Effect of Light and Water flow on growth of the hard Coral *Acropora formosa*

Student ID: 47-116820
Name: Md. Aktar Hossain
Name of the Supervisor: Associate Prof. Yukio Koibuchi
Department of Socio-cultural Environmental Studies
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1. Introduction

Coral reef plays a very important role in marine ecosystem. It is a habitat of many species of fish and other aquatic animals. An estimation found that among all marine species, one third of the species live in coral reef area (Reaka-Kudla, 1997, 2001). Though coral reef consists of very small part of the ocean (0.17%), but it contributes lot to the vast aquatic environment (Smith, 1978). It supplies food, recreation, medicinal products and so on. It also protects the shoreline of any land part from different natural calamities. Coral reef is biologically diverse and very much productive ecosystem. It contributes the tourism of that particular country and provides dollars to the economy of that country (Tunnell et al., 2007). At the same time millions of people are dependent on the coral reef for their food and income (Costanza et al., 1997). The value of contribution of coral reef can not be determined in monitory value but Moore and Best 2001, gives an estimate of 172 billion dollar to 375 billion dollar every year. In some islands coral reef has taken part of the cultural value for the inhabitants of that island (Tunnell et al., 2007). Coral reef produces calcium carbonate that is significant in biogeochemical cycle in the ocean. This calcium carbonate is the main component for the build up of coral reef.

Pollution is a common problem now a days all over the world. Coral reef organisms can be a good source of pollution record. Reef building coral skeleton can be a chemical recorder of the metals and pollution of seawater (Dodge and Gilbert, 1984; Howard and Brown, 1984). Coral reef is very much sensitive and it is used to monitor recent change in marine environment caused by human disturbance (Wilkinson, 1993; Eakin et al., 1997). Coral skeleton's chemical composition is used to determine sea surface temperature and variation of salinity (de Villiers et al., 1995). Thus it can be used to measure the weather record also. About one hundred countries of the world has coastline with coral reefs (Moberg and Folke, 1999). And about 500 million people live in this vicinity. But in the mean time 19% of coral reefs of the world is lost and 35% of coral reef is in serious threat (Wilkinson, 2008). So, reef building corals are in great risk. The species Acropora formosa is one of the hard corals. It is a branchial coral and present research is on this coral species. To protect the coral reef and its species, proper research and its implementation is necessary.

The coral species can grow with in 20-29°C temperature (Borneman 2001). If the temperature fluctuation rate goes beyond this level, it will create stress for the species. If the situation continues for prolonged time, the species will be bleached. If the situation remains for long time, then the species can die. As a result the whole reef will be dead. Growth of the coral also require irradiance. If the irradiance is even too low, the species can not grow. High irradiance along with high temperature, can cause irreversible injury to the species (Lesser et al., 1990). It can bleach the species. Other factors that affects coral growth is salinity (Muthiga and Szmant 1987), calcium carbonate saturation (Gattuso et al., 1998), pH, water flow and nutrients (Ferrier-Pages et al., 2000). The chemical composition of coral skeletons can be used to reconstruct the sea surface temperature of the tropics and to track variations in salinity (de Villiers et al., 1995; Swart and Dodge, 1997; Gagan et al., 1998). Thus detailed study on coral is immensely important for present and future research.

1.1 Background and purpose of the study

Coral reef is a very important element in marine environment. Its growth and existence is important for the ecosystem. Due to different environmental and man made causes coral reef is threatened worldwide. There are many factors that affect coral biology such as light, current, salinity, temperature, photoperiod, turbidity etc. Light and current are considered to be major limiting factors for the growth rate. The two factors are the part and parcel of marine life. Without these two factors growth of coral is stopped. The influence of current and light may accelerate the growth.

Currently, available information on the effect of light and current on coral growth is limited and therefore little is known about the mechanism on growth by the effect of current and light in respect to different environmental factors. This study focuses on the occurrence of growth of hermatypic reef building corals in different light intensity and different pattern of flow.

Hence, the present study is aimed to understand the condition that gives best growth of reef building corals. To achieve the goal, a series of intensive laboratory experiments were performed. The findings from the study would better serve scientists, decision makers and managers in their attempts to address the best possible environmental condition for coral growth and for its better management. The main objectives of the study are as follows:

- To provide a detailed description of coral growth by the influence of current in different pattern and speed.

- To describe the best light intensity (in terms of PAR) for coral growth.

2. Material and Method

2.1 Sample collection:

Coral samples were collected from Okinawa island (Japan). Then the samples were put in a 36 cm long and 28 cm wide tank in the laboratory. The tank has an inlet and outlet for sea water inflow and outflow. The tank has a top and side light (figure 3.1). Some extra lights were also used for light experiment. A pump was set in the tank to circulate and create desirable flow of the water. PAR was measured by using a sensor in the same location of the coral. Two coral colony of *Acroppora formosa* were used for the experiment. However, one coral colony died during the water flow experiment. So the growth rate was less in flow experiment than previous light experiment results.

