HORNIMAN MUSEUM

KING'S College LONDON
University of London

The effect of lighting type on the growth rate of the coral *Montipora capricornis*

A report on a placement with the Horniman Museum in fulfilment of the requirements of the MSc in Aquatic Resource Management of King's College London

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CONTENTS

1. ABSTRACT

Fragments of the coral *Montipora capricornis* were grown under LED, T5 and metal halide lighting to test the hypothesis that metal halide lighting would provide the highest growth rate. The growth of these corals was determined each week over an eight week period. PAR profiles were created for each tank. The LED ($t = 17.247$, 16.788, $p<0.01$), T5 ($t = 14.482$, 14.042, $p<0.01$) and metal halide ($t = 13.532$, 14.095, $p<0.01$) lights all caused the corals to grow significantly. This means that coral farms and aquariums could potentially use LED or T5 lighting as an alternative to the less energy efficient metal halide lamps. The highest growth rates occurred under the metal halide light and the lowest under the LED light. The growth rates over time increased to begin with and then decreased slightly. This was thought to be due to an increase in temperature, an increase in magnesium or intraspecific competition. There was no significant difference between growth rate and tank ($F =0.220$, $p = >0.05$) or growth rate and PAR ($F = 0.946$, p 0.05). Photosynthesis, calcification and coral growth are discussed in detail.

2. ACKNOWLEDGEMENTS

This project would not have been possible without the help and guidance from Jamie Craggs and James Robson at the Horniman Museum. I would also like to thank Gyles Westcott for the donation of the LED light and his help throughout the project. I also thank Stuart Bertram and Ursula Kruger for their information given throughout the project. I would finally like to thank Michael Chadwick for his guidance and help during this project.

3. GENERAL INTRODUCTION

This investigation was carried out at the Horniman Museum, Forest Hill, in the aquarium section. The experiment ran from 15/06/2010 – 10/08/2010. The experiment was run using the reef system in the aquarium. I worked on other sections such as the coastal, jellyfish, mangrove, pond and seahorse systems and was also involved in helping with the *Aurelia aurita* breeding programme.

The Horniman Museum was opened in 1901 to house musical, cultural and natural history artefacts. The aquarium opened in 2006 and is a public aquarium which is governed by a zoo license. This means that it is required to carry out conservation research. They work with a variety of NGO's, other aquariums and academic institutions. They are members of NAW (National Aquarium Workshop), SECORE (Sexual Coral Reproduction) and CARN (Collaborative Action Research Network). Within these groups the Horniman Museum is involved in a number of projects.

The aquarium houses many species from a range of ecosystems. They aim to highlight conservation issues having displays about a number of species such as the Northern pool frog. This display was created with Natural England.

Their key area of research is with scyphozoans. They are currently breeding *Aurelia aurita* and are working with Queen Mary university of London and Southampton University on research into jellyfish reproduction.

In the future the aquarium is planning to carry on its research. It is also planning to create a new coral system where research into coral reproduction will be carried out. They want to try to establish what makes corals release planula larvae and try to determine patterns which may be related to lunar cycles, feeding regimes and temperature. They are also working in-situ with SECORE in Singapore to gather information on coral spawning and reproduction. This data will be vital in reproducing conditions for planula release ex-situ.

The purpose of this investigation was to test three different light sources, LED, T5 and metal halide, in relation to coral growth rate. This was investigated because metal halide lights are considered to be the best for coral growth. However, an actual experiment, using all three lights and measuring growth rate of corals has not been conducted.

If the T5 and LED lights can produce growth rates which are similar to the metal halides then these could possibly be replaced. This would be beneficial because metal halide lights are not as energy efficient as the LED and T5 lights (Bertram, S. personal communication). This would be beneficial for aquariums, coral farms and research institutions because it would reduce their carbon footprint and running costs.

Aquariums are required to reduce their carbon footprint as part of the World Association of Zoos and Aquariums (WAZA) guidelines. Therefore if LED or T5 lights could be used then this would help aquariums meet these guidelines. The fact that coral farms are rarely set up inland in developing countries is due to the increase in costs (Delbeek 2001). Therefore, if the running costs of lighting could be reduced then more inland coral farms could be set up. This would reduce the pressure on natural reefs and create a sustainable livelihood for people who may otherwise be using destructive harvesting methods.

The aquarium staff were involved in setting up the lights. The rest of the work such as preparing the tanks, fragmenting the coral, creating PAR profiles and measuring the corals weight and volume was all carried out by me.

This research may benefit the museum in a number of ways. Firstly if it is found that the other two lights do work as well as the metal halide then the metal halide lamps currently in use could be replaced with more energy efficient lighting. Also the measurement techniques I used to quantify growth rate could be put into use when growing corals in the future.

4. ROUTINE WORK

The ongoing experiment had daily maintenance associated with it. This included cleaning the tanks, feeding the fish, taking temperature and redox readings. Weekly, water chemistry tests were completed on all the systems, and the weight and volume were recorded for all the coral fragments. The weight was determined using the buoyant weight technique (Osinga 2009 in: Leewis *et al*. 2009) and the volume using the volume displacement technique (Osinga 2009 in: Leewis *et al*. 2009).

A PAR profile was created for each light using a Li-cor, Li-192 under water quantum sensor. A PAR reading was taken at 10 cm intervals around the whole tank showing how the lights behaved in each tank.

A maintenance sheet had to be completed daily on all the displays in the aquarium and some of these jobs were allocated to me. This included feeding all the exhibits in the morning and afternoon and target feeding *Scyliorhinus caniculus*, *Scyliorhinus canicula*, *Urticina feline* and *Antennarius commerson*. The filtration systems were cleaned daily, including protein skimmers and filtration bags. The jellyfish kreisels and quarantine tanks were cleaned and jellyfish polyp systems' salinity and temperatures taken. The jellyfish also had to be sorted into different size classes and moved into different kreisels in accordance with the breeding programme.

The reef system had *Tubastrea coccinea* in them which were being monitored for planula release.Planula collection nets were checked daily for any planula; these were collected, the nets cleaned and then the corals placed in buckets and fed with plankton. The *Tubastrea coccinea* were then placed back into the tank and the nets placed over them.

5. INTRODUCTION

5.1 The Decline Of Corals

Growing corals in captivity is becoming increasingly important with natural populations declining and facing future problems. Globally 19 % of coral reefs have been lost and 25 % of reefs are considered to be under threat. Coral reefs are extremely diverse with an average reef supporting 4,000 species of fish and 800 species of reef building corals (Paulay 1997). They are extremely important for species diversity, tourism, fishing and coastal protection. They have an estimated value of £242 billion through these good and services they provide (Costanza *et al*. 1997). The decline of these reefs will ultimately affect the 0.5 billion people who utilise this natural resource (Wilkinson 2002).

Coral reefs are under threat from a range of factors such destructive fishing and overfishing; increase in disease, tourism, increased sedimentation and climate change (Wilkinson 2008).

5.1.1 Climate change

The increases in sea surface temperatures , solar radiation, carbon dioxide concentrations and the occurrence of storms all put coral reefs at risk (Eakin *et al*. 2008 in: Wilkinson 2008). Climate change has been recognised as the greatest threat to coral reefs (Wilkinson 2008). The increases in sea surface temperatures and solar radiation, with 2005 being the warmest year since 1998, can cause mass bleaching of corals. When this occurred in the Caribbean in 2005, there was mass coral mortality due to coral bleaching and increases in hurricanes (Wilkinson 2008).

Increases in carbon dioxide concentrations lower the pH of the water causing ocean acidification. This therefore reduces the availability of carbonate ions which can be utilised by corals for accretion of their calcium carbonate skeleton. This reduces the growth rate of corals, makes them weaker and makes them more susceptible to other impacts (Eakin *et al*. 2008 in: Wilkinson 2008).

5.1.2 Disease

The increase in disease, such a black band disease, have been shown to correlate to increases in sea surface temperatures (Rosenberg and Ben-Haim 2002) and pollution (Bruno *et al*. 2003). Therefore in the future with rising temperatures and coastal populations predicted to increase then the incidence of disease may also increase (Hughes 1994).

5.1.3 Runoff pollution

Pollution from soil erosion, coastal development and agricultural runoff threatens 52 % of coral reefs (Bryant *et al*. 1998). This is prominent in coastal areas due to proximity to the source of pollution (Fabricus 2005). Reefs which are subjected to pollution have shown a 30 % - 50 % decrease in diversity (Edinger *et al*. 1998). Dissolved inorganic nutrients can reduce a coral's ability to secrete a calcium carbonate skeleton. The increase in nutrients may benefit some corals, but this leads to them outcompeting others, producing a simple ecosystem dominated by a few species (Fabricus 2005). The increase in sediments increases the turbidity of the water which reduces the light available to corals, therefore reducing photosynthesis and growth. The increase in sediment can also inhibit coral larvae settlement and growth (Fabricus 2005).

5.1.4 Overfishing and destructive fishing

Many regions with coral reefs experience overfishing. This becomes especially problematic when herbivorous fish are removed from the ecosystem. This results in algal numbers not being controlled and therefore potentially outcompeting corals for space, nutrients and light creating a less diverse ecosystem (Hughes 1994). There are two main forms of destructive fishing, dynamite fishing and cyanide fishing.

Dynamite fishing has been used for the last 20 years and is particularly destructive, a 1 kg bomb killing 50 – 80 % of the coral in the area (Reefs At Risk 2002). The rubble left is not suitable for coral settlement, the habitat complexity is lost and this results in invasive species colonising the area and outcompeting the coral, reducing species diversity (EO Earth 2008).

Cyanide fishing can involve a variety of techniques. One is to use sodium cyanide ($NaCN$) which is placed, with seawater, into a plastic bottle. This would then be squirted at reef fish which become asphyxiated and divers collect them (Johannes and Riepen 1995). Cyanide can also be placed in bait and is thrown into the reef. This can result in some fish being missed meaning the cyanide can work its way through the food web. It can also settle on the substrate which will slowly release cyanide (Johannes and Riepen 1995). Cyanide can also be pumped into the reef. Whichever technique is used corals ultimately come into contact with cyanide. This can reduce photosynthesis and calcification (Chalker and Taylor 1975, Barnes 1985).

5.1.5 The harvesting of corals

The trade in around 2,000 species of corals is monitored by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) under Appendix II (CITES 2003). There has been an increase in the trade of corals from 20 t / year (1989) to 400 t / year (1995) to make up more than 50 % of the global coral trade (Green and Shirley 1999). With 1.5 - 2 million people keeping marine aquariums globally the majority of the species used to stock these come from natural reefs (Bunting *et al*. 2003 in: Cato and Brown 2003). Many of the practices used to collect corals can be unsustainable such as cyanide and dynamite fishing which can decimate coral reefs (Bunting *et al*. 2003 in: Cato and Brown 2003).

The impact on natural reefs has been shown to be large, with one reef which was harvested in Cebu, the Philippines, showing a decrease in coral density by 34% and a decrease in coral cover by 64 % (Ross 1984). Although the harvesting of corals does have a negative impact it does not compare to the impact of other factors such as sedimentation and climate change (Green and Shirley 1999). However, this practice is another pressure which is being put on these vulnerable ecosystems, and therefore sustainable coral farms will need to increase (Bunting *et al*. 2003 in: Cato and Brown 2003).

5.2 Coral Farming

5.2.1 History

Coral farms need to increase globally in order to meet the demand for live corals and reduce the harvesting of wild populations. The first coral farm was set up in 1956 at Noumea aquarium, New Caledonia. This set up relied on natural sunlight and sea water (Carlson 1999). The first aquarium to start the trade between aquaria of live coral was Waikiki Aquarium (Carlson 1999). There are many *in situ* farms being set up in developing countries, such as the Philippines, in order to not only reduce the harvest of live corals but to also provide these communities with a more sustainable living, restore the reefs and to educate the community (Delbeek 2001). Many of these farms still use natural sunlight and are located close to the coastline. In order for more farms to develop inland the costs of lighting and other equipment need to be reduced (Delbeek 2001).

5.2.2 Current status

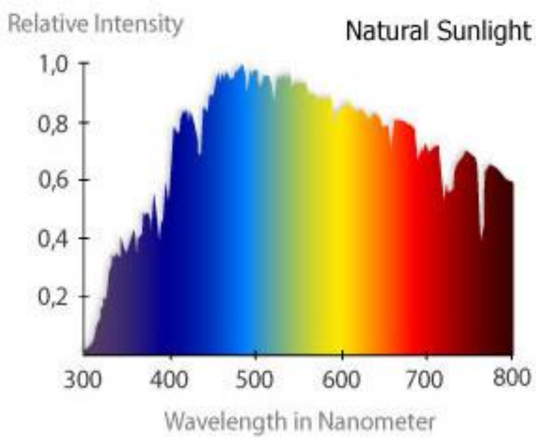
The marine aquarium council (MAC) has developed a certification and labelling initiative. This involves sources of coral and fish from coral reefs being investigated to see if they meet the MAC's standards to gain a certificate. Such standards include not using destructive fishing methods. This will allow public and hobbyist aquaria to source their species from reputable places which limit the damage to natural reefs (MAC 2009).

There are many public aquariums which are leading the field in growing coral *ex situ* and exchange them between one another. These aquariums are playing an important role in educating the public about coral reefs and by keeping a good gene pool. There are groups of aquaria, universities and zoos which exchange information and research, one such group is CORALZOO. The CORALZOO project ran from 2005 to 2009 and its aim was to produce a book of protocols to provide the best way to keep and reproduce stony corals by collaborating information and research from 16 different organisations around Europe (CORALZOO 2009). The book of protocols was produced and included a section on lighting (Osinga 2009 in: Leewis *et al*. 2009). However, this does not mention different types of light, and these lighting types have not been tested to see if there is a difference in the growth rates of corals.

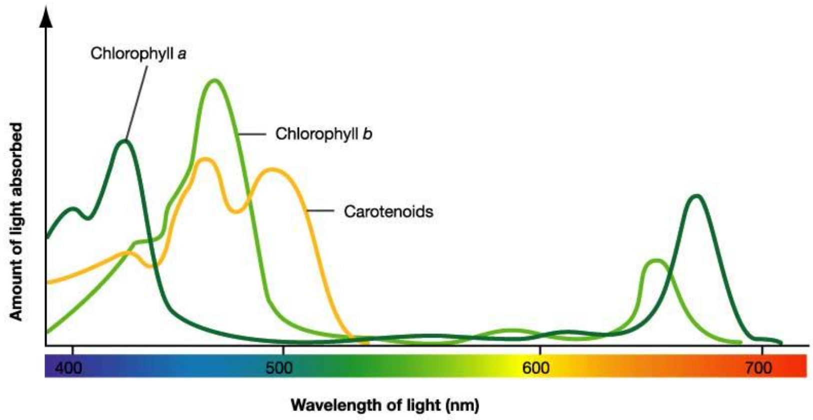
This is important because the World Association of Zoos and Aquariums (WAZA), a global organisation, states that aquariums should do all they can to reduce their carbon footprint. This includes reducing energy consumption (Penning *et al*. 2009).

5.3 Lighting Types

Figure 5.1 shows the spectrum of natural light; however the *Symbiodinium* spp. in corals cannot utilise all of the light intensities in natural sunlight. Figure 5.2 is important as it shows which wavelengths of light chlorophyll pigments absorb most efficiently.



(Reef Keeping Fever 2010)
Figure 5.1 The spectrum of natural light



(University of Illinois at Chicago 2010)

Figure 5.2 The spectrum of PAR

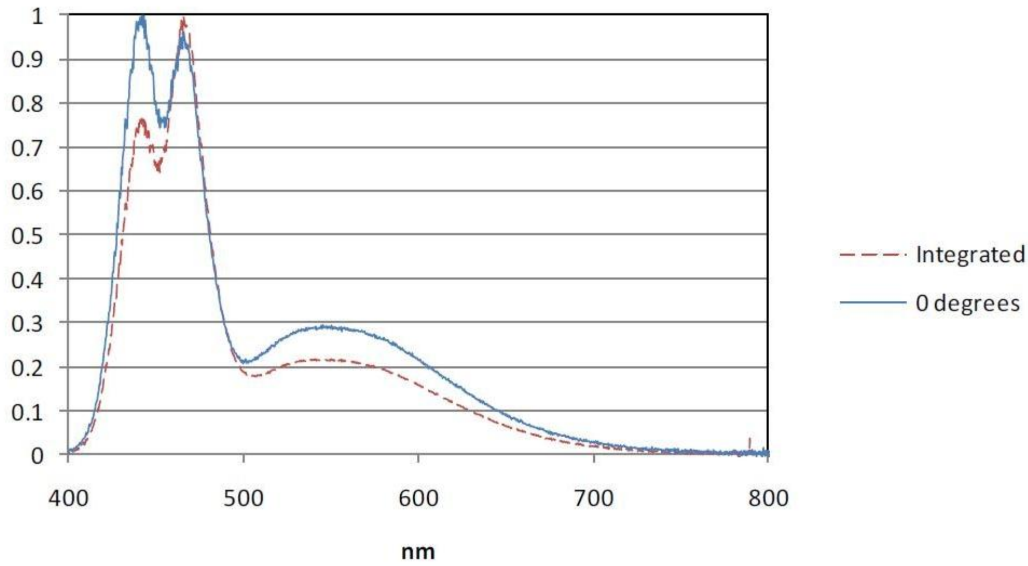
Photosynthetically active radiation (PAR) is the spectrum of light which falls between 400-700 nm. It has been shown that corals grow better, are healthier and have higher concentrations of algae in their cells when grown under blue and white light rather than green and red (Kinzie *et al*. 1984). The PAR spectrum peaks at about 430 nm, 480 nm and 500 nm in the blue spectrum. Light which contains UV wavelengths can be damaging to the coral and therefore aquarium lights should avoid this part of the spectrum (Harm 1980). This shows that it is not only the quantity of light which is important but also the quality of light.

5.3.1 LED (Light Emitting Diode)

LED lighting has become an extremely viable option for lighting a coral aquarium. This is due to the increase in output, selection of wavelengths, good energy efficiency and the price is decreasing. (Marine Bitz 2010). The running costs for one year for the lamps being used are about £13 (Westcott, G. personal communication). They use semiconductor technology to produce light which goes in one direction meaning it does not have to have a high output because the light is concentrated, reducing scattering and loss of light (Strohmeyer 2010). The semiconductor diode emits light as electroluminescence when electricity passes through it (Delbeek and Sprung 2005). This is a point source of light the metal halide, meaning it will penetrate deeper then the T5 (Osinga 2009 in: Leewis *et al*. 2009).

They are more robust than T5s, are smaller, more energy efficient and do not produce any heat output (Delbeek and Sprung 2005). They do not however, have as high a PAR value as metal halides and do not penetrate as deeply as they do and therefore may have limitations in large tanks (Joshi 2010).

The fact that certain wavelengths can be selected for means that the white and blue wavelengths can be increased and useless wavelengths can be left out, increasing the growth and health of corals (Strohmeyer 2010).



(Westcott, G. personal communication)

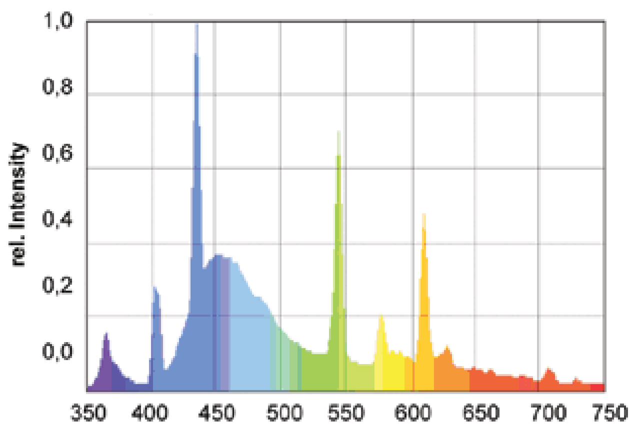
Figure 5.3 Light spectrum produced by the LED light

This LED light matches the peaks in PAR with peaks at 430 nm and 480 nm, matching PAR perfectly. This shows the advantage of being able to select the wavelengths used.

5.3.2 T5

T5 lamps use a mini pin bulb to produce light (Strohmeyer 2010) .The light produced is more evenly spread and does not produce as much heat. (Joshi 2010). However, they have low outputs and cannot penetrate very deeply so are best for growing corals near to the surface or corals which do not need very high light intensities. They are however, improving as they are 12-18 % more efficient then the T8 bulbs (Delbeek and Sprung 2005). It would cost about £17 a year to run the light used in this experiment (Bertram, S. personal communication).

The T5 being used in this study is the Giesmann Aquablue double 39 watt and the colour spectrum it produces is shown in figure 5.4.



(Speciality Lights 2010) nm

Figure 5.4 Light spectrum produced by the T5 light

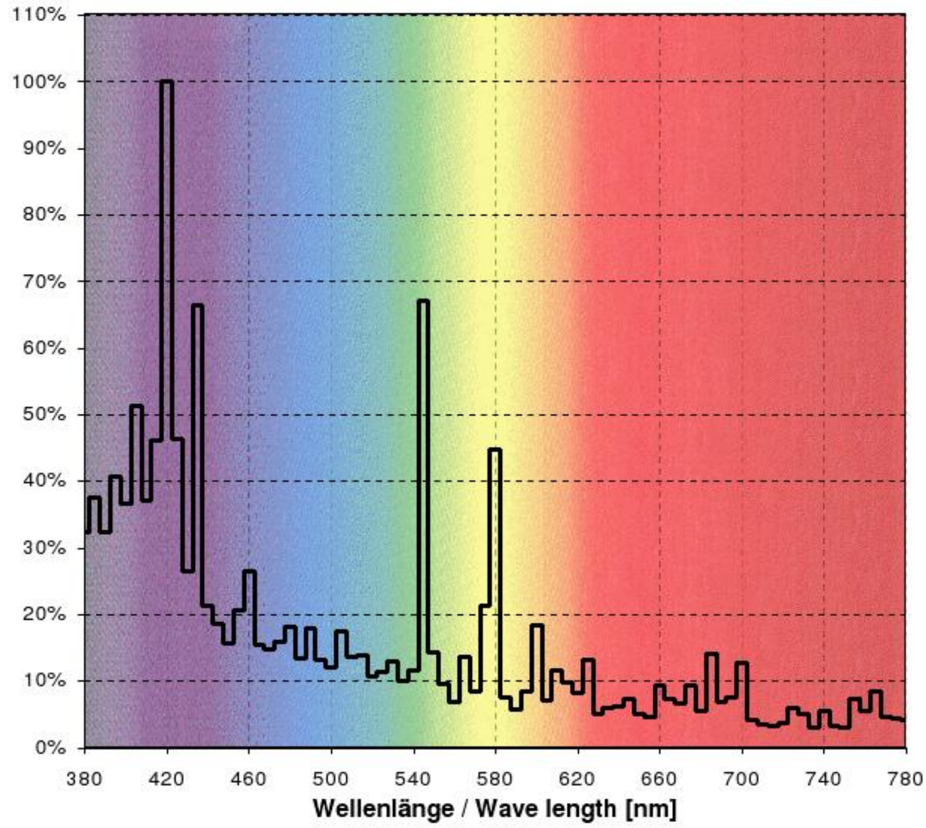
This light has peaks at 430 nm and 450 nm in the blue spectrum which is closer to that of the PAR spectrum when compared to the metal halide lamp.

5.3.3 Metal halide – High Intensity Discharge (HID)

Metal halides are a form of HID lighting and have been used for a long time as the main lighting systems for coral tanks. They produce high PAR values, a good spectrum of light and are able to keep a range of corals alive (Strohmeyer 2010).They work by having a mix of gases including halides, and the light is produced by a small gas bubble in between metal wires. When electricity runs through these, the gas heats up, producing light and heat (Strohmeyer 2010). They are point sources of light which means that they penetrate deep into the water (Strohmeyer 2010).

The heat which halides produce can cause problems to the corals and therefore may have to have a chiller attached increasing costs. The cost of running this light for a year is around £110 (Bertram, S. personal communication), without a chiller.

The metal halide which is going to be used in this study is the Nepturion 10,000K from BLV.



(Kruger, U. personal communication)

Figure 5.5 Light spectrum produced by the metal halide light

Figure 5.5 shows that the Nepturion light being used does emit light at the blue wavelengths. This light does not however match the PAR wavelengths exactly with it having peaks at about 420 nm, 550 nm and 580 nm.

5.4 *Montipora capricornis*

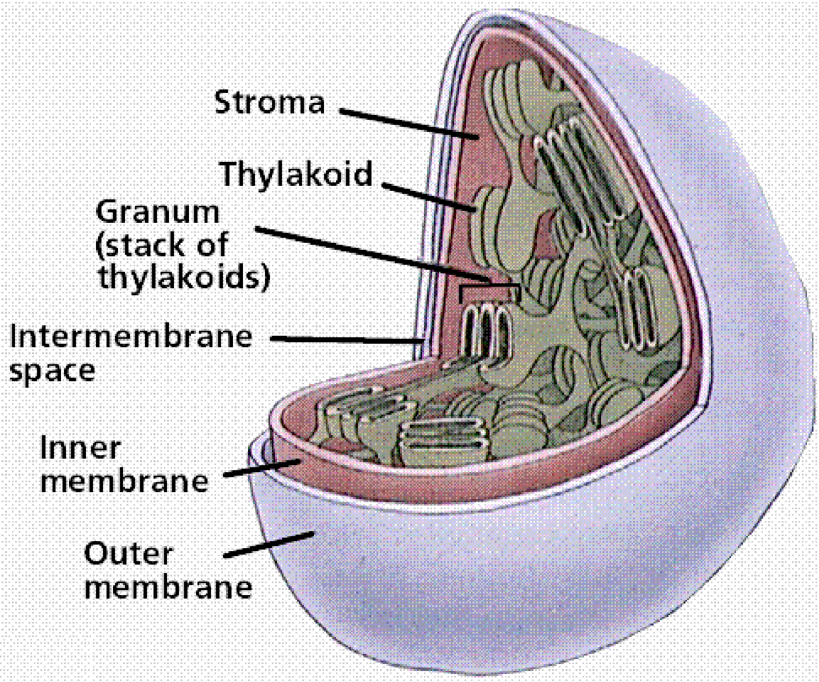
Montipora capricornis is the coral which will be used in this investigation. It was selected because it is a popular coral to be used in reef tanks and coral farming, is hardy and has a fast growth rate (Reef Systems 2010). *Montipora capricornis* is a small polyp stony coral which is typically found in Fiji, Bali and the Indo Pacific. It occurs near to the surface and the middle of the water and is a light loving species requiring high to medium light levels (Aquarium Passion 2008). *Montipora capricornis* have been shown to be able to be grown under metal halides and fluorescent lights such as T5's and very high output (VHO) fluorescent lights. When grown under these lights it has been reported that the growth was higher at shallower depths but they did still grow at middle depths (Fish Lore 2007).

The success of aquaculture and aquariums is dependent on the health and growth of the corals. The lighting and water chemistry are directly linked to the rate of photosynthesis and therefore the health and growth of the corals concerned.

5.5 Light And Photosynthesis

Light is extremely important to reef building hermatypic corals which have a symbiotic relationship with the dinoflagellate alga *Symbiodinium.* While *Symbiodinium* spp. can give the coral host up to 95 % of their photosynthate (Muscatine 1990 in: Dubinsky 1990) which includes sugars , amino acids and carbohydrates (Trench 1979) the *Symbiodinium* spp. gain carbon dioxide, phosphates and nitrogenous compounds (Davies 1984). The *Symbiodinium* spp. also gain protection from herbivores and are housed in an environment which has high light intensities (Weis 2008).

Photosynthetically usable radiation (PUR) is the proportion of PAR which can be utilised by *Symbiodinium* spp. . *Symbiodinium* spp. can be found in symbiosomes which are vacuoles located in the gastrodermal layer (Yellowlees *et al*. 2008). *Symbiodinium* spp. contain chloroplasts containing thylakoid membranes.



(Estrella Mountain Community College 2010)

Figure 5.6 Diagram of a chloroplast

It is within these membranes that the photosynthetic unit (PSU) is located, which is made up of photosystem one and two (PS I and PS II). In these systems are photopigments, including chlorophylls a and $c^{2,}$ peridinin, diadinoxanthin, diatoxanthin and β-carotene (Titlyanov and Titlyanova 2002). PUR falls in the wavelengths of 400-550 nm which is absorbed by chlorophyll a and c^2 and peridinin and 620-700 nm absorbed by chlorophylls a and c^2 (Riddle 2006).

It has been shown that only 1 – 10 % of the PAR which lands on the surface of a coral actually penetrates to the *Symbiodinium* spp. This is due to scattering and absorption by the coral skeleton. Therefore the measurements of PAR are not necessarily a true reflection of the value reaching the *Symbiodinium* spp. (Magnusson *et al*. 2007).

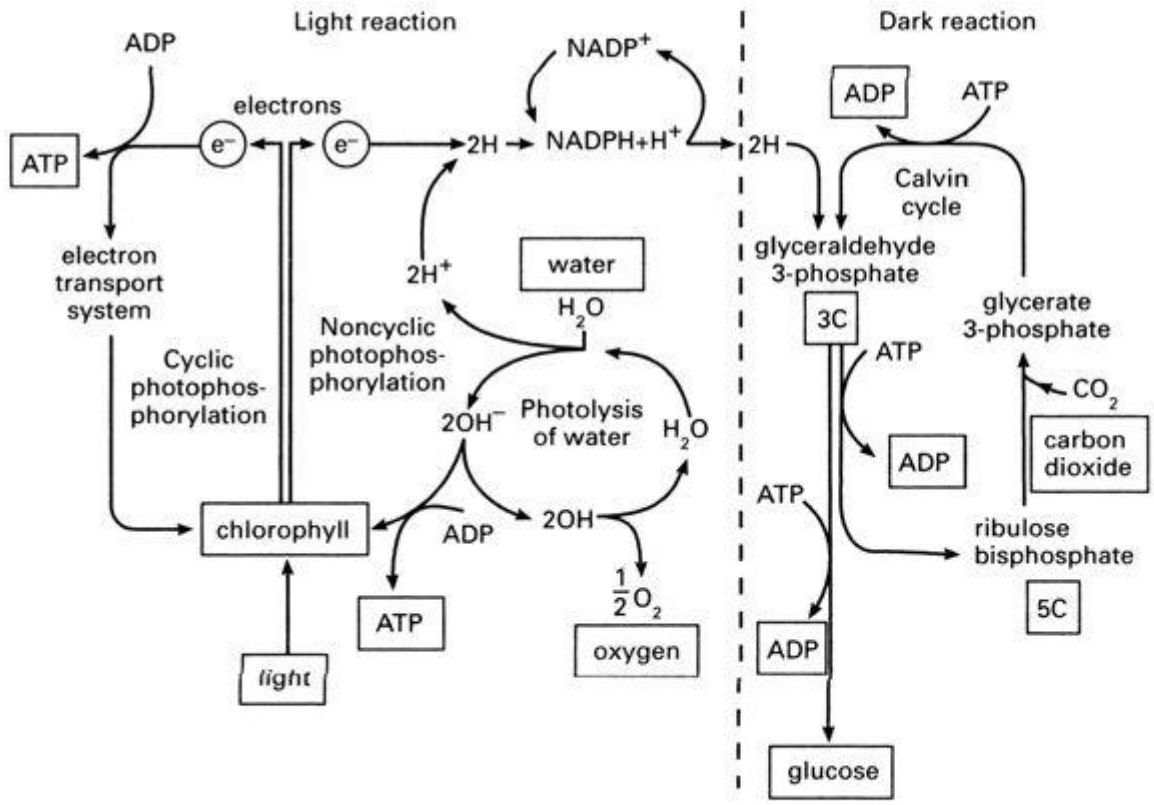
In order for photosynthesis to occur the compensation point of the coral must be met. This is the minimum rate of photosynthesis at which *Symbiodinium* spp. can survive and provide additional energy to the coral host (Craggs, J. personal communication). The ability for a coral to absorb light is actually increased by the structure of its calcium carbonate skeleton. The skeleton can cause scattering which increases the absorption of light (Enriquez *et al*. 2005).

There are two groups of reactions which occur during photosynthesis, light and dark reactions. In terms of this description chlorophyll is going to be the absorbing photopigment because it is the most abundant pigment in corals (Purves *et al*. 2004).

When light hits the thylakoid membrane the photopigments in antenna systems on the membrane become excited and the electron at the centre of the magnesium atom moves up the energy ranks and eventually frees itself from magnesium's orbital. This electron is picked up by a carrier and goes through electron transport where it is transferred through a series of carriers. Every time the electron is passed a redox reaction occurs and energy is released until it is back at ground state and returns back to the magnesium atom (Purves *et al*. 2004)

There are two forms of electron transport, noncyclic and cyclic. Noncyclic electron transport occurs in both PS I and PS II. PS II uses chlorophyll P_{680} as a carrier and the process of electron transport produces ATP. PS I use P_{700} as a carrier and electron transport produces NADPH and $H^{+.}$ Cyclic electron transport uses P_{700} to produce ATP. Protons are pumped into the thylakoid by electron transport pumps in order to create a diffusion gradient for protons into the stroma for ATP production (Purves *et al*. 2004).

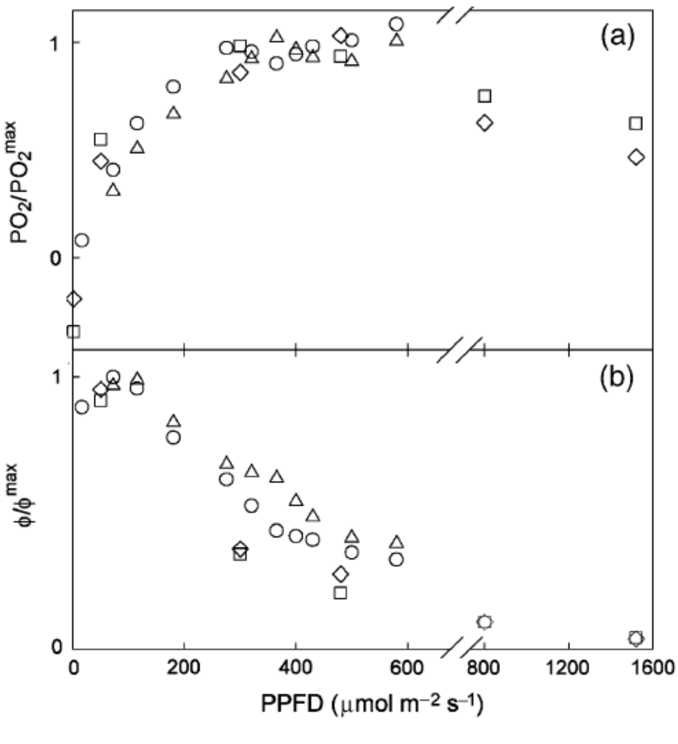
The dark reaction uses the products of the light reaction to make sugars through three processes. Carbon dioxide is fixed, carbohydrates formed and the CO_2 acceptor RuBP is recycled. The dark reaction produces glyceraldehyde-3-phosphate (G3P) which is made into starch and sucrose (Purves *et al*. 2004).



