

**Climate and Conservation
Implications of Coral Thermal
Stress Response in *Capnella* sp.
and *Zoanthus sociatus***

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Abstract

In the last several years, there has been an increase in media coverage and science education related to all ocean health issues, most importantly mass coral bleaching events as a result of climate change. Coral reef ecosystems are a major source of species diversity, and they directly and indirectly affect the survival of at least one-third of all marine species. Corals also sustain many ecosystem services, which include serving as a localized indicator of poor ocean conditions with their bleaching response. Bleaching response is triggered by environmental stress, typically thermal, and is characterized by the coral expelling zooxanthellae that provide the coral with necessary photosynthetic energy and the coral's stereotypical bright colors. In this study, I tested the differential responses to thermal stress between representatives of the subclasses octocorallia (*Capnella* sp.) and hexacorallia (*Zoanthus sociatus*) based on their zooxanthellae interactions. I hypothesized that the octocoral, Kenya tree coral (*Capnella* sp.), are more resistant to bleaching when compared to the hexacoral, green button coral (*Zoanthus sociatus*), due to their decreased dependence on zooxanthellae. Octocoral species, due to their decreased dependence on zooxanthellae interactions, were predicted to be more resistant to this bleaching response and quicker to recover if it does occur. To test this, five 38-liter saltwater aquariums were set up, each with one large fragment of Kenya Tree Coral (*Capnella* sp.) and one rock piece with many Green Button Coral (*Zoanthus sociatus*) polyps. Each tank was maintained at approximate temperatures of 26.5, 27, 27.5, 28, and 28.5°C respectively with the expectation that we should see a decline in coral health at 0.6°C above average. After one month of taking photos and collecting temperature variation data, I found that neither coral species showed any visible signs of

thermal stress or bleaching response, even with spikes up to 29.4°C which is 4.4°C above their known average. The prediction that *Capnella* sp., with less dependence on zooxanthellae, would demonstrate fewer visible signs of thermal stress than *Zoanthus sociatus* following prolonged increased temperatures was not supported and results were inconclusive.

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Introduction

In recent years, the public has become increasingly aware of ocean health issues as a result of worsening impacts on the way that our society functions. Seemingly, the consequences of our culture's anthropocentrism only matter when they begin to harm things that are most valuable to us, such as socioeconomic stability, lifestyle preferences, resource availability, and aesthetic expectations. Spikes in media coverage and science education related to ocean health issues have also aided in this increased awareness, though concern for these outcomes does not always translate to a viable change in human action. The cultural responses to these problems have been too inconsistent to make much significant change in climate action or in marine ecosystem recovery. Many, if not all, current threats to ocean health (e.g., increasing sea temperatures, prevalence of disease, rising sea level, ocean acidification) are directly caused by human activities such as overfishing, pollution, single use plastic waste, burning of fossil fuels, and major coastal development (Hillyer 2016). In the same way that these problems are caused by human activity, it will require a change in human activity to make any sort of sustainable difference for our climate, our oceans, and the species therein.

Beginning with the Industrial Revolution, human activity has caused a steady increase in carbon dioxide emissions in the atmosphere (Skutnik et al. 2020). This collected carbon dioxide prevents heat from escaping, which increases sea surface temperatures across the planet (Skutnik et al. 2020). Some of the first species to experience these changes are corals that exist in shallow reef habitats where less heat

energy is required to raise the temperature of the water (Arizmendi-Meji' et al. 2015). Coral reef systems are a topic of interest both in media exposure and in marine science conservation (Putnam 2021), because they serve as an indicator species as the first to noticeably respond to declining ocean health (Putnam 2021). Corals are an ideal indicator species because of their very visible and traceable bleaching response to unsuitable environmental conditions (e.g., rising temperatures) in our oceans. Reef systems have existed for over 250 million years, and as one of the oldest ecosystem types, the recent deterioration in their ability to survive conveys the severity of current conditions (Hillyer 2016). Most climate models predict that ocean temperatures will continue to rise over the next 50-100 years, up to an additional 4°C by the end of the century, and understanding what this means for coral species survival will be necessary in preserving these ecosystems, especially those already experiencing mass mortality (Arizmendi-Meji' et al. 2015).