2.2 Growth measurement: The growth rate of corals was measured by using Alkalinity method (Hata et al., 2004). The titration alkalinity of seawater was determined from a hydrochloric acid titration of seawater. It was done by using Total Alkalinity Titrator (ATT-05, Produced by Kiroto Electrical Industry). Photosynthesis fixes CO_2 in organic materials, whereas the reverse reaction, respiration, releases it. Overall, the excess organic production in a coral reef community, i.e., the difference between gross primary production and respiration, acts as a CO_2 via the simplified equation:

$$Ca^{2+} + 2HCO_3 \rightarrow CaCO_3 + CO_2 + H_2O \text{----(1)}$$

Edmond (1970) was one of the first to use this method and the technique was automated for the measurements of Total Alkalinity is defined as:

$$TA = [HCO_3] + 2[CO_3^{2-}] + [BOH_4^-] + [OH^-] - [H^+] \text{ -(2)}$$

Inorganic carbon metabolism (Calcification: g µmol/kg/hr) is equal to half the change in TA (Hata et.al., 2004)

$$g = -\frac{\Delta TA}{2} \times \frac{1}{t} \text{ ---- (3)}$$

So from equation 2 and 3 inorganic carbon metabolism (Calcification: g µmol/kg/hr) can be calculated as follows

$$g = -1/2 \times \Delta[HCO_3] + 2[CO_3^{2-}] + [BOH_4^-] + [OH^-] - [H^+] \times 1/t$$

Using this equation the growth rate of coral was measured. The light of the tank was switched on at 06.00 and switched off at 13.00 hour. Rest of the time was night time for the corals.

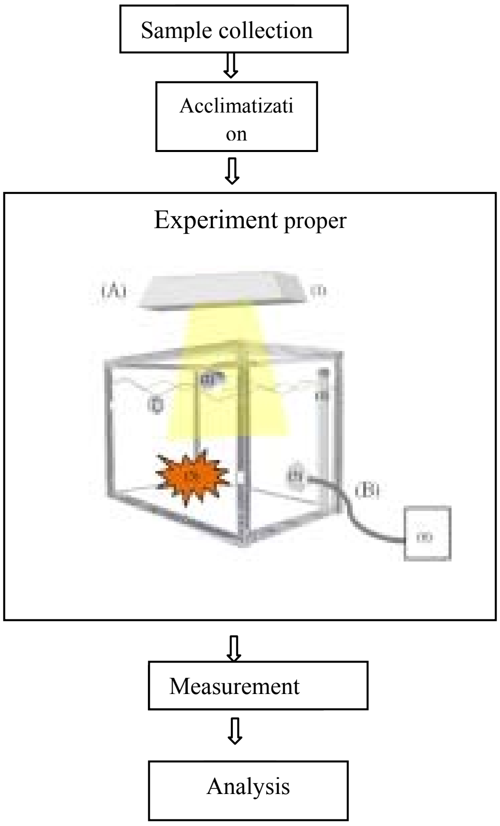

Fig. 1 Flow chart showing the total system of the experiment. (A) Light experiment (B) Water Flow Experiment. (1) Light Bulb/set-up. (2) Inflow of water (3) Coral (4) Outflow (5) Water Pump (6) Control Box of the Pump (7) Side Light

3. Result and Discussion

3.1. Coral Growth with light effect.

The growth rates of *Acropora formosa* were measured under different conditions. Firstly the growth rates during day time and night time were measured. Figure 3 shows that the growth rate during day time is significantly high. Whereas during night time the growth rate is very low and sometimes takes negative value. During day time corals get sunlight and photosynthesis occurs. But during night sunlight is not available so, growth is stopped.

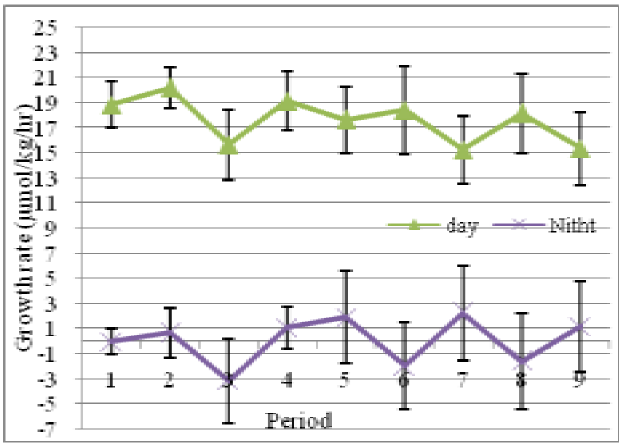

Fig.2 Comparison of hard coral growth in respect with day and night.