(Answers 2010)

Figure 5.7 Diagram of the chemical reactions which occur during photosynthesis

As light intensity increases to begin with you get an increase in quantum efficiency, which is the number of photons needed to make one oxygen molecule, up to a maximum. After this as light intensity increases the quantum efficiency decreases.



(Smith *et al*. 2005)

Figure 5.8 Light responses of coral zooanthellae, (a) = photosynthetic oxygen production, (b) = quantum yield of oxygen production

The relationship between photosynthesis and light intensities becomes nonlinear. This can be explained by a number of factors. The reduced quantum efficiency is due to the fact that the quinone electron acceptors become reduced. As light intensity increases the more acceptors become reduced meaning less electrons can be picked up. The excess energy which is not being used in electron transport is converted to heat (Baker *et al* 2005 in: Smith *et al*. 2005). This heat energy is dissipated by converting xanthophyll diadinoxanthin to diatoxanthin in the xanthophyll cycle (Falkowski and Raven 1997).

Further increases in light intensities lead to photosynthesis becoming more limited by the organism's ability to use up ATP and NADPH which results in a further increase in quinone acceptors being unavailable for electron transport. This causes photosynthesis to slow down (Baker *et al*. 2005 in: Smith *et al*. 2005).

Corals can show acclimatisation to changes in light over a period of days. Such responses include an increase in carotenoids which act as protection during increases in light (Falkowski and Dubinski 1981). It has been shown that corals of the same species at different depths of the water column have different concentrations of pigments associated with thermal dissipation of energy (Shick *et al*. 1995). Corals can also use fluorescent pigments which can dissipate damaging energy (Salih *et al*. 2000).

If there is too much light energy to be used up in photosynthesis there is the possibility of damage to PS II reaction centres. Whenever this occurs the processes for dissipating the excess energy as heat and via other electron acceptors come into play to reduce the likelihood of damage (Porter *et al*. 1989). When these processes cannot remove enough of the energy then damage will occur (Smith *et al*. 2005).

Damage to PS II seems to occur on the acceptor side because the quinone acceptors are all reduced on the binding site on the D1 protein in the reaction centre (Smith *et al*. 2005). The chlorophyll of the reaction centre becomes excited forming Pheophytin$^-$ (Diner and Babcock 1996 in: Ort and Yocum 1996). Reactive oxygen species can be produced, such as singlet oxygen. This is produced when these radicals recombine to form the triplet state of the chlorophyll which can combine with oxygen to make singlet oxygen which can damage the D1 protein (Asada 1996 in: Baker 1996). Corals have enzymes, such as catalase, which can convert reactive oxygen species to oxygen and water (Weis 2008).

However, if this does not occur then photoinhibition and photodamage will follow. This can cause bleaching of the coral and a loss of *Symbiodinium* spp. (Weis 2008). The expulsion of *Symbiodinium* spp. could be a mechanism to prevent further damage (Lesser 1997). The loss of *Symbiodinium* spp. leads to reduced growth and calcification due to the loss of photosynthate products they provide (Glynn 1993). Photoinhibition can be exacerbated by other factors such as high or low temperatures (Greer and Laing 1991, Foyer *et al*. 1994) and increases in UV radiation (Lesser 1996).

When there is no light hitting the membrane then chlorophyll fluorescence stops but the xanthophyll cycle continues, converting diatoxanthin back to diadinoxanthin (Riddle 2004).
This shows how important it is to get the balance within an aquarium right, if the light is too low then the compensation point of the coral will not be met and if it is too high then photoinhibition can occur which can lead to coral bleaching.

5.6 Calcification

Photosynthesis is linked to coral growth in the form of calcification. Calcification is the process by which corals increase in size by laying down a calcium carbonate skeleton. Calcium carbonate skeletons are produced by hermatypic reef building corals in order to provide support, protection and increase photosynthesis. The calcification process occurs in the extracytoplasmic calcifying fluid (ECF) and the calcium skeleton is secreted through the ectoderm where cells secrete calcium ions and bicarbonate which form the calcium carbonate skeleton (PRLog 2010).

The energy gained from photosynthesis therefore could help to increase calcification by providing energy for active transport of calcium. Calcium and carbonate need to be located at the ECF. Calcium comes from the water column where it enters the coelenteron, then moves into the calicoblastic epithelium and then, probably by active transport, enters the ECF (Holmes-Farley 2002c).

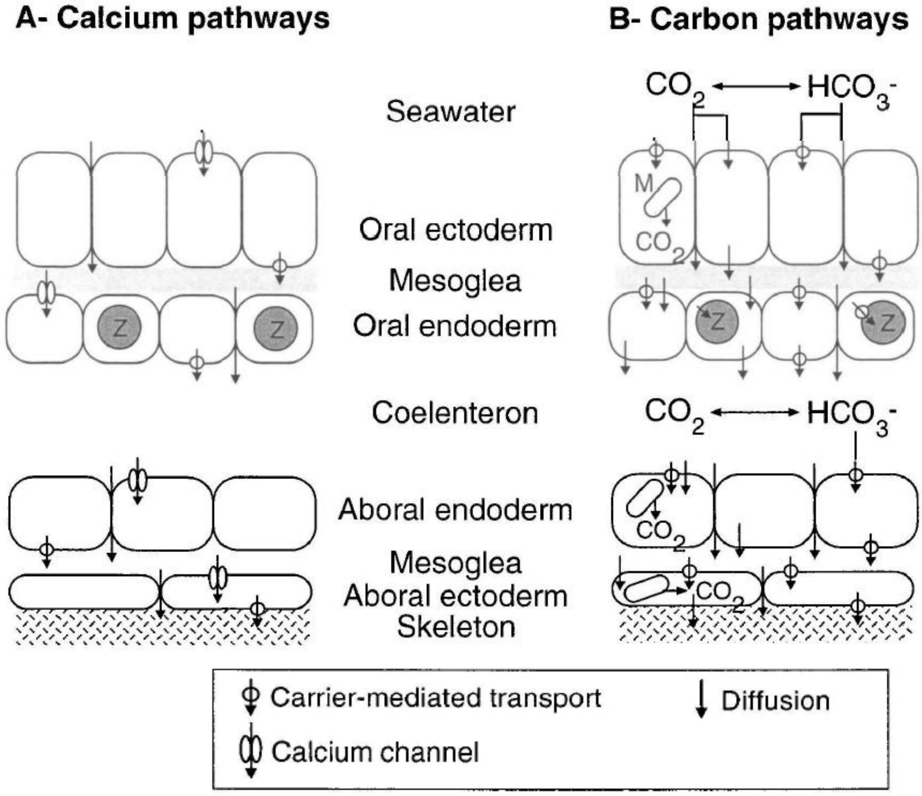
Calcium enters the calicoblastic epithelium via a calcium channel which controls the amount which can enter (Holmes-Farley 2002c) .One theory for the active transport of calcium into the ECF involves a proton antiport where one calcium ion enters and two protons leave the ECF. This would require energy in the form of ATP being converted to ADP (McConneaughey and Whelan 1997). Another theory states that the transport is due to calcium-ATPase (Tambutte *et al*. 1996).

The transport of carbonate could occur in two possible ways. One involves bicarbonate entering the coelenterons from the water column and from cells. This bicarbonate bonds with a proton to form carbon dioxide and can therefore diffuse into the ECF where it is converted into carbonate to be used in calcification (McConneaughey and Whelan 1997). The other theory suggests that active transport moves bicarbonate from the coelenteron into the calicoblastic epithelium and into the ECF where it is also converted into carbonate (Furla *et al*. 2000).

In order to maximise the rate of calcification, corals will saturate the ECF with calcium carbonate by a number of mechanisms. They can actively transport calcium and bicarbonate into and protons out of the ECF and could exclude magnesium and phosphate which can reduce calcification (Holmes-Farley 2002c).

It has been shown that in light conditions the rate of calcification is about three times higher than that in dark conditions. Inorganic carbon is utilised during photosynthesis and calcification within corals (Gattuso *et al*. 1999). There seem to be a number of reasons why photosynthesis increases a coral’s ability to lay down a calcium carbonate skeleton. One is that photosynthesis uses carbon dioxide, phosphates are lowered and products from photosynthesis enhance the calcification process and therefore growth in corals (Pearse and Muscatine 1971). Corals also gain carbon from zooanthellae as glycerol or glucose which provides energy for the calcification process, and it has been estimated that up to 95 % of a coral’s energy can come from this symbiotic relationship (Jungwi 2009).

The relationship between calcification and photosynthesis has still not been clarified and further work in this field is needed especially on cellular level (Tentori and Allemand 2006). There have been some predictions made on the possible ways in which calcium and carbon are transported in corals and these are shown in figure 5.9 (Gattuso *et al*. 1999).



M = Mitochondria, Z = Zooanthellae.
(Gattuso *et al*. 1999)

Figure 5.9 Calcium and carbon pathways involved in scleractinian corals

5.7 Factors Influencing Growth

It is not only light which affects a coral's growth rate, there are number of other variables which need to be considered.

5.7.1 Flow

Flow has been argued to possibly be more important to corals than light itself. This is because some corals do not have a symbiotic relationship with *Symbiodinium* spp. and rely wholly on capturing prey to gain their energy and even photosynthetic corals can survive days and weeks in darkness but not this long if the water is still (Adams 2006).

Flow is important because it increases a coral's ability to capture food particles, helps to prevent waste products building up and increases the diffusion gradient of products required for photosynthesis and respiration, therefore increasing the growth rate of corals (Adams 2006). This has been shown with a variety of corals with higher rates of photosynthesis, respiration and calcification in high flow conditions (Dennison and Barnes 1988, Patterson *et al*. 1991).

It has been shown that an intermediate flow is best for the capture of food particles, if it is too slow then food will not pass often enough and if it is too strong then the corals struggle to keep their tentacles extended (Fabricus 1995). It has also been shown that in higher flow rates there is less coral bleaching (West and Salm 2003) and photoinhibition (Nakamura *et al*. 2005) due to increased diffusion of the waste products of photosynthesis. Therefore corals can photosynthesise more under high light conditions if flow rates are increased.

5.7.2 Feeding

Feeding enhances the growth of corals because they have more energy for the calcification process. It also increases the amino acids available to incorporate into the organic matrix which is deposited, along with calcium during the calcification process, further enhancing growth (Houlbreque *et al*. 2004).

5.7.3 Herbivory

Herbivorous fish and invertebrates can enhance a coral's growth by removing competitive algae which compete with corals for space, light and nutrients (Rose 2009).

5.7.4 Temperature

Corals which experience increases in temperature of about 2°C above the average annual maximum can experience bleaching (Podesta and Glynn 2001). Coral bleaching involves a coral losing its pigmentation due to *Symbiodinium* spp. losing pigments and the coral host itself losing *Symbiodinium* spp. (Fitt *et al*. 2001). The mechanisms by which corals can lose their *Symbiodinium* spp. are similar to that of increases in light intensity. The initial stage of thermal bleaching is photoinhibition and D1 protein damage (Weis 2008). The fact that only a 2°C increase in temperature can cause bleaching means that temperature should be stringently regulated.

5.7.5 Water chemistry

Iodine

The concentration in saltwater is 0.06 mg/L but it an aquarium iodine can be removed by protein skimmers (Saltwater Aquarium Guide 2007). Iodine can be found in inorganic, iodate and iodide, and organic, for example methyl iodide, forms. The concentration has to be kept at trace levels (Craggs, J. personal communication) because it can cause nuisance algae to grow. Excess food which has not been consumed is the usual source of iodine in an aquarium (Holmes-Farley 2003a).

Phosphate

Phosphates should be kept to a minimum in a coral aquarium because they can cause the growth of algae and inhibit calcification (Holmes-Farley 2002a). They inhibit calcification because they are present in the ECF and can bond with calcium carbonate making it unavailable to the coral (Donowitz 2002). Phosphate found in aquariums is mainly inorganic orthophosphates. (Holmes-Farley 2002a). In the tank systems it should be maintained at levels less than 0.1 mg/L (Craggs, J. personal communication).

Magnesium

Magnesium is the third most abundant ion found in seawater, with concentrations of 53 mM. In an aquarium it should be kept at trace levels because it can bind to carbonate ions and become incorporated into the skeleton to form magnesium calcite. Magnesium calcite is not a good compound for further calcium carbonate to be laid down and therefore slows down the calcification process (Holmes-Farley 2003b). Magnesium should be found at concentrations of 1320 – 1360 mg/L (Craggs, J. personal communication).

Alkalinity

The alkalinity of water determines its ability to be able to buffer the solution against acidity (Donowitz 2002). The buffering capacity mainly comes from bicarbonate and carbonate and the total alkalinity is defined as "the amount of acid required to lower the pH to where all bicarbonate and carbonate ions could be converted into carbonic acid" (Holmes-Farley 2002d). Total alkalinity can be measured in degrees of carbonate hardness (dKH) and should be in the range of 7 – 12 dKH within this experimental set up (Craggs, J. personal communication). The alkalinity is not only important in stabilising pH, but bicarbonate and carbonate are both utilised by the coral in the calcification process (Holmes-Farley 2002d) and also in photosynthesis so a large source in needed for a coral aquarium to ensure a good growth rate (Holmes-Farley 2002d).

pH

pH is a measure of the number of hydrogen ions in a solution (Fossa and Nilsen 1996). If the water becomes too acidic then this can reduce the rate of calcification. This is because when the pH in the water column decreases, the pH in the coelenteron also drops. This decreases the concentration gradient, because when the pH is low in the coelenteron it contains high levels of protons, meaning the protons cannot diffuse as efficiently from the calicoblastic epithelium into the coelenteron, therefore slowing calcification (Holmes-Farley 2002b). The pH should be within the range of 8.1 – 8.5.

Nitrogen

Nitrogen can come from excess food and waste products and occurs in many forms, such as ammonia, nitrite and nitrate. The cycling of nitrogen occurs with nitrification converting nitrite into nitrate and the process of dissimilation reducing nitrate into ammonia which can be converted back into nitrite. (Fossa and Nilsen 1996). Nitrite and nitrate are both toxic to marine organisms. Nitrite can oxidise haemoglobin changing it to methemoglobin, and should therefore be maintained at levels less than 0.05 mg/L (Fossa and Nilsen 1996). Nitrates can cause nuisance algae to grow and cause an increase in *Symbiodinium* spp. which utilise the carbon which the coral needs for calcification (Holmes-Farley 2003c). These should therefore be kept at trace levels (Craggs, J. personal communication).

Calcium

As discussed previously, calcium is extremely important for corals as it becomes incorporated into their skeletons. It is therefore important to maintain a high level, around 400 – 450 mg/L (Craggs, J. personal communication), to make it available to corals for their growth (Fossa and Nilsen 1996).

5.8 Aim

This investigation hopes to improve on previous observations of *M. capricornis* by running a standardised experiment not only testing whether they grow but actually measuring the growth rate and testing not only fluorescent lights but also metal halides and LEDs.

There is still much debate as to whether T5 or LED lighting can actually grow corals as well as metal halides can. This study is therefore going to test whether there is any significant difference in the growth rate of corals under the three different lights at different PAR readings. It is hypothesised that the metal halide will be the best light for growing corals due to its high intensity light output.

6. METHODS

6.1 Fragmentation

The coral *Montipora capricornis* was fragmented into 90 pieces by breaking off segments from one piece from the Horniman Museum. These fragments were then stuck onto a plug using milliput epoxy putty. These were then left to acclimatise and encrust the plug for 9 weeks under metal halide lights.

6.2 PAR Profiles

A PAR profile for each tank was created using a Li-cor, Li-192 under water quantum sensor. A PAR reading was taken at 10 cm intervals covering the whole tank along X, Y and Z co-ordinates.

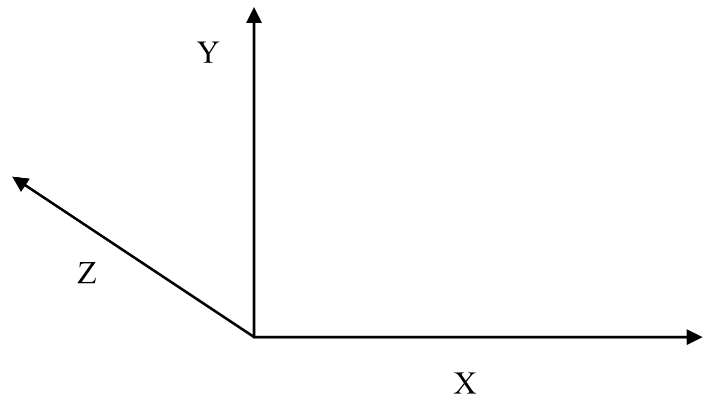


Figure 6.1 Co-ordinates for PAR profile

The exact co-ordinates can be found in appendix tables 11.1 – 11.3.

6.3 Tank Systems

Three tanks were used for the experiments which ran on the same system on a flow through, which also ran through the main reef tank which holds 13,000 L, and therefore had identical water chemistry. The system had a phosphate reactor , RowaPhos FR1016 fluidised reactor , which uses RowaPhos which is a ferric hydroxide material which binds up phosphate in the water, therefore reducing the phosphate levels which if too high can be detrimental to coral growth and increase algae growth (The Aquarium Solution 2010). 6.5 kg of RowaPhos was added on the 21/05/2010 in order to try to reduce phosphate. A calcium reactor, Deltec KM 800, was also used on the system. This slowly releases Kalwasser solution, calcium hydroxide, into the water. The addition of calcium ions has a positive effect on coral growth while the hydroxide ions bind to carbon dioxide to produce bicarbonate helping to buffer pH (Reefscapes 2002). Each tank also contained three *Turbo fluctuosa*.

The LED tank was slightly larger with a volume of 176.24 L and the T5 and metal halide tanks were identical with a volume of 146.54 L each. The lights were moved up and down until all created a PAR value of around 280 µmol s^{-1} m^{-2} at the top crate of the shelving, meaning that the coral's growth would be compared at an even PAR in all three tanks for this level. 280 µmol / s / m^2

was selected because this has been suggested as the optimum PAR for optimum coral growth for corals with symbiotic algae (Joshi 2010).

Each tank contained 30 *Montipora capricornis* fragments, ten at each level of the shelving unit. They were placed onto egg crates as shown in figure 6.2.

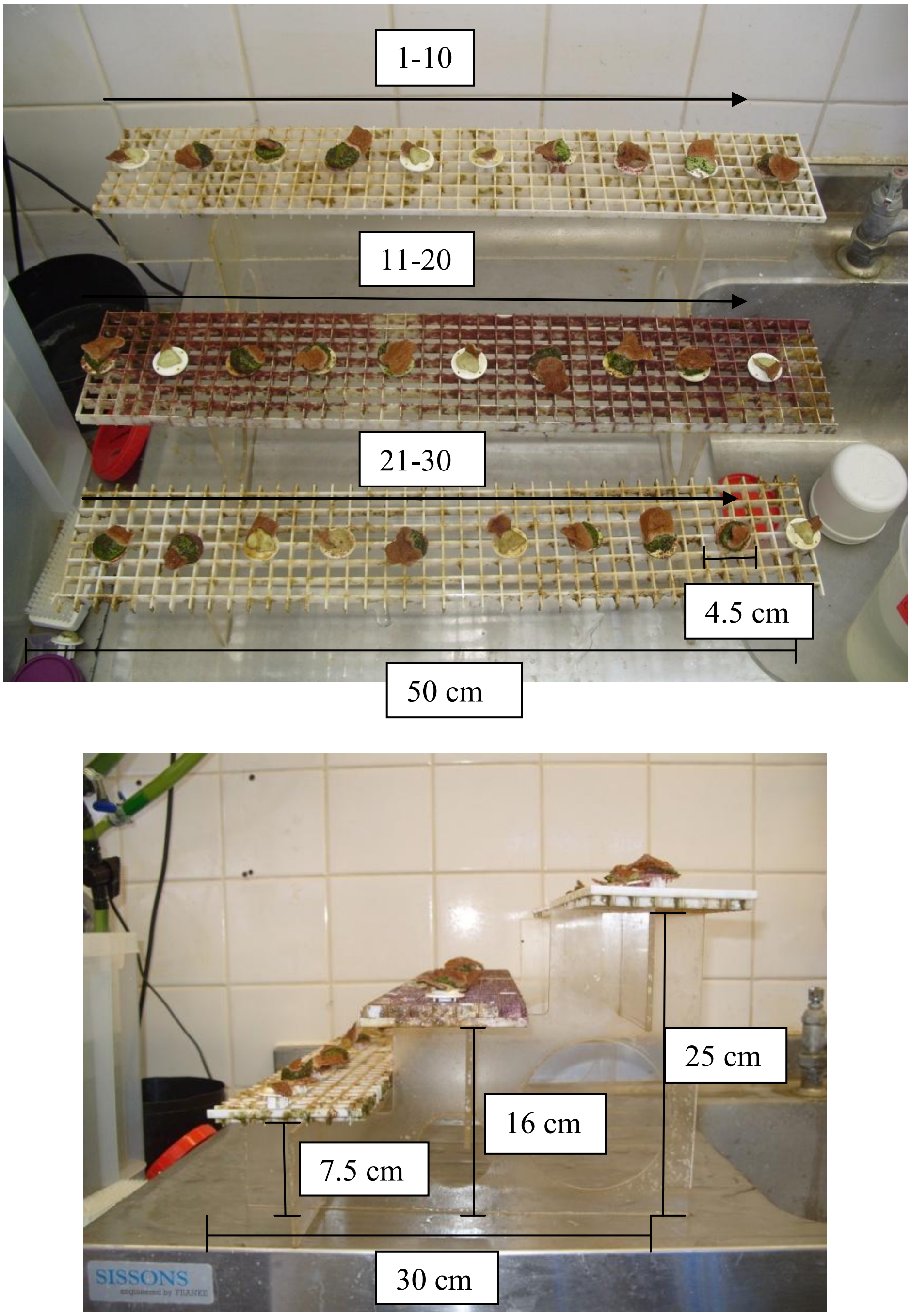


Figure 6.2 Set up of the racks with egg crates and coral fragments

One shelving unit was placed into each tank and left for one week so the corals could acclimatise to the change in lighting. The tanks contained Rio 3 100 pumps which produce a flow rate of 900 gph (Marine and Reef 2007). In order to reduce algal build up in the tanks, one alga eating fish was placed in each tank, *Zebrasoma veliferum* in the LED tank, *Siganus vulpinus* in the T5 tank and *Zebrasoma xanthurum* in the metal halide tank. Also three *Turbo fluctuosa* to help in reducing algae. Three non algae eating fish, *Chromis viridis*, were also placed in each tank. Black plastic boards were placed in between each tank to block out light coming from the other tanks. One shelving unit was placed into each tank and left for one week to acclimatise to the change in lighting. The set up for each tank is shown in figures 6.3 - 6.5.

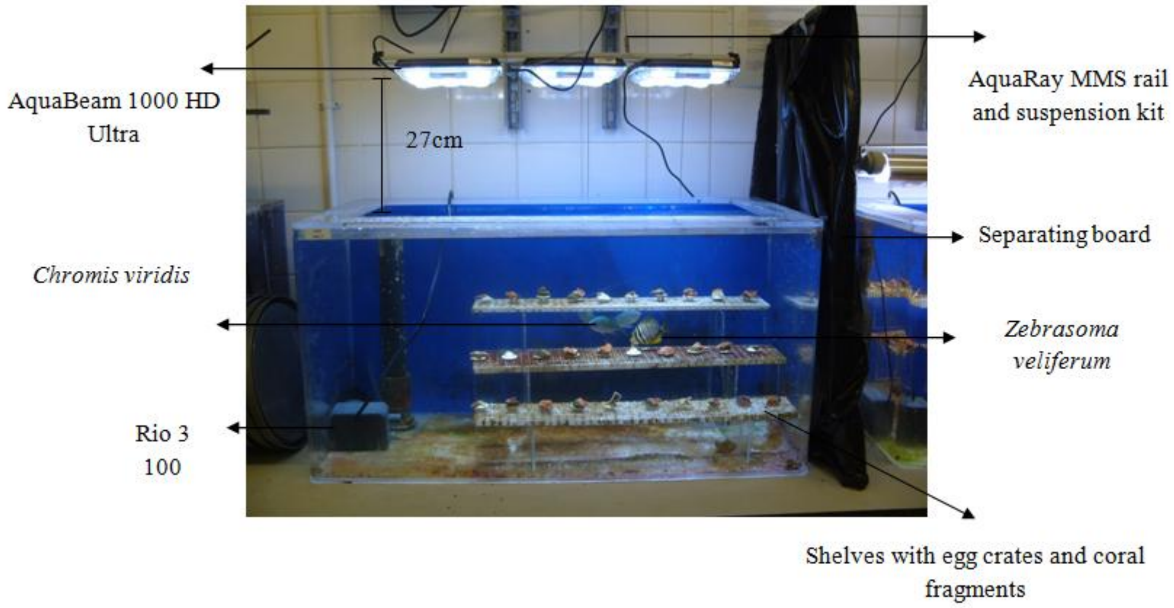


Figure 6.3 LED tank set up

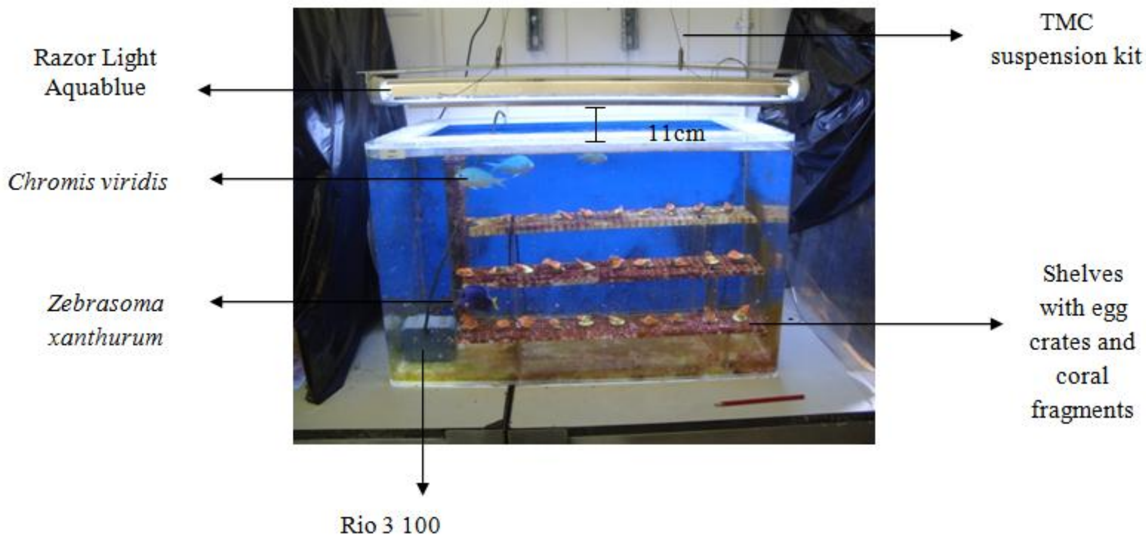


Figure 6.4 T5 tank set up

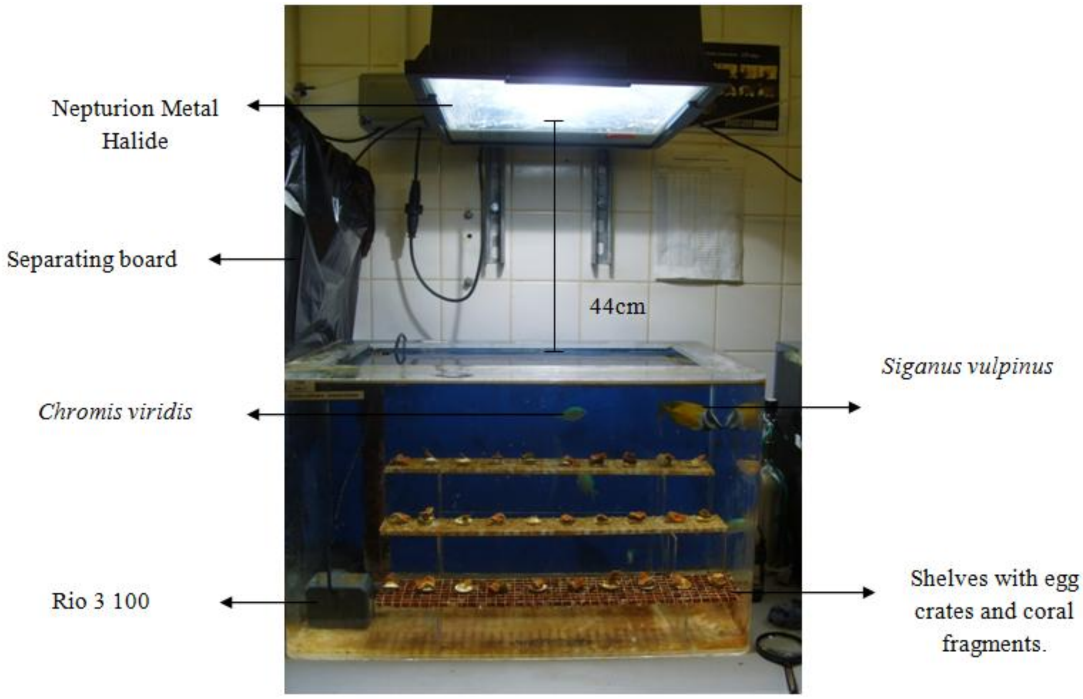


Figure 6.5 Metal halide tank set up

Table 6.1 Details of the lights used and associated costs

Company	Product details	Size (cm)	Product code	Cost	Running cost / year
LED: TMC	Reef white, seven x 14,000 K white LEDS and three x 50,000 K blue LEDS	20 x 20	1903-UK/EU/US	£250	£13
T5: The Aquarium Solution	Two 39 W Aquablue plus tubes with a 60:40 white: blue blend and gullwing reflectors	Length = 89.5 Width = 15.5 Height = 5	PC107/37T	£175.95	£34
Metal Halide: BLV	250 W and 10,000 K in a Gewiss GW85 111 light unit.	Diameter = 4.6 Length = 22.5	227021	£113	£110

(The Aquarium Solution 2010, Viclite 2010, TMC 2010, Bertram, S. personal communication, Westcott, G. personal communication)

Each light was turned on at 08:30 am and off at 18:30 pm, meaning they are on for the recommended ten hours a day (Reef Eden 2006).

6.4 Growth Measurements

6.4.1 Volume

The volume of the corals was taken once a week for eight weeks. This was done using CORALZO's protocols. A 250 ml cylinder was filled up to the 230 ml mark, using 227 ml of aquarium water which was measured out using a 10 ml pipette and a 1 ml pipette. This exact amount was added to the cylinder for each measurement.

Four coral fragments were then taken from the first tank to determine their volume. Four corals were taken at a time in order to minimise the amount of time the corals were out of the tank. The first coral fragment was then attached to a piece of egg crate which is attached to fishing wire. The fragment was then lowered into the cylinder displacing the water. The water displaced was measured using a 1 ml syringe which had a piece of tubing attached allowing it to reach the water line. The syringe took out the displaced water until the bottom of the meniscus had returned to the 230 ml mark. The volume of water displaced was then recorded (Osinga 2009 in: Leewis *et al*. 2009). This was then repeated a further two times, creating three repeats for each fragment. This method was carried out on all corals in the three tanks.