To better understand the impact of coral loss on the biosphere, it is important to first note their importance. Coral reefs sustain the highest centralized biodiversity of all marine ecosystems and are comparable to tropical rainforests in species richness and abundance (Fabricus and De'ath 2008). One third of living marine species may directly depend on coral reef ecosystem interactions for their survival (Vargas 2020). Coral reefs also facilitate a number of ecosystem services, including orchestrating the transfer of energy and nutrients between ocean zones, which is a necessary biological process for the survival of benthic and deep sea organisms (Rossi et al. 2020). Coral species exist in divergent biome types across a wide geographic range due to their high adaptability to various light availability patterns, temperature ranges, specific gravity scales, and

available nutrient compositions (Fabricus and De'ath 2008). Despite the wide variations of conditions that coral species can inhabit within their individual environment, they can be stressed by even minor disturbances (Highsmith 1982). Their specific life requirements, habitat criteria, and inability to escape harsh conditions once cemented also make them a conservation priority.

Related to their unique life requirements and physiology, a majority of coral species depend on an obligate symbiotic relationship with photosynthetic dinoflagellates, commonly referred to as zooxanthellae, in which energy and nutrients are exchanged between them (Fabricus and De'ath 2008). In this relationship, zooxanthellae provide essential nutrition and usable energy for the coral host via photosynthesis while the coral provides carbon dioxide and waste products in return (Sammarco and Strychar 2013). The photosynthetic energy from zooxanthellae is the primary source of nutrition for many corals though, if necessary, most corals retain the ability to suspension feed on marine detritus (Rocha et al. 2013). The ratios of what is conducted through zooxanthellae photosynthesis versus suspension feeding depends on the individual coral species and their characteristics. Suspension feeding can be useful in periods of low light, for example, following catastrophic events such as after a storm when stirred up sediment blocks light from the sun (Rocha et al. 2013). Zooxanthellae are acquired in corals through one of two processes: they can either be passed to the brooding larvae from the parent colony during sexual reproduction or they can be captured from the water column directly (Hillyer 2016). Direct capture is more commonly used throughout the lifespan of the coral during periods of growth or recovery from zooxanthellae loss (Hillyer 2016). The average density of zooxanthellae in any coral polyp is one to two dinoflagellate cells

per one coral host cell (Hillyer 2016). Even a minor increase in stress for the coral can reduce zooxanthellae density in the colony (Highsmith 1982).

The productivity of the symbiotic relationship with zooxanthellae decreases as sea surface temperatures approach the upper end of their acceptable temperature range (Sammarco and Strychar 2013). Increased temperatures also decrease cellular defense, homeostasis, and reproductive ability of the coral colony as energy is redirected to survival rather than to reproduction or growth potential (Arizmendi-Meji' et al. 2015, Madeira et al. 2015). In some coral species, thermal stress ceases metabolic and cellular processes, and if the stress is sustained, the processes necessary for RNA and DNA production are stopped completely, causing coral death (Vargas 2020). Once temperatures extend outside of a coral's acceptable range for a sustained period of time, the coral will expel its zooxanthellae from its cells, which is termed "bleaching" due to loss of color that the zooxanthellae cells provide (Sammarco and Strychar 2013). Other symptoms of bleaching include tissue necrosis, visible skeleton, retracted polyps for several week time spans, and others. (Coles and Brown 2003). When zooxanthellae density is reduced, this inhibits the ability of the coral to meet its own metabolic needs (Highsmith 1982). Bleaching events are then characterized by all of the corals in a specific area demonstrating symptoms of bleaching at the same time due to poor local conditions. The severity of a bleaching event is dependent on the types of corals existing on a reef, the genetic makeup of the zooxanthellae, as some are more resistant to temperature change than others, and the temperature ranges that are typical of the location (Dias and Gondim 2015).

