Effect of feeding and shade on the growth of three Hawaiian corals: *Porites compressa*, *Montipora capitata* and *Pocillopora damicornis*

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Introduction

Coral reefs are one the most diverse and productive biological ecosystems on earth, but have been degrading over the past 2-3 decades in an alarming rate throughout the world (Rinkevich, 2005). They are just one group, out of thousands, of organisms that is facing the consequences of climate change. These Cnidarians are the base of the communities found in the ocean, providing reef fish protection from predators and acts as shelter to the reef fish (Rinkevich, 2005). Without corals, the entire food chain falls apart and shifts. Not only are corals important because of the life it holds, however, it is important economically. Dive tours, fishing, hotels and restaurants, and other businesses based near reef systems provide millions of jobs and contribute billions of dollars all over the world.

There are benefits of studying coral culture include the preservation of biodiversity; rehabilitation of disturbed coral reefs (e.g. Rinkevich, 1995, 2000, 2005); reversing coral – algal phase shift (e.g. McManus and Polsenberg, 2004); and reduction of wild harvesting for the aquarium and curio trade (Forsman et al., 2011). Studying corals will also help us sustain our coral reef environments for an economical growth. Farming coral is an important part of coral restoration projects and will help build our coral reefs back to the way it used to be. In order to do that, investigations on corals must continue to gather more information on their ecology and biology.

Previous studies have shown that for some corals nutritional modes of heterotrophy, deriving its nutritional requirements from complex organic substances, and phototrophy, energy obtained from sunlight to synthesize organic compounds for nutrition can be plastic (e.g. Anthony and Fabricius, 2000: Titlyanov et al., 2001). This plasticity allows the organisms to switch their feeding mode from phototrophs to heterotrophs due to the environmental changes

that causes stress to these organisms. Molecular studies have brought an understanding that there are different types of symbiontic zooxanthellae that exist. *Symbiodinium* has divided the genus into 8 clades (A-H) and numerous subclades (Coffroth and Santos, 2005; LaJeunesse, 2001; LaJeunesse, 2002; Pochon *et al.*, 2006; Rodriguez-Lanetty, 2003; Stat *et al.*, 2006). Different symbionts have different environmental tolerances (e.g., Fitt et al. 2001; Berkelmans & van Oppen 2006; Thornhill et al. 2006; Stat & Gates 2010). For example, *Montipora capitata* is known to have a tolerance of high light intensity. Therefore the zooxanthellae found within its host have little tolerance of high light intensity. This applies to other corals too. Different symbionts provide different amounts of nutrition to their host (e.g, Weis et al. 2001; Rodriguez-Lanetty et al. 2004; Stat et al. 2008).

This study aims to investigate differences in growth rates between corals with different symbiont types that are either 1) fed or not, and 2) shaded or not. A previous investigation found a significant weight increase for fed corals relative to unfed controls but with differences among species (Forsman et al., 2011). This investigation will further those studies by concentrating on the growth differences between three species of corals with different degrees of symbiont specificity: *Porites compressa, Montipora capitata* and *Pocillopora damnicornis.* Growth of each species will be compared under sun or shade and with or without heterotrophic food added to determine whether corals with more variable communities of symbiotic zooxanthellae are more reliant on heterotrophic food for growth than corals with highly specific symbiotic zooxanthellae.

Materials and Methods

Study species

Montipora capitata (*Mc*) is found in the tropical both north and central Pacific. It is an encrusting coral that are most abundant down to depths of around 20 meters (66ft). Previous studies have shown that *Mc* does better in condition with high light intensity and high water flow (Finelli et al., 2005; Nakamura et al., 2005). *Mc* is shown to have high reliance on food and light (Forsman et al., 2011). Symbionts found in *Mc* belongs to Clades C3, C21, C17, C31, &D1(LaJeunesse et al., 2004). *Pocillopora damicornis* (*Pd*) is a tropical species. It is found in the Pacific and the Hawaiian Islands. This branching coral is most likely to be found at shallow depths to around 7 m (~23 ft). *Pd* is under Clade A, B1, C1, C15 & D1 (Magalon et al., 2007). *Porites compressa* (*Pc*) is found in the Pacific and the Hawaiian Islands. *Pc* is a massive coral that can grow for thousands of years. The symbionts found in *Pc* belong exclusively to Clade 15 (Rodriguez-Lanetty et al., 2004). It has been found that artificial food has little impacts on the growth of this coral; however it seems to survive better under high light (Forsman et al., 2011).