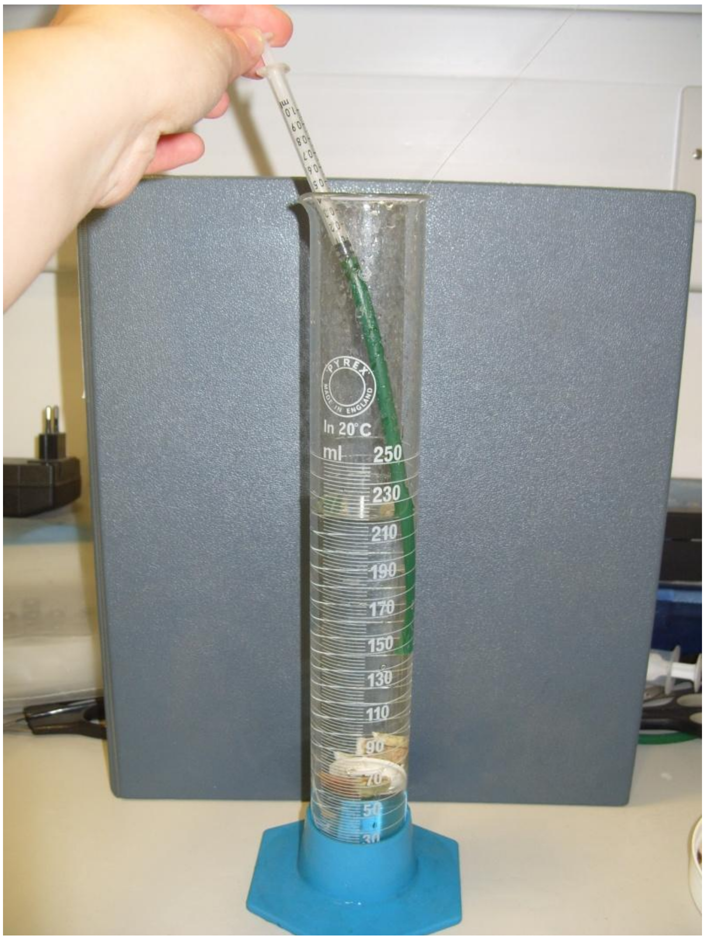


Figure 6.6 Measuring the volume of a coral fragment

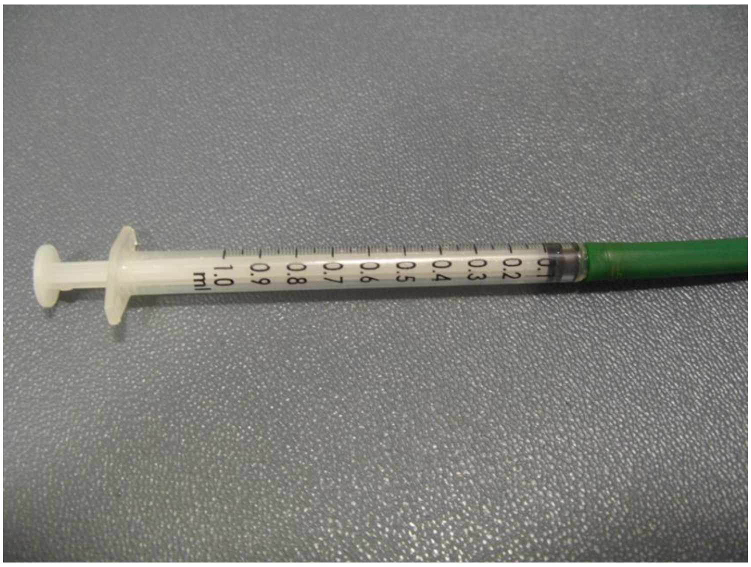


Figure 6.7 Pipette used to measure the volume of coral fragments

6.4.2 Weight

The weight of the coral fragments was also taken once a week at the same time as the volume was determined. Weight was determined using the buoyant weight technique outlined in CORALZOO's protocols. Electronic scales, A and D GX_2000, were set up on a box with a hole cut through the middle. Suspended through this hole was a piece of fishing wire attached to the scales. Attached on the end of the fishing wire was a piece of egg crate which was suspended in a beaker filled with 800 ml of water. A fragment of coral was then placed in the piece of egg crate and suspended in the beaker of water and the buoyant weight recorded (Osinga 2009 in: Leewis *et al*. 2009). This was then repeated a further two times creating three repeats for each coral. This method was used to weigh all corals in the three tanks.

Figure 6.8 Measuring the weight of coral fragments

6.5 General Maintenance

6.5.1 Daily

Each morning the tanks were cleaned of any algae growing by wiping the sides with a white pad. The tanks were also siphoned to remove any excess food or waste products. The fish were fed the same amount of frozen *Mysidopsis bahia* once in the morning and once in the afternoon. Temperatures were taken each day from the control panel and redox readings using a redox probe. Salinities were also measured using a refractometer.

6.5.2 Weekly

Water tests were carried out on the system once a week. The parameters tested and equipment used is shown in table 6.2.

Table 6.2 Water chemistry test kits

Parameter	Equipment	Range
Ammonia	Hach water quality test strips	0 - 6.0 mg/L
Nitrite	Hach water quality test strips	0 - 3.0 mg/L
Nitrate	Hach water quality test strips	0 - 50 mg /L
Phosphate	Rowa high sensitivity phosphate test kits	0.008 - 0.14 ppm
Calcium	Profi test Salifert	10 - 500 ppm
Carbonate hardness / alkalinity	Profi test Salifert	0.3 - 16.0 dKH
Magnesium	Profi test Salifert	30 – 1500 ppm
Iodine	Profi test Salifert	0 - 0.2 ppm
pH	HQ 11d Hach pH meter	-

(Craggs, J. personal communication)

6.6 Statistics

Growth rate using the weight measurements was calculated using the following formula:

$$g = \ln (W_{final} / W_{initial}) / \Delta t$$

g = growth rate, W_{final} = final weight (g), $W_{initial}$ = initial weight (g) and Δt = time (days) (Chadwick and Feminella 2001).

Table 6.3 Statistical tests used

Statistical Test	Variables
Regression analysis	Volume and weight measurements
Two-way ANOVA	PAR, growth rate and tank
Regression analysis	PAR and growth rate
Regression analysis	Magnesium concentration and time
Paired sample t-test	Standard deviation for weight and volume
Paired sample t-test	Start and end weights
Paired sample t-test	Tank and growth rate
Wilcoxon signed rank test	Tank and growth rate

7. RESULTS

7.1 PAR Profiles

The PAR profiles produced show how each light behaves in the tanks used for this investigation. Actual data for the PAR profiles can be found in appendix tables 11.1 – 11.3.

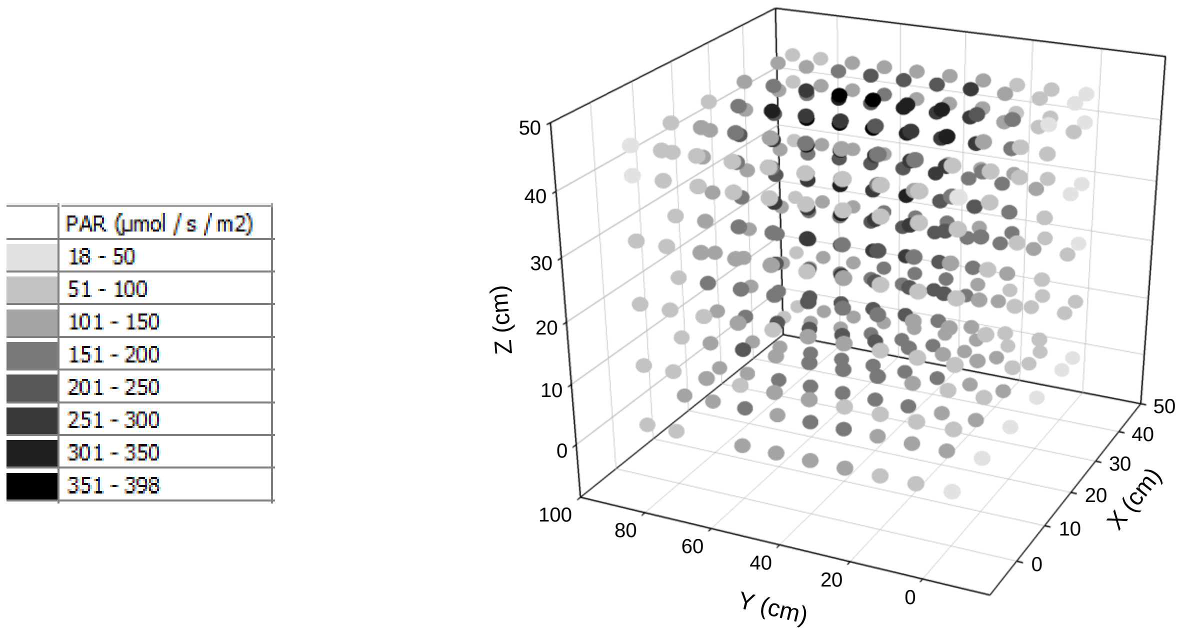


Figure 7.1 PAR profile for the LED tank

The LED light has deep penetration of PAR but not as deep as the metal halide light (Figure 7.3). It also has a wide spread of PAR when compared to the metal halide but is not as evenly spread as the T5 (Figure 7.2).

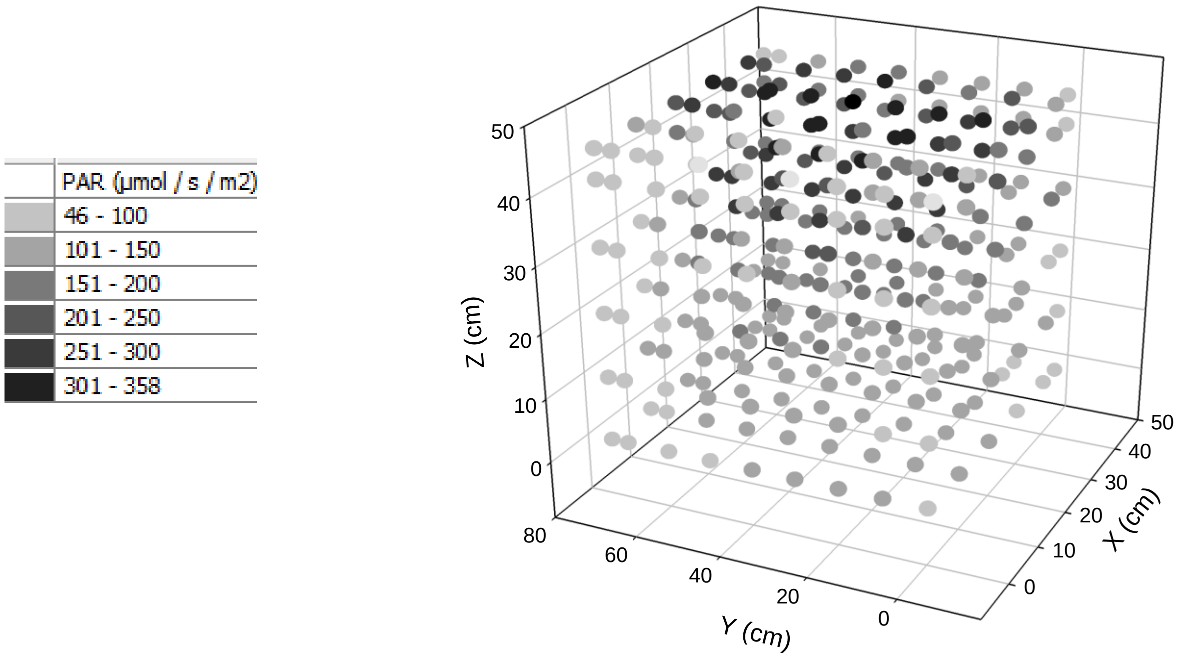


Figure 7.2 PAR profile for the T5 tank

The T5's PAR values drop off quite quickly with depth. It does provide a more uniform spread of light compared to the other two lights.

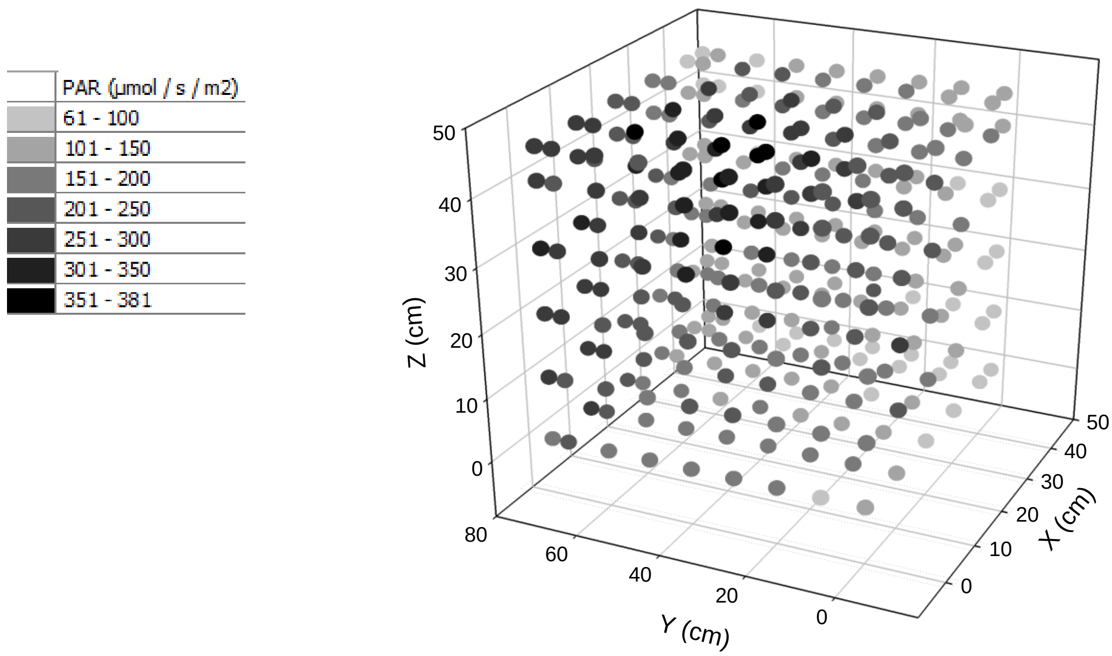


Figure 7.3 PAR profile for the metal halide tank

The metal halide light penetrates much deeper than the other two lights. It has a more even spread of light then the LED but not as much as the T5 light. More of the tank gains a higher PAR value compared to the other two lights.

7.2 Weight And Volume

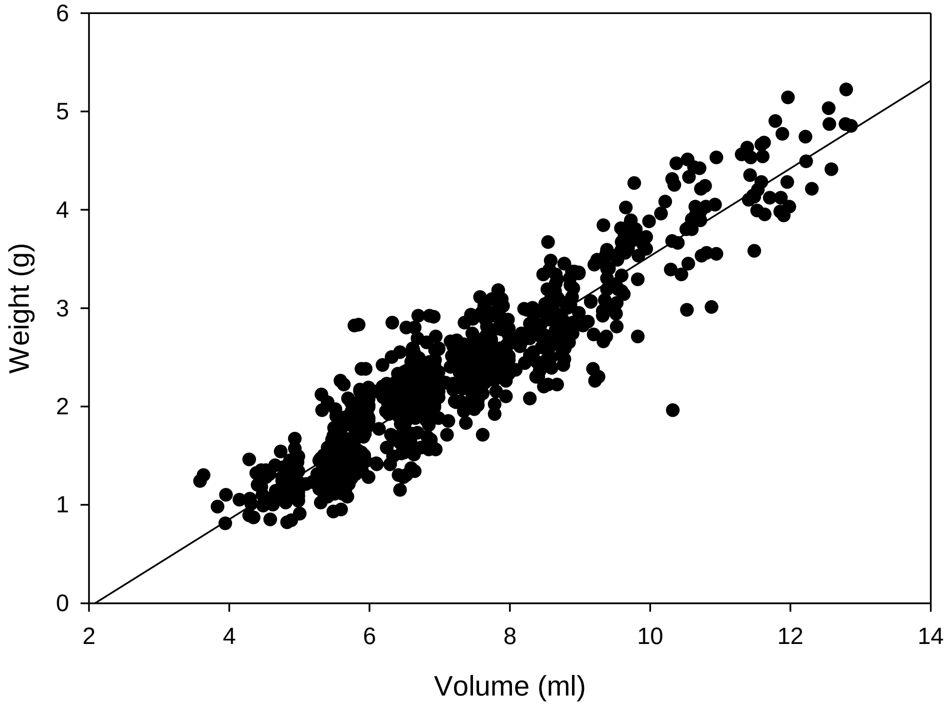


Figure 7.4 Relationship between volume and weight measurements

The regression analysis carried out on all the data for weight and volume gave a significant relationship (R = 0.930, p = <0.01). The raw data can be found in appendix tables 11.5 – 11.7.
The standard deviation for weight and volume measurements was calculated for the LED tanks for start week and weeks four and eight.

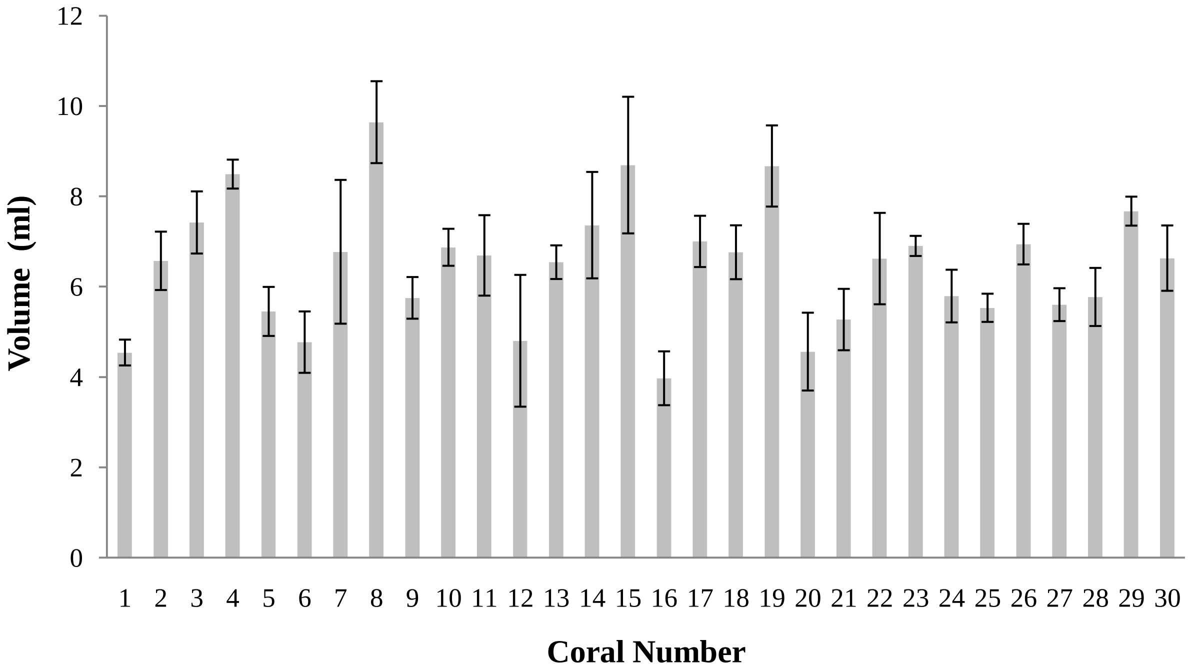


Figure 7.5 Volume measurements for start week in the LED tank and the associated standard deviation error bars

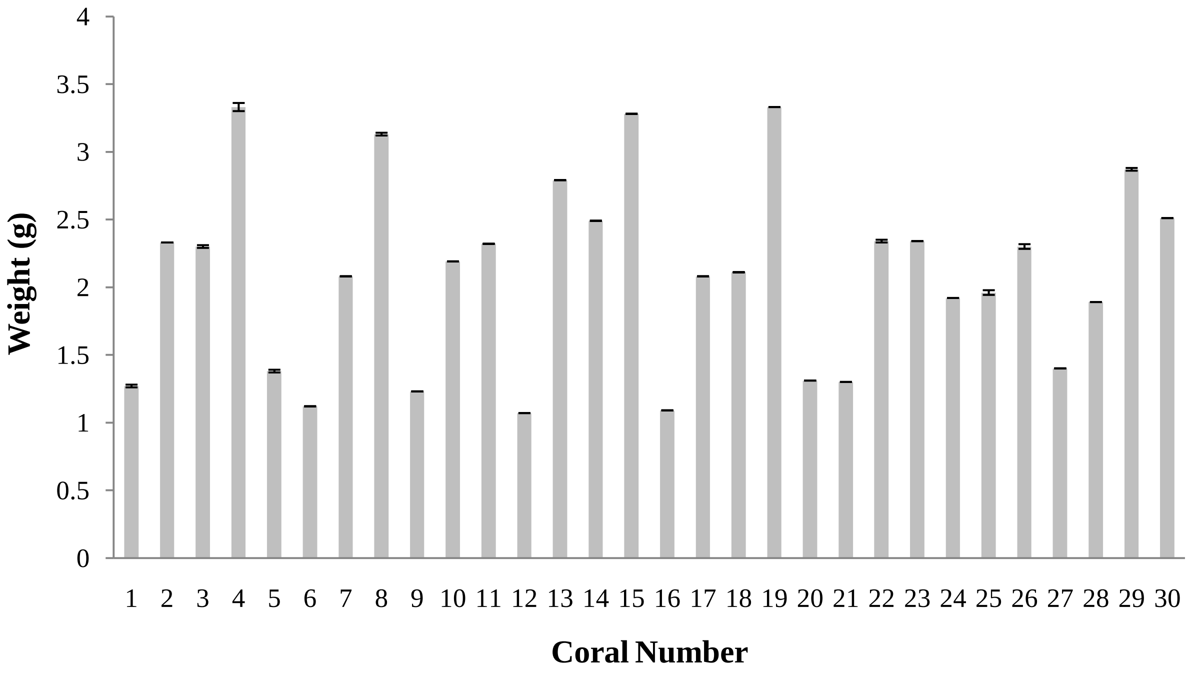


Figure 7.6 Weight measurements for start week in the LED tank and the associated standard deviation error bars

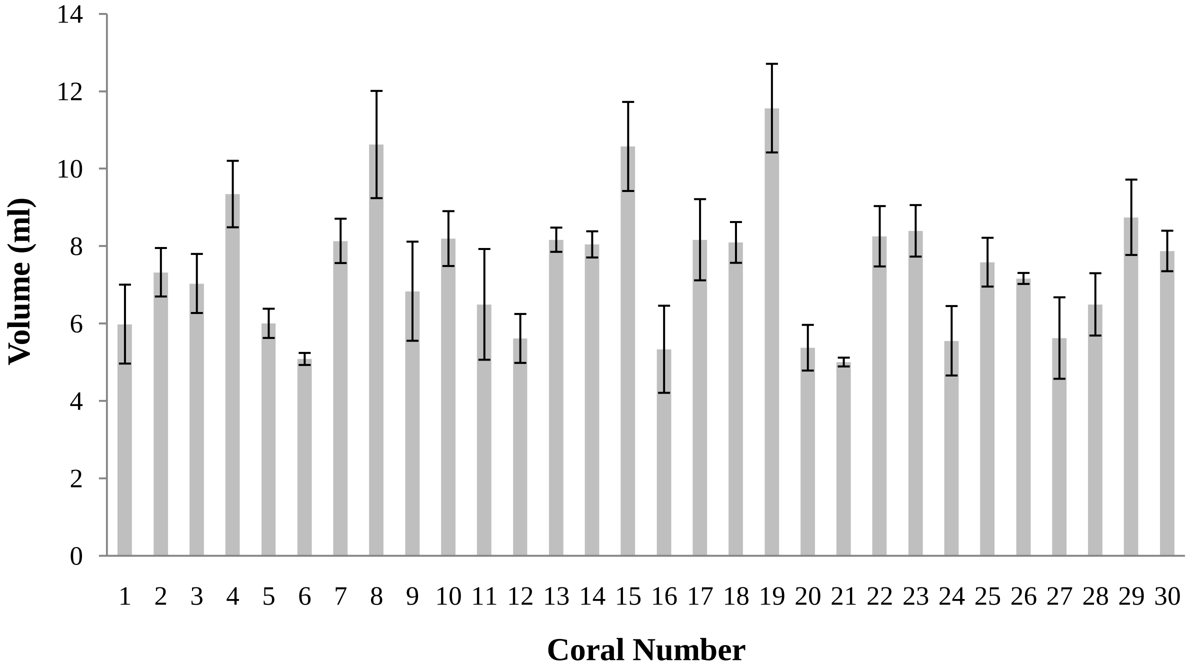


Figure 7.7 Volume measurements for week four in the LED tank and the associated standard deviation error bars

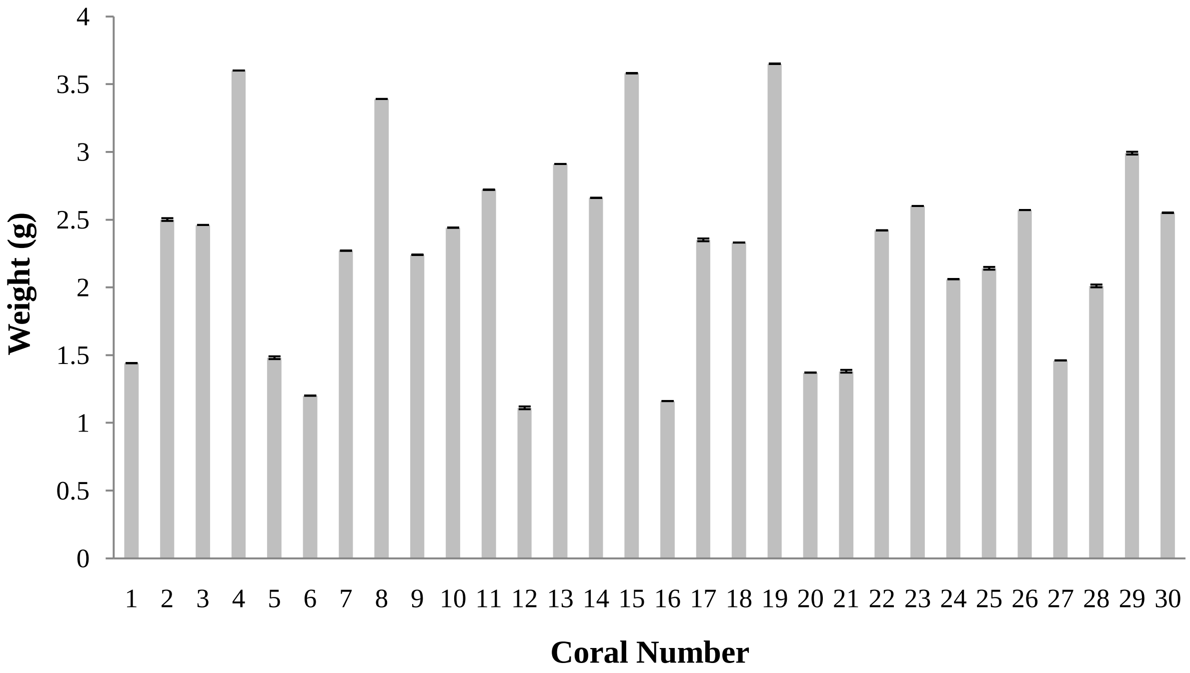


Figure 7.8 Weight measurements for week four in the LED tank and the associated standard deviation error bars

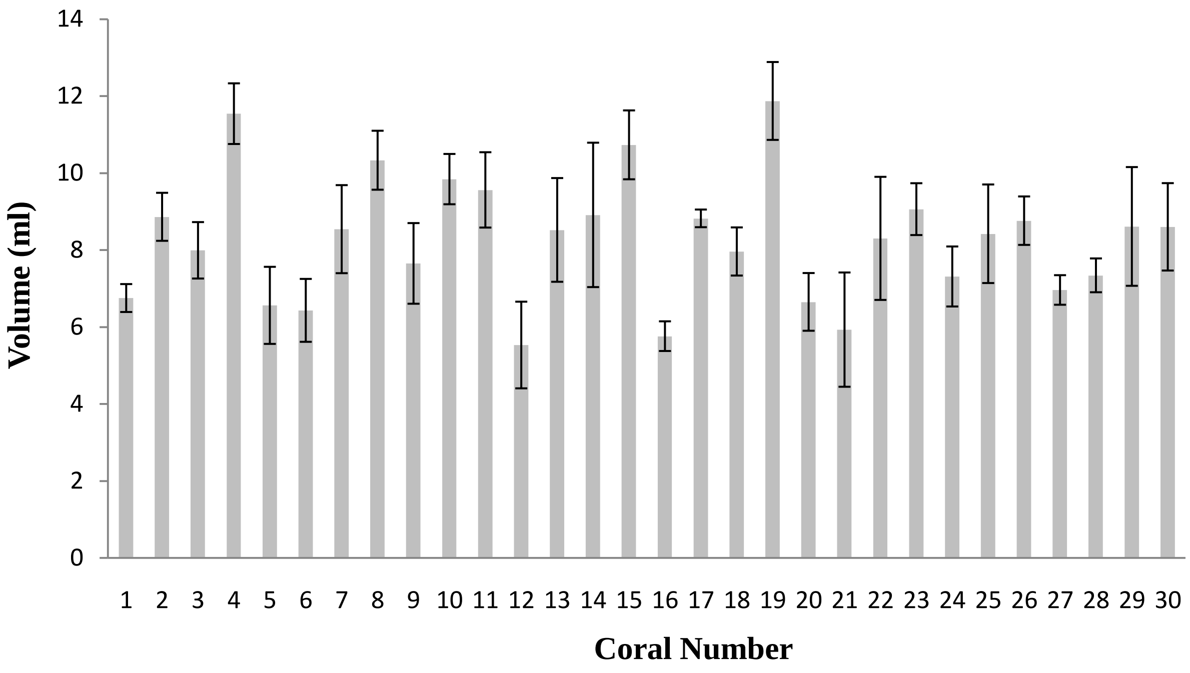


Figure 7.9 Volume measurements for week eight in the LED tank and the associated standard deviation error bars

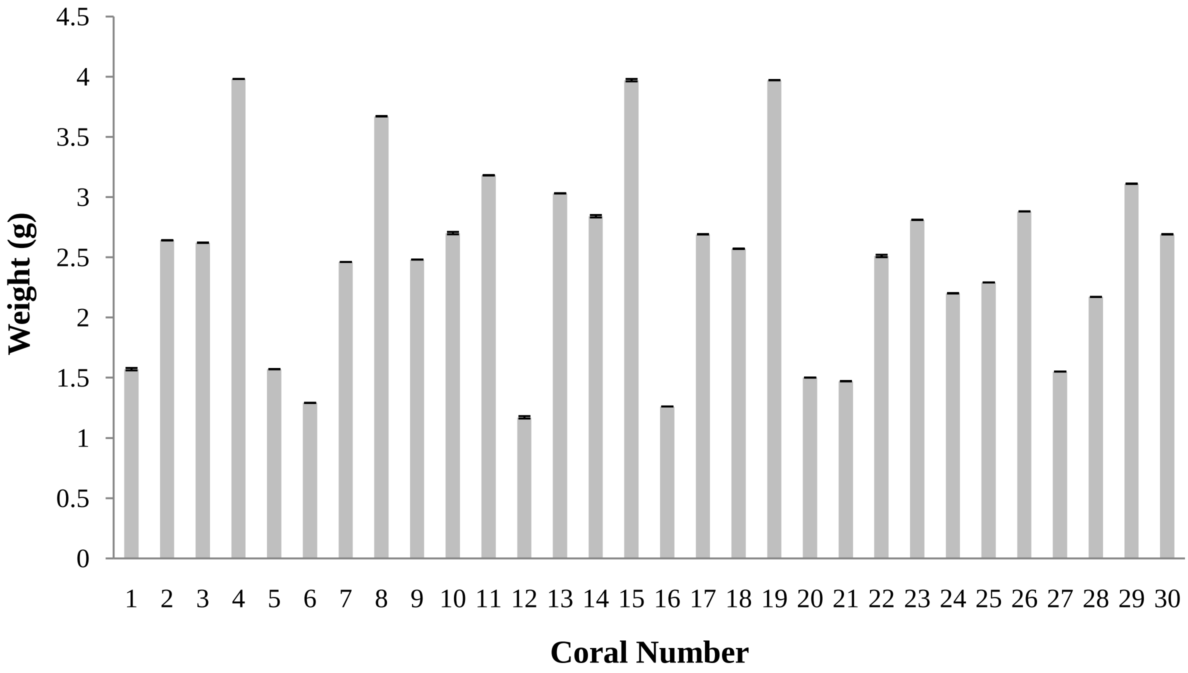


Figure 7.10 Weight measurements for week eight in the LED tank and the associated standard deviation error bars

Figures 7.5 – 7.10 show that the standard deviation associated with the volume measurement is much larger then that with weight. There is a significant difference between the standard deviations associated with weight and volume for these weeks ($t = 5.044, 19.438, p<0.01$). Therefore only weight was used for further statistical analysis because it had the lowest random error associated with it. These three weeks were chosen as a representation of the whole experiment. The raw data for these figures can be found in appendix tables 11.8 – 11.13.

7.3 Growth

A t-test showed that there was a significant difference between the start weight and end weight in the LED tank ($t = 17.247, 16.788, p<0.01$), the T5 tank ($t = 14.482, 14.042, p<0.01$) and the metal halide tank ($t = 13.532, 14.095, p<0.01$).

7.3.1 Overall growth rate

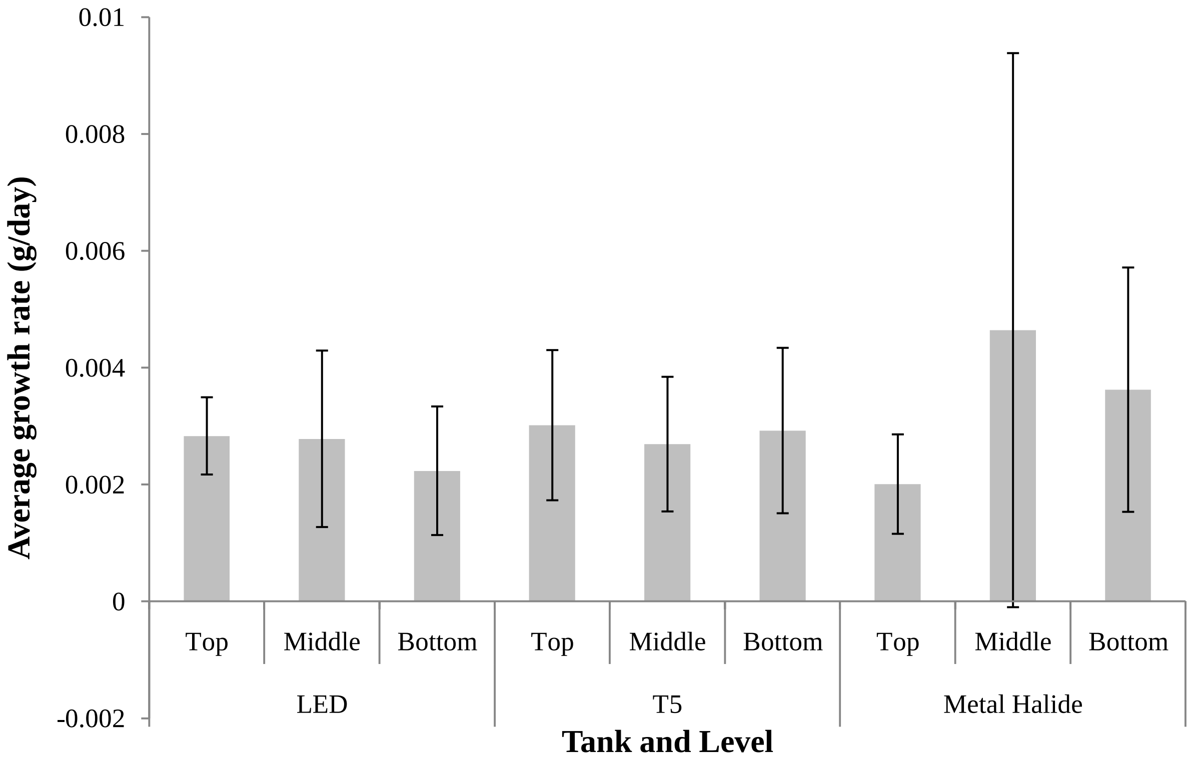


Figure 7.11 Average growth rates for each tank at the three different levels with associated standard deviations

The highest growth rate was experienced in the metal halide tank in the middle level , however its associated standard deviation is also relatively large. The metal halide also experienced the lowest growth rate for corals positioned on the top level.

