Coral Bleaching and Genetic Modified Coral Restoration:

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BIO376: Marine Biology

March 27, 2023

Coral Reefs and Coral Bleaching:

Fun fact: Did you know that coral reefs are considered to be animals? Coral reefs are present in tropical and subtropical waters worldwide and have some of the most diverse biological ecosystems (Bellwood et al., 2004). Due to their diversity, coral reefs provide a habitat to thousands of marine life species and food to millions of people (Bellwood et al., 2004). There are two types of corals in the world: hard reef-building corals confined to the tropics, and soft non-reef-building corals found everywhere, as seen in Figure 1 (McMeans, 2022). Coral reefs are primary producers, as well as primary and secondary consumers, making them very important for ecosystems because they provide the energy to enter other food webs (Sheppard, 2021).

Moreover, coral reefs are essential because they help shorelines reduce the impacts of natural disasters by dampening the effects of storm surges and erosion (Cinner et al., 2018). However, the most significant threat to coral reefs posed by climate change is the rising ocean temperatures (Heron et al., 2016). As the ocean temperature increases, corals become stressed and eject algae, causing them to appear bleached and eventually die, as shown in Figure 2 in the Great Barrier Reef (Heron et al., 2016). So what now? There are ways to save coral reefs, and some studies have shown that coral restoration might be one of those ways.

Coral Reefs: What and How Are They An Animal?

Coral reefs are often mistaken for marine plants, but in reality, they are a group of primitive animals called cnidarians, characterized by the tentacle-like stinging cells they all possess to catch prey (Sheppard, 2021). Corals are made up of basic units called polyps, similar to sea anemones with tentacles surrounding the mouth of their sac-like bodies. The polyps secrete limestone, or calcium carbonate, forming a cup-like structure in which they live. Over time, the polyps grow vertically and divide horizontally over the limestone structure. The polyps' tentacles have stinging cells called nematocysts, which can inject venom to catch and pull zooplankton toward the mouth (Sheppard, 2021).

The bottom part of the tentacles contains thousands of single-celled algae called zooxanthellae, which are primary producers and provide the polyps with nutrients and sugars from primary production. The zooxanthellae also take in animal waste, giving the coral its brownish-green appearance. The dynamic relationship between the zooxanthellae and polyps allows them to live in symbiosis, with the algae providing more nutrients than the amount of zooplankton being captured (Sheppard, 2021).

The complexity and variation of polyps within the animal kingdom enable coral reefs to harbour and maintain diverse marine life (Bellwood et al., 2004). The primary producers such as zooxanthellae survive and grow, providing energy for other food webs (Sheppard, 2021). The physical structures of coral reefs support and protect a high level of biodiversity, allowing for more primary and secondary production. In a meta-analysis, it was found that reef crests, along with natural hazards, reduce impact by an average of 97%, providing protection to the coast (Ferrario et al., 2014).

Despite the resilience of corals and the massive reefs they form, they have a fragile relationship with the symbiotic algae. If the relationship is disrupted, corals will die. This underscores the importance of preserving coral reefs and the symbiotic relationship between the polyps and zooxanthellae to maintain the biodiversity and ecological functions of these vital marine ecosystems (Sheppard, 2021).

The Bleaching! The Horror! The Problemz!:

Climate change has had many impacts on the world, not just on the air we breathe, but also on the oceans. One of the impacts of climate change has been the rising water temperatures, causing many marine organisms in the tropics to be very close to the maximum temperature they can survive in (Sheppard, 2021). The warming in the tropic comes in pulses, called marine heatwaves, killing corals and reefs in significant numbers, and are the biggest threat to their survival (Sheppard, 2021). On top of climate change, the ocean is taking in much more carbon dioxide, changing the pH levels of the ocean and making the ocean more acidic (De'ath et al., 2009). Due to the ocean's decreased pH levels, coral reefs cannot grow their exoskeleton (De'ath et al., 2009). More new studies have shown that their exoskeletons are also declining with the increase in ocean acidification (De'ath et al., 2009).