On a cellular level, zooxanthellae use chloroplasts to conduct photosynthesis for the coral host (Nielsen et al. 2018). Tied to an increase in ocean temperatures comes an increase in light refraction from atmospheric greenhouse gases (Nielsen et al. 2018). An excess of light directed onto chloroplast cells causes damage to the chloroplasts (Nielsen et al. 2018). These damaged chloroplast cells then release a toxin called reactive oxygen species that harm the coral host cell (Nielsen et al. 2018). Additionally, the protein repair mechanism established to fix chloroplasts that have been damaged by sunlight operate more slowly in higher temperature waters (Nielsen et al. 2018). At this point, the coral host is forced to expel or digest the zooxanthellae to avoid further damage caused by the reactive oxygen species (Nielsen et al. 2018). Bleaching response does not certify coral death, it only increases the likelihood of death from the inability to meet its energy needs. Corals are only able to survive bleaching events if the minimum zooxanthellae density is restored before the coral host cells die from insufficient energy production (Roche et al. 2018).

For example, corals in the subclass Octocorallia have been shown to be more resistant to severe environmental stress than other coral types and are much quicker to restore reefs after mass bleaching events (Vargas 2020). In some areas, this is creating octocoral dominant reefs where octocorals have outcompeted all other species (Schubert et al. 2016). This makes them extremely valuable in reef conservation and restoration practices. Octocorallia is a highly varied subclass of corals that consists of over three hundred genera that span across all latitudes and depth zones (Kahng et al. 2011). In Indo-Pacific Reefs, octocorals cover up to 25% of combined reef surface area, and this abundance makes their health a priority when considering overall sustainability of a reef

system (Fabricus and De'ath 2008). Octocorals also demonstrate a number of reproductive methods including simple fission, fragmentation, polyp release, budding, and branching growth making them valuable in conservation strategies (Kahng et al. 2011, Lasker et al. 2020).

Octocorals are proportionally understudied when compared to their more common reef counterparts, especially considering their unique relationships with their zooxanthellae, which may make them more resistant to thermal stress specifically (Schubert et al. 2016). In their evolutionary history, octocorals have gained and lost their ability to house zooxanthellae many times, which, in terms of living species, has produced individuals that may or may not house symbionts, and those that do are less dependent on them compared to other subclasses of corals (Fabricus and De'ath 2008). Many octocorals will suspension feed on phytoplankton or other small organisms in the water column when light is not available to them (Fabricus and De'ath 2008). Octocorals are considered to be mixotrophic based on their varied dependency on zooxanthellae photosynthesis and suspension feeding on debris from the water column (Schubert et al. 2016). Since octocorals are less dependent on their symbiotic interactions for nutrition, even if they were to bleach, they are more likely to recover because of their ability to conserve energy and meet their requirements through suspension feeding (Schubert et al. 2016). For example, in response to bleaching events or hurricane damage, octocorals only take a few years to fully recover while other coral types recover at a much slower rate (Lasker et al. 2020). The relationship between zooxanthellae and other coral types are well studied, but much less is known about octocoral relationships despite these leads in their stress responses (Schubert et al. 2016).

Octocoral species like Kenya Tree Corals (*Capnella* sp.) are quite common in the aquarium industry but are vastly understudied in the wild and in lab settings. This study is currently the first to evaluate the thermal stress threshold of this species. Little is known about them outside of bare minimum classification attempts and baseline captive care requirements. Even classification attempts are limited, and the many known species of *Capnella* are very difficult to distinguish without genetic sequencing. According to Farrant (1985), *Capnella gabonensis* is the most abundant and widely distributed octocoral in Australian waters, but he states that there is very little information on the life history. Farrant (1985) found that colonies occupy a wide range of reef depths but tend to have a clumped aggregation in shallow habitats. Colonies of *Capnella gabonensis* have a small polyp size and are very highly branched to occupy more cover (Farrant 1985). These physical traits are typical of what is known about all *Capnella* species, which is part of what makes distinguishing between species difficult.