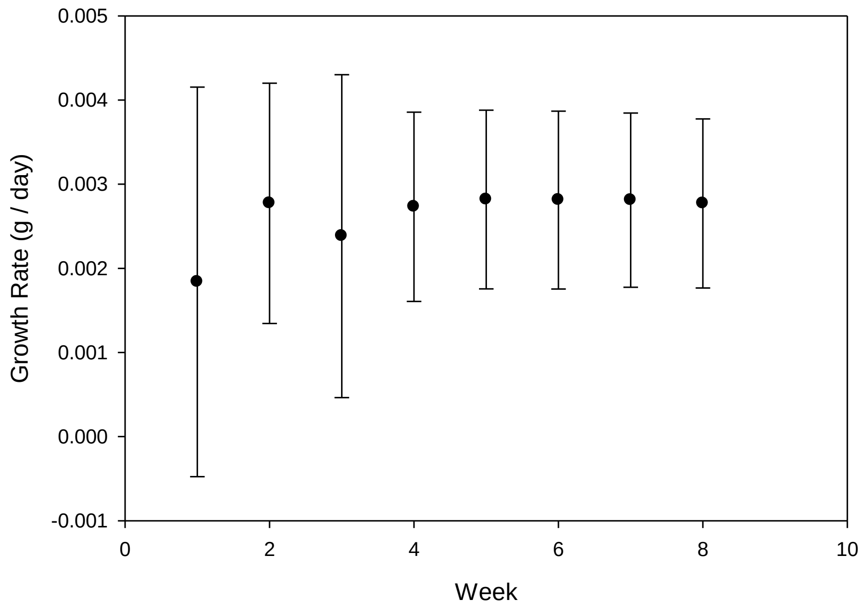


Figure 7.12 Growth rates of corals over the course of the experiment for the LED tank with associated standard deviations

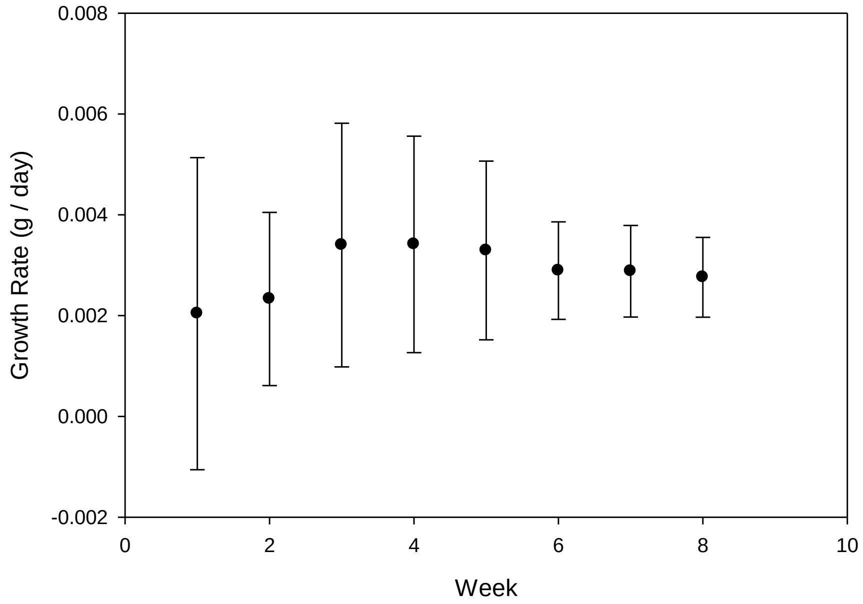


Figure 7.13 Growth rates of corals over the course of the experiment for the T5 tank with associated standard deviations

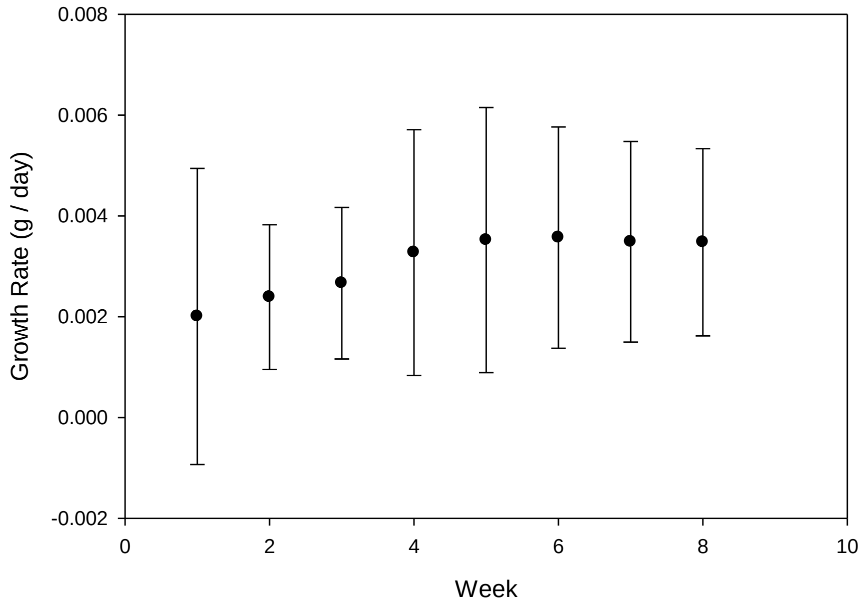


Figure 7.14 Growth rates of corals over the course of the experiment for the metal halide tank with associated standard deviations

The growth rate for each tank increases to begin with and then starts to decrease. The corals under the metal halide light show a more rapid increase in growth and a higher growth rate overall.

A paired sample t-test showed no significant difference between the LED growth rate over time and the T5 ($t = -1.610$, $p > 0.05$) and between the T5 and the metal halide ($t = 0.986$, $p > 0.05$). There was, however, a significant difference between the metal halide and the LED ($W = 30$, $p < 0.05$) when a Wilcoxon signed rank test was completed. The raw data for figures 7.12 – 7.14 can be found in appendix tables 11.14 – 11.16.

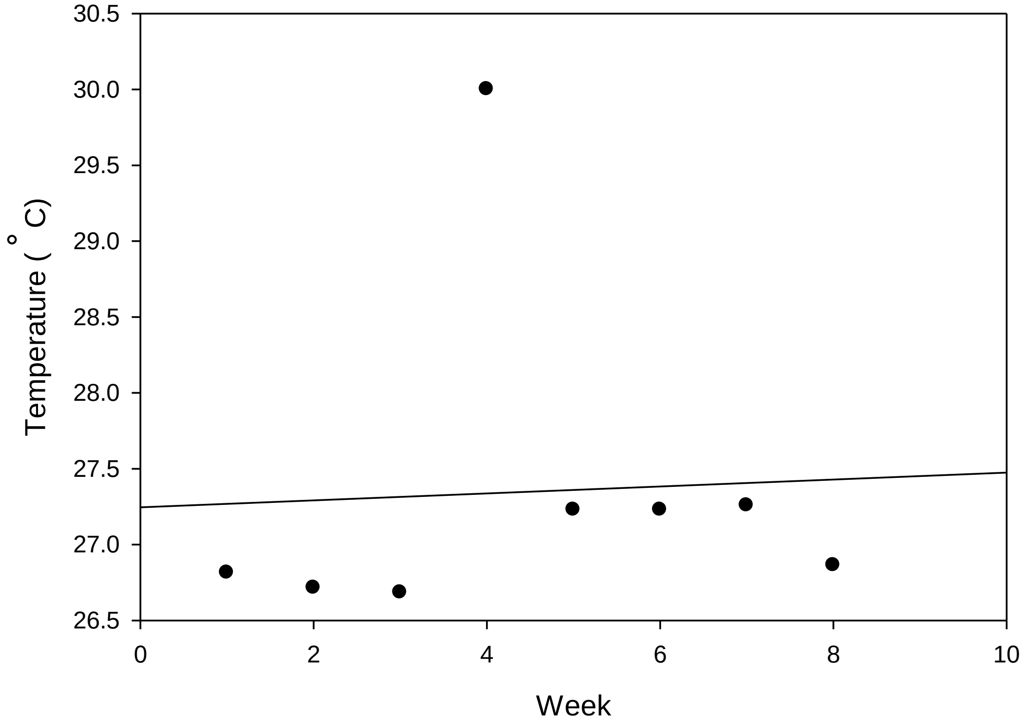


Figure 7.15 Changes in temperature throughout the course of the experiment

The temperature gradually increases throughout the course of the experiment with a sudden increase in temperature, up to 30 °C, during week four. The raw data for figure 7.15 can be found in appendix table 11.17.

Table 7.1 Weekly chemistry data

Date	NH_3 /NH_4 Ammonia (mg/L)	NO_2 Nitrite (mg/L)	NO_3 Nitrate (mg/L)	PO_4 Phosphate (ppm)	Ca Calcium (ppm)	Carbonate Hardness (dKH)	Mg Magnesium (mg/L)	pH	Total Iodine (ppm)
Start	0	0.15	5	0.045	480	13	1350	9.24	0.01
Week 1	0	0	5	0.045	480	9.9	1320	8.33	0
Week 2	0	0	10	0.06	450	9.6	1320	9.01	
Week 3	0	0	5	0.03	470	9.3	1380		
Week 4	0	0	5	0.03	475	9	1410	7.99	0
Week 5	0	0.15	5	0.045	470	9.9	1410	8.04	0.01
Week 6	0	0.15	5	0.03	470	9.6	1425	8.06	0.01
Week 7	0	0	5	0.03	470	10.2	1440	8	0.01
Week 8	0	0	5	0.045	490	8.3	1410	7.95	0.01

Ammonia was never traced in the water, nitrite only ever reached 0.15 mg/L and the highest value for nitrate was 10 mg/L, all of which fell within the recommended trace levels. Phosphate levels should not exceed 0.1 mg/L and all readings fell below this value. Calcium should be maintained at values of 400 – 450 mg/L. The calcium was normally found at levels higher than this. Carbonate hardness fell between the optimum range of 7 – 12 dKH, except for the start value which was higher at 13 dKH. The pH should range between 8.1 – 8.5, the pH was outside of this range during the starting week and weeks two, four, seven and eight. Iodine was found at the trace levels expected (Craggs, J. personal communication).

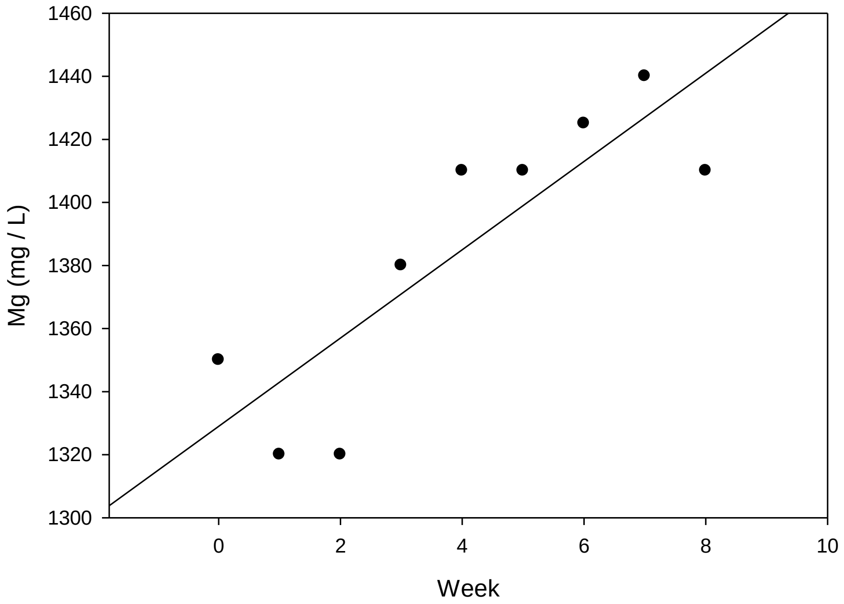


Figure 7.16 Changes in magnesium concentration over the course of the experiment

The magnesium increased throughout the experiment as seen in figure 7.16, this was a significant increase, ($R = 0.852$, $p<0.01$). This increased above the recommended range of 1320 – 1360 mg/L on week three.

7.3.2 Growth rate and PAR

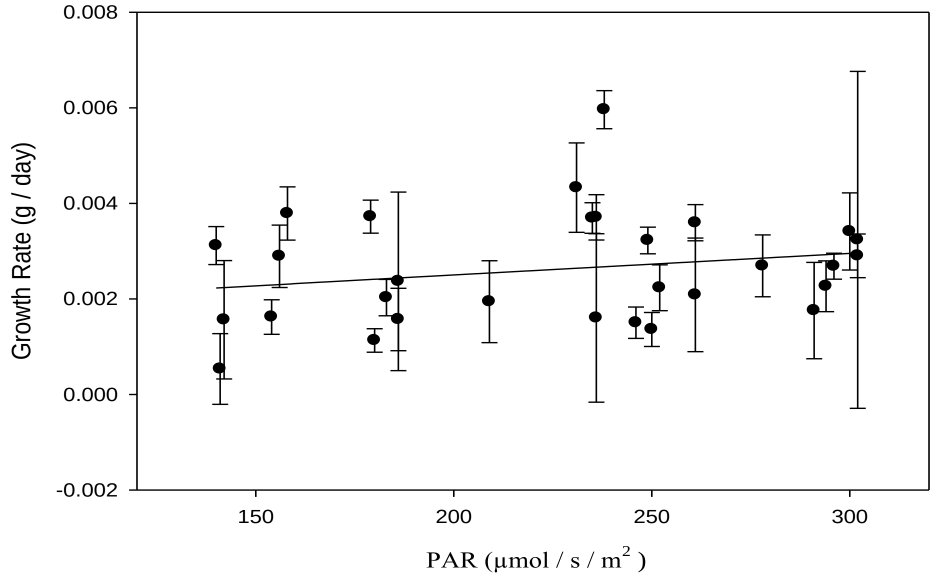


Figure 7.17 Relationship between growth rate and PAR for the LED tank with associated standard deviations

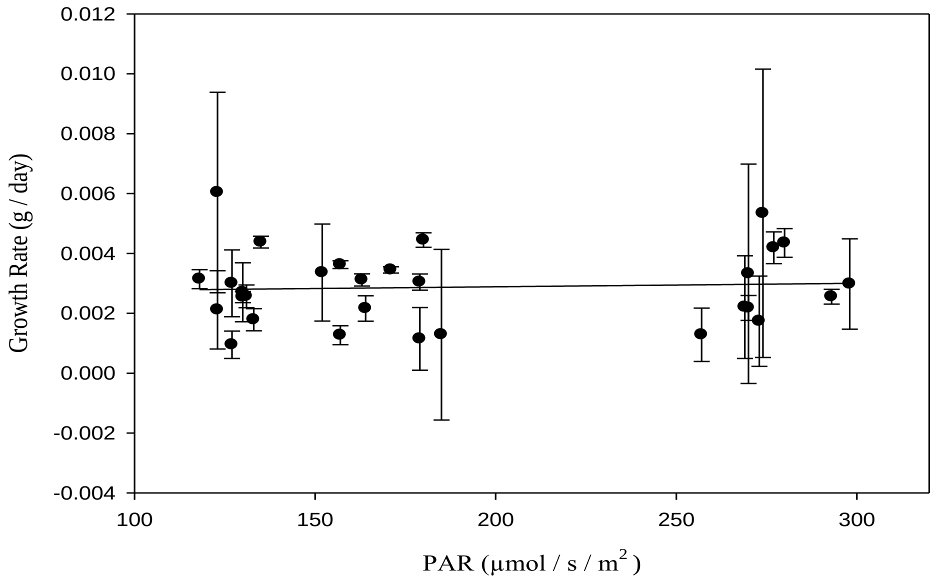


Figure 7.18 Relationship between growth rate and PAR for the T5 tank with associated standard deviations

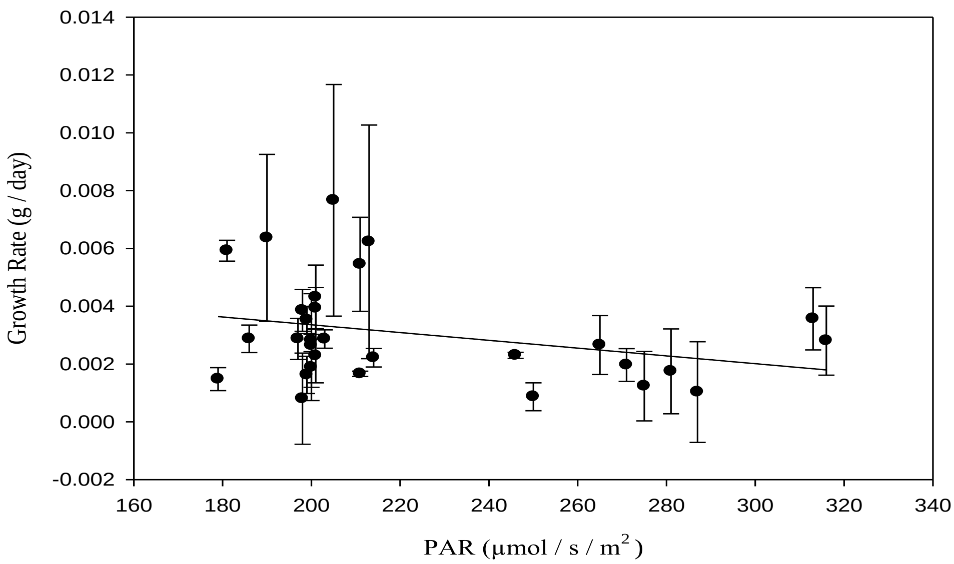


Figure 7.19 The relationship between growth rate and PAR for the metal halide tank with associated standard deviations

A positive relationship between PAR and growth rate was seen for the LED and T5 tanks, and a negative relationship for the metal halide tank.

A two-way ANOVA was carried out to see if there was a significant difference between PAR, growth rate and tank. It showed no significant difference between growth rate and tank ($F = 0.220$, $p = >0.05$) and growth rate and PAR ($F = 0.946$, p 0.05). The raw data for figures 7.17 – 7.19 can be found in appendix tables 11.14 – 11.16.

8. DISCUSSION

8.1 PAR Profiles

The PAR profiles created illustrate the point source nature of a metal halide light (Figure 7.3) and LED (Figure 7.1) while the T5 lights show a more even spread of light across the tanks (Figure 7.2). The metal halide did provide a more even spread of light in comparison to the LED and penetrated deeper than all the other lights.

This means that corals on the peripheries of the LED tank did not receive as high a PAR value. This is because it is a point source light which is not as powerful as the metal halide. The metal halide light is very powerful meaning higher PAR values were seen at deeper points in the tank (Strohmeyer 2010). This means that corals on the lower shelves were receiving more usable light energy.

8.2 Overall Growth Rate

During this experiment all of the corals showed a significant difference between their start and end weight, i.e. LED light ($t = 17.247, 16.788, p<0.01$), T5 light ($t = 14.482, 14.042, p<0.01$) and metal halide ($t = 13.532, 14.095, p<0.01$). The light energy reaching the corals is therefore providing sufficient energy for the *Symbiodinium* spp. to survive and produce photosynthates which the coral can use for growth. In other words the compensation point was met (Craggs, J. personal communication).

All the corals grew significantly and therefore the PAR levels were not high enough to cause photoinhibition. If the PAR readings were too high then we would not have seen an increase in growth in the beginning stages of the experiment and then a slight decrease (Figures 7.12 – 7.14). The light levels were kept constant at each coral and we would only see this pattern of growth if the light intensity was increased throughout the experiment.

Figure 7.11 shows that the lowest growth rate was experienced on the top level of the metal halide tank. The range of light on the top level for the LED tank was 302 – 236 µmol / s / m^2 giving a range of just 66 µmol / s / m^2, the T5 was 298 – 257 µmol / s / m^2 with a range of 41 µmol / s / m^2 and the halide was 316 – 200 µmol / s / m^2 giving a large range of 116 µmol / s / m^2. This shows that although the average PAR on the top levels were all similar the range of PARs for the metal halide means that some of the corals were gaining less light then the corals in the other two tanks.

All three tanks showed the same relationship between growth rates over the course of the experiment. All showed an initial increase in growth rate to a maximum and then the growth rate started to decrease. The LED light showed the slowest increase in growth rate and the metal halide the fastest. The LED and T5 ended up at about the same growth rate but the metal halide ended on a much higher average growth rate.

Light intensities were not changed during the course of the experiment so this cannot explain the trend seen. However, there was an increase in temperature, with a sudden rise occurring on week four up to 30 °C (Figure 7.15). The temperature did decrease after this but still remained about 1 °C higher than the previous weeks. This could explain the decrease in growth rate.

This increase in temperature could have caused an increase in photosynthesis. This could have resulted in more quinone acceptors becoming reduced and there therefore being less available to accept electrons. This could then lead to electron transport being slowed down, producing less energy and therefore a slower growth rate (Baker *et al*. 2005). The increase in temperature could also have produced reactive oxygen species. If these cannot be converted into oxygen and water by enzymes then damage to the D1 protein in photosystem II can occur. This can cause bleaching in extreme cases but here it may have just slowed down the growth rate (Weis 2008).

The reason for this pattern may be due to the fact that the concentration of magnesium increased above the recommended levels of 1200 to 1400 mg/L (Craggs, J. personal communication) at week four, the same time that the growth rate started to decrease (Figure 7.16). There was a significant increase in magnesium over the course of the experiment ($R = 0.852$, $p<0.01$).

It has been shown in previous experiments that magnesium can slow the growth rate of corals (Swart 1981). This is because it can bind with carbonate ions and become incorporated into the skeleton to form magnesium calcite. Magnesium calcite is not a good compound for further calcium carbonate to be laid down and therefore slows down the calcification process (Holmes-Farley 2003b).

It is also possible that as the corals grew and came close together, intraspecific competition may have decreased the growth rate. This has been demonstrated by Rinkevich and Loya (1985) with *Stylophora pistillata*. Intraspecific competition involves many different processes. One can occur by the use of pheromones released by neighboring corals which can reduce growth rate and also change growth patterns causing "retreat growth". If a change in growth pattern was observed where a more rounded shape occurred, as opposed to the typical plating form, then less light may reach the *Symbiodinium* spp. due to a decrease in the surface area to volume ratio. The pheromones released work over short distances, centimeters, which was the same proximity the corals were in during this investigation (Rinkevich and Loya 1983). The increase in energy being used in producing these chemicals therefore reduces the amount which could have been used on growth (Rinkevich and Loya 1985).

The pattern seen in these graphs may not be a true representation of what is actually occurring. This is because the error associated with each of the growth rates plotted is quite large and therefore the values for growth rate could fall anywhere within these error bars seen on figures 7.12 – 7.14.

There was no significant difference between the LED growth rate over time and the T5 ($t = -1.610$, $p > 0.05$) and between the T5 and the metal halide ($t = 0.986$, $p>0.05$). There was, however, a significant difference between the metal halide and the LED ($W = 30$, $p < 0.05$). The fact that the metal halide produced the largest overall growth rate means the results support the initial hypothesis. This may be because the metal halide's light intensity penetrated deeper (Figure 7.3) meaning more corals had a higher PAR reaching them then the LED or T5.

Light quality is also important. It has been shown that corals grown under light which peaks in the blue and white wavelengths show a better growth rate, health and algal densities (Kinzie *et al*. 1984). In terms of the lights used in this study all three lights show peaks in the blue spectrum. The LED lights even have white lights incorporated into them meaning they also provide white light. Although the metal halide has the least correspondence with the ideal spectrum it still produced the highest growth rates. This suggests that the overriding influence in this experiment is the deeper penetration from the metal halide source not quality of light.

However, it has been shown that all three lights at all depths did cause a significant increase in weight. Meaning *Montipora capricornis*, under these experimental conditions, can be grown and survive under all three lights tested.

8.3 Growth Rate And PAR

Figures 7.17 and 3.18 show that both the LED and T5 light showed a positive correlation with increases in PAR, and the metal halide showed a negative correlation with increases in PAR (Figure 7.19). The relationship between growth rate and tank ($F = 0.446$, $p = > 0.05$) and growth rate and PAR ($F = 0.946$, $p > 0.05$) were not significant .This means that the growth rate of the corals did not depend on the light under which they were grown or the PAR which they were subjected to.

8.4 Implications Of This Finding

The fact that all lights grew the corals means that the less efficient metal halides may not be the only option for growing corals. Metal halides, could in theory be replaced by more energy efficient lights in public aquariums and coral farms.

Table 8.1 The different lights costs and running costs

Light	Cost	Running cost / year
LED	£250	£13
T5	£175.95	£34
Metal Halide	£113	£110

(Bertram, S. personal communication, Westcott, G. personal communication)

8.4.1 Public aquariums

Metal halides have been widely used in the past because of the high output of light and they have also been found to offer the best option for public aquariums in terms of public viewing experience (Osinga 2009 in : Leewis *et al*. 2009).

The results of this experiment indicate that public aquariums may be able to replace less energy efficient metal halides with LED or T5 lights. It may not be practical to replace them with T5 lights because of the fact that the lights had to be in close proximity to the water's surface in order to achieve the growth rates found. Therefore in terms of cleaning, feeding and animal husbandry of the tanks, having the lights within 11 cm, compared to 27 cm for the LED and 44 cm for the metal halide lights, may not be feasible. Therefore the best option for replacement would be to use LED lights instead of metal halides.

This would mean that aquariums would further reduce their carbon footprint in accordance with WAZA's goals of reducing energy consumption in public aquariums (Penning *et al*. 2009). This replacement would depend on the size of the tanks. If the tank is quite deep then the output from an LED light may not be powerful enough to grow corals at deeper depths. These larger tanks may also require more LED lights compared to metal halides to reach the whole tank. There are, however submersible waterproof LED lights which could be placed within the tank allowing corals at depth to be lit and allow a good growth rate (Aquarium LED Lighting 2009).

8.4.2 Coral farms

Being able to use LED lights would also make it a more viable option for developing countries to grow corals inland because even though the initial costs are higher than those for metal halides the annual running costs will be reduced. This could therefore provide more employment options to people to move away from destructive fishing methods and into a more sustainable industry. The increase in coral farms would therefore reduce the pressure on wild populations (Delbeek 2001).

If, however, the coral farms need a fast growth rate to produce large corals quickly then the metal halide lights may be the best option. However, if an even spread of growth is required then a T5 may be the best option.

8.4.3 Research

In terms of scientific research a fast growth rate may be needed to reduce the time the experiment will need to be run which would reduce costs. However, if the experiment is going to run over a long period of time, and fast growth rates are not required, the LED or T5 may suffice and reduce the overall running costs of the research.

8.5 Further Work

This investigation has provided some useful information but it is still rather limited to an experimental set up. In order to see if these lights can actually sustain this coral and others in practical situations further experiments are needed.

Firstly, a wider range of corals would need to be tested. *Montipora capricornis* was chosen for this experiment because it is a hardy coral. The fact that it grew significantly under all three lights may not be representative for other more light sensitive species.

Also the fact that the metal halide did not have a wide a range of PARs as the other two lamps means that a deeper tank would be needed in order to test this light efficiently. Therefore a further experiment would involve more depths and more levels at which the corals would be placed. It would also be useful to measure the corals growth at a depth where a PAR reading of 0 occurred to see whether the corals can still grow and for how long they could grow with no light. Trying the lights out at deeper depths may also show the limitations of using the LED and T5 lights for larger tanks as they are not as powerful as the metal halide. This would give a more realistic outcome of their ability to be used in larger public aquarium tanks and coral farms. Further work would also involve testing out fully submersible waterproof LED lights to see what growth rates they produce and what sort of PAR profiles they could create.

The fact that the method for measuring volume created such high error associated with it would mean that a different method for measuring changes in volume would be needed. The reason this method was not very accurate was due to the subjective nature of determining when the bottom of the meniscus had reached the 230 ml mark. A more accurate way of measuring volume would be 3D photometry. This is where two cameras would be placed underwater to gain a 2D image which can then be analysed by software to create a much more accurate measure of volume (Abdo *et al*. 2006).

Other methods to measure photosynthesis directly would also be useful so it could be seen exactly how much growth can be attributed to photosynthesis directly. Such measures could include oxygen production with an oxygen electrode (Falkowski *et al.* 1990 in: Dubinsky 1990) or by measuring chlorophyll fluorescence with a flourometer (Rosenburg and Loya 2004). This provides' a more accurate test of the light's effects on photosynthetic rates.

The possible influence of intraspecific competition between corals means that in future experiments the fragments should be grown further apart. Intraspecific competition has not been studied in as much detail as interspecific competition and therefore this may be an interesting topic for further investigation. Also the fact that the increase in magnesium may also be slowing the growth rates of corals means that this may have to be controlled more stringently.

The influences from the other factors in the tank such as feeding and herbivory could also be eliminated. By not adding food and by removing herbivores only the effect of light would be being tested.

The experiment was also only run for eight weeks, and therefore in order to gain a more accurate picture a longer study running over years would be needed. This would allow other costs such as bulb replacement to be assessed and any effects due to deterioration of light sources over time to be recorded.

9. CONCLUSION

The increasing threats to coral reefs emphasise the importance of coral aquariums and farms. This study is important because it looked at the possibility of replacing metal halide lights with more energy efficient T5 and LED lighting. All three lights used do have the capabilities to grow *Montipora capricornis*. Even though the metal halide did produce the highest growth rates, the other two lights still significantly increased the weight of the corals. Therefore it depends on the function the lights need to perform as to which ones can be used. If a fast growth rate is required then the metal halides are still the best option. However, if a steady growth is required then there is the possibility for T5 or LED lighting being used. This would reduce the cost and increase the energy efficiency of these operations globally. However, these lights need to be tested in larger tanks, with a wider range of corals and for a longer period of time to fully determine the future of coral tank lighting.