Sampling

Four coral colonies were collected from around Coconut Island in Kaneohe Bay and were placed into tanks with flow-through seawater. Four replicate fragments were removed from each of the four parent colonies for each of the three species listed above. The four small replicate fragments (~1 cm^2) were cut from larger colonies using bone shears and each fragment was attached to a color-coded 1.5ml plastic tube using marine epoxy (ITW Devcon #80345 S-80). Fragments were allowed to recover in the flow through water table for a week after fragmenting before being moved into the standing tank experiment described below. Tanks started being fed on June 27, 2012 and ended on July 19, 2012.

Tank set up

We used six 45L tanks, each divided into three equal sections by siliconed glass dividers. Each section of each tank was then filled with 15L of sea water. Each tank was filled from a hose that ran from a sprinkler valve at a rate of ~7L per min. Tanks were cleaned and seawater in the system is changed twice each week (Tuesday & Friday) to maintain water quality, but the water is turned off the rest of the time and left to recirculate using small submersible water pumps (Hydor Pico Evolution 200, 70gph powerhead) for the feeding treatment described below. Tanks were checked daily to make sure that the tanks are clean, the water pumps are running, and there are no algae overgrowing coral samples.

Treatments

A random number generator was used to determine which tank belongs to which treatment (Table 1). Three tanks were assigned to each the sun (SU) and shade (SH) treatment. Sun treatment tanks were covered with a mosquito-screen shade cloth, and shade treatment tanks were covered with 50% shade cloth. Average light (PAR) values and 95% confidence intervals for these treatments were 855 ± 241 μmol/m^2/s for SU and 301 ± 101 μmol/m^2/s for SH. Within each tank, 9 partitions were assigned by random number to the fed treatment (A) and 9 unfed (B) treatments (Table 1). Corals in the fed treatments were given commercial coral foods (Reef Chili or Reef-Roids) on alternating days following the instructions found on the artificial food.

Tank 1(SH)	Tank 2(SU)	Tank3(SU)	Tank 4(SU)	Tank 5(SH)	Tank 6(SH)
EX	A	A	EX	A	B
B	A	A	B	B	A
B	B	B	B	A	A

Table 1: Treatments for tanks and for sections of each tank. (SH: shade, SU: sun, A: fed, B: not fed, EX: extra pieces)

Determining sizes of coral

Initial weight and volume of each coral fragment was recorded. Corals were patted dry on a papertowel and then the wet weight was recorded to the nearest 0.1g using an electronic balance. Displacement volume of each coral fragment was determined using a graduated cylinder by recording much sea water it displaces when placed into the cylinder. After 23 days or 3 weeks, the same procedure is followed to collect the final size of each coral fragment in a factorial design of the four different treatments: Sun and Fed, Sun and Unfed, Shade and Fed, and Shade and Unfed.

