1	0	0	0	0	0	0	0
50	Blue	vertical	rock	4.4	2	0	0	0	0	0	0	0
51	Blue	vertical	rock	1.63 + 1.5	0.25	0	0	0	3	0	0	0
52	Blue	vertical	rock	1.63 + 1.5	1	0	0	0	0	0	0	0
53	Blue	vertical	rock	1.63 + 1.5	2	0	0	0	4	0	0	0
54	Blue	vertical	rock	1.63 + 1.5	3	1	0	0	0	0	0	0
55	Blue	vertical	rock	1.63 + 1.5	3.5	2	2	0	0	0	1	0
56	Blue	vertical	rock	1.63 + 1.5	4	0	0	0	0	0	0	0
57	Blue	vertical	rock	1.63 + 1.5	5	0	0	0	0	0	0	0
58	Blue	flat	rock	1.63 + 1.5	5.2	3	0	0	0	0	0	0
59	Blue	flat	rock	1.63 + 1.5	5.5	0	0	0	0	0	0	0
60	Blue	vertical	rock	1.63 + 1.5	6	2	0	0	0	0	0	0
61	Blue	vertical	wall	1.63 + 1.5	6.25	1	0	0	0	2	0	0
62	Blue	vertical	wall	1.63 + 1.5	6.5	0	0	0	0	1	0	0
35	Blue	vertical	pipes			0	0	0	0	0	0	6
36	Blue	vertical	pipes			0	0	0	0	0	0	7
37	Blue	vertical	pipes			0	0	0	0	0	0	6
179	center	vertical	rock	center	0.25	2	0	0	0	0	0	0
180	center	vertical	rock	center	1	3	0	0	0	0	0	0
181	center	vertical	rock	center	2	3	0	0	0	0	0	0
182	center	vertical	rock	center	3	3	0	0	0	0	0	0
183	center	vertical	rock	center	4	2	2	0	0	0	2	0
184	center	flat	rock	center	4	2	2	0	0	0	2	0
136	Green	vertical	rock	2.9	0.25	1	0	0	0	0	0	0
137	Green	vertical	rock	2.9	1	3	0	0	0	0	0	0
138	Green	vertical	rock	2.9	2	0	0	0	0	0	0	0
139	Green	flat	rock	2.9	2	1	5	0	0	0	0	0
140	Green	vertical	rock	2.9	3	1	0	0	0	0	0	0
141	Green	vertical	rock	2.9	4	3	0	0	0	0	1	0
142	Green	exclusion	wall	2.9	4	0	0	0	0	0	0	0
143	Green	exclusion	wall	2.9	4	0	0	0	0	0	0	0
144	Green	vertical	rock	2.9	5	3	0	0	0	0	0	0
145	Green	vertical	rock	2.9	5.3	2	1	0	0	0	0	0
146	Green	vertical	rock	2.9	5.5	2	1	0	0	0	0	0
147	Green	vertical	rock	2.9	6	2	1	0	0	0	0	0