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11. APPENDICES

11.1 PAR Profiles

Table 11.1 PAR values found at each co-ordinate in the LED tank

X (cm)	Y (cm)	Z (cm)	PAR (µmol / s / m^2)
0	0	0	35
0	0	10	42
0	0	20	40
0	0	30	33
0	0	40	18
0	0	44.5	21
10	0	0	90
10	0	10	102
10	0	20	119
10	0	30	110
10	0	40	86
10	0	44.5	65
20	0	0	95
20	0	10	115
20	0	20	148
20	0	30	136
20	0	40	112
20	0	44.5	98
30	0	0	111
30	0	10	138
30	0	20	175
30	0	30	168
30	0	40	146
30	0	44.5	116
40	0	0	127
40	0	10	153
40	0	20	183
40	0	30	187
40	0	40	158
40	0	44.5	125
50	0	0	126
50	0	10	154
50	0	20	187
50	0	30	190
50	0	40	165
50	0	44.5	148
60	0	0	111
60	0	10	143

60	0	20	185
60	0	30	188
60	0	40	155
60	0	44.5	126
70	0	10	153
70	0	20	166
70	0	30	174
70	0	40	140
70	0	44.5	120
80	0	0	75
80	0	10	125
80	0	20	136
80	0	30	146
80	0	40	125
80	0	44.5	110
89	0	0	66
89	0	10	104
89	0	20	115
89	0	30	106
89	0	40	96
89	0	44.5	82
0	10	0	73
0	10	10	75
0	10	20	78
0	10	30	85
0	10	40	60
0	10	44.5	55
10	10	0	80
10	10	10	83
10	10	20	101
10	10	30	96
10	10	40	83
10	10	44.5	70
20	10	0	84
20	10	10	120
20	10	20	134
20	10	30	130
20	10	40	103
20	10	44.5	87
30	10	0	100
30	10	10	153
30	10	20	198
30	10	30	186
30	10	40	157
30	10	44.5	114
40	10	0	113

40	10	10	183
40	10	20	220
40	10	30	230
40	10	40	203
40	10	44.5	158
50	10	0	102
50	10	10	179
50	10	20	223
50	10	30	219
50	10	40	180
50	10	44.5	158
60	10	0	96
60	10	10	140
60	10	20	206
60	10	30	238
60	10	40	194
60	10	44.5	164
70	10	0	114
70	10	10	209
70	10	20	233
70	10	30	225
70	10	40	152
70	10	44.5	125
80	10	0	80
80	10	10	141
80	10	20	170
80	10	30	159
80	10	40	145
80	10	44.5	120
89	10	0	68
89	10	10	90
89	10	20	111
89	10	30	124
89	10	40	108
89	10	44.5	90
0	20	0	65
0	20	10	72
0	20	20	75
0	20	30	72
0	20	40	56
0	20	44.5	34
10	20	0	75
10	20	10	106
10	20	20	130
10	20	30	123
10	20	40	114

10	20	44.5	95
20	20	0	93
20	20	10	143
20	20	20	203
20	20	30	198
20	20	40	194
20	20	44.5	163
30	20	0	121
30	20	10	173
30	20	20	218
30	20	30	236
30	20	40	178
30	20	44.5	138
40	20	0	109
40	20	10	178
40	20	20	238
40	20	30	253
40	20	40	208
40	20	44.5	156
50	20	0	92
50	20	10	210
50	20	20	252
50	20	30	260
50	20	40	230
50	20	44.5	164
60	20	0	107
60	20	10	164
60	20	20	236
60	20	30	263
60	20	40	210
60	20	44.5	163
70	20	0	80
70	20	10	196
70	20	20	236
70	20	30	214
70	20	40	163
70	20	44.5	143
80	20	0	72
80	20	10	181
80	20	20	142
80	20	30	163
80	20	40	184
80	20	44.5	125
89	20	0	71
89	20	10	96
89	20	20	118

89	20	30	124
89	20	40	108
89	20	44.5	89
0	30	0	61
0	30	10	67
0	30	20	73
0	30	30	64
0	30	40	45
0	30	44.5	42
10	30	0	57
10	30	10	106
10	30	20	164
10	30	30	160
10	30	40	108
10	30	44.5	80
20	30	0	97
20	30	10	161
20	30	20	234
20	30	30	227
20	30	40	183
20	30	44.5	101
30	30	0	115
30	30	10	228
30	30	20	260
30	30	30	240
30	30	40	171
30	30	44.5	116
40	30	0	94
40	30	10	176
40	30	20	264
40	30	30	302
40	30	40	278
40	30	44.5	138
50	30	0	120
50	30	10	277
50	30	20	314
50	30	30	261
50	30	40	222
50	30	44.5	157
60	30	0	120
60	30	10	176
60	30	20	291
60	30	30	302
60	30	40	227
60	30	44.5	146
70	30	0	129

70	30	10	173
70	30	20	265
70	30	30	296
70	30	40	231
70	30	44.5	146
80	30	0	78
80	30	10	137
80	30	20	193
80	30	30	236
80	30	40	180
80	30	44.5	122
89	30	0	69
89	30	10	97
89	30	20	114
89	30	30	112
89	30	40	106
89	30	44.5	80
0	40	0	65
0	40	10	73
0	40	20	70
0	40	30	59
0	40	40	54
0	40	44.5	45
10	40	0	71
10	40	10	160
10	40	20	177
10	40	30	182
10	40	40	93
10	40	44.5	66
20	40	0	75
20	40	10	150
20	40	20	282
20	40	30	252
20	40	40	126
20	40	44.5	75
30	40	0	87
30	40	10	156
30	40	20	267
30	40	30	297
30	40	40	268
30	40	44.5	129
40	40	0	84
40	40	10	172
40	40	20	280
40	40	30	350
40	40	40	287

40	40	44.5	124
50	40	0	82
50	40	10	170
50	40	20	317
50	40	30	369
50	40	40	326
50	40	44.5	135
60	40	0	73
60	40	10	168
60	40	20	387
60	40	30	370
60	40	40	213
60	40	44.5	170
70	40	0	89
70	40	10	163
70	40	20	291
70	40	30	359
70	40	40	310
70	40	44.5	137
80	40	0	58
80	40	10	120
80	40	20	215
80	40	30	242
80	40	40	168
80	40	44.5	112
89	40	0	50
89	40	10	72
89	40	20	105
89	40	30	132
89	40	40	110
89	40	44.5	81
0	44.5	0	48
0	44.5	10	59
0	44.5	20	61
0	44.5	30	48
0	44.5	40	47
0	44.5	44.5	38
10	44.5	0	58
10	44.5	10	83
10	44.5	20	137
10	44.5	30	183
10	44.5	40	85
10	44.5	44.5	64
20	44.5	0	81
20	44.5	10	179
20	44.5	20	311

20	44.5	30	231
20	44.5	40	125
20	44.5	44.5	78
30	44.5	0	83
30	44.5	10	189
30	44.5	20	270
30	44.5	30	302
30	44.5	40	259
30	44.5	44.5	103
40	44.5	0	76
40	44.5	10	139
40	44.5	20	213
40	44.5	30	346
40	44.5	40	209
40	44.5	44.5	107
50	44.5	0	77
50	44.5	10	161
50	44.5	20	271
50	44.5	30	398
50	44.5	40	249
50	44.5	44.5	129
60	44.5	0	68
60	44.5	10	138
60	44.5	20	291
60	44.5	30	378
60	44.5	40	219
60	44.5	44.5	130
70	44.5	0	64
70	44.5	10	176
70	44.5	20	311
70	44.5	30	297
70	44.5	40	173
70	44.5	44.5	115
80	44.5	0	54
80	44.5	10	106
80	44.5	20	183
80	44.5	30	195
80	44.5	40	126
80	44.5	44.5	94
89	44.5	0	48
89	44.5	10	59
89	44.5	20	92
89	44.5	30	112
89	44.5	40	109
89	44.5	44.5	83

The data found in table 7.1 has been used to create the PAR profile for the LED tank in figure 7.1.

Table 11.2 PAR values found at each co-ordinate in the T5 tank

X (cm)	Y (cm)	Z (cm)	PAR (µmol / s / m^2)
0	0	0	94
0	0	10	104
0	0	20	116
0	0	30	76
0	0	40	67
0	0	44.5	63
10	0	0	106
10	0	10	118
10	0	20	126
10	0	30	114
10	0	40	80
10	0	44.5	63
20	0	0	108
20	0	10	123
20	0	20	127
20	0	30	128
20	0	40	117
20	0	44.5	111
30	0	0	115
30	0	10	128
30	0	20	127
30	0	30	143
30	0	40	129
30	0	44.5	116
40	0	0	101
40	0	10	131
40	0	20	140
40	0	30	142
40	0	40	135
40	0	44.5	127
50	0	0	85
50	0	10	112
50	0	20	125
50	0	30	138
50	0	40	135
50	0	44.5	122
60	0	0	78
60	0	10	114
60	0	20	121
60	0	30	126
60	0	40	131

60	0	44.5	122
70	0	0	80
70	0	10	91
70	0	20	116
70	0	30	123
70	0	40	132
70	0	44.5	123
74	0	0	74
74	0	10	92
74	0	20	112
74	0	30	136
74	0	40	126
74	0	44.5	101
0	10	0	96
0	10	10	129
0	10	20	124
0	10	30	127
0	10	40	101
0	10	44.5	72
10	10	0	96
10	10	10	130
10	10	20	134
10	10	30	130
10	10	40	106
10	10	44.5	103
20	10	0	114
20	10	10	123
20	10	20	142
20	10	30	129
20	10	40	119
20	10	44.5	110
30	10	0	106
30	10	10	118
30	10	20	140
30	10	30	162
30	10	40	165
30	10	44.5	140
40	10	0	123
40	10	10	133
40	10	20	177
40	10	30	176
40	10	40	165
40	10	44.5	161
50	10	0	115
50	10	10	123
50	10	20	163

50	10	30	177
50	10	40	157
50	10	44.5	154
60	10	0	92
60	10	10	135
60	10	20	164
60	10	30	168
60	10	40	162
60	10	44.5	143
70	10	0	79
70	10	10	114
70	10	20	132
70	10	30	145
70	10	40	152
70	10	44.5	135
74	10	0	74
74	10	10	124
74	10	20	145
74	10	30	150
74	10	40	148
74	10	44.5	140
0	20	0	91
0	20	10	122
0	20	20	140
0	20	30	107
0	20	40	70
0	20	44.5	64
10	20	0	92
10	20	10	117
10	20	20	145
10	20	30	161
10	20	40	144
10	20	44.5	115
20	20	0	95
20	20	10	114
20	20	20	152
20	20	30	169
20	20	40	151
20	20	44.5	144
30	20	0	103
30	20	10	119
30	20	20	164
30	20	30	185
30	20	40	170
30	20	44.5	151
40	20	0	105

40	20	10	120
40	20	20	185
40	20	30	196
40	20	40	184
40	20	44.5	176
50	20	0	117
50	20	10	141
50	20	20	179
50	20	30	208
50	20	40	192
50	20	44.5	107
60	20	0	84
60	20	10	109
60	20	20	157
60	20	30	176
60	20	40	179
60	20	44.5	160
70	20	0	73
70	20	10	109
70	20	20	152
70	20	30	170
70	20	40	179
70	20	44.5	177
74	20	0	69
74	20	10	91
74	20	20	138
74	20	30	179
74	20	40	172
74	20	44.5	158
0	30	0	76
0	30	10	135
0	30	20	168
0	30	30	168
0	30	40	172
0	30	44.5	102
10	30	0	74
10	30	10	127
10	30	20	175
10	30	30	163
10	30	40	138
10	30	44.5	125
20	30	0	73
20	30	10	146
20	30	20	256
20	30	30	257
20	30	40	250

20	30	44.5	147
30	30	0	102
30	30	10	235
30	30	20	243
30	30	30	293
30	30	40	260
30	30	44.5	200
40	30	0	64
40	30	10	149
40	30	20	299
40	30	30	277
40	30	40	216
40	30	44.5	185
50	30	0	82
50	30	10	127
50	30	20	257
50	30	30	270
50	30	40	254
50	30	44.5	186
60	30	0	97
60	30	10	152
60	30	20	266
60	30	30	274
60	30	40	239
60	30	44.5	172
70	30	0	81
70	30	10	104
70	30	20	200
70	30	30	252
70	30	40	269
70	30	44.5	183
74	30	0	90
74	30	10	83
74	30	20	119
74	30	30	254
74	30	40	230
74	30	44.5	187
0	40	0	55
0	40	10	120
0	40	20	210
0	40	30	195
0	40	40	139
0	40	44.5	96
10	40	0	58
10	40	10	104
10	40	20	263

10	40	30	280
10	40	40	238
10	40	44.5	123
20	40	0	57
20	40	10	122
20	40	20	160
20	40	30	290
20	40	40	260
20	40	44.5	145
30	40	0	55
30	40	10	223
30	40	20	335
30	40	30	309
30	40	40	228
30	40	44.5	142
40	40	0	60
40	40	10	228
40	40	20	325
40	40	30	275
40	40	40	185
40	40	44.5	144
50	40	0	55
50	40	10	135
50	40	20	312
50	40	30	324
50	40	40	242
50	40	44.5	161
60	40	0	56
60	40	10	70
60	40	20	157
60	40	30	305
60	40	40	243
60	40	44.5	174
70	40	0	82
70	40	10	90
70	40	20	116
70	40	30	248
70	40	40	306
70	40	44.5	267
74	40	0	93
74	40	10	99
74	40	20	186
74	40	30	201
74	40	40	244
74	40	44.5	179
0	44.5	0	46

0	44.5	10	67
0	44.5	20	178
0	44.5	30	209
0	44.5	40	144
0	44.5	44.5	88
10	44.5	0	59
10	44.5	10	123
10	44.5	20	290
10	44.5	30	309
10	44.5	40	206
10	44.5	44.5	108
20	44.5	0	54
20	44.5	10	108
20	44.5	20	309
20	44.5	30	329
20	44.5	40	196
20	44.5	44.5	132
30	44.5	0	48
30	44.5	10	71
30	44.5	20	170
30	44.5	30	347
30	44.5	40	296
30	44.5	44.5	146
40	44.5	0	51
40	44.5	10	135
40	44.5	20	314
40	44.5	30	358
40	44.5	40	303
40	44.5	44.5	158
50	44.5	0	46
50	44.5	10	64
50	44.5	20	165
50	44.5	30	349
50	44.5	40	291
50	44.5	44.5	158
60	44.5	0	67
60	44.5	10	95
60	44.5	20	200
60	44.5	30	323
60	44.5	40	280
60	44.5	44.5	144
70	44.5	0	83
70	44.5	10	100
70	44.5	20	259
70	44.5	30	297
70	44.5	40	242

70	44.5	44.5	171
74	44.5	0	83
74	44.5	10	102
74	44.5	20	211
74	44.5	30	308
74	44.5	40	284
74	44.5	44.5	172

The data found in table 11.2 has been used to create the PAR profile for the T5 tank in figure 7.2.

Table 11.3 PAR values found at each co-ordinate in the metal halide tank

X (cm)	Y (cm)	Z (cm)	PAR (µmol / s / m^2)
0	0	0	102
0	0	10	119
0	0	20	93
0	0	30	63
0	0	40	59
0	0	44.5	61
10	0	0	87
10	0	10	155
10	0	20	138
10	0	30	114
10	0	40	100
10	0	44.5	79
20	0	0	165
20	0	10	158
20	0	20	128
20	0	30	100
20	0	40	89
20	0	44.5	84
30	0	0	175
30	0	10	183
30	0	20	134
30	0	30	108
30	0	40	96
30	0	44.5	89
40	0	0	172
40	0	10	180
40	0	20	156
40	0	30	128
40	0	40	114
40	0	44.5	100
50	0	0	176
50	0	10	170
50	0	20	141

50	0	30	119
50	0	40	100
50	0	44.5	97
60	0	0	153
60	0	10	190
60	0	20	152
60	0	30	130
60	0	40	112
60	0	44.5	98
70	0	0	243
70	0	10	231
70	0	20	188
70	0	30	134
70	0	40	127
70	0	44.5	109
74	0	0	186
74	0	10	257
74	0	20	214
74	0	30	175
74	0	40	140
74	0	44.5	111
0	10	0	177
0	10	10	235
0	10	20	174
0	10	30	130
0	10	40	86
0	10	44.5	74
10	10	0	155
10	10	10	193
10	10	20	170
10	10	30	138
10	10	40	106
10	10	44.5	99
20	10	0	182
20	10	10	198
20	10	20	162
20	10	30	133
20	10	40	102
20	10	44.5	99
30	10	0	218
30	10	10	214
30	10	20	187
30	10	30	165
30	10	40	128
30	10	44.5	201
40	10	0	240

40	10	10	205
40	10	20	173
40	10	30	148
40	10	40	130
40	10	44.5	103
50	10	0	195
50	10	10	190
50	10	20	173
50	10	30	145
50	10	40	128
50	10	44.5	101
60	10	0	219
60	10	10	210
60	10	20	197
60	10	30	160
60	10	40	133
60	10	44.5	115
70	10	0	240
70	10	10	268
70	10	20	220
70	10	30	204
70	10	40	160
70	10	44.5	120
74	10	0	270
74	10	10	264
74	10	20	216
74	10	30	171
74	10	40	144
74	10	44.5	128
0	20	0	200
0	20	10	265
0	20	20	178
0	20	30	142
0	20	40	100
0	20	44.5	90
10	20	0	205
10	20	10	213
10	20	20	174
10	20	30	144
10	20	40	130
10	20	44.5	124
20	20	0	186
20	20	10	224
20	20	20	186
20	20	30	163
20	20	40	136

20	20	44.5	119
30	20	0	228
30	20	10	258
30	20	20	213
30	20	30	187
30	20	40	141
30	20	44.5	114
40	20	0	223
40	20	10	251
40	20	20	200
40	20	30	171
40	20	40	142
40	20	44.5	119
50	20	0	208
50	20	10	231
50	20	20	200
50	20	30	167
50	20	40	143
50	20	44.5	111
60	20	0	216
60	20	10	242
60	20	20	179
60	20	30	139
60	20	40	118
60	20	44.5	102
70	20	0	288
70	20	10	276
70	20	20	222
70	20	30	191
70	20	40	172
70	20	44.5	132
74	20	0	254
74	20	10	289
74	20	20	238
74	20	30	207
74	20	40	163
74	20	44.5	139
0	30	0	246
0	30	10	248
0	30	20	213
0	30	30	180
0	30	40	90
0	30	44.5	83
10	30	0	185
10	30	10	232
10	30	20	208

10	30	30	169
10	30	40	122
10	30	44.5	99
20	30	0	248
20	30	10	246
20	30	20	201
20	30	30	165
20	30	40	147
20	30	44.5	115
30	30	0	287
30	30	10	305
30	30	20	281
30	30	30	316
30	30	40	171
30	30	44.5	130
40	30	0	307
40	30	10	354
40	30	20	311
40	30	30	313
40	30	40	172
40	30	44.5	126
50	30	0	267
50	30	10	314
50	30	20	268
50	30	30	250
50	30	40	164
50	30	44.5	129
60	30	0	276
60	30	10	270
60	30	20	230
60	30	30	200
60	30	40	150
60	30	44.5	100
70	30	0	296
70	30	10	273
70	30	20	241
70	30	30	189
70	30	40	122
70	30	44.5	111
74	30	0	315
74	30	10	308
74	30	20	250
74	30	30	240
74	30	40	132
74	30	44.5	104
0	40	0	228

0	40	10	243
0	40	20	215
0	40	30	196
0	40	40	155
0	40	44.5	102
10	40	0	214
10	40	10	260
10	40	20	228
10	40	30	177
10	40	40	152
10	40	44.5	117
20	40	0	278
20	40	10	297
20	40	20	256
20	40	30	189
20	40	40	171
20	40	44.5	118
30	40	0	316
30	40	10	341
30	40	20	272
30	40	30	214
30	40	40	163
30	40	44.5	117
40	40	0	337
40	40	10	372
40	40	20	369
40	40	30	286
40	40	40	198
40	40	44.5	129
50	40	0	289
50	40	10	326
50	40	20	317
50	40	30	269
50	40	40	216
50	40	44.5	125
60	40	0	276
60	40	10	320
60	40	20	272
60	40	30	203
60	40	40	198
60	40	44.5	99
70	40	0	250
70	40	10	247
70	40	20	220
70	40	30	157
70	40	40	115

70	40	44.5	96
74	40	0	269
74	40	10	272
74	40	20	239
74	40	30	166
74	40	40	106
74	40	44.5	95
0	45	0	239
0	45	10	221
0	45	20	195
0	45	30	150
0	45	40	144
0	45	44.5	116
10	45	0	236
10	45	10	250
10	45	20	233
10	45	30	168
10	45	40	150
10	45	44.5	109
20	45	0	290
20	45	10	310
20	45	20	268
20	45	30	201
20	45	40	185
20	45	44.5	122
30	45	0	320
30	45	10	354
30	45	20	296
30	45	30	233
30	45	40	170
30	45	44.5	134
40	45	0	340
40	45	10	381
40	45	20	371
40	45	30	299
40	45	40	186
40	45	44.5	119
50	45	0	250
50	45	10	339
50	45	20	299
50	45	30	243
50	45	40	230
50	45	44.5	150
60	45	0	288
60	45	10	356
60	45	20	311

60	45	30	280
60	45	40	203
60	45	44.5	100
70	45	0	264
70	45	10	269
70	45	20	240
70	45	30	164
70	45	40	127
70	45	44.5	109
74	45	0	259
74	45	10	281
74	45	20	234
74	45	30	170
74	45	40	100
74	45	44.5	94

The data found in table 11.3 has been used to create the PAR profile for the metal halide tank in figure 7.3.

Table 11.4 PAR value at each coral fragment in all three tanks

Coral	LED PAR (µmol / s / m^2)	T5 PAR (µmol / s / m^2)	Metal Halide PAR (µmol / s / m^2)
1	302	257	265
2	294	280	275
3	261	293	281
4	278	298	316
5	291	277	287
6	302	273	313
7	300	270	271
8	296	269	250
9	261	270	246
10	236	274	200
11	238	152	186
12	246	157	199
13	250	164	213
14	252	171	211
15	249	179	200
16	236	185	198
17	231	180	201
18	235	179	200
19	186	163	181
20	142	157	179
21	183	123	198
22	180	127	201
23	179	118	214
24	156	127	211

25	140	131	205
26	158	133	203
27	186	130	197
28	209	123	190
29	154	130	199
30	141	135	201

The PAR values for each coral were used to create figures 7.17 – 7.19.

11.2 Weight And Volume

Table 11.5 Measurements of volume and weight over the course of the experiment for the LED tank

		Volume (ml)				Weight (g)			
Week	**Coral**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
Start	1	4.31	4.45	4.86	4.54	1.27	1.26	1.28	1.27
15/06/2010	2	7.1	6.76	5.85	6.57	2.33	2.33	2.33	2.33
	3	7.3	8.16	6.8	7.42	2.29	2.31	2.3	2.3
	4	8.12	8.68	8.67	8.49	3.3	3.33	3.36	3.33
	5	4.84	5.63	5.88	5.45	1.38	1.37	1.39	1.38
	6	4.01	5.32	4.98	4.77	1.12	1.12	1.12	1.12
	7	5.1	6.94	8.27	6.77	2.08	2.08	2.08	2.08
	8	8.83	9.47	10.62	9.64	3.13	3.12	3.14	3.13
	9	5.31	6.23	5.71	5.75	2.03	2.03	2.03	2.03
	10	6.43	6.94	7.24	6.87	2.19	2.19	2.19	2.19
	11	6.73	7.56	5.78	6.69	2.32	2.32	2.32	2.32
	12	3.68	4.27	6.45	4.8	1.07	1.07	1.07	1.07
	13	6.31	6.97	6.34	6.54	2.79	2.79	2.79	2.79
	14	6.54	6.83	8.71	7.36	2.49	2.49	2.49	2.49
	15	7.3	8.47	10.3	8.69	3.28	3.28	3.28	3.28
	16	3.43	4.61	3.87	3.97	1.09	1.09	1.09	1.09
	17	6.53	6.84	7.63	7	2.08	2.08	2.08	2.08
	18	6.22	6.66	7.4	6.76	2.11	2.11	2.11	2.11
	19	8.93	9.41	7.67	8.67	3.33	3.33	3.33	3.33
	20	3.73	4.5	5.45	4.56	1.31	1.31	1.31	1.31
	21	5.36	5.9	4.55	5.27	1.3	1.3	1.3	1.3
	22	5.73	6.41	7.72	6.62	2.34	2.33	2.35	2.34
	23	7.14	6.86	6.7	6.9	2.34	2.34	2.34	2.34
	24	6.31	5.16	5.9	5.79	1.92	1.92	1.92	1.92
	25	5.63	5.78	5.18	5.53	1.98	1.95	1.95	1.96
	26	7.44	6.81	6.57	6.94	2.29	2.32	2.29	2.3
	27	5.66	5.21	5.93	5.6	1.4	1.4	1.4	1.4
	28	6.51	5.45	5.35	5.77	1.89	1.89	1.89	1.89
	29	8.04	7.48	7.49	7.67	2.86	2.88	2.87	2.87
	30	5.8	7.13	6.96	6.63	2.51	2.51	2.51	2.51
Week 1	1	5.76	4.61	4.63	5	1.33	1.33	1.33	1.33

22/06/2010	2	6.47	7.54	6.24	6.75	2.37	2.37	2.37	2.37
	3	6.48	7.23	6	6.57	2.29	2.29	2.29	2.29
	4	9.66	8.34	8.82	8.94	3.36	3.36	3.36	3.36
	5	4.81	5.71	6.19	5.57	1.38	1.38	1.38	1.38
	6	5.64	5.1	3.84	4.86	1.15	1.15	1.15	1.15
	7	7.4	6.84	6.67	6.97	2.16	2.16	2.16	2.16
	8	8.24	9.64	7.77	8.55	3.18	3.18	3.18	3.18
	9	6.9	7.24	6.53	6.89	2.07	2.07	2.07	2.07
	10	8.11	7.37	7.5	7.66	2.23	2.23	2.23	2.23
	11	6.53	7.94	8.06	7.51	2.43	2.43	2.43	2.43
	12	4.76	5.17	5.07	5	1.08	1.08	1.08	1.08
	13	8.46	7.38	7.23	7.69	2.78	2.81	2.81	2.8
	14	8.19	7.27	7.79	7.75	2.51	2.51	2.51	2.51
	15	9.68	9.11	8.21	9	3.33	3.36	3.33	3.34
	16	5.49	5.73	5.04	5.42	1.07	1.07	1.07	1.07
	17	6.34	7.08	9.35	7.59	2.11	2.11	2.11	2.11
	18	7.69	6.8	7.14	7.21	2.16	2.16	2.16	2.16
	19	10.27	9.54	9.71	9.84	3.28	3.28	3.28	3.28
	20	5.36	4.81	3.06	4.59	1.3	1.3	1.3	1.3
	21	4.73	5.44	6.54	5.57	1.31	1.31	1.31	1.31
	22	7.64	7.18	7.38	7.4	2.35	2.35	2.35	2.35
	23	8.16	8.75	7.06	7.99	2.41	2.41	2.41	2.41
	24	7.41	6.37	5.72	6.5	1.98	1.98	1.98	1.98
	25	6.84	6.99	6.99	6.94	2	2	2	2
	26	8.61	7.17	7.05	7.61	2.33	2.35	2.34	2.34
	27	4.87	5.67	5.51	5.35	1.4	1.4	1.4	1.4
	28	7.18	6.66	5.45	6.43	1.89	1.9	1.88	1.89
	29	7.51	7.69	7.18	7.46	2.92	2.92	2.92	2.92
	30	8.43	7.35	6.93	7.57	2.51	2.48	2.48	2.49
Week 2	1	5.83	5.06	5.7	5.53	1.36	1.36	1.36	1.36
29/06/2010	2	7.36	6.49	6.04	6.63	2.42	2.42	2.42	2.42
	3	7.67	6.94	6.21	6.94	2.4	2.42	2.41	2.41
	4	9.18	8.85	8.34	8.79	3.44	3.44	3.44	3.44
	5	5.44	4.84	3.73	4.67	1.39	1.39	1.39	1.39
	6	4.1	5.48	3.83	4.47	1.17	1.16	1.18	1.17
	7	5.34	6.99	8.04	6.79	2.18	2.18	2.18	2.18
	8	8.35	7.81	9.85	8.67	3.24	3.24	3.24	3.24
	9	7.24	6.73	6.91	6.96	2.15	2.15	2.15	2.15
	10	6.15	7.92	7.92	7.33	2.31	2.31	2.31	2.31
	11	7.77	6.82	7.91	7.5	2.54	2.54	2.54	2.54
	12	4.88	5.07	6.61	5.52	1.11	1.1	1	1.1
	13	8.67	7.19	6.25	7.37	2.85	2.84	2.83	2.84
	14	7.68	6.1	7.07	6.95	2.56	2.56	2.56	2.56
	15	10.27	9.11	8.28	9.22	3.43	3.43	3.43	3.43
	16	5.74	4.25	4.11	4.7	1.11	1.11	1.11	1.11
	17	7.54	6.37	5.68	6.53	2.22	2.22	2.22	2.22

	18	7.63	6.81	5.9	6.78	2.24	2.24	2.24	2.24
	19	9.53	8.71	9.54	9.26	3.48	3.48	3.48	3.48
	20	4.29	5.16	6.54	5.33	1.32	1.33	1.34	1.33
	21	4.31	5.95	3.36	4.54	1.34	1.34	1.34	1.34
	22	7.09	6.58	7.06	6.91	2.37	2.37	2.37	2.37
	23	7.46	6.84	5.86	6.72	2.48	2.48	2.48	2.48
	24	7.74	6.38	5.74	6.62	1.99	2.01	2	2
	25	5.6	6.22	5.31	5.71	2.07	2.07	2.07	2.07
	26	8.05	7.33	7.18	7.52	2.42	2.42	2.42	2.42
	27	5.46	4.87	4.31	4.88	1.44	1.44	1.44	1.44
	28	5.82	6.67	6.89	6.46	1.93	1.93	1.93	1.93
	29	8.16	7.48	7.94	7.86	2.94	2.94	2.94	2.94
	30	7.4	6.88	9.42	7.9	2.52	2.52	2.52	2.52
Week 3	1	7.43	6.38	5.54	6.45	1.13	1.15	1.14	1.14
06/07/2010	2	8.21	7.86	6.61	7.56	2.38	2.38	2.38	2.38
	3	7.02	6.61	6.2	6.61	2.44	2.44	2.44	2.44
	4	10.18	9.35	9.06	9.53	3.52	3.52	3.52	3.52
	5	5.09	4.52	5.36	4.99	1.42	1.42	1.42	1.42
	6	5.68	4.41	5.24	5.11	1.2	1.2	1.2	1.2
	7	6.48	5.55	6.75	6.26	2.22	2.23	2.21	2.22
	8	9.06	8.78	8.77	8.87	3.29	3.29	3.29	3.29
	9	7.15	8.85	6.29	7.43	2.2	2.2	2.2	2.2
	10	8.27	7.91	7.82	8	2.39	2.39	2.39	2.39
	11	9.62	8.34	7.69	8.55	2.64	2.64	2.64	2.64
	12	5.3	4.11	5.29	4.9	1.09	1.09	1.09	1.09
	13	8.23	7.65	6.59	7.49	2.88	2.88	2.88	2.88
	14	7.35	6.62	8.11	7.36	2.62	2.62	2.62	2.62
	15	9.81	10.47	9.27	9.85	3.52	3.52	3.52	3.52
	16	4.43	6.31	5.25	5.33	1.13	1.14	1.15	1.14
	17	6.37	7.3	9.01	7.56	2.29	2.29	2.29	2.29
	18	6.28	7.95	8.87	7.7	2.3	2.3	2.3	2.3
	19	10.56	9.87	8.22	9.55	3.48	3.48	3.48	3.48
	20	5.63	4.13	3.65	4.47	1.34	1.34	1.34	1.34
	21	6.72	5.47	4.61	5.6	1.36	1.36	1.36	1.36
	22	7.87	6.32	6.42	6.87	2.4	2.39	2.41	2.4
	23	8.91	7.32	8.82	8.35	2.54	2.54	2.54	2.54
	24	6.86	5.49	7.45	6.6	2.05	2.05	2.05	2.05
	25	7.35	6.41	5.5	6.42	2.11	2.11	2.11	2.11
	26	7.56	8.36	7.45	7.79	2.5	2.5	2.5	2.5
	27	4.1	5.78	3.02	4.3	1.45	1.45	1.45	1.45
	28	7.63	6.66	5.15	6.48	1.97	1.97	1.97	1.97
	29	6.38	7.1	9.44	7.64	2.97	2.97	2.97	2.97
	30	7	6.36	5.99	6.45	2.54	2.54	2.54	2.54
Week 4	1	5.98	4.34	6.21	5.41	1.44	1.44	1.44	1.44
13/07/2010	2	7.32	8.46	7.44	7.74	2.49	2.5	2.51	2.5
	3	7.03	6.15	7.67	6.95	2.46	2.46	2.46	2.46

	4	9.34	10.68	9.08	9.7	3.6	3.6	3.6	3.6
	5	6	5.47	6.2	5.89	1.48	1.47	1.49	1.48
	6	5.08	4.91	4.77	4.92	1.2	1.2	1.2	1.2
	7	8.13	7.26	7.05	7.48	2.27	2.27	2.27	2.27
	8	10.62	9.76	7.91	9.43	3.39	3.39	3.39	3.39
	9	6.83	5.18	7.7	6.57	2.24	2.24	2.24	2.24
	10	8.19	7.82	9.19	8.4	2.44	2.44	2.44	2.44
	11	6.49	7.38	9.29	7.72	2.72	2.72	2.72	2.72
	12	5.61	4.82	4.36	4.93	1.1	1.12	1.11	1.11
	13	8.16	7.59	7.65	7.8	2.91	2.91	2.91	2.91
	14	8.04	7.44	7.47	7.65	2.66	2.66	2.66	2.66
	15	10.57	9.36	8.27	9.4	3.58	3.58	3.58	3.58
	16	5.33	6.41	4.16	5.3	1.16	1.16	1.16	1.16
	17	8.16	7.88	6.22	7.42	2.34	2.35	2.36	2.35
	18	8.09	7.38	7.06	7.51	2.33	2.33	2.33	2.33
	19	11.56	10.4	9.27	10.41	3.65	3.65	3.65	3.65
	20	5.37	4.19	4.81	4.79	1.37	1.37	1.37	1.37
	21	5	4.82	4.79	4.87	1.37	1.39	1.38	1.38
	22	8.25	6.92	6.88	7.35	2.42	2.42	2.42	2.42
	23	8.39	7.41	8.68	8.16	2.6	2.6	2.6	2.6
	24	5.55	6.18	7.32	6.35	2.06	2.06	2.06	2.06
	25	7.58	6.98	6.32	6.96	2.15	2.14	2.13	2.14
	26	7.16	6.95	6.89	7	2.57	2.57	2.57	2.57
	27	5.62	4.15	6.19	5.32	1.46	1.46	1.46	1.46
	28	6.49	5.97	7.55	6.67	2	2.02	2.01	2.01
	29	8.74	7.23	9.05	8.34	2.98	3	2.99	2.99
	30	7.87	6.91	7.03	7.27	2.55	2.55	2.55	2.55
Week 5	1	5.63	4.97	5.72	5.44	1.47	1.45	1.46	1.46
20/07/2010	2	8.31	7.43	6.28	7.34	2.55	2.55	2.55	2.55
	3	7.53	6.91	7.13	7.19	2.5	2.5	2.5	2.5
	4	10.06	9.47	9.9	9.81	3.69	3.69	3.69	3.69
	5	6.82	5.61	4.88	5.77	1.5	1.5	1.5	1.5
	6	4.32	5.67	5.76	5.25	1.23	1.23	1.23	1.23
	7	8.16	7.61	8.05	7.94	2.32	2.32	2.32	2.32
	8	10.44	9.38	8.17	9.33	3.47	3.48	3.46	3.47
	9	6	7.64	6.91	6.85	2.3	2.3	2.3	2.3
	10	8.17	9.14	8.94	8.75	2.51	2.51	2.51	2.51
	11	8.46	7.83	8.85	8.38	2.83	2.83	2.83	2.83
	12	6.94	5.06	4.02	5.34	1.13	1.13	1.13	1.13
	13	6.48	7.28	9.07	7.61	2.94	2.94	2.94	2.94
	14	8.39	7.11	9.64	8.38	2.72	2.72	2.72	2.72
	15	10.01	9.36	9.97	9.78	3.68	3.68	3.68	3.68
	16	5.74	4.83	4.37	4.98	1.18	1.18	1.18	1.18
	17	8.61	7.95	5.49	7.35	2.45	2.45	2.45	2.45
	18	8.34	7.12	6.05	7.17	2.39	2.39	2.39	2.39
	19	10.43	9.27	9.76	9.82	3.74	3.73	3.72	3.73