Coral growth is strongly affected by the presence of light (Gattuso et al., 1999). This is because of the symbiotic algae. Light plays major role in photosynthesis process. There is some other complex process or mechanism that accelerates the calcification of the coral (Allemand et al., 1998). But the mechanism or process behind this is till not very clear to the researchers. Day and night growth rate (Figure 2) gives clear idea about the effect of light on coral growth. During night light is not available, thus it stops all kind of photosynthesis and growth activity of coral. Some explanation about the relationship between calcification and photosynthesis was given by Chalker, 1975; Goreau, 1961; Gladfelter, 1983; Johnston, 1980. They argued that during photosynthesis process CO2 is removed thus intracellular pH is increased. Again state of intracellular saturation become more favorable for crystallization and deposition of carbonate. Another explanation regarding calcification and photosynthesis is the necessity of energy for the production of organic matrix, Calcium ion and carbonate ion transport etc. And these things are being influenced by the status of energy of the coral that the host gets from the symbiotic algae. The symbiotic algae produces the energy from photosynthesis. The more the photosynthesis the more production of food and more supply to the host and more growth.

In figure 3 the growth rate is plotted against different PAR. At the initial PAR 124.02 growth was 9.83 µmol/kg/hr. As PAR increased, growth is higher till

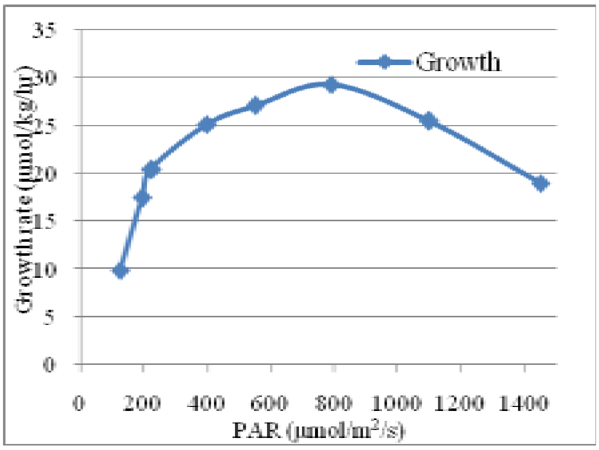

Fig.3 Light curve in different PAR (Photosynthetically Active Radiation).

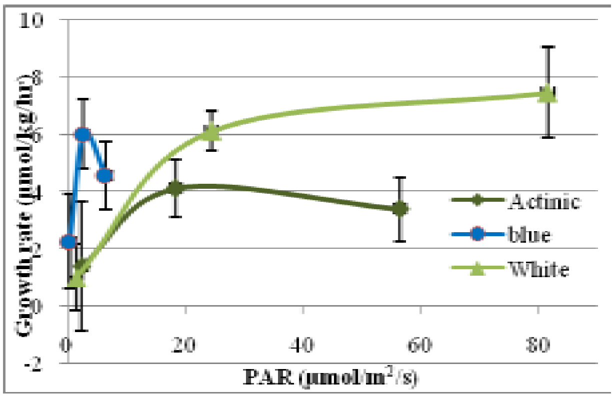

Fig.4 Single light growth performance.

PAR 789.15. At this PAR growth is 29.23 µmol/kg/hr. After this PAR growth does not increase. Highest pick of growth is from PAR 124.02 to 398.35. This result agrees with the experiment of Marubini, F. et al., (2001)

In Figure 4 single light Actinic, Blue and White color was used to show the growth performance. In this case blue light PAR was very low but it gives more growth in comparison with Actinic and white color. But PAR 2.71 gives maximum growth 6 µmol/kg/hr. When PAR is increased to 6.45 µmol/m^2/s, growth is decreased to 4.57 µmol/kg/hr. For Actinic it is also true. PAR 18.35 gives 4.11 µmol/kg/hr growth but PAR 56.44 gives 3.39 µmol/kg/hr growth. White color growth increased as PAR increased. But the growth curve falls after 24.47 PAR. It gives an idea that only single color can not give expected growth for *Acropora formosa*.