126	Green	vertical	bottom	3	0	1	0	0	0	0	0	0	0
127	Green	vertical	wall	3	0.25	0	0	0	0	5	0	0	0
128	Green	vertical	wall	3	1	1	0	0	0	0	0	0	0
129	Green	vertical	wall	3	2	0	0	0	0	0	0	0	0
130	Green	vertical	wall	3	3	0	0	0	0	0	0	0	0
131	Green	vertical	wall	3	4	0	0	0	0	0	0	0	0
132	Green	vertical	wall	3	5	0	0	0	0	0	0	0	0
133	Green	vertical	wall	3	5.3	0	0	0	0	0	0	0	0
134	Green	vertical	wall	3	5.5	0	0	0	0	0	0	2	0
135	Green	vertical	wall	3	6	0	0	0	0	0	0	4	0
148	Green	vertical	bottom	6	0	0	3	0	0	0	2	0	0
149	Green	vertical	wall	6	0	0	3	0	0	0	2	0	0
150	Green	vertical	wall	6	0.25	2	1	0	0	0	0	0	0
154	Green	vertical	rock	6	0.25	1	0	0	0	0	0	0	0
155	Green	vertical	rock	6	1	1	0	0	0	0	0	0	0
156	Green	vertical	rock	6	2	1	0	0	0	0	2	0	0
157	Green	flat	rock	6	3	2	7	0	0	0	1	0	0
158	Green	flat	rock	6	3	4	5	0	0	0	0	0	0
159	Green	vertical	rock	6	3	1	0	0	0	0	2	0	0
160	Green	vertical	rock	6	4	0	0	0	0	0	0	0	0
151	Green	vertical	wall	6	5	0	0	0	0	0	0	0	0
161	Green	vertical	rock	6	5	0	0	0	0	0	0	0	0
152	Green	vertical	wall	6	5.5	0	5	0	0	0	0	0	0
162	Green	vertical	rock	6	5.5	0	5	0	0	0	0	0	0
153	Green	vertical	rock	6	6	0	0	0	0	0	0	7	0
163	Green	vertical	rock	6	6	0	0	0	0	0	0	7	0
168	Green	vertical	rock	0.7 + 2.35	0.25	0	0	0	0	0	0	0	0
167	Green	vertical	rock	0.7 + 2.35	1	0	0	0	0	0	0	0	0
165	Green	flat	rock	0.7 + 2.35	2	1	6	0	0	0	2	0	0
166	Green	vertical	rock	0.7 + 2.35	2	2	0	0	0	0	0	0	0
164	Green	vertical	rock	0.7 + 2.35	3	2	0	0	0	0	0	0	0
22	Green	vertical	rock	0.7+ 2.35	3.45	1	0	0	0	0	0	0	0
21	Green	vertical	rock	0.7+ 2.35	4.45	0	0	0	0	0	1	0	0
20	Green	vertical	rock	0.7+ 2.35	5.45	1	5	0	0	0	1	0	0
19	Green	vertical	rock	0.7+ 2.35	6	1	0	0	0	0	0	0	0
18	Green	vertical	rock	0.7+ 2.35	6.25	20	0	0	0	0	0	0	0
17	Green	vertical	rock	0.7+ 2.35	6.5	6	0	0	0	0	11	2	0
	Green	vertical	pipes	Botom outlet	0.25	0	0	0	0	0	0	4	0
	Green	vertical	pipes	upper outlet	6	0	0	0	0	0	0	6	0
177	plunger	flat	glass	inner wall	6	2	2	0	0	0	0	2	0
178	plunger	vertical	wall	outer wall	6	4	0	0	0	0	0	0	0
	purple	vertical	rock		1	0.25	0	0	0	0	0	0	0
	purple	vertical	rock		1	1	0	0	0	0	0	0	0
	purple	vertical	rock		1	2	3	0	0	0	3	0	0
	purple	flat	rock		1	2	0	2	0	0	4	0	0
	purple	flat	rock		1	2.7	3	1	0	0	2	0	0
	purple	vertical	rock		1	3	4	0	0	0	1	0	0
	purple	vertical	rock		1	4	2	0	0	0	2	0	0
	purple	vertical	rock		1	5	1	0	0	0	0	0	0
	purple	vertical	rock		1	5.5	3	0	0	0	0	0	0
	purple	vertical	rock		1	6	2	0	0	0	0	0	0
	purple	vertical	rock		3.3	0.25	0	0	0	1	0	0	0
	purple	vertical	rock		3.3	0.25	0	0	0	0	0	0	0
	purple	vertical	wall		3.3	1	0	0	0	0	0	0	0
	purple	vertical	wall		3.3	2.5	0	0	0	0	0	0	0