	20	6.08	5.53	5.19	5.6	1.44	1.43	1.42	1.43
	21	3.27	4.97	6.34	4.86	1.4	1.4	1.4	1.4
	22	7.99	6.54	8.27	7.6	2.44	2.45	2.46	2.45
	23	7.28	8.94	9.55	8.59	2.65	2.65	2.65	2.65
	24	7.83	6.12	5.73	6.56	2.11	2.11	2.11	2.11
	25	6.33	7	7.07	6.8	2.18	2.18	2.18	2.18
	26	9.36	8.43	6.81	8.2	2.66	2.66	2.66	2.66
	27	4.25	5.76	6.07	5.36	1.49	1.49	1.49	1.49
	28	7.08	6.91	6.56	6.85	2.07	2.05	2.06	2.06
	29	7.77	6.14	9.04	7.65	3.01	3.01	3.01	3.01
	30	6.84	7.92	7.74	7.5	2.58	2.58	2.58	2.58
Week 6	1	6.16	5.29	5.56	5.67	1.47	1.47	1.47	1.47
27/07/2010	2	8.04	7.81	6.86	7.57	2.56	2.56	2.56	2.56
	3	6.32	7.81	8.1	7.41	2.47	2.47	2.47	2.47
	4	11.03	10.67	10.01	10.57	3.81	3.81	3.81	3.81
	5	6.24	5.5	4.97	5.57	1.55	1.54	1.53	1.54
	6	4.38	5.75	6.58	5.57	1.26	1.26	1.26	1.26
	7	6.48	7.63	8.87	7.66	2.37	2.37	2.37	2.37
	8	10.43	9.67	8.07	9.39	3.54	3.54	3.54	3.54
	9	6.32	7.18	9.18	7.56	2.38	2.38	2.38	2.38
	10	8.94	6.22	8.36	7.84	2.56	2.56	2.56	2.56
	11	10.43	9.16	8.43	9.34	2.96	2.96	2.96	2.96
	12	4.29	5.61	6	5.3	1.15	1.15	1.15	1.15
	13	7.28	8.31	9.07	8.22	2.98	2.98	2.98	2.98
	14	7.79	8.17	8.04	8	2.78	2.78	2.78	2.78
	15	11.27	10.39	9.93	10.53	3.79	3.78	3.8	3.79
	16	6.05	5.62	4.41	5.36	1.21	1.21	1.21	1.21
	17	7.58	6.37	11.73	8.56	2.55	2.55	2.55	2.55
	18	8.33	7.61	6.65	7.53	2.45	2.46	2.47	2.46
	19	9.43	10.86	11.54	10.61	3.79	3.79	3.79	3.79
	20	6.86	5.27	4.1	5.41	1.45	1.45	1.45	1.45
	21	6.09	5.53	5.12	5.58	1.43	1.43	1.43	1.43
	22	6.76	7.03	9.1	7.63	2.47	2.47	2.47	2.47
	23	9	8.16	11.01	9.39	2.7	2.7	2.7	2.7
	24	7.38	6.19	9.08	7.55	2.12	2.13	2.14	2.13
	25	8.69	6.23	7.52	7.48	2.21	2.21	2.21	2.21
	26	9.47	8.91	8.35	8.91	2.74	2.73	2.72	2.73
	27	4.8	5.39	7	5.73	1.52	1.52	1.52	1.52
	28	6.52	7.17	8.75	7.48	2.09	2.08	2.1	2.09
	29	9.02	8.88	8.08	8.66	3.05	3.05	3.05	3.05
	30	6.23	7.98	9.01	7.74	2.61	2.61	2.61	2.61
Week 7	1	7.18	6.24	6.38	6.6	1.52	1.53	1.54	1.53
03/08/2010	2	7.83	8.29	9.8	8.64	2.62	2.62	2.62	2.62
	3	8	6.82	8.07	7.63	2.58	2.58	2.58	2.58
	4	9.51	10.89	11.43	10.61	3.89	3.89	3.89	3.89
	5	5.34	4.86	6.48	5.56	1.55	1.55	1.55	1.55

	6	5.41	6.37	4.57	5.45	1.27	1.27	1.27	1.27
	7	7.36	6.43	8.17	7.32	2.43	2.42	2.41	2.42
	8	10.03	9.75	10.1	9.96	3.59	3.59	3.59	3.59
	9	6.41	7.28	8.87	7.52	2.42	2.42	2.42	2.42
	10	10.53	9.62	7.9	9.35	2.65	2.65	2.65	2.65
	11	9.27	8.53	9.71	9.17	3.06	3.06	3.06	3.06
	12	6.13	5.48	4.32	5.31	1.16	1.16	1.16	1.16
	13	8.09	7.8	7.87	7.92	3.01	3.01	3.01	3.01
	14	8.62	7.38	10.1	8.7	2.81	2.81	2.81	2.81
	15	9.34	10.56	10.1	10	3.87	3.87	3.87	3.87
	16	6.46	5.22	5.3	5.66	1.23	1.23	1.23	1.23
	17	7.14	8.62	9.74	8.5	2.64	2.64	2.64	2.64
	18	8.68	7.23	7.4	7.77	2.51	2.51	2.51	2.51
	19	11.46	10.73	10	10.73	3.88	3.88	3.88	3.88
	20	4.83	5.06	6.46	5.45	1.48	1.48	1.48	1.48
	21	5.6	4.85	5.45	5.3	1.45	1.44	1.43	1.44
	22	6.92	7.41	8.71	7.68	2.49	2.49	2.49	2.49
	23	8.66	7.89	9.61	8.72	2.78	2.78	2.78	2.78
	24	6.53	7.15	6.66	6.78	2.18	2.18	2.18	2.18
	25	7.17	6.38	7.18	6.91	2.25	2.25	2.25	2.25
	26	9.24	8.62	8.24	8.7	2.79	2.8	2.81	2.8
	27	4.98	6.75	5.1	5.61	1.53	1.53	1.53	1.53
	28	8	7.55	7.91	7.82	2.15	2.14	2.13	2.14
	29	6.31	7.52	9.45	7.76	3.08	3.08	3.08	3.08
	30	8.28	7.01	8.71	8	2.64	2.64	2.64	2.64
Week 8	1	7.03	6.34	6.88	6.75	1.56	1.58	1.57	1.57
10/08/2010	2	9.23	8.14	9.21	8.86	2.64	2.64	2.64	2.64
	3	8.63	7.19	8.15	7.99	2.62	2.62	2.62	2.62
	4	12.43	11.26	10.93	11.54	3.98	3.98	3.98	3.98
	5	7.62	6.43	5.63	6.56	1.57	1.57	1.57	1.57
	6	6.83	5.49	6.97	6.43	1.29	1.29	1.29	1.29
	7	7.25	8.94	9.43	8.54	2.46	2.46	2.46	2.46
	8	9.65	10.18	11.16	10.33	3.67	3.67	3.67	3.67
	9	6.83	7.29	8.83	7.65	2.48	2.48	2.48	2.48
	10	10.57	9.64	9.31	9.84	2.69	2.7	2.71	2.7
	11	9	8.99	10.69	9.56	3.18	3.18	3.18	3.18
	12	5.58	4.38	6.63	5.53	1.17	1.16	1.18	1.17
	13	8.31	7.29	9.96	8.52	3.03	3.03	3.03	3.03
	14	8.52	7.26	10.95	8.91	2.85	2.84	2.83	2.84
	15	11.62	10.74	9.83	10.73	3.97	3.96	3.98	3.97
	16	6.16	5.39	5.73	5.76	1.26	1.26	1.26	1.26
	17	9.02	8.57	8.87	8.82	2.69	2.69	2.69	2.69
	18	8.43	7.25	8.2	7.96	2.57	2.57	2.57	2.57
	19	11	12.98	11.63	11.87	3.97	3.97	3.97	3.97
	20	5.84	6.79	7.32	6.65	1.5	1.5	1.5	1.5
	21	4.89	5.27	7.63	5.93	1.47	1.47	1.47	1.47

22	9.64	8.73	6.53	8.3	2.5	2.51	2.52	2.51
23	8.35	9.14	9.69	9.06	2.81	2.81	2.81	2.81
24	7.77	6.41	7.75	7.31	2.2	2.2	2.2	2.2
25	9.72	8.38	7.16	8.42	2.29	2.29	2.29	2.29
26	9.46	8.24	8.58	8.76	2.88	2.88	2.88	2.88
27	7.08	6.53	7.27	6.96	1.55	1.55	1.55	1.55
28	7.27	6.94	7.81	7.34	2.17	2.17	2.17	2.17
29	7.35	8.15	10.33	8.61	3.11	3.11	3.11	3.11
30	9.73	8.61	7.46	8.6	2.69	2.69	2.69	2.69

Table 11.5 contains the three repeat measurements for weight and volume and the averages of these for each coral in the LED tank. The averages for weight were used to determine growth rate.

Table 11.6 Measurements of volume and weight over the course of the experiment for the T5 tank

		Volume (ml)				Weight (g)			
Week	**Coral**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
Start	1	5.9	6.81	6.49	6.4	2.06	2.06	2.06	2.06
15/06/2010	2	4.65	6.2	6.55	5.8	1.64	1.64	1.64	1.64
	3	5.83	4.68	5.6	5.37	1.23	1.23	1.24	1.22
	4	8.5	7.52	7.86	7.96	2.25	2.25	2.25	2.25
	5	6.89	5.74	7.5	6.71	2.07	2.07	2.07	2.07
	6	4.86	5.37	7.02	5.75	1.45	1.44	1.45	1.46
	7	4.75	4.63	4.69	4.69	1.12	1.12	1.12	1.12
	8	5.61	6.32	4.81	5.58	1.42	1.42	1.42	1.42
	9	5.95	6.57	7.67	6.73	2.14	2.14	2.14	2.14
	10	7.56	6.49	6.44	6.83	2.64	2.64	2.64	2.64
	11	9.24	8.34	7.92	8.5	2.94	2.94	2.94	2.94
	12	6.15	7.89	5.55	6.53	2.13	2.13	2.13	2.13
	13	5.53	5.74	5.17	5.48	1.65	1.65	1.65	1.65
	14	11.5	10.49	9.72	10.57	4.32	4.32	4.32	4.32
	15	4	4.67	4.53	4.4	1.31	1.31	1.31	1.31
	16	10.84	9.37	9.16	9.79	4.26	4.26	4.26	4.26
	17	5.18	6.4	6.3	5.96	2.37	2.37	2.37	2.37
	18	6.57	6.33	6.72	6.54	2.35	2.35	2.35	2.35
	19	4.94	5.46	6.25	5.55	1.62	1.62	1.62	1.62
	20	9.41	8.22	8.11	8.58	3.38	3.37	3.39	3.38
	21	11.59	10	9.34	10.31	3.38	3.38	3.38	3.38
	22	5.3	8.45	6.47	6.74	2.33	2.33	2.32	2.34
	23	7.54	7.33	7.09	7.32	2.41	2.41	2.41	2.41
	24	6.04	7.77	5.06	6.29	2.19	2.19	2.19	2.19
	25	5.4	4.28	5.32	5	1.48	1.48	1.48	1.48
	26	4.61	4.85	4.85	4.77	1.27	1.27	1.27	1.27
	27	6.14	6.87	4.99	6	1.84	1.83	1.84	1.85
	28	6	5.37	6.54	5.97	1.89	1.89	1.89	1.89
	29	8.64	7.55	8.71	8.3	2.68	2.68	2.68	2.68

	30	6.44	5.67	5.11	5.74	1.55	1.55	1.55	1.55
Week 1	1	6.79	6.42	6.77	6.66	2.02	2.05	2.08	2.05
22/06/2010	2	5.87	6.27	5.65	5.93	1.67	1.64	1.73	1.68
	3	5.44	5.91	5.33	5.56	1.25	1.23	1.27	1.25
	4	8.34	6.62	7.42	7.46	2.25	2.26	2.21	2.24
	5	7.16	6.55	6.78	6.83	2.16	2.15	2.14	2.15
	6	6.82	5.76	4.34	5.64	1.43	1.43	1.43	1.43
	7	4.61	4.92	4.51	4.68	1.13	1.13	1.13	1.13
	8	7.13	6.24	5.56	6.31	1.4	1.4	1.4	1.4
	9	5.27	6.38	8.81	6.82	2.12	2.14	2.13	2.13
	10	8.61	7.39	7.25	7.75	2.65	2.68	2.68	2.67
	11	10.22	10.14	8.26	9.54	3.04	3.04	3.04	3.04
	12	6.43	6.81	6.71	6.65	2.14	2.14	2.14	2.14
	13	6.37	7.16	6.24	6.59	1.67	1.67	1.67	1.67
	14	11.1	10.64	10.18	10.64	4.42	4.42	4.42	4.42
	15	5.71	6.38	4.8	5.63	1.28	1.31	1.31	1.3
	16	11.67	12.3	10.68	11.55	4.19	4.19	4.19	4.19
	17	7.19	6.48	6.94	6.87	2.44	2.44	2.44	2.44
	18	8.61	7.46	5.98	7.35	2.41	2.41	2.41	2.41
	19	5.5	4.96	4.39	4.95	1.66	1.66	1.66	1.66
	20	8.63	9	8.17	8.6	3.47	3.47	3.47	3.47
	21	10.61	9.41	8.93	9.65	3.72	3.72	3.72	3.72
	22	6.27	6.94	7.79	7	2.35	2.34	2.33	2.34
	23	8.35	7.19	7.17	7.57	2.47	2.47	2.47	2.47
	24	6.66	6.38	6.58	6.54	2.19	2.19	2.19	2.19
	25	6.45	5.6	4.96	5.67	1.5	1.5	1.5	1.5
	26	5.32	4.85	4.62	4.93	1.28	1.28	1.28	1.28
	27	7.15	6.43	7.27	6.95	1.88	1.88	1.88	1.88
	28	7.36	6.86	5.94	6.72	1.9	1.88	1.89	1.89
	29	8.43	7.17	6.84	7.48	2.73	2.73	2.73	2.73
	30	5.69	5.62	5.1	5.47	1.6	1.6	1.6	1.6
Week 2	1	5.32	6.95	6.36	6.21	2.07	2.09	2.08	2.08
29/06/2010	2	6.38	5.24	5.03	5.55	1.72	1.73	1.74	1.73
	3	5.94	6.31	5.75	6	1.27	1.27	1.27	1.27
	4	7.35	6.54	8.91	7.6	2.33	2.34	2.35	2.34
	5	7.15	6.76	5.74	6.55	2.18	2.18	2.18	2.18
	6	6.83	5.66	5.33	5.94	1.49	1.49	1.49	1.49
	7	5.38	4.07	5.04	4.83	1.15	1.15	1.15	1.15
	8	6.21	7.68	5.16	6.35	1.48	1.48	1.48	1.48
	9	6.92	7.61	6.47	7	2.21	2.21	2.21	2.21
	10	7.5	6.18	7.2	6.96	2.69	2.71	2.7	2.7
	11	11.05	10.47	10.1	10.54	2.97	2.97	2.97	2.97
	12	5.39	6.21	7.78	6.46	2.18	2.18	2.18	2.18
	13	4.82	6.37	5.61	5.6	1.69	1.69	1.69	1.69
	14	12.62	11.38	10.86	11.62	4.53	4.53	4.53	4.53
	15	6.46	5.92	4.54	5.64	1.32	1.32	1.32	1.32

	16	11.11	12.68	12.21	12	4.02	4.02	4.02	4.02
	17	8.31	7.47	7.23	7.67	2.53	2.53	2.53	2.53
	18	7.5	8.41	8.09	8	2.46	2.46	2.46	2.46
	19	6.18	5.95	4.37	5.5	1.69	1.68	1.7	1.69
	20	10.74	9.34	8.9	9.66	3.55	3.55	3.55	3.55
	21	10.57	11.32	12.61	11.5	3.57	3.57	3.57	3.57
	22	8.62	7.33	7.57	7.84	2.48	2.48	2.48	2.48
	23	6.28	7.43	9.27	7.66	2.52	2.52	2.52	2.52
	24	5.42	6.38	5.15	5.65	2.21	2.21	2.21	2.21
	25	5.55	4.41	4.29	4.75	1.53	1.53	1.53	1.53
	26	5.37	6.14	5.08	5.53	1.3	1.3	1.3	1.3
	27	7.16	6.92	5.15	6.41	1.95	1.95	1.95	1.95
	28	6.05	5.65	5.82	5.84	1.91	1.91	1.91	1.91
	29	9.61	8.25	8.15	8.67	2.77	2.77	2.77	2.77
	30	7.32	6.14	5.89	6.45	1.64	1.64	1.64	1.64
Week 3	1	6.1	5.41	6.37	5.96	2.13	2.13	2.13	2.13
06/07/2010	2	7.05	6.13	7.4	6.86	1.8	1.8	1.8	1.8
	3	6.73	5.38	7.51	6.54	1.29	1.29	1.29	1.29
	4	7.46	6.83	8.12	7.47	2.43	2.43	2.43	2.43
	5	7.34	6.65	8.72	7.57	2.27	2.27	2.27	2.27
	6	5.94	6	7.59	6.51	1.51	1.53	1.52	1.52
	7	5.23	6.43	5.08	5.58	1.17	1.18	1.19	1.18
	8	4.31	6.82	5.52	5.55	1.49	1.5	1.51	1.5
	9	9.25	8.07	7.58	8.3	2.75	2.76	2.74	2.75
	10	10	9.36	9.23	9.53	3.22	3.22	3.22	3.22
	11	11.38	11.2	10.09	10.89	3	3	3	3
	12	6.89	5.52	7.87	6.76	2.19	2.19	2.19	2.19
	13	7.32	5.61	6.93	6.62	1.7	1.71	1.72	1.71
	14	12.78	11.35	10.67	11.6	4.65	4.65	4.65	4.65
	15	5.83	6.24	5.57	5.88	1.36	1.36	1.36	1.36
	16	12.2	11.47	10.68	11.45	4.52	4.52	4.52	4.52
	17	7	8.64	9.86	8.5	2.6	2.6	2.6	2.6
	18	8.05	7.11	8.54	7.9	2.5	2.5	2.5	2.5
	19	7.23	6.14	6.28	6.55	1.73	1.73	1.73	1.73
	20	10.07	9.53	9.23	9.61	3.66	3.66	3.66	3.66
	21	11.74	10.86	9.53	10.71	3.92	3.92	3.92	3.92
	22	6.5	7.28	9.11	7.63	2.51	2.51	2.51	2.51
	23	7.63	6.61	9.19	7.81	2.56	2.55	2.57	2.56
	24	6.21	7.03	7.55	6.93	2.23	2.23	2.23	2.23
	25	5.57	4.99	4.29	4.95	1.56	1.56	1.56	1.56
	26	6.38	5.21	5.06	5.55	1.31	1.31	1.31	1.31
	27	7.89	6.16	5.33	6.46	2	2.02	2.01	2.01
	28	7.34	6.51	6.1	6.65	1.93	1.93	1.93	1.93
	29	8.03	7.55	8.12	7.9	2.83	2.83	2.83	2.83
	30	6.38	7.73	8.78	7.63	1.7	1.7	1.7	1.7
Week 4	1	6.64	5.83	5.89	6.12	2.14	2.14	2.14	2.14

13/07/2010	2	5.94	6.53	5.53	6	1.87	1.87	1.87	1.87
	3	6.38	7.22	6.38	6.66	1.33	1.33	1.33	1.33
	4	7.38	6.99	8.58	7.65	2.49	2.49	2.49	2.49
	5	7.03	6.45	6.59	6.69	2.33	2.32	2.31	2.32
	6	7.38	6.28	6.92	6.86	1.56	1.55	1.54	1.55
	7	6.19	5.83	5.14	5.72	1.2	1.2	1.2	1.2
	8	6.38	6.15	4.63	5.72	1.54	1.54	1.54	1.54
	9	9.08	8.22	7.87	8.39	2.28	2.29	2.3	2.29
	10	9.62	10.54	8.64	9.6	3.8	3.8	3.8	3.8
	11	11.42	10.37	9.59	10.46	3.32	3.33	3.34	3.33
	12	6.23	7.86	6.91	7	2.19	2.19	2.19	2.19
	13	5.31	6.85	5.84	6	1.79	1.79	1.79	1.79
	14	12.47	11.35	11.88	11.9	4.76	4.76	4.76	4.76
	15	5.5	6.38	6.48	6.12	1.4	1.4	1.4	1.4
	16	11	10.92	12.28	11.4	4.62	4.62	4.62	4.62
	17	8.34	7.62	8.04	8	2.71	2.71	2.71	2.71
	18	6	7.26	6.66	6.64	2.56	2.56	2.56	2.56
	19	5.49	6.85	4.19	5.51	1.77	1.77	1.77	1.77
	20	10.02	9.43	9.74	9.73	3.76	3.75	3.74	3.75
	21	11.57	10.61	9.8	10.66	4.01	4.03	4.02	4.02
	22	6.37	7.85	6.78	7	2.58	2.58	2.58	2.58
	23	8.31	7.89	7.05	7.75	2.66	2.66	2.66	2.66
	24	5.62	6.34	4.84	5.6	2.25	2.25	2.25	2.25
	25	6.38	5.16	5.71	5.75	1.59	1.59	1.59	1.59
	26	5.07	4.33	5.27	4.89	1.33	1.33	1.33	1.33
	27	7.56	6.43	5.54	6.51	1.96	1.96	1.96	1.96
	28	5.23	6.91	7.33	6.49	2.03	2.04	2.05	2.04
	29	7.09	6.86	6.84	6.93	2.9	2.9	2.9	2.9
	30	7.1	5.81	5.54	6.15	1.77	1.76	1.75	1.76
Week 5	1	6.79	6.52	7.39	6.9	2.19	2.19	2.19	2.19
20/07/2010	2	8.32	7.64	6.12	7.36	1.94	1.94	1.94	1.94
	3	7.06	6.85	5.92	6.61	1.36	1.36	1.36	1.36
	4	8.16	7.43	8.05	7.88	2.58	2.58	2.58	2.58
	5	6.48	5.73	10.41	7.54	2.37	2.38	2.39	2.38
	6	6.67	5.72	6.39	6.26	1.57	1.57	1.57	1.57
	7	5.31	6.82	3.47	5.2	1.23	1.22	1.21	1.22
	8	6.37	5.92	3.97	5.42	1.57	1.57	1.57	1.57
	9	9.5	8.13	7.69	8.44	2.36	2.34	2.35	2.35
	10	8.73	8.34	10.98	9.35	2.82	2.83	2.84	3.83
	11	11.38	10.62	9.68	10.56	3.44	3.44	3.44	3.44
	12	6.38	7.05	8.2	7.21	2.22	2.22	2.22	2.22
	13	6.51	5	5.44	5.65	1.79	1.79	1.79	1.79
	14	12.13	11.57	11.7	11.8	4.89	4.89	4.89	4.89
	15	6.83	5.47	4.8	5.7	1.36	1.36	1.36	1.36
	16	13.62	12.36	10.71	12.23	4.73	4.73	4.73	4.73
	17	8.82	7.14	7.56	7.84	2.79	2.77	2.78	2.78

	18	8.42	7.37	6.89	7.56	2.6	2.6	2.6	2.6
	19	7.26	6.33	5.79	6.46	1.81	1.81	1.81	1.81
	20	10.15	9.21	9.83	9.73	3.84	3.84	3.84	3.84
	21	10.56	11.72	12.88	11.72	4.12	4.1	4.11	4.11
	22	6.59	7.62	8.02	7.41	2.61	2.61	2.61	2.61
	23	9.36	8.26	7.94	8.52	2.71	2.71	2.71	2.71
	24	7.18	5.99	6.48	6.55	2.27	2.28	2.29	2.28
	25	6.83	5.06	5.12	5.67	1.66	1.66	1.66	1.66
	26	3.97	4.56	5.93	4.82	1.36	1.36	1.36	1.36
	27	7.27	6.14	5.79	6.4	1.98	1.98	1.98	1.98
	28	7.45	6.47	5.79	6.57	2.09	2.09	2.09	2.09
	29	9.17	7.14	8.74	8.35	2.93	2.93	2.93	2.93
	30	7.75	6.86	7.56	7.39	1.82	1.83	1.81	1.82
Week 6	1	8.32	6.56	7.56	7.48	2.22	2.22	2.22	2.22
27/07/2010	2	6.83	7.07	8.78	7.56	1.99	2	2.01	2
	3	4.93	5.67	6.05	5.55	1.37	1.37	1.37	1.37
	4	9.16	8.27	8.52	8.65	2.66	2.65	2.64	2.65
	5	8.14	7.82	7.92	7.96	2.45	2.45	2.45	2.45
	6	5.34	6.67	7.52	6.51	1.6	1.6	1.6	1.6
	7	4.25	5.19	4.87	4.77	1.23	1.23	1.23	1.23
	8	7.84	6.52	5.08	6.48	1.6	1.6	1.6	1.6
	9	7.16	7.43	8.21	7.6	2.4	2.4	2.4	2.4
	10	8.85	7.51	7.61	7.99	2.87	2.86	2.88	2.87
	11	9.99	10.73	12.16	10.96	3.54	3.54	3.54	3.54
	12	7.62	6.89	6.01	6.84	2.26	2.26	2.26	2.26
	13	6.37	5.02	6.43	5.94	1.82	1.82	1.82	1.82
	14	12.64	12.83	12.21	12.56	5.02	5.02	5.02	5.02
	15	6.51	5.76	4.59	5.62	1.39	1.39	1.39	1.39
	16	13.26	12.63	12.75	12.88	4.84	4.84	4.84	4.84
	17	9.83	8.27	7.58	8.56	2.88	2.87	2.86	2.87
	18	8.32	7.49	9.93	8.58	2.65	2.65	2.65	2.65
	19	7.21	6.92	6.33	6.82	1.85	1.85	1.85	1.85
	20	11.46	10.83	12.66	11.65	3.94	3.94	3.94	3.94
	21	12.06	11.41	12.29	11.92	3.93	3.93	3.93	3.93
	22	8.4	9.57	6.24	8.07	2.64	2.64	2.64	2.64
	23	8.26	7.19	10.83	8.76	2.68	2.69	2.7	2.69
	24	6.35	7.81	8.7	7.62	2.31	2.31	2.31	2.31
	25	7.35	6.29	5.89	6.51	1.66	1.66	1.66	1.66
	26	6.13	5.52	5.33	5.66	1.39	1.39	1.39	1.39
	27	7	6.43	6.37	6.6	2	2	2	2
	28	8.46	7.1	7.12	7.56	2.17	2.16	2.15	2.16
	29	8.37	7.26	10.35	8.66	2.94	2.94	2.94	2.94
	30	7.34	6.89	6.23	6.82	1.88	1.87	1.86	1.87
Week 7	1	7.36	6.12	7.31	6.93	2.26	2.26	2.26	2.26
03/08/2010	2	8.31	7.86	6.51	7.56	2.05	2.05	2.05	2.05
	3	6.27	5.92	6.14	6.11	1.4	1.41	1.42	1.41

	4	8.53	7.63	10.24	8.8	2.63	2.63	2.63	2.63
	5	8.26	7.11	7.85	7.74	2.52	2.52	2.52	2.52
	6	7.15	6.82	5.38	6.45	1.62	1.62	1.62	1.62
	7	4.76	5.39	6.95	5.7	1.26	1.26	1.26	1.26
	8	6.41	5.98	7.41	6.6	1.63	1.63	1.63	1.63
	9	7.08	8.36	9.25	8.23	2.43	2.43	2.43	2.43
	10	8.53	7.1	7.95	7.86	2.93	2.93	2.93	2.93
	11	11.56	10.42	10.27	10.75	3.52	3.52	3.52	3.52
	12	7.61	6.35	5.81	6.59	2.28	2.28	2.28	2.28
	13	4.51	5.92	7.12	5.85	1.85	1.85	1.85	1.85
	14	12.64	11.74	11.56	11.98	5.12	5.13	5.14	5.13
	15	6.38	5.13	5.56	5.69	1.4	1.41	1.42	1.41
	16	13	12.42	12.29	12.57	4.86	4.86	4.86	4.86
	17	10.58	9.24	8.77	9.53	2.93	2.93	2.93	2.93
	18	7.62	6.38	9.07	7.69	2.71	2.71	2.71	2.71
	19	5.83	6.47	4.74	5.68	1.88	1.88	1.88	1.88
	20	11.75	10.23	10.45	10.81	4.02	4.02	4.02	4.02
	21	12.04	11.86	12.01	11.97	4.27	4.27	4.27	4.27
	22	8.52	7.26	10.08	8.62	2.68	2.68	2.68	2.68
	23	10.85	9.67	8.1	9.54	2.79	2.8	2.81	2.8
	24	7	6.38	7.42	6.9	2.34	2.34	2.34	2.34
	25	4.68	5.37	7.32	5.79	1.68	1.68	1.68	1.68
	26	6.28	5.61	4.79	5.56	1.41	1.41	1.41	1.41
	27	7.97	6.1	6.09	6.72	2.03	2.03	2.03	2.03
	28	8.64	7.92	9.51	8.69	2.21	2.21	2.21	2.21
	29	8.94	7.35	10.29	8.86	3.05	3.04	3.03	3.04
	30	8.32	7.61	7.47	7.8	1.91	1.91	1.91	1.91
Week 8	1	8.43	7.28	7.78	7.83	2.29	2.29	2.29	2.29
10/08/2010	2	8.03	7.85	8	7.96	2.09	2.09	2.09	2.09
	3	6.23	5.94	5.02	5.73	1.42	1.42	1.42	1.42
	4	9.34	8.67	9.62	9.21	2.72	2.72	2.72	2.72
	5	8.2	7.14	11.06	8.8	2.58	2.58	2.58	2.58
	6	6.51	5.55	7.2	6.42	1.66	1.66	1.66	1.66
	7	6.43	5.29	7.78	6.5	1.27	1.27	1.27	1.27
	8	6.98	5.24	8.45	6.89	1.65	1.65	1.65	1.65
	9	8.73	7.64	10	8.79	2.46	2.47	2.48	2.47
	10	8.97	7.51	10.01	8.83	3	3	3	3
	11	11.45	10.83	10.18	10.82	3.55	3.55	3.55	3.55
	12	8.32	7.16	8.52	8	2.32	2.32	2.32	2.32
	13	6.53	7.81	5.67	6.67	1.87	1.87	1.87	1.87
	14	13.61	12.07	12.75	12.81	5.21	5.21	5.21	5.21
	15	6.73	5.24	5.91	5.96	1.44	1.43	1.42	1.43
	16	11.75	12.38	14.27	12.8	4.86	4.87	4.85	4.86
	17	9.55	10.37	8.58	9.5	2.98	2.98	2.98	2.98
	18	8.73	7.61	9.82	8.72	2.75	2.75	2.75	2.75
	19	7.06	6.83	6.81	6.9	1.89	1.89	1.89	1.89

20	12.43	11.71	10.12	11.42	4.09	4.08	4.1	4.09
21	11.7	12.53	11.31	11.88	4.11	4.11	4.11	4.11
22	6.91	6.84	9.29	7.68	2.71	2.71	2.71	2.71
23	9.46	8.37	9.56	9.13	2.85	2.84	2.86	2.85
24	6.15	7.28	7.12	6.85	2.36	2.36	2.36	2.36
25	6.89	5.16	5.8	5.95	1.71	1.71	1.71	1.71
26	6	5.24	6.46	5.9	1.43	1.43	1.43	1.43
27	7.46	6.25	8.22	7.31	2.03	2.04	2.05	2.04
28	6.92	6.17	10.31	7.8	2.26	2.26	2.26	2.26
29	8.97	7.31	10.42	8.9	3.1	3.1	3.1	3.1
30	7.64	6.83	8.06	7.51	1.96	1.96	1.96	1.96

Table 11.6 contains the three repeat measurements for weight and volume and the averages of these for each coral in the T5 tank. The averages for weight were used to determine growth rate.