Within a related subclass, Hexacorallia, there is variation in thermal stress responses because of the major changes in characteristics between orders. For example, stony corals (Scleractinia) leave behind a calcium carbonate skeleton after bleaching while hexacorals in the order Zoantheria do not have a skeleton and are only able to display tissue necrosis and color loss (Coles and Brown 2003). Because of this, it is difficult to compare thermal stress response between these dissimilar coral orders, and it is even more difficult to make generalized conclusions about hexacorals as a whole. What is known is that corals in the order Scleractinia were found to be more dependent on photosynthetic interactions for meeting nutritional requirements than octocoral species (Schubert et al. 2016). This increased dependence on energy from zooxanthellae creates a

higher risk for bleaching lethality if the zooxanthellae were to be expelled (Schubert et al. 2016). Zoantharia consist of button corals (*Zoanthus sociatus*) which are also severely understudied despite their popularity in the aquarium industry. In Brazil, Costa et al. (2013) found that wild *Zoanthus sociatus* demonstrated significant seasonal changes in their zooxanthellae densities based on surrounding environmental factors. Trench (1974) found that *Z. sociatus* do not respond to food particles in the water column if acceptable lighting is available, demonstrating major dependence on photosynthetic zooxanthellae interactions. This preference for photosynthetic energy is what is anticipated in many hexacoral species, making Green Button Corals (*Zoanthus sociatus*) a great representative.

In this study, I tested the differential responses to thermal stress between representatives of the subclasses Octocorallia (Kenya Tree Coral, *Capnella* sp.) and Hexacorallia (Green Button Coral, *Zoanthus sociatus*) based on their respective zooxanthellae interactions. Based on what is known about the corals' zooxanthellae dependence and the life history, I hypothesized that the Kenya Tree Coral (*Capnella* sp.) are more resistant to bleaching when compared to the Green Button Coral (*Zoanthus sociatus*) due to their decreased dependence on zooxanthellae. If this hypothesis is correct, then *Capnella* sp., with less dependence on zooxanthellae, should demonstrate fewer visible signs of thermal stress than *Zoanthus sociatus* following prolonged increased temperatures.

Methods

To test this hypothesis, five 38-liter saltwater aquariums were set up two weeks in advance of the experimental research to allow for proper nitrogen cycling, salinity stability (at a specific gravity of 1.025), and adequate thermal regulation. The tanks were insulated on all four sides with styrofoam, fiberglass wall insulation, and cardboard. Then, 34 liters of deionized water and 1300 grams of Instant Ocean aquarium salt were added to each tank. Each of the five aquariums were set up with one mini wavemaker to ensure proper water flow throughout the tank, two Fluval E50 adjustable heaters set to the determined tank temperature, and one AikTryee aquarium thermometer to monitor the overall tank temperatures. The tanks were set to 26.5, 27, 27.5, 28, and 28.5°C. Lough et al. (2018) predicted a major change in coral health (bleaching response) when sea surface temperatures reach 0.6°C above average, so I attempted to mirror this prediction using 0.5°C increments. In their study, they also made future projections for location specific sea surface temperature changes given past and current climate data and estimated the timeframe and reef outcomes at 1.5, 2, and 3°C above average (Lough et al. 2018). Those provided benchmarks served as comparatives for the temperature goals in our study. Lough et al. (2018) also uses a degree heating month index (DHMI) statistic to map the average changes in temperature over time. Based on this technique, I created a maximum of 3.5 DHMI scale equivalent to what was observed in the 2009-2010 warming event. Our DHMI of 3.5 is about 2.5 greater than the 0.92 DHMI currently observed in the world's oceans (Lough et al. 2018). This is relevant when considering future projections.

The tanks also shared two Viparspectra 165W lighting systems set to 40% blue light and 5% white light on twelve hour timers. Two digital USB microscopes with photo and video capability recorded photos of the thermometers in each of the tank systems

every sixty seconds throughout the study. This was to monitor the temperatures inside the tanks in 24 hour windows to determine if there were any major deviations from their set target temperatures. Minor variations in temperature were accepted as long as all of the tanks stayed an average of 0.5 degrees apart. The temperature of the room was maintained at 25°C to better sustain tank temperatures. Once the tanks were cycled and showed stable temperatures, five similarly sized colonies of Kenya Tree Coral (*Capnella* sp.) were collected from Malone University's display aquariums and placed into the study tanks. Similarly sized Green Button Coral (*Zoanthus sociatus*) polyps were added to the same five tanks. Malone University's display aquariums are maintained at 25°C, so the increments from 26.5°C to 28.5°C seemed sufficient to induce thermal stress.