However, the biggest threat is the warming temperatures, as reefs are the most sensitive ecosystem to climate change (Heron et al., 2016). When analyzing the sea surface temperature, around 97% of reef pixels warmed from 2008-2012 (Heron et al., 2016). Coral bleaching occurs when the seawater is warmed and the corals are stressed, causing them to expel the symbiotic algal cells (Heron et al., 2016). The loss of the zoozooxanthellae causes the corals to lose their colour and show the calcium carbonate skeleton, which is white (Heron et al., 2016). As the zoozooxanthellae make almost ninety percent of photosynthesis for the coral, the corals die over a long period of stress and warmth (Heron et al., 2016). But, suppose the warming is not too severe, as in duration and temperature. In that case, the algae may recolonize and later restore the coral (Heron et al., 2016). It is also predicted that with seawater becoming warmer, coral bleaching events will become more frequent and severe (Heron et al., 2016). This can be seen in the studies when monitoring the sea surface temperatures from 2012 compared to 1980; the reef pixels were shown to be almost three times more exposed to bleaching-level thermal stress (Heron et al., 2016).

Studies have shown that thermally stressed corals have a higher vulnerability to disease, lower reproductivity output and reduced skeletal growth (Heron et al., 2016). This can also factor in the higher acidic levels that might reduce skeletal growth (De'ath et al., 2009). With the longest bleaching event being from 2014 to 2016, the impacts of bleached corals have reduced the reef's area, coral cover and biodiversity, as in the local close extinction of coral species (Heron et al., 2016). Other studies have found reefs with bleached corals provide lower-quality habitats for fish and other species, including humans, with fewer ecosystem goods and services (Heron et al., 2016).

Restoration To the Rescue? Or Not?

Climate change has significantly affected coral reefs and the planet, as seen with higher temperatures, poor water quality, coastal development, destructive fishing, overharvesting, and invasive species becoming the norm in marine life (Oppen et al., 2017). Despite this, there is hope for coral reefs. A recent meta-analysis on coral restoration has shown a success rate of sixty to seventy percent, indicating that restoration is possible (Boström-Einarsson et al., 2020). Coral reefs can also adapt and react differently to coral bleaching (Morikawa & Palumbi, 2019).

To clarify, ecological restoration aims to recover degraded, damaged or destroyed ecosystems and create self-sustainable communities (Oppen et al., 2017). However, in the case of coral reefs, the ecosystem has been changed to the degree that cannot be reversed, such as with the ocean's temperature (Oppen et al., 2017). Therefore, a broader and more flexible term of intervention ecology might be needed for coral reefs, which focuses on managing future changes while retaining historical states or using a new system that meets the desired ecosystem attributes and maintains the goods and services of the older system (Oppen et al., 2017).

One study has shown that some coral reefs can adapt to higher temperatures by hosting specifically adapted zooxanthellae (Rowan, 2004). While this could assist in keeping coral reefs alive, it might also be a trade-off, as thermal tolerance by the algae is associated with slower growth, lower lipid storage, and smaller egg sizes during reproduction in the coral (Oppen et al., 2017). Furthermore, it is worth noting that most coral reefs cannot survive due to the increased heat and acidic ocean (Rowan, 2004).

Reports have also shown that coral restorations have been dominated by small, short-term projects and a lack of clear and achievable goals. Most studies have poorly designed projects (Boström-Einarsson et al., 2020). While restoration projects have only looked at fast-growing branching corals, standardized monitoring and reporting are crucial to ensure the success of coral restoration efforts (Boström-Einarsson et al., 2020). However, many restorations have shown areas of success at around sixty or higher percent (Boström-Einarsson et al., 2020).

In conclusion, the success of coral restoration efforts gives hope for coral reefs' future, but it is crucial to implement standardized monitoring and reporting and consider more flexible approaches such as intervention ecology to manage future changes in coral reef ecosystems. Global warming has not only raised the ocean's temperatures but also has had many other complications, like ocean acidification. Due to the ever-changing results of global warming these new restoration techniques, such as assisted genetic modification and restoration with other types of algae, might be able to keep corals alive and well (Boström-Einarsson et al., 2020).

<u>What shall we do?</u>

In conclusion, there are ways to help coral reefs stay alive and well, but these are human interventions and restoration processes. As we still do not know the long-term costs and benefits of these new genetic restoration processes, we do know to what extent they are needed to keep coral reefs alive. Other types of help, like optimal conservation outcomes, should include habitat protection and restoration, which might help mitigate the loss of reefs (Boström-Einarsson et al., 2020). However, many studies have shown that with global warming increasing, the heat waves will increase as well, and coral bleaching will become more frequent and more dangerous to corals (Heron et al., 2016). Meanwhile, other problems like ocean acidification will also hinder the growth of reefs in the long run (De'ath et al., 2009).