85	purple	vertical	wall	3.3	5.75	0	0	0	0	0	0	0	0
84	purple	vertical	wall	3.3	6	0	0	0	0	5	0	0	0
83	purple	vertical	wall	3.3	6.3	0	0	0	0	5	0	0	1
82	purple	vertical	rock	5.6	0.25	5	0	0	5	0	0	0	0
81	purple	vertical	rock	5.6	1	2	1	0	0	0	0	0	0
80	purple	vertical	rock	5.6	2	1	1	0	0	0	3	0	0
78	purple	vertical	rock	5.6	3	0	0	0	0	0	0	0	0
79	purple	flat	rock	5.6	3	2	0	0	0	0	1	0	0
76	purple	vertical	rock	5.6	4	0	0	0	0	0	0	0	0
77	purple	flat	rock	5.6	4	4	4	0	0	0	1	0	0
75	purple	vertical	rock	5.6	5	2	0	0	0	0	0	0	0
74	purple	vertical	wall	5.6	6	3	0	0	0	0	0	0	0
73	purple	vertical	wall	5.6	6.25	0	0	0	0	0	0	0	0
72	purple	vertical	rock	5.6	6.55	0	0	0	0	5	0	0	0
176	purple	vertical			6	5	0	0	0	0	0	0	0
105	red	vertical	bottom	3	0	0	0	0	0	0	0	0	0
106	red	vertical	wall	3	0.25	0	0	0	0	0	0	0	0
107	red	vertical	wall	3	1	0	0	0	0	0	0	0	0
108	red	vertical	wall	3	2	0	0	0	0	0	0	0	0
109	red	vertical	wall	3	3	0	0	0	0	0	0	0	0
110	red	vertical	wall	3	4	0	0	0	0	0	0	0	0
111	red	vertical	wall	3	5	0	0	0	0	0	0	0	0
112	red	vertical	wall	3	5.5	0	0	0	0	0	0	0	0
113	red	vertical	wall	3	6	0	0	0	0	5	0	0	5
92	red	flat	bottom	6	0	0	0	0	0	0	0	0	0
93	red	vertical	rock	6	0.25	0	0	0	5	0	0	0	0
94	red	vertical	rock	6	1	0	0	0	5	0	0	0	0
95	red	vertical	rock	6	2	0	0	0	2	0	0	0	0
96	red	flat	rock	6	2.3	1	0	0	0	0	1	0	0
97	red	flat	rock	6	2.3	1	1	0	1	0	3	0	0
98	red	vertical	wall	6	2.3	0	0	0	0	0	0	0	0
99	red	vertical	wall	6	3	1	0	0	0	0	0	0	0
100	red	vertical	wall	6	4	1	0	0	0	0	0	0	0
101	red	vertical	wall	6	5	3	0	0	0	0	1	0	0
102	red	vertical	wall	6	5.7	0	0	0	0	0	0	0	0
103	red	vertical	wall	6	5.8	0	0	0	0	0	0	0	0
104	red	vertical	wall	6	6	0	0	0	0	0	0	0	2
116	red	flat	bottom	9	0	0	0	0	0	0	0	0	0
117	red	vertical	wall	9	0.25	0	0	0	0	5	0	0	0
118	red	vertical	wall	9	1	0	0	0	0	0	0	0	0
119	red	vertical	wall	9	2	0	0	0	0	0	0	0	0
120	red	vertical	wall	9	3	0	0	0	0	0	0	0	0
121	red	vertical	wall	9	4	2	0	0	0	0	0	0	0
122	red	vertical	wall	9	5	0	0	0	0	0	0	0	0
123	red	vertical	wall	9	5.3	0	0	0	0	0	0	0	0
124	red	vertical	wall	9	5.5	0	0	0	0	0	0	0	0
125	red	vertical	wall	9	6	0	0	0	0	5	0	0	0
114	seal	flat	wall	Over fill	0	3	3	0	0	3	0	0	0
115	seal	vertical	rock	Over fill	0	3	3	0	3	0	0	0	0
1	yellow	vertical	wall	1.56	0.25	0	0	0	0	0	0	0	0
24	yellow	vertical	wall	1.56	1.2	0	0	0	0	0	0	0	0
2	yellow	vertical	wall	2.7	0.25	0	0	0	0	0	0	0	0
25	yellow	vertical	wall	2.7	1.2	4	0	0	0	0	0	0	0
58	yellow	vertical	wall	2.8	6.5	3	0	0	0	0	0	0	0
57	yellow	vertical	wall	2.8	6.75	1	0	0	0	5	0	0	0