To compare the responses of octocorals and hexacorals to prolonged increased temperatures, every week for one full month, photos were taken of each colony to track any visible change throughout the study. Following the month of thermal data collection, each coral colony was assessed visually, and the photos were analyzed for any differential signs of stress, damage, or bleaching.

The tanks were inspected frequently with in person temperature and salinity checks. Deionized water was added as needed to maintain salinity at a specific gravity reading of 1.025 using a refractometer.

I used the collected hourly temperatures from the microscope videos to determine the actual average temperature of each tank throughout the study. I also used standard error to determine the accuracy and spread of each of these averages.

Results

No visible bleaching response or other damage was observed in the weekly photographs with the exception of initial shock responses to being placed in the tank. This temporary initial shock was observed as dark coloration in *Zoanthus sociatus* and disappeared after a few days (Figure 1). In *Capnella* sp., the fragments were unable to cement right away and could not maintain the hydrostatic pressure to stand up until the second week (Figure 2). It was also noted that in some of the photographs, *Zoanthus sociatus* appears agitated, observed as retraction of polyps, though as this is a short-term behavior, it was not categorized as an indefinite thermal stress response (Figure 1). *Capnella* sp. stayed consistently an ideal coloration and did not demonstrate any visible signs of stress; in fact, it continued to grow, even at the highest recorded temperature spike of 29.4°C. The actual average tank temperatures were calculated from hourly recorded thermometer readings and the actual averages varied some from the ideal tank temperature goals (26.1 [± 0.4], 26.45 [± 0.2], 27.7 [± 0.5], 28.2 [± 0.2], 28.4 [± 0.2]) (Figure 3). Visual inspection of microscopic photographs also did not reveal any certain loss of zooxanthellae density or loss of coloration due to bleaching.

Discussion

Based on the lack of identifiable response from either species, it is inconclusive whether *Capnella* sp. is better at resisting thermal stress than *Zoanthus sociatus*. The prediction that *Capnella* sp., with less dependence on zooxanthellae, would demonstrate fewer visible signs of thermal stress than *Zoanthus sociatus* following prolonged increased temperatures was not supported. At temperatures 3.5°C above their ideal temperature of 25°C, signs of thermal stress, such as significant color loss, tissue

necrosis, visible skeleton, and retracted polyps for several week time spans should have been observable, if not a full bleaching response (Coles and Brown 2003). With this expectation, it is interesting that neither species showed no damage, had fully cemented to the substrate, and appeared visually to have even grown slightly from the first week. Following the conclusion of the study period, the tanks were ignored and unmaintained for one week before lab tear down, and during that week, the tanks showed consistent temperature spikes of 29.4°C and tissue damage in the coral polyps consistent with pre-bleaching response. These results will not be considered as viable because they were found after the conclusion of the one month study period and other variables may have contributed though this may be important information for future attempts of this study or similar studies.

I cannot conclude any viable reason why no response would have occurred in the study period other than a lack of research and interdisciplinary knowledge about the acceptable temperature ranges of both species. It is apparent that these results are not a product of major methodological failure due to improper water quality parameters because if they were, coral death or damage would have resulted. One possibility to explain these results could be that the one month span was not a long enough data collection time to see significant damage. However, based on the extreme temperature increase, I expected that one month would be enough. This new knowledge that *Capnella* sp. and *Zoanthus sociatus* show survivability at an average water temperature of 28.4°C with spikes to 29.4°C may expand their accepted temperature range both in the aquarium trade as well as for use in conservation and restoration practices. In future studies, I would recommend a longer time scale, potentially 3 months, as well as temperature

progression above 28.5°C to find the thresholds for bleaching in both species. It might also be interesting to include more representative coral species just to get a better idea of comparative response through other classification groups.