Appendix:

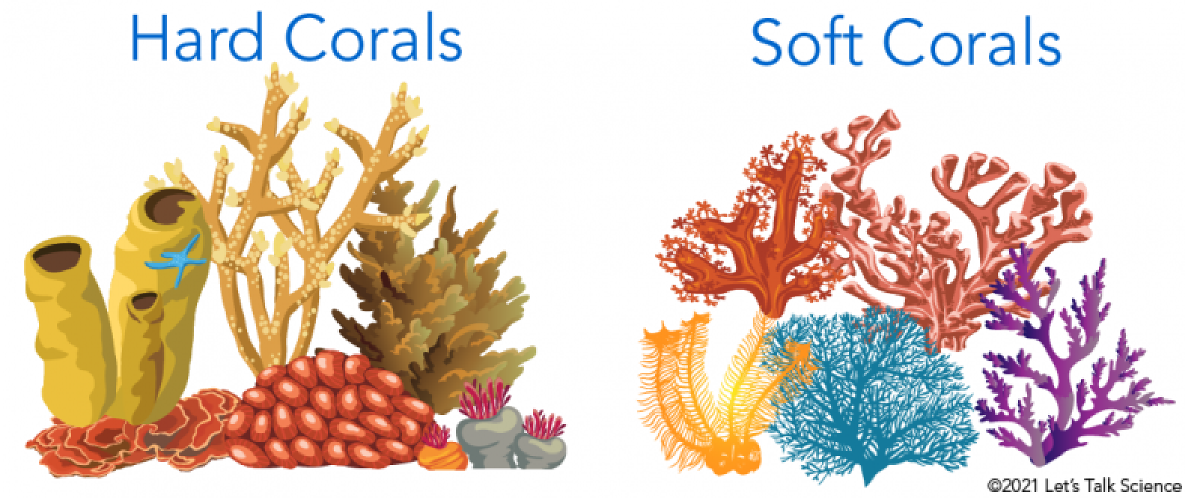

Figure 1: This figure shows how a hard coral on the left might look and what a soft coral looks like (Coral Ecosystems, 2021).

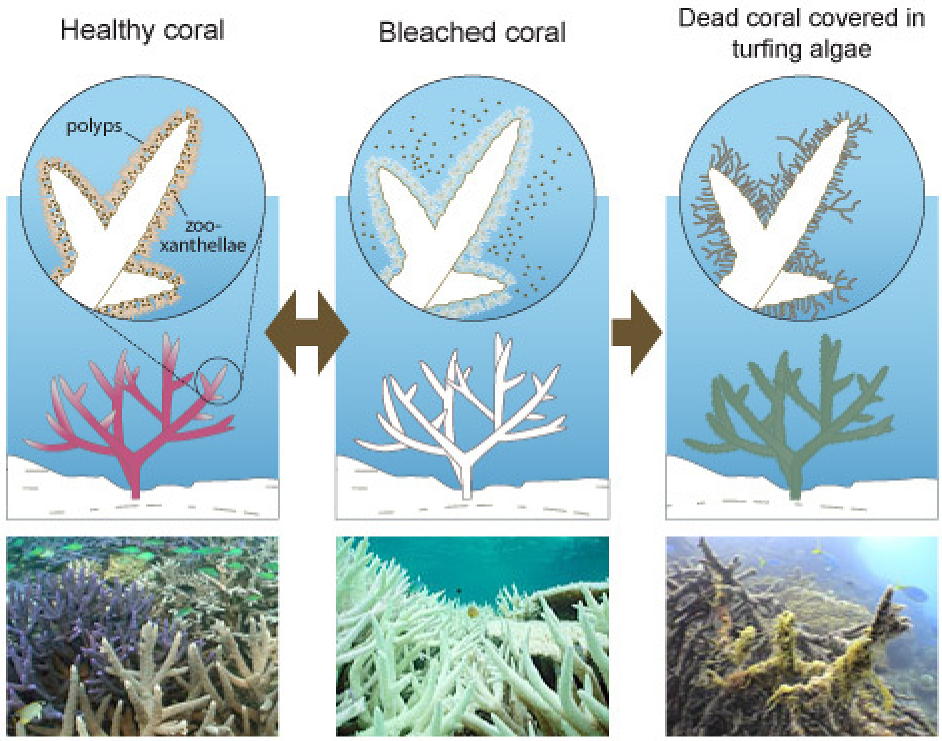

Figure 2: This figure shows how the surfaces of healthy coral, bleached corals and dead corals compare and contrast in the Great Barrier Reef.

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