4 yellow	flat	wall	3.8	0.3	0	12
26 yellow	vertical	wall	3.8	1.2	0	0
55 yellow	vertical	wall	3.8	6.25	1	0
54 yellow	vertical	wall	3.8	6.5	0	0
53 yellow	vertical	wall	5	6.25	3	0
52 yellow	vertical	wall	5	6.5	2	0
3 yellow	vertical	wall	5.2	0.25	0	0
40 yellow	vertical	pipes	Botom outlet	0.25	0	0
30 yellow	flat	wall	Over fill	depth 15	3	15
31 yellow	flat	wall	Over fill	depth 15	6	10
32 yellow	flat	wall	Over fill	depth 15	8	7
33 yellow	flat	wall	Over fill	depth 15	2	17
34 yellow	flat	wall	Over fill	depth 15	7	13
TOTAL					201	146

0	3	0	0	0
0	0	0	0	0
0	0	0	0	0
0	0	5	0	2
0	0	0	0	0
0	0	10	0	0
0	0	0	0	0
0	0	0	0	0
0	0	0	0	3
0	0	0	0	4
0	0	0	0	5
0	0	0	0	3
0	0	0	0	6
4	41	87	63	89

0	0	0	0	0	1	10	0	0
0	0	4	11	0	0	4	0	8
0	0	2	2	0	0	0	0	0
0	0	0	0	0	0	0	0	5
0	0	2	0	0	0	3	0	0
0	0	1	0	0	0	1	0	4
0	0	1	1	0	1	1	0	5
15	0	0	0	0	0	0	0	0
0	1	0	0	0	0	5	0	0
0	2	0	0	0	0	12	0	0
0	4	0	0	0	0	11	0	0
0	3	0	0	0	0	6	0	0
0	5	0	0	0	0	9	0	0
131	37	175	791	2	28	940	5	268

Derbesia marina	Diatoms	Ecklonia maxima	Ectocarpus spp.	Enteromorpha spp.	Ephymentia capensis	Epymenia obtusa	Filamentous diatoms	Hildenbrandia sp	Kallymenia schizophylla
7	0	0	0	0	0	0	0	14	0
0	0	0	0	0	0	0	0	15	0
3	0	0	0	0	0	0	0	11	0
0	0	0	0	0	0	4	0	0	0
0	0	3	0	0	0	0	1	0	0
0	0	7	0	0	0	3	0	0	0
0	0	5	0	0	0	3	1	0	0
0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	12	0	0	0	0	0	0	0
0	0	7	0	0	0	2	0	0	0
0	0	5	0	1	0	0	0	0	0
12	3	0	9	3	0	0	0	1	19
5	1	6	9	0	0	2	2	1	14
0	1	3	5	0	0	6	2	1	7
0	1	4	1	0	0	0	5	1	3
0	1	1	1	0	0	0	4	0	2
0	1	1	2	0	0	0	4	0	1
0	0	0	0	0	0	0	0	13	0
0	0	0	0	0	0	2	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	7	0	0	11
3	0	0	0	0	0	6	0	0	6
3	0	0	0	0	0	4	0	0	1
9	0	0	0	0	0	2	0	0	0
0	0	4	0	0	0	4	0	0	0
8	0	2	0	0	0	0	0	0	0
5	0	4	0	0	0	0	0	0	0
0	0	6	0	0	0	6	2	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	4	3	0	0
1	0	9	0	0	0	2	0	0	0
12	0	0	0	0	0	0	0	0	0
0	0	0	2	1	0	0	0	0	0
0	0	0	3	2	0	0	0	0	0
0	0	0	3	3	0	0	0	0	0
0	0	0	0	0	0	2	1	0	0
0	0	8	0	0	0	3	0	0	0
0	0	8	0	0	0	3	0	0	0
0	0	8	0	0	0	3	0	0	0
2	0	2	0	0	0	2	2	0	1
2	0	2	0	0	0	2	2	0	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	3	0	0	18
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	3	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	3	1	0	3
0	0	0	0	0	0	2	0	0	5
0	0	0	0	0	0	2	0	0	5
0	0	0	0	0	0	2	0	0	5