Results

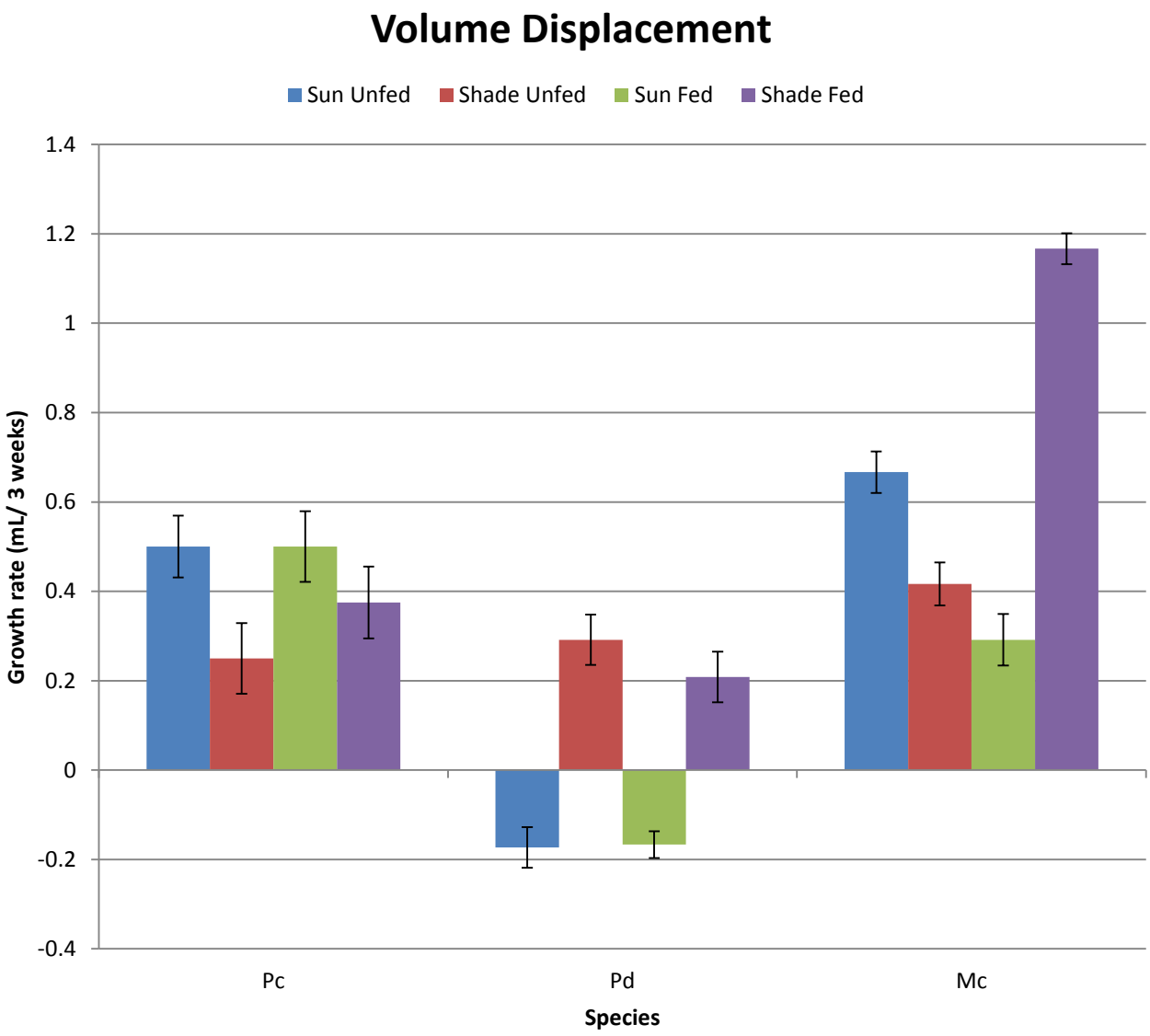

Figure 1a:Volume displacement changes on Mc, Pc, Pd in four different treatments: Sun Unfed, Shade Unfed, Sun Fed, and Shade Unfed (mL: milliliter, Mc: Montipora capitata, Pc: Porites compressa, Pd: Pocillopora damicornis).