To further explain this unexpected result, it is helpful to draw a comparison to other Anthozoans and their response to thermal stress. Reitzel et al. (2013) found that starlet sea anemones (*Nematostella vectensis*) had strict cut offs within their acceptable temperature range where lethality occurred quickly once this range was exceeded, especially in earlier life stages. Even so, they observed that wild individuals in areas with higher temperatures become acclimated to the average temperatures of that area, even if they meet or exceed this specific thermal range (Reitzel et al. 2013). In their lab study, they found that individuals from higher latitudes with lower maximum temperatures had significantly decreased growth rates at temperatures of 29°C (4°C over ambient temperature) (Reitzel et al. 2013). Additionally, Chomsky et al. (2004) found that Mediterranean sea anemones (*Actinia equina*) kept at 25°C and 30°C lost body mass due to an imbalance in energy lost from thermal stress response with energy required for survival. The anemones showed the ability to acclimate as necessary in these conditions but were not able to maintain body mass, let alone promote ideal growth (Chomsky et al. 2004). The findings from these studies demonstrate the opposite of what was observed in my *Capnella* sp. kept at higher temperatures. These mixed results within Anthozoans make it difficult to form the necessary general conclusions about marine species survival that help to inform decisions related to climate change and protection of these animals.

Due to the declining health of coral reefs around the world, research linking coral bleaching and climate change has increased over the past 20 years with emphasis on

conservation solutions (Bowden-Kerby 2001). Current conservation strategies are utilizing countless different approaches in an attempt to prevent any further damage or mass bleaching events on our remaining healthy reefs. One of the most common coral restoration practices is coral farming, in which fragments from healthy wild colonies are taken back to the lab to grow until they are large enough to survive on their own and establish their own colonies. Fragmentation is an adapted asexual reproduction technique that is naturally occurring and can be induced by coral experts as a method for rapid growth in conservation lab settings, which makes this strategy great in terms of simplicity and usability. One major disadvantage is that asexual reproduction by fragmentation only creates clones of the parent, so it is not sustainable in terms of species genetic diversity (Highsmith 1982). Another major disadvantage is that transplantation of fragmented coral polyps between reefs is not considered to be a reliable method due to the high mortality rate, though techniques are being developed to improve this strategy (Forsman et al. 2006). One controversial idea that is becoming more popular in coral restoration discussions is utilizing human-assisted evolution to force corals to become more genetically resistant to thermal stress and bleaching responses (Putnam 2021). These corals could then be outplanted, and this would solve the issues of farming restoration survivability and also loss of genetic diversity. The biggest disadvantage here would be the time needed to successfully test and develop these genetic editing or other technologies quickly enough to race the impacts of climate change (Anthony et al. 2020). There are also a number of ethical concerns surrounding this practice, which causes difficulty in acquiring support for this idea (Putnam 2021). The central idea here is that

none of our current restoration strategies are perfect, though it becomes more imperative to find these solutions as reef health continues to decline.

The recent demand for coral bleaching research and solutions has led to some incredible developments, but even so, there are still many gaps in our knowledge of coral reef ecology, especially related to climate change and thermal stress impacts. Based on the past several years of data, climate models predict an increase in ocean surface temperature of 2.9 to 3.4°C within this current century (Anthony et al. 2020). Even if by some chance, it stays below a 1.5°C increase (which has a 1% probability of occurring), sea surface temperatures will still increase by 0.3°C at minimum estimates, with continued potential to harm marine species (Anthony et al. 2020). Around 75% of reef habitats are currently considered to be threatened or destroyed, and this number is predicted to increase proportionally to the severity of stress (Hillyer 2016). Research shows that coral reef ecosystems are not able to recover completely on their own and that it is becoming urgently necessary for humans to intervene if we want to restore degraded reef systems (Bowden-Kerby 2001).