0	2	0	0	0	0	0	0	0	13	0
8	0	0	0	0	0	0	7	0	3	0
0	0	11	0	0	1	2	0	0	0	0
5	0	0	0	5	0	0	0	0	0	0
0	0	2	0	0	6	0	0	0	0	0
4	0	0	0	2	4	0	0	0	0	0
12	2	0	0	0	0	0	0	0	12	0
0	0	0	0	0	1	0	0	0	0	0
0	0	0	1	3	3	0	0	0	0	0
0	0	0	2	2	3	0	0	0	0	0
0	0	0	3	4	5	0	0	0	0	0
0	0	0	2	1	3	0	0	0	0	0
0	0	0	1	3	1	0	0	0	0	0
293	30	250	90	66	220	73	6	511		34

<i>Pachymenia carnosa</i>	<i>Polysiphonia namibiensis</i>	<i>Polysiphonia scopulorum</i>	<i>Porphyra capensis</i>	<i>Pugetia harveyana</i>	Red crusts	<i>Rhodophysema</i>	<i>Rhodymenia natalensis</i>	<i>Schieymania obovata</i>
0	0	0	0	0	0	14	0	0
0	3	3	3	0	0	0	0	0
0	0	0	0	0	0	11	0	0
0	0	0	0	0	0	0	8	0
0	1	1	1	0	1	0	12	0
0	0	0	0	0	0	0	4	0
0	0	0	0	0	1	0	0	0
0	1	1	1	0	1	0	0	0
0	0	0	0	0	2	0	5	0
0	0	0	0	0	2	0	3	0
0	0	0	0	0	0	0	15	0
0	0	0	0	0	0	0	10	0
0	0	1	1	0	0	0	9	0
1	2	1	1	0	0	0	5	1
0	0	0	0	0	0	6	0	3
0	0	0	0	0	9	9	0	0
0	0	0	0	0	2	0	25	0
0	0	0	0	0	1	0	17	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	2
0	0	0	0	0	0	0	7	0
0	0	0	0	0	4	0	0	5
0	0	0	0	0	0	0	3	6
0	0	0	0	0	0	0	10	0
0	0	0	0	0	0	5	0	0
0	0	0	0	0	1	0	0	4
0	0	0	0	0	4	0	0	0
0	0	0	0	0	3	0	0	0
0	0	0	0	0	0	0	0	6
0	0	0	0	0	3	0	0	0
2	0	0	0	0	2	4	0	4
0	0	0	0	0	0	0	0	2
0	4	4	4	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	4	0	6	2
0	0	0	0	0	0	0	7	3
0	0	0	0	0	0	0	7	3
0	0	0	0	0	0	0	7	3
0	1	1	1	0	0	1	2	2
0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	1	3
0	0	0	0	0	0	0	3	0
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	2	3
0	0	0	0	0	0	0	5	0
0	0	0	0	0	0	0	5	0
0	0	0	0	0	0	0	0	3
0	5	5	5	0	0	0	0	2
0	5	5	5	0	0	0	0	2
0	5	5	5	0	0	0	0	2

0	0	0	0	0	0	0	0	0	0
4	4	4	0	2	0	3	0	10	
0	0	0	0	0	11	0	1	0	
0	3	3	0	0	0	0	0	0	
0	0	0	0	0	11	0	6	0	
0	3	3	0	0	0	0	2	0	
0	6	4	0	1	0	8	0	1	
0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	
0	0	0	0	0	1	0	0	0	
0	0	0	0	0	2	0	0	0	
0	0	0	0	0	4	0	0	0	
0	0	0	0	0	1	0	0	0	
0	0	0	0	0	1	0	0	0	
39	354	362	26	125	147	483	187	59	