Table 11.7 Measurements of volume and weight over the course of the experiment for the metal halide tank

		Volume (ml)				Weight (g)			
Week	**Coral**	**1**	**2**	**3**	**Average**	**1**	**2**	**3**	**Average**
Start	1	7.26	6.58	6.59	6.81	2	2	2	2
15/06/2010	2	4.61	5.37	3.91	4.63	1	1	1	1
	3	5.5	4.21	4.81	4.84	0.8	0.81	0.82	0.81
	4	5.31	4.95	4.74	5	1.12	1.12	1.12	1.12
	5	7.18	6.41	7.71	7.1	2.23	2.23	2.23	2.23
	6	6.48	6.88	6.62	6.66	2.04	2.04	2.04	2.04
	7	9.76	8.51	7.41	8.56	3.66	3.66	3.66	3.66
	8	7.64	6.38	5.87	6.63	2.57	2.58	2.59	2.58
	9	10.84	10.37	10.8	10.67	3.94	3.94	3.94	3.94
	10	5.62	6.71	5.52	5.95	1.86	1.86	1.86	1.86
	11	5.82	6.43	7.7	6.65	2.19	2.19	2.19	2.19
	12	11.2	10.46	10.74	10.8	4.23	4.23	4.23	4.23
	13	5.71	4.44	3.11	4.42	1.19	1.19	1.19	1.19
	14	6.24	5.09	8.65	6.66	1.88	1.88	1.88	1.88
	15	6.24	5.91	5.85	6	1.86	1.86	1.89	1.87
	16	5.41	6.37	5.5	5.76	1.94	1.94	1.94	1.94
	17	6.56	5.99	4.4	5.65	1.83	1.83	1.83	1.83
	18	7.18	8.25	8.12	7.85	3.17	3.17	3.17	3.17
	19	7.34	7.82	7.07	7.41	2.29	2.29	2.29	2.29
	20	6.47	5.49	7.27	6.41	2.07	2.05	2.06	2.06
	21	4.83	5.37	3.66	4.62	1.03	1.03	1.03	1.03
	22	7.51	6.26	8.7	7.49	2.5	2.52	2.51	2.51
	23	4.67	3.76	3.12	3.85	0.97	0.97	0.97	0.97
	24	6.91	5.86	7.84	6.87	2.91	2.91	2.91	2.91
	25	7.16	6.48	5.77	6.47	1.51	1.51	1.51	1.51
	26	8.05	7.61	8.01	7.89	2.85	2.85	2.85	2.85
	27	5.38	6.18	4.97	5.51	1.62	1.62	1.62	1.62

	28	5.71	6.85	6.76	6.44	1.93	1.93	1.93	1.93
	29	6.49	5.45	6.03	5.99	1.89	1.89	1.89	1.89
	30	7.86	6.73	6.08	6.89	2.29	2.29	2.29	2.29
Week 1	1	7.46	6.38	7.85	7.23	2.04	2.04	2.04	2.04
22/06/2010	2	4.37	5.61	3.94	4.64	0.99	0.99	0.99	0.99
	3	4.58	4.17	3.13	3.96	0.8	0.8	0.8	0.8
	4	5.36	4.91	4.7	4.75	1.12	1.12	1.12	1.12
	5	6.3	5.41	7.07	6.26	2.18	2.18	2.18	2.18
	6	6.5	5.12	6.17	5.93	2.08	2.08	2.08	2.08
	7	10.47	9.46	9.29	9.74	3.68	3.68	3.68	3.68
	8	6.85	7.77	8.18	7.6	2.58	2.57	2.59	2.58
	9	10.62	9.13	9.35	9.67	4.01	4.01	4.01	4.01
	10	6.4	5.76	5.51	5.89	1.86	1.86	1.86	1.86
	11	6.5	6.89	5.96	6.45	2.22	2.22	2.22	2.22
	12	11.2	10.48	9.31	10.33	4.3	4.3	4.3	4.3
	13	5.61	4.35	4.62	4.86	1.19	1.18	1.17	1.18
	14	8.17	6.48	7.76	7.47	2	2	2	2
	15	6.41	7.54	7.05	7	1.88	1.86	1.87	1.87
	16	6.49	4.66	6.31	5.82	2	2	2	2
	17	7.08	6.32	6.19	6.53	1.83	1.83	1.83	1.83
	18	9.4	8.16	9.08	8.88	3.22	3.23	3.21	3.22
	19	8.43	7.38	7.92	7.91	2.4	2.4	2.4	2.4
	20	6.41	5.82	5.47	5.9	2.07	2.07	2.07	2.07
	21	5	4.63	4.83	4.82	1.02	1	1.01	1.01
	22	8.07	7.83	8.01	7.97	2.61	2.61	2.61	2.61
	23	4.94	3.68	4.88	4.5	0.98	0.98	0.98	0.98
	24	7.8	7.65	7.8	7.75	2.95	2.93	2.94	2.94
	25	5.61	5.99	5.95	5.85	1.54	1.54	1.54	1.54
	26	7.54	6.85	5.74	6.71	2.91	2.91	2.91	2.91
	27	6.75	6.14	6.19	6.36	1.65	1.65	1.65	1.65
	28	6.66	5.38	5.57	5.87	2	2.03	2.03	2.02
	29	6.38	5.73	5.83	5.98	1.95	1.95	1.95	1.95
	30	7.31	7.68	7.63	7.54	2.4	2.4	2.4	2.4
Week 2	1	8.33	9.25	7.32	8.3	2.08	2.06	2.07	2.07
29/06/2010	2	5.64	6.17	4.15	5.32	1.01	1.01	1.01	1.01
	3	5	5.15	4.55	4.9	0.84	0.82	0.83	0.83
	4	5.68	6.37	4.93	5.66	1.16	1.16	1.16	1.16
	5	7.42	6.39	7.19	7	2.27	2.27	2.27	2.27
	6	7.35	6.24	7.41	7	2.14	2.14	2.14	2.14
	7	10.44	9.85	9.14	9.81	3.75	3.75	3.75	3.75
	8	6.32	7.56	7.75	7.21	2.59	2.6	2.61	2.6
	9	11	10.37	9.32	10.23	4.07	4.07	4.07	4.07
	10	5.87	6.11	5.69	5.89	1.89	1.89	1.89	1.89
	11	7.18	7.37	8.37	7.64	2.3	2.28	2.29	2.29
	12	10.37	11.46	9.25	10.36	4.25	4.25	4.22	4.24
	13	3.72	2.96	4.12	3.6	1.25	1.23	1.21	1.23

	14	6.64	5.85	5.51	6	2.06	2.06	2.06	2.06
	15	6.52	7.38	5.48	6.46	1.9	1.9	1.9	1.9
	16	7.3	6.38	8.07	7.25	2.03	2.03	2.03	2.03
	17	5.31	6.84	4.47	5.54	1.89	1.89	1.89	1.89
	18	9.57	8.88	9.75	9.4	3.29	3.29	3.29	3.29
	19	7.18	6.92	8.76	7.62	2.47	2.47	2.47	2.47
	20	7.68	6.34	5.96	6.66	2.1	2.1	2.1	2.1
	21	5.2	6.31	3.49	5	1.03	1.03	1.03	1.03
	22	7.28	6.3	8.2	7.26	2.66	2.65	2.64	2.66
	23	4.49	6.34	2.16	4.33	1	1	1	1
	24	7.45	6.94	9.16	7.85	2.98	2.98	2.98	2.98
	25	6.44	5.37	8.92	6.91	1.58	1.58	1.58	1.58
	26	7.36	8.19	9.23	8.26	2.97	2.97	2.97	2.97
	27	6.38	7.41	5.41	6.4	1.68	1.68	1.68	1.68
	28	6.76	5.46	5.78	6	1.99	1.98	1.97	1.98
	29	5.38	6.37	6.25	6	2	2	2	2
	30	9	8.32	8.51	8.61	2.38	2.38	2.38	2.38
Week 3	1	8.43	7.81	7.16	7.8	2.01	2.01	2.01	2.01
06/07/2010	2	5.55	4.61	3.55	4.57	1.02	1.02	1.02	1.02
	3	4.85	3.73	5.22	4.6	0.83	0.84	0.85	0.84
	4	4.75	5.19	4.46	4.8	1.19	1.19	1.19	1.19
	5	7.63	6.08	7.05	6.92	2.29	2.29	2.29	2.29
	6	8.48	7.36	7.41	7.75	2.28	2.28	2.28	2.28
	7	10.36	9.4	9.67	9.81	3.8	3.79	3.78	3.79
	8	6.81	7.53	7.86	7.4	2.61	2.61	2.61	2.61
	9	12.31	11.67	10.52	11.5	4.12	4.12	4.12	4.12
	10	6.73	4.91	5.01	5.55	1.9	1.9	1.9	1.9
	11	6.49	7.72	8.86	7.69	2.32	2.32	2.32	2.32
	12	11.36	10.22	10.58	10.72	4.41	4.41	4.41	4.41
	13	4.43	3.29	3.23	3.65	1.29	1.29	1.29	1.29
	14	8	7.16	7.73	7.63	2.12	2.12	2.12	2.12
	15	6.38	7.04	5.33	6.25	1.95	1.94	1.93	1.94
	16	7.33	6.86	6.39	6.86	2.06	2.08	2.07	2.07
	17	6.19	5.53	7.39	6.37	1.93	1.93	1.93	1.93
	18	9.01	8.35	9.34	8.9	3.37	3.36	3.35	3.36
	19	7.61	8.34	9.46	8.47	2.59	2.59	2.59	2.59
	20	6.62	5.89	6.69	6.4	2.11	2.11	2.11	2.11
	21	4	5.81	3.99	4.6	1.05	1.05	1.05	1.05
	22	8.34	7.64	8.56	8.18	2.73	2.73	2.73	2.73
	23	5.61	4.47	3.81	4.63	1.02	1.02	1.02	1.02
	24	9.16	8.49	8.99	8.88	3.02	3.02	3.02	3.02
	25	6.6	5.31	5.22	5.71	1.62	1.62	1.62	1.62
	26	10.03	9.04	8.44	9.17	3.05	3.05	3.05	3.05
	27	6.14	5.89	8.07	6.7	1.72	1.72	1.72	1.72
	28	6.37	5.44	7.09	6.3	2.13	2.13	2.13	2.13
	29	5.58	6.83	3.85	5.42	2.03	2.03	2.03	2.03

	30	7.11	8.5	8.39	8	2.5	2.5	2.5	2.5
Week 4	1	7.33	6.59	8.37	7.43	2.17	2.17	2.17	2.17
13/07/2010	2	4.25	5.12	4.46	4.61	1.04	1.06	1.05	1.05
	3	4.52	3.98	4.58	4.36	0.86	0.86	0.86	0.86
	4	5.12	4.67	5.21	5	1.22	1.22	1.22	1.22
	5	6.83	5.18	7.52	6.51	2.34	2.34	2.34	2.34
	6	6.34	7.25	6.69	6.76	2.13	2.13	2.13	2.13
	7	10.27	9.61	9.34	9.74	3.87	3.88	3.89	3.88
	8	7.65	6.25	7.61	7.17	2.66	2.65	2.64	2.65
	9	10.34	11.26	10.62	10.74	4.2	4.2	4.2	4.2
	10	5.08	5.75	5.19	5.34	1.95	1.95	1.95	1.95
	11	6.16	5.75	5.79	5.9	2.36	2.37	2.38	2.37
	12	11.63	10.42	9.12	10.39	4.45	4.47	4.46	4.46
	13	6	5.24	6.46	5.9	1.52	1.52	1.52	1.52
	14	9.33	8.16	8.01	8.5	2.19	2.19	2.19	2.19
	15	5.2	5.89	4.9	5.33	2.11	2.11	2.11	2.11
	16	7.32	6.55	5.78	6.55	2.1	2.1	2.1	2.1
	17	7.08	6.91	6.83	6.94	1.98	1.98	1.98	1.98
	18	10.27	9.83	8.1	9.4	3.39	3.39	3.39	3.39
	19	8.76	7.86	8.79	8.47	2.69	2.69	2.69	2.69
	20	6.43	5.97	6.83	6.41	2.15	2.15	2.15	2.15
	21	5.34	4.99	3.92	4.75	1.07	1.07	1.07	1.07
	22	8.73	7.64	8.92	8.43	2.78	2.79	2.8	2.79
	23	4	3.95	4.53	4.16	1.04	1.04	1.04	1.04
	24	9.14	8.49	8.08	8.57	3.05	3.05	3.05	3.05
	25	5.36	6.61	6.03	6	2.18	2.18	2.18	2.18
	26	8.21	7.82	6.74	7.59	3.1	3.1	3.1	3.1
	27	5.33	6.54	5.53	5.8	1.78	1.77	1.76	1.77
	28	6.02	5.75	5.87	5.88	2.14	2.15	2.13	2.14
	29	7.86	6.37	5.51	6.58	2.06	2.07	2.08	2.07
	30	8.56	7.68	7.25	7.83	2.56	2.56	2.56	2.56
Week 5	1	7.36	6.19	6.22	6.59	2.22	2.22	2.22	2.22
20/07/2010	2	3.87	4.28	6.1	4.75	1.05	1.07	1.06	1.06
	3	3.68	4.52	4.7	4.3	0.88	0.88	0.88	0.88
	4	6.21	5.94	3.93	5.36	1.26	1.26	1.26	1.26
	5	7.35	6.46	8.18	7.33	2.36	2.36	2.36	2.36
	6	6.53	7	8.37	7.3	2.33	2.33	2.33	2.33
	7	11.2	10.35	8.96	10.17	3.95	3.95	3.95	3.95
	8	8.14	7.85	6.54	7.51	2.69	2.69	2.69	2.69
	9	11.67	10.26	12.87	11.6	4.28	4.27	4.26	4.27
	10	6.66	5.31	6.03	6	2	2	2	2
	11	6.18	5.98	6.44	6.2	2.41	2.41	2.41	2.41
	12	10.34	11.62	9.69	10.55	4.5	4.5	4.5	4.5
	13	6.82	7.16	6.54	6.84	4.68	4.68	4.68	4.68
	14	9.65	8.39	7.64	8.56	2.21	2.21	2.21	2.21
	15	5.38	6.97	5.29	5.88	2.16	2.16	2.16	2.16

	16	7.03	6.35	7.38	6.92	2.21	2.21	2.21	2.21
	17	6.22	5.38	7.24	6.28	2	2.01	2.02	2.01
	18	10.56	9.26	8.26	9.36	3.48	3.48	3.48	3.48
	19	9.15	8.96	7.24	8.45	2.81	2.81	2.81	2.81
	20	6.23	5.84	7.64	6.57	2.19	2.18	2.2	2.19
	21	4.33	5.81	3.99	4.71	1.09	1.09	1.09	1.09
	22	8.19	7.87	8.84	8.3	2.83	2.83	2.83	2.83
	23	4.27	3.93	4.73	4.31	1.05	1.05	1.05	1.05
	24	8.36	7.18	8.16	7.9	3.08	3.08	3.08	3.08
	25	7.05	6.38	7.45	6.96	2.23	2.23	2.23	2.23
	26	9.61	8.64	7.85	8.7	3.09	3.09	3.09	3.09
	27	7.68	6.32	4.96	6.32	1.7	1.7	1.7	1.7
	28	6	5.28	6.12	5.8	2.8	2.82	2.81	2.81
	29	6.14	5.26	7.5	6.3	2.14	2.13	2.12	2.13
	30	8.12	7.85	9.71	8.56	2.67	2.67	2.67	2.67
Week 6	1	6.91	7.23	9.26	7.8	2.29	2.29	2.29	2.29
27/07/2010	2	6.27	5.8	4.16	5.41	1.1	1.1	1.1	1.1
	3	5.34	4.29	5.43	5.02	0.9	0.9	0.9	0.9
	4	6.19	5.87	5.4	5.82	1.3	1.3	1.3	1.3
	5	8	7.24	7.59	7.61	2.41	2.41	2.41	2.41
	6	9.71	8.39	7.58	8.56	2.4	2.4	2.4	2.4
	7	11.04	10.56	11.22	10.94	4.03	4.04	4.05	4.04
	8	8.59	7.83	6.65	7.69	2.68	2.68	2.68	2.68
	9	10.8	11.64	11.88	11.44	4.34	4.34	4.34	4.34
	10	5.31	6.49	7.73	6.51	2.08	2.09	2.1	2.09
	11	6.24	5.87	6.88	6.33	2.49	2.48	2.5	2.49
	12	11.58	10.43	10.87	10.96	4.53	4.52	4.51	4.52
	13	6.32	7.16	7.88	7.12	4.7	4.7	4.7	4.7
	14	10.43	8.95	8.31	9.23	2.25	2.25	2.25	2.25
	15	6.47	5.08	7.05	6.2	2.19	2.19	2.19	2.19
	16	6.81	7.26	7.98	7.35	7	7	7	7
	17	5.86	6.57	6.92	6.45	2.05	2.05	2.05	2.05
	18	10.24	9.28	9.28	9.6	3.57	3.57	3.57	3.57
	19	8.66	9.13	9.21	9	2.94	2.94	2.94	2.94
	20	8.27	7.02	6.79	7.36	2.23	2.23	2.23	2.23
	21	5.45	4.19	4.61	4.75	1.11	1.11	1.11	1.11
	22	8.58	9.29	10.15	9.34	2.91	2.91	2.91	2.91
	23	4.31	5.44	7.35	5.7	1.07	1.07	1.07	1.07
	24	9	8.72	8.26	8.66	3.13	3.13	3.13	3.13
	25	6.62	7.38	9.16	7.72	2.31	2.31	2.31	2.31
	26	8.51	9.79	10.53	9.61	3.16	3.15	3.17	3.16
	27	5.88	6.15	7.8	6.61	1.89	1.89	1.89	1.89
	28	6.28	5.43	5.87	5.86	2.83	2.82	2.81	2.82
	29	7.11	6.38	7.33	6.94	2.16	2.16	2.16	2.16
	30	8.93	7.31	10.31	8.85	2.77	2.77	2.77	2.77
Week 7	1	7.83	6.34	9.17	7.78	2.35	2.35	2.35	2.35

03/08/2010	2	6.23	5.41	5.25	5.63	1.1	1.1	1.1	1.1
	3	6.19	5.82	4.49	5.5	0.92	0.92	0.92	0.92
	4	6.03	5.79	5.91	5.91	1.33	1.34	1.32	1.33
	5	6.38	7.52	8.48	7.46	2.44	2.45	2.43	2.44
	6	8.26	7.12	8.5	7.96	2.47	2.47	2.47	2.47
	7	10.93	11.82	11.69	11.48	4.13	4.13	4.13	4.13
	8	8.63	7.51	7.59	7.91	2.77	2.77	2.77	2.77
	9	11.3	12.57	13.93	12.6	4.4	4.4	4.4	4.4
	10	7.25	6.13	7.17	6.85	2.15	2.15	2.15	2.15
	11	6.38	5.09	8.51	6.66	2.52	2.52	2.52	2.52
	12	12.34	11.18	10.44	11.32	4.55	4.55	4.55	4.55
	13	7.23	6.92	7.27	7.14	4.84	4.85	4.83	4.84
	14	10.53	9.37	7.94	9.28	2.29	2.29	2.29	2.29
	15	6.28	5.15	7.71	6.38	2.23	2.23	2.23	2.23
	16	8.36	7.81	7.26	7.81	2.42	2.42	2.42	2.42
	17	6.38	5.92	7.62	6.64	2.08	2.08	2.08	2.08
	18	10.06	9.61	10.09	9.92	3.63	3.63	3.63	3.63
	19	9.42	8.73	9.96	9.37	3.06	3.07	3.08	3.07
	20	7.36	6.86	6.06	6.76	2.24	2.24	2.24	2.24
	21	5.31	4.35	4.89	4.85	1.12	1.12	1.12	1.12
	22	7.24	8.73	10.55	8.84	2.99	2.99	2.99	2.99
	23	5.5	4.74	3.23	4.49	1.09	1.09	1.09	1.09
	24	8	9.25	8.73	8.66	3.16	3.17	3.15	3.16
	25	8.18	8.53	7.59	8.1	2.36	2.36	2.36	2.36
	26	8.88	9.61	10.34	9.61	3.32	3.32	3.32	3.32
	27	6.52	5.13	7.22	6.29	1.9	1.92	1.91	1.91
	28	7.65	6.41	5.92	6.66	2.79	2.79	2.79	2.79
	29	6.3	5.68	7.97	6.65	2.22	2.22	2.22	2.22
	30	9.62	8.37	8.26	8.75	2.81	2.81	2.81	2.81
Week 8	1	7.53	8.14	10.67	8.78	2.41	2.41	2.41	2.41
10/08/2010	2	6.28	5.51	4.92	5.57	1.12	1.12	1.12	1.12
	3	5.24	6.92	4.67	5.61	0.94	0.94	0.94	0.94
	4	5.41	5.28	6.77	5.82	1.37	1.37	1.37	1.37
	5	8.31	7.43	10.06	8.6	2.48	2.48	2.48	2.48
	6	7.58	6.51	9.07	7.72	2.54	2.54	2.54	2.54
	7	13.27	12.08	11.61	12.32	4.2	4.2	4.2	4.2
	8	8.46	7.38	7.74	7.86	2.77	2.78	2.79	2.78
	9	12.57	11.36	12.79	12.24	4.48	4.48	4.48	4.48
	10	7.67	6.43	6.63	6.91	2.25	2.25	2.25	2.25
	11	7.18	6.2	6.72	6.7	2.68	2.69	2.67	2.68
	12	11.54	10.68	12.7	11.64	4.66	4.68	2.67	4.67
	13	9.87	10.46	10.69	10.34	4.95	4.95	4.95	4.95
	14	8.52	9.19	9.89	9.2	2.37	2.37	2.37	2.37
	15	6.37	5.81	7.08	6.42	2.32	2.32	2.32	2.32
	16	8	7.14	8.56	7.9	2.5	2.5	2.5	2.5
	17	7.08	6.42	7.29	6.93	2.12	2.12	2.12	2.12

18	10.02	9.75	10.11	9.96	3.71	3.71	3.71	3.71
19	9.45	8.61	10.14	9.4	3.18	3.18	3.18	3.18
20	7.58	6.66	8.56	7.6	2.27	2.27	2.27	2.27
21	5.37	4.92	6.72	5.67	1.15	1.14	1.13	1.14
22	8.31	8.96	9.13	8.8	3.04	3.05	3.03	3.04
23	5.16	4.79	4.9	4.95	1.1	1.1	1.1	1.1
24	8	9.64	9.12	8.92	3.19	3.19	3.19	3.19
25	6.49	7.84	7.48	7.27	2.41	2.42	2.43	2.42
26	9.34	8.78	8.88	9	3.35	3.35	3.35	3.35
27	6.35	5.37	7.93	6.55	1.95	1.95	1.95	1.95
28	7.05	6.31	5.66	6.34	2.84	2.85	2.83	2.84
29	7.49	6.73	8.97	7.73	2.25	2.27	2.26	2.26
30	9.64	8.71	8.41	8.92	2.83	2.83	2.83	2.83

Table 11.7 contains the three repeat measurements for weight and volume and the averages of these for each coral in the metal halide tank. The averages for weight were used to determine growth rate.

Table 11.8 Measurements and standard deviation of volume for the LED tank during week 1

		Volume (ml)			
Coral	**1**	**2**	**3**	**Average**	**Standard Deviation**
1	4.31	4.45	4.86	4.54	0.285832119
2	7.1	6.76	5.85	6.57	0.646297145
3	7.3	8.16	6.8	7.42	0.687895341
4	8.12	8.68	8.67	8.49	0.320468407
5	4.84	5.63	5.88	5.45	0.542862782
6	4.01	5.32	4.98	4.77	0.679779376
7	5.1	6.94	8.27	6.77	1.591822854
8	8.83	9.47	10.62	9.64	0.907028114
9	5.31	6.23	5.71	5.75	0.461302504
10	6.43	6.94	7.24	6.87	0.409511905
11	6.73	7.56	5.78	6.69	0.890673902
12	3.68	4.27	6.45	4.8	1.459075049
13	6.31	6.97	6.34	6.54	0.372692903
14	6.54	6.83	8.71	7.36	1.178091677
15	7.3	8.47	10.3	8.69	1.512051586
16	3.43	4.61	3.87	3.97	0.596322061
17	6.53	6.84	7.63	7	0.567186036
18	6.22	6.66	7.4	6.76	0.596322061
19	8.93	9.41	7.67	8.67	0.898665678
20	3.73	4.5	5.45	4.56	0.861568337
21	5.36	5.9	4.55	5.27	0.679485099
22	5.73	6.41	7.72	6.62	1.011484058
23	7.14	6.86	6.7	6.9	0.222710575
24	6.31	5.16	5.9	5.79	0.582837885
25	5.63	5.78	5.18	5.53	0.3122499
26	7.44	6.81	6.57	6.94	0.449332839

27	5.66	5.21	5.93	5.6	0.36373067
28	6.51	5.45	5.35	5.77	0.642806347
29	8.04	7.48	7.49	7.67	0.320468407
30	5.8	7.13	6.96	6.63	0.723809367

Table 11.9 Measurements and standard deviation of weight for the LED tank during week 1

	Weight (g)				
Coral	1	2	3	Average	Standard Deviation
1	1.27	1.26	1.28	1.27	0.01
2	2.33	2.33	2.33	2.33	0
3	2.29	2.31	2.3	2.3	0.01
4	3.3	3.33	3.36	3.33	0.03
5	1.38	1.37	1.39	1.38	0.01
6	1.12	1.12	1.12	1.12	0
7	2.08	2.08	2.08	2.08	0
8	3.13	3.12	3.14	3.13	0.01
9	1.23	1.23	1.23	1.23	0
10	2.19	2.19	2.19	2.19	0
11	2.32	2.32	2.32	2.32	0
12	1.07	1.07	1.07	1.07	0
13	2.79	2.79	2.79	2.79	5.44E-16
14	2.49	2.49	2.49	2.49	0
15	3.28	3.28	3.28	3.28	0
16	1.09	1.09	1.09	1.09	0
17	2.08	2.08	2.08	2.08	0
18	2.11	2.11	2.11	2.11	0
19	3.33	3.33	3.33	3.33	0
20	1.31	1.31	1.31	1.31	0
21	1.3	1.3	1.3	1.3	0
22	2.34	2.33	2.35	2.34	0.01
23	2.34	2.34	2.34	2.34	0
24	1.92	1.92	1.92	1.92	0
25	1.98	1.95	1.95	1.96	0.017321
26	2.29	2.32	2.29	2.3	0.017321
27	1.4	1.4	1.4	1.4	2.72E-16
28	1.89	1.89	1.89	1.89	0
29	2.86	2.88	2.87	2.87	0.01
30	2.51	2.51	2.51	2.51	0

Table 11.10 Measurements and standard deviation of volume for the LED tank during week 5

	Volume (ml)				
Coral	1	2	3	Average	Standard Deviation
1	5.98	4.34	6.21	5.41	1.019754873
2	7.32	8.46	7.44	7.74	0.626418391
3	7.03	6.15	7.67	6.95	0.763151361

4	9.34	10.68	9.08	9.7	0.858603517
5	6	5.47	6.2	5.89	0.377226722
6	5.08	4.91	4.77	4.92	0.155241747
7	8.13	7.26	7.05	7.48	0.572625532
8	10.62	9.76	7.91	9.43	1.384810456
9	6.83	5.18	7.7	6.57	1.279960937
10	8.19	7.82	9.19	8.4	0.708731261
11	6.49	7.38	9.29	7.72	1.430629232
12	5.61	4.82	4.36	4.93	0.632218317
13	8.16	7.59	7.65	7.8	0.313209195
14	8.04	7.44	7.47	7.65	0.33808283
15	10.57	9.36	8.27	9.4	1.150521621
16	5.33	6.41	4.16	5.3	1.12529996
17	8.16	7.88	6.22	7.42	1.048618138
18	8.09	7.38	7.06	7.51	0.527162214
19	11.56	10.4	9.27	10.41	1.145032751
20	5.37	4.19	4.81	4.79	0.590254183
21	5	4.82	4.79	4.87	0.113578167
22	8.25	6.92	6.88	7.35	0.779679421
23	8.39	7.41	8.68	8.16	0.665507325
24	5.55	6.18	7.32	6.35	0.897162193
25	7.58	6.98	6.32	6.96	0.63023805
26	7.16	6.95	6.89	7	0.141774469
27	5.62	4.15	6.19	5.32	1.052568288
28	6.49	5.97	7.55	6.67	0.805232886
29	8.74	7.23	9.05	8.34	0.973704267
30	7.87	6.91	7.03	7.27	0.523067873

Table 11.11 Measurements and standard deviation of weight for the LED tank during week 5

	Weight (g)				
Coral	**1**	**2**	**3**	**Average**	**Standard Deviation**
1	1.44	1.44	1.44	1.44	2.71948E-16
2	2.49	2.5	2.51	2.5	0.01
3	2.46	2.46	2.46	2.46	0
4	3.6	3.6	3.6	3.6	0
5	1.48	1.47	1.49	1.48	0.01
6	1.2	1.2	1.2	1.2	0
7	2.27	2.27	2.27	2.27	0
8	3.39	3.39	3.39	3.39	0
9	2.24	2.24	2.24	2.24	0
10	2.44	2.44	2.44	2.44	0
11	2.72	2.72	2.72	2.72	0
12	1.1	1.12	1.11	1.11	0.01
13	2.91	2.91	2.91	2.91	0
14	2.66	2.66	2.66	2.66	0
15	3.58	3.58	3.58	3.58	0

16	1.16	1.16	1.16	1.16	0
17	2.34	2.35	2.36	2.35	0.01
18	2.33	2.33	2.33	2.33	0
19	3.65	3.65	3.65	3.65	0
20	1.37	1.37	1.37	1.37	0
21	1.37	1.39	1.38	1.38	0.01
22	2.42	2.42	2.42	2.42	0
23	2.6	2.6	2.6	2.6	0
24	2.06	2.06	2.06	2.06	0
25	2.15	2.14	2.13	2.14	0.01
26	2.57	2.57	2.57	2.57	0
27	1.46	1.46	1.46	1.46	0
28	2	2.02	2.01	2.01	0.01
29	2.98	3	2.99	2.99	0.01
30	2.55	2.55	2.55	2.55	0

Table 11.12 Measurements and standard deviation of volume for the LED tank during week 9

	Volume (ml)				
Coral	**1**	**2**	**3**	**Average**	**Standard Deviation**
1	7.03	6.34	6.88	6.75	0.362905
2	9.23	8.14	9.21	8.86	0.623618
3	8.63	7.19	8.15	7.99	0.733212
4	12.43	11.26	10.93	11.54	0.788226
5	7.62	6.43	5.63	6.56	1.001349
6	6.83	5.49	6.97	6.43	0.817068
7	7.25	8.94	9.43	8.54	1.143722
8	9.65	10.18	11.16	10.33	0.766094
9	6.83	7.29	8.83	7.65	1.047473
10	10.57	9.64	9.31	9.84	0.653376
11	9	8.99	10.69	9.56	0.978621
12	5.58	4.38	6.63	5.53	1.125833
13	8.31	7.29	9.96	8.52	1.347331
14	8.52	7.26	10.95	8.91	1.87566
15	11.62	10.74	9.83	10.73	0.895042
16	6.16	5.39	5.73	5.76	0.385876
17	9.02	8.57	8.87	8.82	0.229129
18	8.43	7.25	8.2	7.96	0.62554
19	11	12.98	11.63	11.87	1.011583
20	5.84	6.79	7.32	6.65	0.749867
21	4.89	5.27	7.63	5.93	1.484453
22	9.64	8.73	6.53	8.3	1.598968
23	8.35	9.14	9.69	9.06	0.673573
24	7.77	6.41	7.75	7.31	0.779487
25	9.72	8.38	7.16	8.42	1.280469
26	9.46	8.24	8.58	8.76	0.629603

27	7.08	6.53	7.27	6.96	0.384318
28	7.27	6.94	7.81	7.34	0.439204
29	7.35	8.15	10.33	8.61	1.542336
30	9.73	8.61	7.46	8.6	1.135033

Table 11.13 Measurements and standard deviation of weight for the LED tank during week 9

		Weight (g)			
Coral	**1**	**2**	**3**	**Average**	**Standard Deviation**
1	1.56	1.58	1.57	1.57	0.01
2	2.64	2.64	2.64	2.64	0
3	2.62	2.62	2.62	2.62	0
4	3.98	3.98	3.98	3.98	0
5	1.57	1.57	1.57	1.57	0
6	1.29	1.29	1.29	1.29	0
7	2.46	2.46	2.46	2.46	0
8	3.67	3.67	3.67	3.67	0
9	2.48	2.48	2.48	2.48	0
10	2.69	2.7	2.71	2.7	0.01
11	3.18	3.18	3.18	3.18	0
12	1.17	1.16	1.18	1.17	0.01
13	3.03	3.03	3.03	3.03	0
14	2.85	2.84	2.83	2.84	0.01
15	3.97	3.96	3.98	3.97	0.01
16	1.26	1.26	1.26	1.26	0
17	2.69	2.69	2.69	2.69	0
18	2.57	2.57	2.57	2.57	0
19	3.97	3.97	3.97	3.97	0
20	1.5	1.5	1.5	1.5	0
21	1.47	1.47	1.47	1.47	0
22	2.5	2.51	2.52	2.51	0.01
23	2.81	2.81	2.81	2.81	0
24	2.2	2.2	2.2	2.2	0
25	2.29	2.29	2.29	2.29	0
26	2.88	2.88	2.88	2.88	5.44E-16
27	1.55	1.55	1.55	1.55	0
28	2.17	2.17	2.17	2.17	0
29	3.11	3.11	3.11	3.11	0
30	2.69	2.69	2.69	2.69	0

Tables 11.8 – 11.13 data were used to create figures 7.5 – 7.10.