While human intervention may be necessary for reef recovery, it is important to acknowledge that many of the issues that reefs are dealing with are also caused by human activity (Bowden-Kerby 2001). This is most commonly a result of the incessant contribution of generalized carbon emissions that are the direct cause of increased ocean temperatures (Bowden-Kerby 2001). Another example of harm caused by human activity is the destructive fishing practices that are reinforced by a high demand for the seafood industry (Bowden-Kerby 2001). Their heavy netting and equipment often physically destroy coral reef cover (Bowden-Kerby 2001). In terms of ecological balance,

overfishing impacts dynamics of the reef ecosystem and dependence on food webs. For example, herbivorous fish that predominantly eat algae off of corals are disappearing, and this may impact survival and reproductive ability of corals (Bowden-Kerby 2001).

Another notable threat to coral reefs generally is the overharvesting of healthy corals for the saltwater aquarium trade. Especially when reef ecosystems are struggling, collection of wild corals is not sustainable for reef health and preservation (Rocha et al. 2013).

These are just a few examples of human behavioral concerns that could be reduced or ceased if not for the anthropocentric values that are rooted in the way our society operates. Taking the responsibility and the initiative for a change in human behavior will be an integral part of ocean conservation and restoration attempts. Coral reefs also provide a great deal of instrumental value for humans in the forms of tourism, attracting species for food sources, pharmaceuticals, and coastline protection (Hillyer 2016). Citing these benefits and increasing localized understanding of them may be one way to encourage behavioral change and further engagement from citizens in conservation practices.

Figures

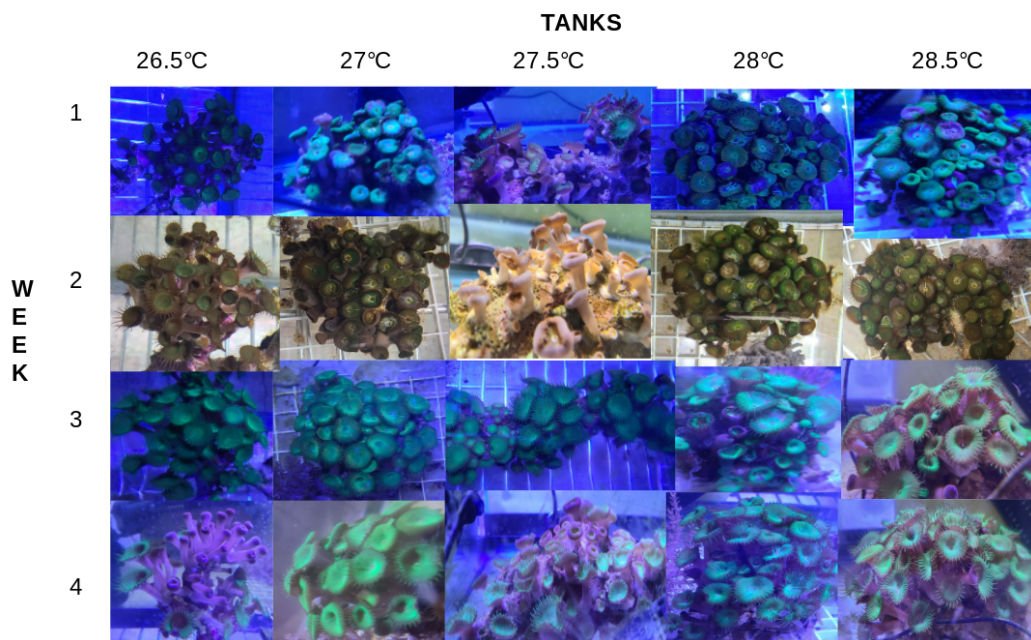


Figure 1: Weekly photos taken of *Zoanthus sociatus* to compare for any visual polyp damage between weeks. Note the retracted polyps in some and the dark coloration in the first week.