Schimmelmannia elegans	Stypocaulon funiculare	Young reds	Ulva rigida
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	1	0
0	0	6	0
0	0	8	0
0	0	0	0
0	0	0	0
0	0	1	0
0	0	4	0
0	0	0	0
0	0	2	2
1	0	1	0
1	0	1	0
0	0	1	0
0	0	1	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	3	3	0
0	6	3	0
0	0	0	0
0	0	0	0
0	0	2	0
0	0	0	0
0	0	0	0
0	0	11	0
0	0	6	0
0	0	7	0
0	0	7	0
0	0	4	0
20	0	0	0
20	0	0	0
20	0	0	0
0	0	1	0
0	0	2	0
0	0	2	0
0	0	2	0
0	0	2	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	4	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	3	0
0	0	0	0
0	0	0	0
0	0	0	0

0	0	0	0
0	2	3	0
0	0	7	0
0	0	0	0
0	0	0	0
0	0	4	0
0	0	1	1
0	0	0	0
0	0	0	4
0	0	0	1
0	0	0	3
0	0	0	1
0	0	0	2
108	11	207	28

THE FOLLOWING IS A CONTENTS PAGE OF DESCRIPTIONS OF ALL ALGAL SPECIES FOUND IN THE KELP TANK.

It is intended to be a reference for the TOA as per the agreement reached with Pat Garratt (curator of the TOA) and the author's project proposal for studying in the kelp tank.

Division: Chlorophyta
Key to the genera

Class: Chlorophyceae

Order: Ulvales

Family: Ulvaceae

Blidingia (Kylin)

Key to the species

Blidingia minima (Naegeli ex Kuetzing) Kylin

Enteromorpha (Link)

Key to the species

Enteromorpha atroviridis (Levring) Wynne

Enteromorpha compressa (L.) Greville

Enteromorpha flexuosa (Wolfen) J. Agardh

Enteromorpha intestinalis (L.) Von Esenbeck

Enteromorpha linza (L.) J. Agardh

Enteromorpha prolifera (Mueller) J. Agardh

Ulva (Linnaeus)

Key to the species

Ulva rigida (C. Agardh)

Order: Cladophorales

Family: Cladophoraceae

Chaetomorpha (Kuetzing)

Key to the species

Chaetomorpha robusta (Aresch.) Papenfuss

Cladophora (Kuetzing)

Key to the species

Cladophora capensis (C. Agardh) De Toni

Cladophora radiosa (Suhr) Kuetzing

Order: Codiales

Family: Codiaceae

Codium (Stackhouse)

Key to the species

Codium papenfussii (Silva)

Order: Derbesiales

Family: Derbesiaceae

Derbesia (Solier)

Key to the species

Derbesia hollenbergii (Taylor)

Derbesia marina (Lyngbye) Solier

Division: Phaeophyta
Class: Phaeophyceae
Key to the families and genera

Order: Ectocarpales
Family: Ectocarpaceae
Ectocarpus (Lyngbye)
Key to the species
Ectocarpus acutus (Setchell et Gardner)
Ectocarpus fasciculatus (Harvey)
Ectocarpus siliculosus (Dillwyn) Lyngbye

Order: Chordariales
Family: Ralfsiaceae
Ralfsia (Berkeley in Smith & Sowerby)
Ralfsia verrucosa (Areschoug) J. Agardh

Order: Sphacelariales
Family: Sphacelariaceae
Sphacelaria (Lyngbye in Hornemann)
Key to the species
Sphacelaria brachygonia (Montagne)
Sphacelaria rigidula (Kuetzing)

Family: Stypocaulaceae
Stypocaulon (Kuetzing)
Stypocaulon funiculare (Montagne) Kuetzing

Order: Scytosiphonales
Family: Scytosiphonaceae
Petalonia (Derbès & Solier)
Petalonia fascia (O. F. Mueller) Kuntze

Order: Laminariales
Family: Alariaceae
Ecklonia (Hornemann)
Key to the species
Ecklonia maxima (Osbeck) Papenfuss