11.3 Growth Rates

Table 11.14 Corals volume and weight for each week and their growth rate for the LED tank

Week	Coral Number	Volume (ml)	Weight (g)	Growth Rate (g/day)
Start 15/06/2010	1	4.54	1.27	
	2	6.57	2.33	
	3	7.42	2.3	
	4	8.49	3.33	
	5	5.45	1.38	
	6	4.77	1.12	
	7	6.77	2.08	
	8	9.64	3.13	
	9	5.75	2.03	
	10	6.87	2.19	
	11	6.69	2.32	
	12	4.8	1.07	
	13	6.54	2.79	
	14	7.36	2.49	
	15	8.69	3.28	
	16	3.97	1.09	
	17	7	2.08	
	18	6.76	2.11	
	19	8.67	3.33	
	20	4.56	1.31	
	21	5.27	1.3	
	22	6.62	2.34	
	23	6.9	2.34	
	24	5.79	1.92	
	25	5.53	1.96	
	26	6.94	2.3	
	27	5.6	1.4	
	28	5.77	1.89	
	29	7.67	2.87	
	30	6.63	2.51	
Week 1 22/06/2010	1	5	1.33	0.006594577
	2	6.75	2.37	0.00243167
	3	6.57	2.29	-0.000622472
	4	8.94	3.36	0.001281239
	5	5.57	1.38	0
	6	4.86	1.15	0.00377618
	7	6.97	2.16	0.005391475
	8	8.55	3.18	0.002264027
	9	6.89	2.07	0.002787545
	10	7.66	2.23	0.00258572
	11	7.51	2.43	0.006617725

	12	5	1.08	0.001328913
	13	7.69	2.8	0.000511117
	14	7.75	2.51	0.001142863
	15	9	3.34	0.002589626
	16	5.42	1.07	-0.002645578
	17	7.59	2.11	0.002045722
	18	7.21	2.16	0.003345753
	19	9.84	3.28	-0.002161269
	20	4.59	1.3	-0.001094696
	21	5.57	1.31	0.001094696
	22	7.4	2.35	0.0006092
	23	7.99	2.41	0.004210831
	24	6.5	1.98	0.004395951
	25	6.94	2	0.002886101
	26	7.61	2.34	0.002463115
	27	5.35	1.4	0
	28	6.43	1.89	0
	29	7.46	2.92	0.00246737
	30	7.57	2.49	-0.001142863
Week 2	1	5.53	1.36	0.004890557
29/06/2010	2	6.63	2.42	0.002707091
	3	6.94	2.41	0.003336973
	4	8.79	3.44	0.002321369
	5	4.67	1.39	0.000515732
	6	4.47	1.17	0.003119647
	7	6.79	2.18	0.00335407
	8	8.67	3.24	0.002467166
	9	6.96	2.15	0.004102289
	10	7.33	2.31	0.003810427
	11	7.5	2.54	0.006471207
	12	5.52	1.1	0.001975109
	13	7.37	2.84	0.001268747
	14	6.95	2.56	0.001980325
	15	9.22	3.43	0.00319406
	16	4.7	1.11	0.001298737
	17	6.53	2.22	0.004652807
	18	6.78	2.24	0.004270566
	19	9.26	3.48	0.003147142
	20	5.33	1.33	0.001082272
	21	4.54	1.34	0.002164668
	22	6.91	2.37	0.00090993
	23	6.72	2.48	0.004150545
	24	6.62	2	0.002915857
	25	5.71	2.07	0.003900295
	26	7.52	2.42	0.003632744
	27	4.88	1.44	0.002012205

	28	6.46	1.93	0.001495941
	29	7.86	2.94	0.001721254
	30	7.9	2.52	0.000284011
Week 3	1	6.45	1.14	-0.005142316
06/07/2010	2	7.56	2.38	0.001011058
	3	6.61	2.44	0.002813758
	4	9.53	3.52	0.002642318
	5	4.99	1.42	0.001360637
	6	5.11	1.2	0.003285375
	7	6.26	2.22	0.003101872
	8	8.87	3.29	0.002374027
	9	7.43	2.2	0.003829598
	10	8	2.39	0.004161515
	11	8.55	2.64	0.00615294
	12	4.9	1.09	0.000881859
	13	7.49	2.88	0.001511843
	14	7.36	2.62	0.00242341
	15	9.85	3.52	0.003362741
	16	5.33	1.14	0.002135741
	17	7.56	2.29	0.004580187
	18	7.7	2.3	0.00410577
	19	9.55	3.48	0.002098095
	20	4.47	1.34	0.001078213
	21	5.6	1.36	0.002148592
	22	6.87	2.4	0.00120561
	23	8.35	2.54	0.003905388
	24	6.6	2.05	0.003119743
	25	6.42	2.11	0.003511594
	26	7.79	2.5	0.003970553
	27	4.3	1.45	0.001671015
	28	6.48	1.97	0.001974129
	29	7.64	2.97	0.001630949
	30	6.45	2.54	0.000565778
Week 4	1	5.41	1.44	0.00448665
13/07/2010	2	7.74	2.5	0.002515088
	3	6.95	2.46	0.002401865
	4	9.7	3.6	0.002784341
	5	5.89	1.48	0.002498521
	6	4.92	1.2	0.002464031
	7	7.48	2.27	0.003121855
	8	9.43	3.39	0.00284989
	9	6.57	2.24	0.003515717
	10	8.4	2.44	0.003860589
	11	7.72	2.72	0.005680882
	12	4.93	1.11	0.001310763
	13	7.8	2.91	0.001503982

	14	7.65	2.66	0.002358693
	15	9.4	3.58	0.003125692
	16	5.3	1.16	0.00222294
	17	7.42	2.35	0.004358837
	18	7.51	2.33	0.003542154
	19	10.41	3.65	0.003276959
	20	4.79	1.37	0.001599414
	21	4.87	1.38	0.00213283
	22	7.35	2.42	0.001200593
	23	8.16	2.6	0.003762876
	24	6.35	2.06	0.0025136
	25	6.96	2.14	0.003137906
	26	7	2.57	0.003964171
	27	5.32	1.46	0.001498721
	28	6.67	2.01	0.002198496
	29	8.34	2.99	0.001462906
	30	7.27	2.55	0.000564665
Week 5	1	5.44	1.46	0.003983415
20/07/2010	2	7.34	2.55	0.00257786
	3	7.19	2.5	0.002382332
	4	9.81	3.69	0.002932976
	5	5.77	1.5	0.002382332
	6	5.25	1.23	0.002676728
	7	7.94	2.32	0.00311998
	8	9.33	3.47	0.002946331
	9	6.85	2.3	0.003567809
	10	8.75	2.51	0.003896606
	11	8.38	2.83	0.005677415
	12	5.34	1.13	0.001558828
	13	7.61	2.94	0.001496228
	14	8.38	2.72	0.002524262
	15	9.78	3.68	0.003287695
	16	4.98	1.18	0.002266764
	17	7.35	2.45	0.004677718
	18	7.17	2.39	0.003560155
	19	9.82	3.73	0.003241027
	20	5.6	1.43	0.002504209
	21	4.86	1.4	0.002117371
	22	7.6	2.45	0.001312488
	23	8.59	2.65	0.003554535
	24	6.56	2.11	0.002696079
	25	6.8	2.18	0.00303944
	26	8.2	2.66	0.004154771
	27	5.36	1.49	0.001780111
	28	6.85	2.06	0.002460833
	29	7.65	3.01	0.001360801

	30	7.5	2.58	0.000785904
Week 6	1	5.67	1.47	0.003482036
27/07/2010	2	7.57	2.56	0.002241405
	3	7.41	2.47	0.001697834
	4	10.57	3.81	0.003206116
	5	5.57	1.54	0.002611879
	6	5.57	1.26	0.002804358
	7	7.66	2.37	0.003107668
	8	9.39	3.54	0.002930803
	9	7.56	2.38	0.003787255
	10	7.84	2.56	0.003716803
	11	9.34	2.96	0.005800526
	12	5.3	1.15	0.001716745
	13	8.22	2.98	0.001568612
	14	8	2.78	0.002623053
	15	10.53	3.79	0.003441014
	16	5.36	1.21	0.00248673
	17	8.56	2.55	0.004850606
	18	7.53	2.46	0.003654129
	19	10.61	3.79	0.003080803
	20	5.41	1.45	0.002417534
	21	5.58	1.43	0.00226929
	22	7.63	2.47	0.001287315
	23	9.39	2.7	0.003407163
	24	7.55	2.13	0.002471352
	25	7.48	2.21	0.002858287
	26	8.91	2.73	0.004080773
	27	5.73	1.52	0.00195805
	28	7.48	2.09	0.002394934
	29	8.66	3.05	0.001448323
	30	7.74	2.61	0.000930178
Week 7	1	6.6	1.53	0.003801037
03/08/2010	2	8.64	2.62	0.002394001
	3	7.63	2.58	0.002344495
	4	10.61	3.89	0.003172181
	5	5.56	1.55	0.002370846
	6	5.45	1.27	0.002565066
	7	7.32	2.42	0.003089789
	8	9.96	3.59	0.002798351
	9	7.52	2.42	0.003586362
	10	9.35	2.65	0.003890982
	11	9.17	3.06	0.005649954
	12	5.31	1.16	0.001648191
	13	7.92	3.01	0.001548949
	14	8.7	2.81	0.002467383
	15	10	3.87	0.003375736

	16	5.66	1.23	0.00246605
	17	8.5	2.64	0.004865531
	18	7.77	2.51	0.003542751
	19	10.73	3.88	0.00311965
	20	5.45	1.48	0.002490101
	21	5.3	1.44	0.002087323
	22	7.68	2.49	0.001267996
	23	8.72	2.78	0.003516326
	24	6.78	2.18	0.00259183
	25	6.91	2.25	0.002816036
	26	8.7	2.8	0.004014496
	27	5.61	1.53	0.001812153
	28	7.82	2.14	0.002535286
	29	7.76	3.08	0.001441175
	30	8	2.64	0.001030534
Week 8	1	6.75	1.57	0.003786763
10/08/2010	2	8.86	2.64	0.002230547
	3	7.99	2.62	0.002326164
	4	11.54	3.98	0.003184098
	5	6.56	1.57	0.002303431
	6	6.43	1.29	0.002523456
	7	8.54	2.46	0.002996312
	8	10.33	3.67	0.002842119
	9	7.65	2.48	0.003575407
	10	9.84	2.7	0.003738397
	11	9.56	3.18	0.005630607
	12	5.53	1.17	0.001595448
	13	8.52	3.03	0.00147359
	14	8.91	2.84	0.002348595
	15	10.73	3.97	0.003409333
	16	5.76	1.26	0.002588108
	17	8.82	2.69	0.00459238
	18	7.96	2.57	0.003521749
	19	11.87	3.97	0.003139175
	20	6.65	1.5	0.002418535
	21	5.93	1.47	0.00219461
	22	8.3	2.51	0.001252354
	23	9.06	2.81	0.003268456
	24	7.31	2.2	0.002430932
	25	8.42	2.29	0.002778703
	26	8.76	2.88	0.004015735
	27	6.96	1.55	0.001817548
	28	7.34	2.17	0.00246697
	29	8.61	3.11	0.00143412
	30	8.6	2.69	0.001236758

Table 11.15 Corals volume and weight for each week and their growth rate for the T5 tank

Week	Coral Number	Volume (ml)	Weight (g)	Growth Rate (g/day)
Start 15/06/2010	1	6.4	2.06	
	2	5.8	1.64	
	3	5.37	1.23	
	4	7.96	2.25	
	5	6.71	2.07	
	6	5.75	1.45	
	7	4.69	1.12	
	8	5.58	1.42	
	9	6.73	2.14	
	10	6.83	2.64	
	11	8.5	2.94	
	12	6.53	2.13	
	13	5.48	1.65	
	14	10.57	4.32	
	15	4.4	1.31	
	16	9.79	4.26	
	17	5.96	2.37	
	18	6.54	2.35	
	19	5.55	1.62	
	20	8.58	3.38	
	21	10.31	3.38	
	22	6.74	2.33	
	23	7.32	2.41	
	24	6.29	2.19	
	25	5	1.48	
	26	4.77	1.27	
	27	6	1.84	
	28	5.97	1.89	
	29	8.3	2.68	
	30	5.74	1.55	
Week 1 22/06/2010	1	6.66	2.05	-0.00069517
	2	5.93	1.68	0.003442507
	3	5.56	1.25	0.002304197
	4	7.46	2.24	-0.000636336
	5	6.83	2.15	0.005417034
	6	5.64	1.43	-0.001984159
	7	4.68	1.13	0.00126985
	8	6.31	1.4	-0.002026376
	9	6.82	2.13	-0.000669121
	10	7.75	2.67	0.001614222
	11	9.54	3.04	0.004778276
	12	6.65	2.14	0.000669121
	13	6.59	1.67	0.001721191

	14	10.64	4.42	0.003269185
	15	5.63	1.3	-0.001094696
	16	11.55	4.19	-0.002366918
	17	6.87	2.44	0.004158298
	18	7.35	2.41	0.003601631
	19	4.95	1.66	0.003484493
	20	8.6	3.47	0.003754126
	21	9.65	3.72	0.013692566
	22	7	2.34	0.000611809
	23	7.57	2.47	0.003513058
	24	6.54	2.19	0
	25	5.67	1.5	0.001917574
	26	4.93	1.28	0.001120454
	27	6.95	1.88	0.003072315
	28	6.72	1.89	0
	29	7.48	2.73	0.002640688
	30	5.47	1.6	0.004535528
Week 2	1	6.21	2.08	0.000690136
29/06/2010	2	5.55	1.73	0.003816083
	3	6	1.27	0.002285909
	4	7.6	2.34	0.00280148
	5	6.55	2.18	0.003698305
	6	5.94	1.49	0.001943755
	7	4.83	1.15	0.00188809
	8	6.35	1.48	0.002956087
	9	7	2.21	0.002299049
	10	6.96	2.7	0.001605204
	11	10.54	2.97	0.000725169
	12	6.46	2.18	0.00165735
	13	5.6	1.69	0.001710946
	14	11.62	4.53	0.003390467
	15	5.64	1.32	0.000543186
	16	12	4.02	-0.004141947
	17	7.67	2.53	0.004666382
	18	8	2.46	0.003267573
	19	5.5	1.69	0.003021599
	20	9.66	3.55	0.003505135
	21	11.5	3.57	0.00390642
	22	7.84	2.48	0.004456449
	23	7.66	2.52	0.003188011
	24	5.65	2.21	0.000649355
	25	4.75	1.53	0.002373261
	26	5.53	1.3	0.001667669
	27	6.41	1.95	0.004147414
	28	5.84	1.91	0.000751887
	29	8.67	2.77	0.002359323

	30	6.45	1.64	0.004031522
Week 3	1	5.96	2.13	0.001591238
06/07/2010	2	6.86	1.8	0.004432877
	3	6.54	1.29	0.002268002
	4	7.47	2.43	0.003664811
	5	7.57	2.27	0.004391963
	6	6.51	1.52	0.002245085
	7	5.58	1.18	0.002485036
	8	5.55	1.5	0.002609916
	9	8.3	2.75	0.011942623
	10	9.53	3.22	0.009457259
	11	10.89	3	0.000962034
	12	6.76	2.19	0.001322836
	13	6.62	1.71	0.001700861
	14	11.6	4.65	0.003505325
	15	5.88	1.36	0.001783693
	16	11.45	4.52	0.002821087
	17	8.5	2.6	0.004410547
	18	7.9	2.5	0.002946448
	19	6.55	1.73	0.003128346
	20	9.61	3.66	0.003789878
	21	10.71	3.92	0.007057902
	22	7.63	2.51	0.003543547
	23	7.81	2.56	0.002875262
	24	6.93	2.23	0.000861907
	25	4.95	1.56	0.002506844
	26	5.55	1.31	0.001476678
	27	6.46	2.01	0.004208055
	28	6.65	1.93	0.000997294
	29	7.9	2.83	0.002593329
	30	7.63	1.7	0.00439873
Week 4	1	6.12	2.14	0.001360709
13/07/2010	2	6	1.87	0.004687221
	3	6.66	1.33	0.002791599
	4	7.65	2.49	0.003619732
	5	6.69	2.32	0.004072092
	6	6.86	1.55	0.002381835
	7	5.72	1.2	0.002464031
	8	5.72	1.54	0.002897341
	9	8.39	2.29	0.0024195
	10	9.6	3.8	0.013007934
	11	10.46	3.33	0.004448669
	12	7	2.19	0.000992127
	13	6	1.79	0.002908583
	14	11.9	4.76	0.003464009
	15	6.12	1.4	0.002373039

	16	11.4	4.62	0.002897341
	17	8	2.71	0.00478781
	18	6.64	2.56	0.003056855
	19	5.51	1.77	0.003162621
	20	9.73	3.75	0.003710005
	21	10.66	4.02	0.006193078
	22	7	2.58	0.00364004
	23	7.75	2.66	0.003524978
	24	5.6	2.25	0.00096531
	25	5.75	1.59	0.002560426
	26	4.89	1.33	0.001648644
	27	6.51	1.96	0.002256389
	28	6.49	2.04	0.002727606
	29	6.93	2.9	0.002817641
	30	6.15	1.76	0.004537817
Week 5	1	6.9	2.19	0.001748445
20/07/2010	2	7.36	1.94	0.004799764
	3	6.61	1.36	0.002870587
	4	7.88	2.58	0.003910262
	5	7.54	2.38	0.003987197
	6	6.26	1.57	0.002271773
	7	5.2	1.22	0.002443491
	8	5.42	1.57	0.002869107
	9	8.44	2.35	0.002674557
	10	9.35	3.83	0.010631025
	11	10.56	3.44	0.004487483
	12	7.21	2.22	0.001182435
	13	5.65	1.79	0.002326867
	14	11.8	4.89	0.003541054
	15	5.7	1.36	0.001070216
	16	12.23	4.73	0.002990173
	17	7.84	2.78	0.004558885
	18	7.56	2.6	0.00288846
	19	6.46	1.81	0.003168591
	20	9.73	3.84	0.003645619
	21	11.72	4.11	0.005587066
	22	7.41	2.61	0.003242342
	23	8.52	2.71	0.003352054
	24	6.55	2.28	0.001150683
	25	5.67	1.66	0.0032793
	26	4.82	1.36	0.001956223
	27	6.4	1.98	0.002095179
	28	6.57	2.09	0.002873921
	29	8.35	2.93	0.002548161
	30	7.39	1.82	0.004588045
Week 6	1	7.48	2.22	0.001780981

27/07/2010	2	7.56	2	0.004725022
	3	5.55	1.37	0.002566585
	4	8.65	2.65	0.003895939
	5	7.96	2.45	0.004012843
	6	6.51	1.6	0.002343811
	7	4.77	1.23	0.002230607
	8	6.48	1.6	0.002841589
	9	7.6	2.4	0.002730069
	10	7.99	2.87	0.001988884
	11	10.96	3.54	0.004421837
	12	6.84	2.26	0.001410544
	13	5.94	1.82	0.002334791
	14	12.56	5.02	0.003575584
	15	5.62	1.39	0.001411348
	16	12.88	4.84	0.00303918
	17	8.56	2.87	0.004557668
	18	8.58	2.65	0.002860579
	19	6.82	1.85	0.00316094
	20	11.65	3.94	0.003650119
	21	11.92	3.93	0.003589612
	22	8.07	2.64	0.002974063
	23	8.76	2.69	0.002617011
	24	7.62	2.31	0.001270142
	25	6.51	1.66	0.00273275
	26	5.66	1.39	0.002149687
	27	6.6	2	0.001985276
	28	7.56	2.16	0.003179319
	29	8.66	2.94	0.00220459
	30	6.82	1.87	0.004468655
Week 7	1	6.93	2.26	0.001890997
03/08/2010	2	7.56	2.05	0.00455395
	3	6.11	1.41	0.002787256
	4	8.8	2.63	0.003184768
	5	7.74	2.52	0.004014496
	6	6.45	1.62	0.002262502
	7	5.7	1.26	0.002403735
	8	6.6	1.63	0.002814758
	9	8.23	2.43	0.00259358
	10	7.86	2.93	0.00212701
	11	10.75	3.52	0.003674519
	12	6.59	2.28	0.001388846
	13	5.85	1.85	0.002334905
	14	11.98	5.13	0.003507148
	15	5.69	1.41	0.001501277
	16	12.57	4.86	0.002689169
	17	9.53	2.93	0.004328826

	18	7.69	2.71	0.002908843
	19	5.68	1.88	0.003037666
	20	10.81	4.02	0.003538902
	21	11.97	4.27	0.004770166
	22	8.62	2.68	0.002856092
	23	9.54	2.8	0.003061075
	24	6.9	2.34	0.001352028
	25	5.79	1.68	0.00258677
	26	5.56	1.41	0.002134139
	27	6.72	2.03	0.002005515
	28	8.69	2.21	0.003192157
	29	8.86	3.04	0.00257226
	30	7.8	1.91	0.00426221
Week 8	1	7.83	2.29	0.001890104
10/08/2010	2	7.96	2.09	0.004329783
	3	5.73	1.42	0.002565048
	4	9.21	2.72	0.00338753
	5	8.8	2.58	0.003932871
	6	6.42	1.66	0.002415251
	7	6.5	1.27	0.002244432
	8	6.89	1.65	0.002680686
	9	8.79	2.47	0.002560934
	10	8.83	3	0.002282739
	11	10.82	3.55	0.00336675
	12	8	2.32	0.001525807
	13	6.67	1.87	0.002235056
	14	12.81	5.21	0.00334508
	15	5.96	1.43	0.00156513
	16	12.8	4.86	0.002353023
	17	9.5	2.98	0.004089881
	18	8.72	2.75	0.002806885
	19	6.9	1.89	0.002752691
	20	11.42	4.09	0.003404808
	21	11.88	4.11	0.003491916
	22	7.68	2.71	0.002697864
	23	9.13	2.85	0.002994504
	24	6.85	2.36	0.001335001
	25	5.95	1.71	0.002579487
	26	5.9	1.43	0.002118885
	27	7.31	2.04	0.001842576
	28	7.8	2.26	0.003192643
	29	8.9	3.1	0.002599738
	30	7.51	1.96	0.004190885

Table 11.16 Corals volume and weight for each week and their growth rate for the metal halide tank

Week	Coral Number	Volume (ml)	Weight (g)	Growth Rate (g/day)
Start 15/06/2010	1	6.81	2	
	2	4.63	1	
	3	4.84	0.81	
	4	5	1.12	
	5	7.1	2.23	
	6	6.66	2.04	
	7	8.56	3.66	
	8	6.63	2.58	
	9	10.67	3.94	
	10	5.95	1.86	
	11	6.65	2.19	
	12	10.8	4.23	
	13	4.42	1.19	
	14	6.66	1.88	
	15	6	1.87	
	16	5.76	1.94	
	17	5.65	1.83	
	18	7.85	3.17	
	19	7.41	2.29	
	20	6.41	2.06	
	21	4.62	1.03	
	22	7.49	2.51	
	23	3.85	0.97	
	24	6.87	2.91	
	25	6.47	1.51	
	26	7.89	2.85	
	27	5.51	1.62	
	28	6.44	1.93	
	29	5.99	1.89	
	30	6.89	2.29	
Week 1 22/06/2010	1	7.23	2.04	0.002828947
	2	4.64	0.99	-0.001435762
	3	3.96	0.8	-0.001774646
	4	4.75	1.12	0
	5	6.26	2.18	-0.00323953
	6	5.93	2.08	0.002774012
	7	9.74	3.68	0.000778515
	8	7.6	2.58	0
	9	9.67	4.01	0.002515788
	10	5.89	1.86	0
	11	6.45	2.22	0.001943665
	12	10.33	4.3	0.002344719

	13	4.86	1.18	-0.001205553
	14	7.47	2	0.008839343
	15	7	1.87	0
	16	5.82	2	0.004351315
	17	6.53	1.83	0
	18	8.88	3.22	0.002235682
	19	7.91	2.4	0.006702417
	20	5.9	2.07	0.000691803
	21	4.82	1.01	-0.00280121
	22	7.97	2.61	0.005581067
	23	4.5	0.98	0.001465214
	24	7.75	2.94	0.001465214
	25	5.85	1.54	0.002810395
	26	6.71	2.91	0.002976298
	27	6.36	1.65	0.002621306
	28	5.87	2.02	0.006511073
	29	5.98	1.95	0.004464649
	30	7.54	2.4	0.006702417
Week 2	1	8.3	2.07	0.002457245
29/06/2010	2	5.32	1.01	0.000710738
	3	4.9	0.83	0.001742247
	4	5.66	1.16	0.002506523
	5	7	2.27	0.001269875
	6	7	2.14	0.003418287
	7	9.81	3.75	0.001735192
	8	7.21	2.6	0.000551575
	9	10.23	4.07	0.002318734
	10	5.89	1.89	0.001142882
	11	7.64	2.29	0.003189305
	12	10.36	4.24	0.000168663
	13	3.6	1.23	0.00236149
	14	6	2.06	0.006531015
	15	6.46	1.9	0.001136818
	16	7.25	2.03	0.00323913
	17	5.54	1.89	0.002304347
	18	9.4	3.29	0.002653998
	19	7.62	2.47	0.005404738
	20	6.66	2.1	0.001373669
	21	5	1.03	0
	22	7.26	2.66	0.004145955
	23	4.33	1	0.002175658
	24	7.85	2.98	0.001697873
	25	6.91	1.58	0.0032368
	26	8.26	2.97	0.002945926
	27	6.4	1.68	0.002597689
	28	6	1.98	0.001826917

	29	6	2	0.004040739
	30	8.61	2.38	0.002753476
Week 3	1	7.8	2.01	0.000237502
06/07/2010	2	4.57	1.02	0.000942982
	3	4.6	0.84	0.001731793
	4	4.8	1.19	0.002886887
	5	6.92	2.29	0.001264297
	6	7.75	2.28	0.005296459
	7	9.81	3.79	0.001662042
	8	7.4	2.61	0.000550515
	9	11.5	4.12	0.002127259
	10	5.55	1.9	0.001013209
	11	7.69	2.32	0.002745983
	12	10.72	4.41	0.001984414
	13	3.65	1.29	0.003842329
	14	7.63	2.12	0.005721158
	15	6.25	1.94	0.001749978
	16	6.86	2.07	0.003088602
	17	6.37	1.93	0.002533526
	18	8.9	3.36	0.002771876
	19	8.47	2.59	0.005862193
	20	6.4	2.11	0.001141998
	21	4.6	1.05	0.000915779
	22	8.18	2.73	0.004000898
	23	4.63	1.02	0.002393421
	24	8.88	3.02	0.001766845
	25	5.71	1.62	0.003348405
	26	9.17	3.05	0.003229647
	27	6.7	1.72	0.002852292
	28	6.3	2.13	0.004695332
	29	5.42	2.03	0.003402808
	30	8	2.5	0.004178044
Week 4	1	7.43	2.17	0.002913571
13/07/2010	2	4.61	1.05	0.001742506
	3	4.36	0.86	0.002139219
	4	5	1.22	0.003054363
	5	6.51	2.34	0.001719619
	6	6.76	2.13	0.001541863
	7	9.74	3.88	0.002084715
	8	7.17	2.65	0.00095608
	9	10.74	4.2	0.002282279
	10	5.34	1.95	0.001687603
	11	5.9	2.37	0.002821015
	12	10.39	4.46	0.001890956
	13	5.9	1.52	0.008741322
	14	8.5	2.19	0.005451063

	15	5.33	2.11	0.004312483
	16	6.55	2.1	0.002830335
	17	6.94	1.98	0.002813603
	18	9.4	3.39	0.002396369
	19	8.47	2.69	0.005749621
	20	6.41	2.15	0.001527209
	21	4.75	1.07	0.001360709
	22	8.43	2.79	0.003777102
	23	4.16	1.04	0.002488569
	24	8.57	3.05	0.001678161
	25	6	2.18	0.013114829
	26	7.59	3.1	0.003002968
	27	5.8	1.77	0.003162621
	28	5.88	2.14	0.00368878
	29	6.58	2.07	0.003248992
	30	7.83	2.56	0.003980551
Week 5	1	6.59	2.22	0.002981715
20/07/2010	2	4.75	1.06	0.001664826
	3	4.3	0.88	0.002368219
	4	5.36	1.26	0.00336523
	5	7.33	2.36	0.001618858
	6	7.3	2.33	0.00379767
	7	10.17	3.95	0.002178641
	8	7.51	2.69	0.001192908
	9	11.6	4.27	0.002298089
	10	6	2	0.002073448
	11	6.2	2.41	0.002735006
	12	10.55	4.5	0.001767869
	13	6.84	4.68	0.039124137
	14	8.56	2.21	0.004620593
	15	5.88	2.16	0.004119137
	16	6.92	2.21	0.003722987
	17	6.28	2.01	0.002680536
	18	9.36	3.48	0.002665734
	19	8.45	2.81	0.005846648
	20	6.57	2.19	0.001748445
	21	4.71	1.09	0.001617683
	22	8.3	2.83	0.003428399
	23	4.31	1.05	0.002264268
	24	7.9	3.08	0.001622186
	25	6.96	2.23	0.01113977
	26	8.7	3.09	0.00231006
	27	6.32	1.7	0.001377203
	28	5.8	2.81	0.010733271
	29	6.3	2.13	0.003415576
	30	8.56	2.67	0.004386476

Week 6	1	7.8	2.29	0.00322392
27/07/2010	2	5.41	1.1	0.00226929
	3	5.02	0.9	0.002508584
	4	5.82	1.3	0.003548466
	5	7.61	2.41	0.001848218
	6	8.56	2.4	0.003869498
	7	10.94	4.04	0.002351942
	8	7.69	2.68	0.000905414
	9	11.44	4.34	0.002302229
	10	6.51	2.09	0.002775895
	11	6.33	2.49	0.003056694
	12	10.96	4.52	0.00157881
	13	7.12	4.7	0.032704981
	14	9.23	2.25	0.004277582
	15	6.2	2.19	0.003761026
	16	7.35	2.35	0.004564937
	17	6.45	2.05	0.002702948
	18	9.6	3.57	0.002829381
	19	9	2.94	0.005948994
	20	7.36	2.23	0.001887991
	21	4.75	1.11	0.001780981
	22	9.34	2.91	0.003520722
	23	5.7	1.07	0.002336139
	24	8.66	3.13	0.001735236
	25	7.72	2.31	0.01012233
	26	9.61	3.16	0.002458406
	27	6.61	1.89	0.003670254
	28	5.86	2.82	0.009028973
	29	6.94	2.16	0.003179319
	30	8.85	2.77	0.004530845
Week 7	1	7.78	2.35	0.003291187
03/08/2010	2	5.63	1.1	0.001945106
	3	5.5	0.92	0.002598764
	4	5.91	1.33	0.003507148
	5	7.46	2.44	0.001836662
	6	7.96	2.47	0.003903436
	7	11.48	4.13	0.002465597
	8	7.91	2.77	0.001450162
	9	12.6	4.4	0.002253547
	10	6.85	2.15	0.002956966
	11	6.66	2.52	0.002864436
	12	11.32	4.55	0.00148827
	13	7.14	4.84	0.028631866
	14	9.28	2.29	0.004026123
	15	6.38	2.23	0.003593126
	16	7.81	2.42	0.004511828

	17	6.64	2.08	0.002613305
	18	9.92	3.63	0.002765328
	19	9.37	3.07	0.005982158
	20	6.76	2.24	0.001709589
	21	4.85	1.12	0.001709589
	22	8.84	2.99	0.003571237
	23	4.49	1.09	0.002380345
	24	8.66	3.16	0.001682019
	25	8.1	2.36	0.009113305
	26	9.61	3.32	0.00311522
	27	6.29	1.91	0.003360757
	28	6.66	2.79	0.007520849
	29	6.65	2.22	0.003284293
	30	8.75	2.81	0.004176177
Week 8	1	8.78	2.41	0.003329992
10/08/2010	2	5.57	1.12	0.002023727
	3	5.61	0.94	0.002657958
	4	5.82	1.37	0.003597894
	5	8.6	2.48	0.001897446
	6	7.72	2.54	0.003914541
	7	12.32	4.2	0.002457525
	8	7.86	2.78	0.001333242
	9	12.24	4.48	0.002293613
	10	6.91	2.25	0.003399174
	11	6.7	2.68	0.003605629
	12	11.64	4.67	0.001767091
	13	10.34	4.95	0.025454183
	14	9.2	2.37	0.004136039
	15	6.42	2.32	0.003850513
	16	7.9	2.5	0.004528621
	17	6.93	2.12	0.002626788
	18	9.96	3.71	0.002808934
	19	9.4	3.18	0.005863025
	20	7.6	2.27	0.001733462
	21	5.67	1.14	0.001811955
	22	8.8	3.04	0.003420978
	23	4.95	1.1	0.002245882
	24	8.92	3.19	0.001640497
	25	7.27	2.42	0.008422462
	26	9	3.35	0.002886453
	27	6.55	1.95	0.003310772
	28	6.34	2.84	0.006897929
	29	7.73	2.26	0.003192643
	30	8.92	2.83	0.003780802

The data in tables 11.14 –11.16 were used to create figures 7.11 – 7.14 and 7.17 – 7.19.

11.4 Water Chemistry

Table 11.17 Temperature, redox , salinity, water change amount and any comments on the system

Date	Tamperature (°C)	Redox (mV)	Salinity (%)	Water Change (l)	Comments
19/04/2010	26.2				
20/04/2010	26.2				
21/04/2010	26.6		34	1000	
22/04/2010	26.2				
23/04/2010	26	175			
24/04/2010	25.8	172			
25/04/2010	26	181			
26/04/2010	25.9	167			
27/04/2010	26.1	168			
28/04/2010	26		32.9	800	
29/04/2010	26.9	178			
30/04/2010	28.1	170			
01/05/2010	26.8	181			
02/05/2010	26.5	184			
03/05/2010	26.6	164			
04/05/2010	26.7	159			
05/05/2010	27	186	34.1	1000	
06/05/2010	26.6	212			
07/05/2010	26.9	241			
08/05/2010	26.5	235			
09/05/2010	26.7	240			
10/05/2010	26.5	254			
11/05/2010	26.6	265			

12/05/2010	26.5	272	34.1	1500	
13/05/2010	26.6	278			
14/05/2010	26.6	278			
15/05/2010	26.6	257			
16/05/2010	26.7	254			
17/05/2010	26.8	257			
18/05/2010	26.9	254			
19/05/2010	26.8	262	34.3	1000	
20/05/2010	26.7	261			
21/05/2010	26.8	263			6.5kg RowaPhos added
22/05/2010	26.8	271			
23/05/2010	26.6	271			
24/05/2010	28.2	264			
25/05/2010	27.2	274			
26/05/2010	26.9	275	34.9	1000	
27/05/2010	26.9	277			
28/05/2010	26.5	273			
29/05/2010	26.9	275			
30/05/2010	27.1	276			
31/05/2010	26.9	278			
01/06/2010	26.9	283			
02/06/2010	26.8	289	34.7	800	
03/06/2010	26.9	283			
04/06/2010	26.9	283			
05/06/2010	26.8	283			
06/06/2010	26.6	282			
07/06/201	27.1	282			

0				
08/06/2010	26.8	288		
09/06/2010	26.6	282	34.1	1400
10/06/2010	26.6	287		
11/06/2010	26.6	285		
12/06/2010	26.9	290		
13/06/2010	26.9	291		
14/06/2010	26.9	292		
15/06/2010	26.7	287		
16/06/2010	26.8	301	34	1000
17/06/2010	26.8	297		
18/06/2010	26.9	300		
19/06/2010	26.9	301		
20/06/2010	26.8	299		
21/06/2010	26.8	300		
22/06/2010	26.9	300		
23/06/2010	26.9	301	32	600
24/06/2010	26.7	297		
25/06/2010	26.7	295		
26/06/2010	26.5	308		
27/06/2010	26.6	313		
28/06/2010	26.7	309		
29/06/2010	26.7	312		
30/06/2010	26.9	312	33	1000
01/07/2010	26.6	310		
02/07/2010	26.6	311		
03/07/2010	26.8	298		

04/07/2010	26.5	301		
12/07/2010	30	322		
13/07/2010	27	329		
14/07/2010	27.2	330	35	2000
15/07/2010	27.1	328		
16/07/2010	27.7	331		
17/07/2010	27.4	334		
18/07/2010	27.1	205		
19/07/2010	27.1	338		
20/07/2010	27.2	339		
21/07/2010	27.3	343	35	1000
22/07/2010	27.3	340		
23/07/2010	27.4	343		
24/07/2010	27.4	341		
25/07/2010	27	345		
26/07/2010	27	347		
27/07/2010	27	346		
28/07/2010	27.3	351	34	1000
29/07/2010	27.3	350		
30/07/2010	27.3	335		
31/07/2010	27.2	357		
01/08/2010	27.4	362		
02/08/2010	27.3	367		
03/08/2010	27.4	371		
04/08/2010	27.3	373	33	1000
05/08/2010	27.1	375		
06/08/201	27.3	372		

0		
07/08/2010	27	363
08/08/2010	26.3	361
09/08/2010	26.4	367
10/08/2010	26.1	367

The red text relates to the period when the corals were acclimatising and the data in black relates to when the experiment had begun. The data in black were used to create figure 7.15.

Table 11.18 Weekly water chemistry data

Date	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Phosphate (ppm)	Calcium (ppm)	Carbonate Hardness (dKH)	Magnesium (ppm)	pH
14/04/2010	0	0	10	0.11	550	12.2	1170	8.83
05/05/2010	0	0	10	0.08	430	11.5	1470	9.1
26/05/2010	0	0	10	0.045	560	9.6	1410	8

The data in table 11.18 relates to the period when corals were acclimatising.

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