3.2 Coral growth in respect with water flow.

Present study made some scheme of water flow and found different growth rate in laboratory condition of branchial hard coral Acropora formosa (figure 5). Some of the previous study also did the same experiment which is also discussed. In all cases the respond to flow speed varied significantly. Besides that, different coral species that might respond differently to flow speed were used in previous studies, thus making it difficult to compare results. Therefore, from the available data, it is difficult to make any final comment about flow and coral growth. Present study did different flow treatments on a single species of hard coral Acropora formosa. The result (figure 5) of the present research shows clear acceleration of growth of hard coral with increased flow rate. Schutter et al, (2010) did the same study and found water flow is important for scleractinian coral growth. Corals get lower growth rate in the stagnant condition. Generally flowing condition refreshes the ambient condition of the coral. It affects the renewal of nutrients. The ultimate result is the increased growth of the coral.

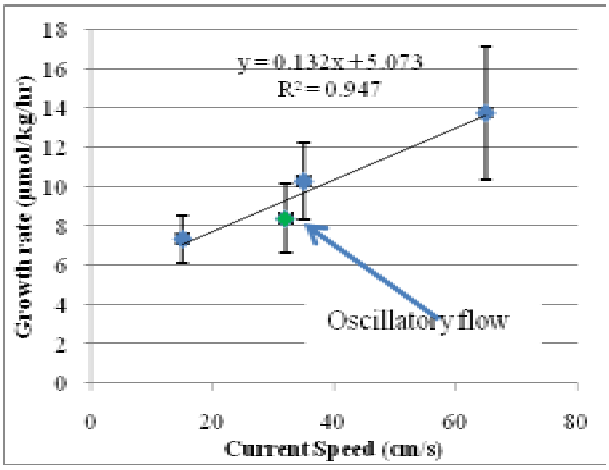

Fig.5 Growth of coral in different flowing condition with PAR value 320 µmol /m2/s.

In figure 5, different flow pattern gives different growth rate. It is noticeable that as flow rate increases, the growth of coral is also increases. It is due to the availability of nutrient element and fresh water inflow. In case of oscillatory flow, the growth rate of *Acroppora formosa* is comparatively less than highest water flow 65 cm/sec.

Normal water flow and oscillatory water flow is applied in different speed in the tank of the experiment room. Highest flow is 70 cm/s and lowest flow speed is 22 cm/s. According to flow speed the growth rate of *Acroppora formosa* increases with irregular variation. In case of normal flow the highest and lowest growth was 12.98 µmol/kg/hr and 6.08 µmol/kg/hr in 70 cm/s and 22 cm/s flow speed respectively. In case of Oscillatory flow the highest and lowest growth is 12.54 µmol/kg/hr and 6.17 µmol/kg/hr in 70 cm/s and 22 cm/s flow speed respectively. From the figure 7 we can observe that growth with normal flow is higher than oscillatory flow till 55 cm/s flow speed. Below this flowing condition, oscillatory flow gives better growth than normal flow. From this graph, it is clear that low speed oscillatory flow is better for coral growth.

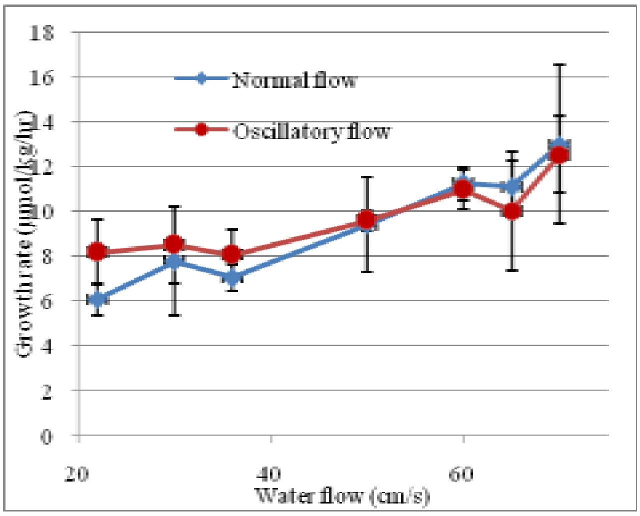

Fig.6 Growth of the coral *Acropora formosa* in consecutive period by using Oscillatory flow and Oscillatory flow with covering the top of the tank by plastic cover.

4. Conclusion

This study of *Acropora formosa* shows that light and water motion have effects on coral growth. Increased PAR increases growth of *Acropora formosa* at a certain limit. After that limit the irradiance makes obstacles for the photosynthesis of the symbiotic algae thus hinders the coral growth of the species. At that point light inhibition of calcification occurs. At the same time water flow increases coral growth. The mechanism behind this accelerated growth with increased water flow is the renewal of the ambient water. New nutrient is brought and waste product produced from the metabolism of coral is washed away. Strong water flow also affects the skeletal density of coral.

Research on corals can reveal many unknown knowledge. Understanding biological process of coral growth in respect to different abiotic factor is studied in this research. It was an attempt to find out how this factors affect growth of *Acroppora formosa*. Optimum condition for coral growth may vary from location to location.