Order: Fucales
Family: Sargassaceae
Anthophycus (Kuetzing)
Anthophycus longifolius (Turner) Kuetzing

Division: Rhodophyta
Key to the families and genera

Class: Bangiophyceae

Order: Bangiales

Family: Bangiaceae

Bangia (Lyngbye)

Bangia atropurpurea (Roth) C. Agardh

Porphyra (C. Agardh)

Key to the species

Porphyra capensis (Kuetzing)

Class: Florideophyceae

Order: Nemalionales

Key to genera and species

Family: Chaetangiaceae

Nothogenia (Montagne)

Key to the species

Nothogenia erinacea (Turner) Parkinson

Family: Gelidiaceae

Gelidium (Lamouroux)

Key to the Species

Gelidium capense (S. G. Gmelin) Silva

Order: Palmariales

Family: Rhodophysemataceae

Rhodophysetema (Batters)

Order: Hildenbrandiales

Family: Hildenbrandiaceae

Hildenbrandia (Nardo)

Key to the species

Hildenbrandia lecanellierii (Hariot)

Hildenbrandia rubrai (Sommerfelt) Meneghini

Order: Cryptonemiales

Family: Halymeniaceae

Key to the genera and species

Grateloupia (C. Agardh)

Grateloupia doryphora (Montagne) Howe

Grateloupia filicina (Lamouroux) C. Agardh

Pachymenia (J. Agardh)

Pachymenia carmosa (J. Agardh) J. Agardh

- Family:** Kallymeniaceae
 Key to the species
Kallymenia (J. Agardh)
Kallymenia schizophylla (J. Agardh)
Pugetia (Kyllin)
Pugetia harveyana (J. Agardh) R.E. Norris
- Order:** Gigartinales
Family: Gymnophloeaceae
Schizymenia (J. Agardh)
Schizymenia obovata (J. Agardh) J. Agardh
- Family:** Plocamiaceae
Plocamium (Lamouroux)
 Key to the species
Plocamium suhrii (Kuetzing)
- Family:** Phylloporaceae
 Key to the genera
Ahnfeltiopsis (Silva & De Cew)
 Key to the species
Ahnfeltiopsis glomerata (J. Agardh)
 Silva & de Cew
- Family:** Gigartinaceae
 Key to the genera
Gigartina (Stackhouse)
 Key to the species
Gigartina polycarpa (ex. *radula*)
 (J. Agardh)
- Order:** Rhodymeniales
Family: Rhodymeniaceae
Epymenia (Kuetzing)
 Key to the species
Epymenia capensis (J. Agardh) Papenfuss
Epymenia obtusa (Greville) Kuetzing
Rhodymenia (Greville)
 Key to the species
Rhodymenia natalensis (Kyllin)
- Family:** Champiaceae
Champia (Desveaux)
 Key to the species
Champia compressa (Harvey)

- Order:** Ceramiales
Family: Ceramiaceae
 Key to the genera
 Carpoblepharis (Kuetzing)
 Key to the species
 Carpoblepharis flaccida (C. Agardh)
 Kuetzing
- Family:** Delesseriaceae
 Key to the genera
 Delesseria (Lamouroux)
 Delesseria papenfussii (Wynne)
- Family:** Rhodomelaceae
 Key to the genera
 Polysiphonia (Greville)
 Key to the species
 Polysiphonia namibiensis (Stegenga & Engledow)
 Engledow
 Polysiphonia scopulorum (Harvey)
- Order:** Corallines
Family: Corallinaceae
 Key to the genera
 Crustose corallines (not dealt with here)
 Arthrocardia (Decaisne)
 Key to the species
 Arthrocardia corymbrosa (Lamarck)
 Decaisne
 Arthrocardia flabellata (Kuetzing)
 Manza
 Arthrocardia filicula (Lamarck)
 Johansen
- Family:** Gloiosiphoniaceae
 Schimmelmannia (Schousb)
 Schimmelmannia elegans (Baardseth)