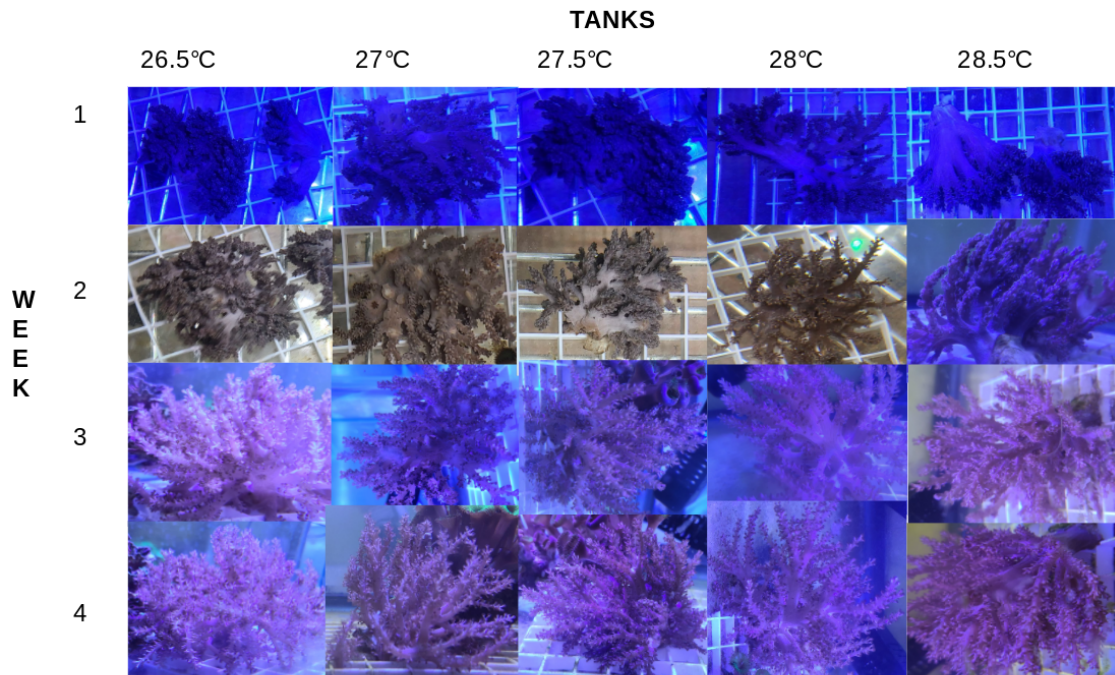


Figure 2: Weekly photos taken of *Capnella* sp. to compare for any visual damage between weeks. Note the deflated look in the first two weeks due to low hydrostatic pressure.

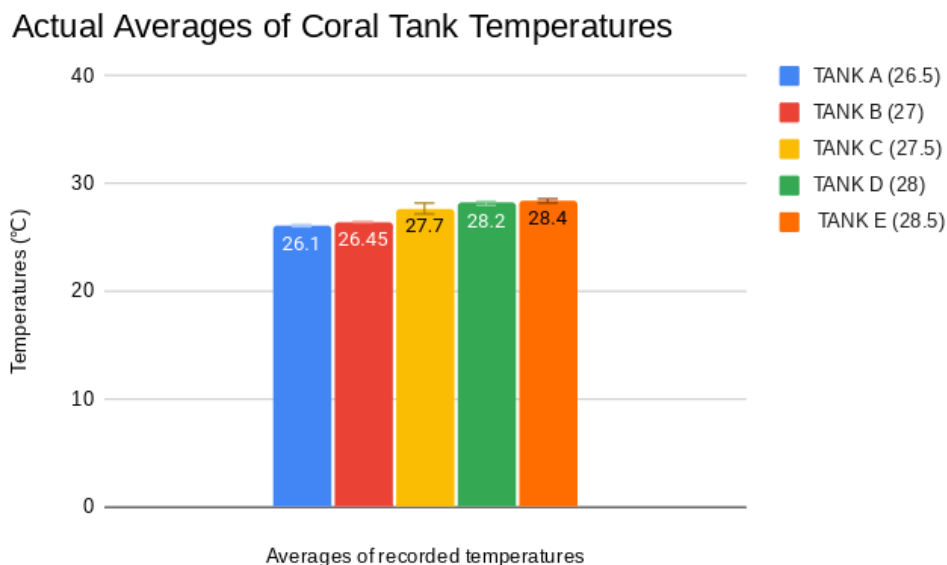


Figure 3: Shows the actual calculated average tank temperatures based on recorded hourly thermometer readings.

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