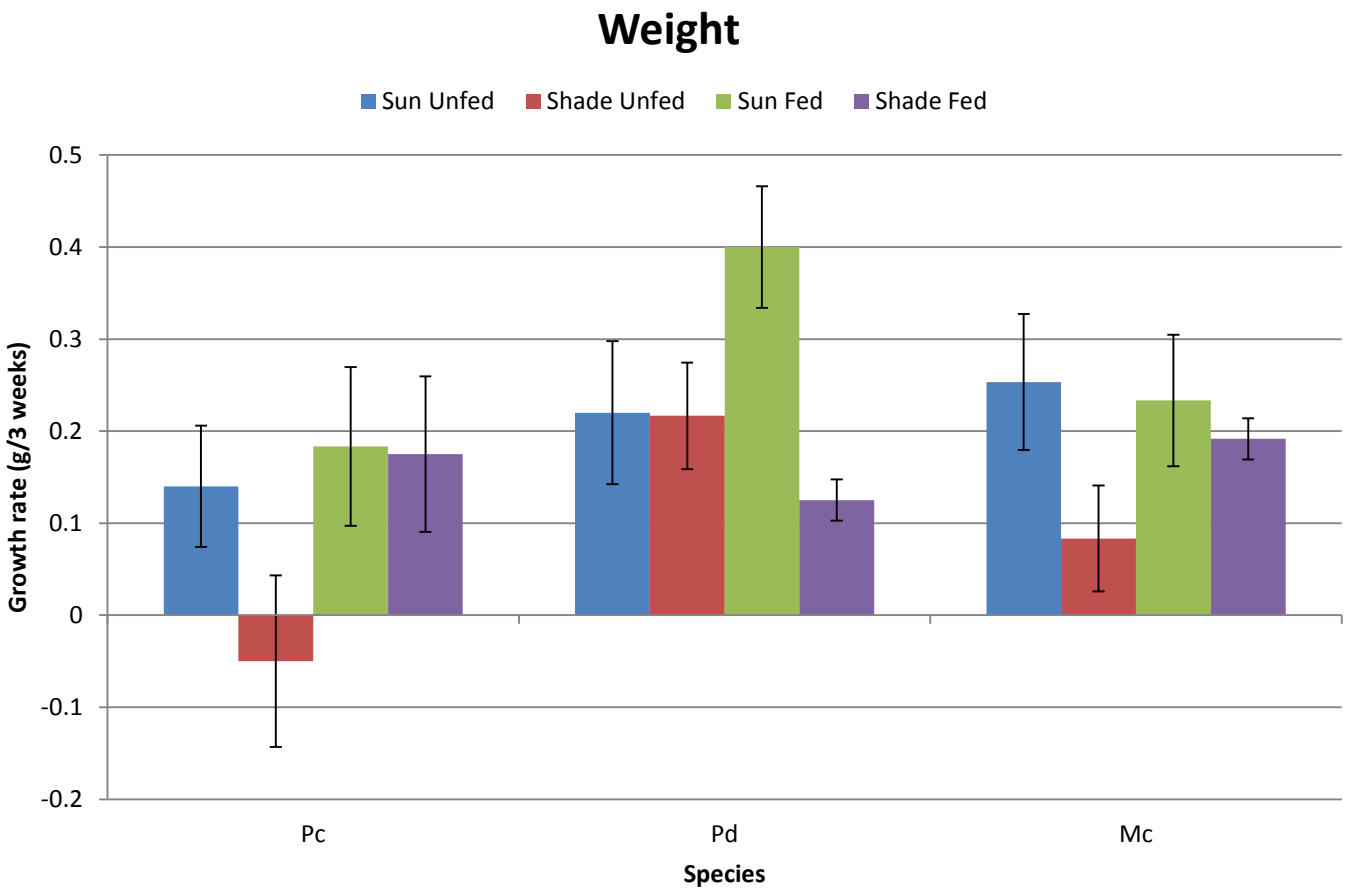

Figure 1b: Weight differences of Mc, Pc, Pd in four different treatments: Sun Unfed, Shade Unfed, Sun Fed, and Shade Unfed (mL: milliliter, Mc: Montipora capitata, Pc: Porites compressa, Pd: Pocillopora damicornis).

Discussion

I hypothesized that how well each coral does in the light depends on their distribution on the reef. If the maximum depth they are found are high in the water column, then they will tend to do well because they are found where more light penetrates. For the three species this study focused on, *Pd* will likely do better when exposed to more light, followed by *Mc*, then *Pc*. I also

think that the coral with the bad symbionts, meaning they did not do very well light, could be helped grown by feeding.

This could be an indication that this could be because an error occurred during the experiment. Maybe during the maintenance of the tanks, when corals were being cleaned some of them fell off the tube and had to be clued back into the epoxy. Next time when conducted, cleaning corals gently is suggested to avoid skewed data.

Pc showed an increase in volume displacement when it was exposed to more light than it did when it was under shade (Fig. 1a). Just as reported in Forsman et al. (2011), *Pc* grew best in high-light, low-flow conditions. Unlike lighting, *Pc* showed little difference in growth rate when exposed to artificial food in culture. To me, this suggests that symbionts provide most of the nutrients needed for *Pc*, and that the coral does not benefit much from feeding (Fig. 1a). However, the treatment shade fed seems to show that only when needed does *Pc* change its nutritional mode from phototrophy to heterotrophy.

Unlike *Pc* above, *Pd* shows negative growth in both sun treatments and positive growth in both shaded treatments. I believe this shows that *Pd* has a low tolerance for light. According Forsman et al. (2011), *Pd* average growth rate increased when being fed. In my experiment that was not the case, however (Fig. 1a). This difference could be due to a variable response of the coral, but Forsman et al. (2011) ran for 3 months, so it could also simply result from not enough time in the experimental treatment to show the effect. In any case, the trend is clearly that both sun treatments declined whereas both shade treatments grew for *Pd* (Fig. 1a).*Mc* showed the greatest average growth rate of all corals in the experiment. Surprisingly, the shade fed treatment showed the greatest growth, followed by the sun unfed, then the shade unfed and finally the shade fed treatments (Fig. 1a). These results suggest that *Mc* is more flexible with its

nutritional modes, but I would have expected the sun fed treatment to be higher in this case. It is possible that some error was made, or that there is an unpredictable interaction between light and feeding in *Mc*.

Conclusion & Recommendations

The depth hypothesis stated that corals that are found higher in the water column will do better when exposed light than those found deeper in the water column. Therefore I hypothesized that *Pd* will do better followed by *Mc,* and *Pc* will not do very well. However, data shown above proved otherwise as *Pc* showed more increase in growth, followed by *Mc* then *Pd.* However, *Mc* shows that corals with bad symbionts could be helped grown by feeding. All three species in the treatment shade fed showed an increase in growth by volume displacement which indicates that corals were helped by feeding them. Recommendation for future experiments will be carefully brushing algae over growing coral fragment to avoid skewing data. The amount of time allowed to these corals for growth was not enough in this trial and should carried out for a longer time period. Finally shortening the handle time to prevent coral fragments from losing their wet weight through osmosis would give optimal weight readings.

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