

Coral bleaching in the Great Barrier Reef: Can acquired thermal tolerance save the corals?



Fig 1. The Great Barrier Reef as seen from outer space. (source: Australia's Great Natural Wonder, n.d.).

The Great Barrier Reef (GBR) is one of the Seven Natural Wonders of the world with the largest coral reef on the planet—so large that it can be seen from outer space (see Figure 1) (Australia's Great Natural Wonder, n.d.). Aside from being a popular tourist attraction, the reef is a very rich and biologically diverse ecosystem that is home to more than 3000 reef systems, 400 different kinds of coral, 1500 species of tropical fish, 200 bird species, 20 species of reptiles such as sea turtles, and many more marine animals (About the Great Barrier reef, n.d.; Australia's Great Natural Wonder, n.d.). The GBR acts as an important refuge, breeding ground, and nursery ground for many marine animals, plants, fungi, and bacteria (About the Great Barrier reef, n.d; Hoegh-Guldberg, 2010; Veron et al., 2009).

The reef itself is made of many living organisms called coral polyps that live together in colonies (see Figure 2) (Britannica, 2014; Hohn & Merico, 2012). Corals have zooxanthellae, which are symbiotic, photosynthetic algae from the genus *Symbiodinium*, that live inside the gastrodermal cells of the corals and transfer 60-80% of their fixed carbon to the corals (Hoegh-Guldberg, 2010; Peixoto et al., 2017). Corals use this energy to grow, reproduce, respire, and expand the reef through a process called calcification, in which large amounts of calcium carbonate are produced and deposited to build coral reef structures (Hoegh-Guldberg, 2010; Peixoto et al., 2017).

A growing problem with the coral reef systems in the GBR is that there has been an increase in coral bleaching events throughout the past couple of decades (Ainsworth et al., 2016). Coral bleaching is when corals turn white (revealing their calcium skeletons) because they expel their zooxanthellae (see Figure 3) (Peixoto et al., 2017). Without their zooxanthellae, corals may not get enough energy they need to build reefs and sustain themselves which may lead to the degradation of the reefs. Severe, long-term coral bleaching has been known to result in extensive coral death (Linares, Pratchett, & Coker, 2011).

Coral bleaching occurs as a general response to stress (Hoegh-Guldberg, 2010). Scientists have found that thermal stress, where ocean temperatures are above the corals' thermal threshold, has been linked to coral bleaching (Berkelmans & Willis, 1999; Hoegh-Guldberg,

2010; Kennedy, Ordoñez, & Diaz-Pulido, 2018; Peixoto et al., 2017). The rise in ocean temperatures can be anthropogenically caused (i.e. climate change) or naturally caused (e.g. El Niño) (Kennedy, Ordoñez, & Diaz-Pulido, 2018; Linares, Pratchett, & Coker, 2011). Unfortunately, corals are very sensitive to changes in ocean temperatures and increases in ocean temperatures by as little as 1-2°C above the summer monthly temperatures (>29°C) may lead to coral bleaching (Berkelmans & Willis, 1999).

For example, a study conducted by Kennedy, Ordoñez, and Diaz-Pulido (2018) found that the southern area of the GBR that was thought to have escaped bleaching during the 2016 thermal heat stress event, had in fact experienced bleaching. Between April 7 and April 9 of 2016, they examined 14 shallow fringing reef sites with high coral cover near the Keppel Islands in the GBR. At that time, sea surface temperatures were above the normal seasonal average by 0.7°C. They looked for coral bleaching and categorized the sites as either no bleaching, partial bleaching, white, bleached and partially dead, or recently dead. They found that all sites had mild bleaching (corals paling), with only two sites having severe bleaching. Fortunately, no areas were marked partially dead or recently dead. This led the researchers to suggest looking into resilience frameworks to help identify which sites were the most resilient and to encourage the propagation of resilient reefs. Planned development on the islands would have to also take into account the reefs that are vulnerable so as to minimize stress to sensitive reefs.

Another study, conducted by Ainsworth and colleagues (2016), looked at the effects of protective sub-bleaching (corals exposed to low thermal stress recover and then get exposed to bleaching temperatures), single bleaching (corals exposed to bleaching temperatures), and repetitive bleaching (corals exposed to bleaching temperatures twice with a recovery time in between) on the physiological response of the coral *Acropora aspera* in the GBR. They found that in the protective sub-bleaching condition, corals and their zooxanthellae actually developed a thermal tolerance that resulted in low coral bleaching and coral cell mortality. In the single and repetitive bleaching conditions, corals did not develop a thermal tolerance and had increased coral bleaching and coral cell mortality. Having time to acclimate to low thermal stress helped the corals to build thermal tolerance.

Ideally, the solution to preventing coral death from coral bleaching would be to reverse climate change. However, that task is difficult both politically and economically, and even if there was a 50% reduction in fossil fuels, it would take several years before there would even be improvements in the remaining coral reef ecosystems (Goreau, McClanahan, Hayes, & Strong, 2000). Thus, scientists are now thinking about reducing coral death due to bleaching by looking into the development and genetics behind thermal tolerance in corals. That way, corals can adapt or acclimate to higher ocean temperatures and survive in those temperatures. For example, Ainsworth and colleagues (2016) suggested that management actions for reducing coral reef degradation can focus on decreasing cumulative environmental stress with particular prioritization for corals with thermal tolerance. That way, coral reefs could build resilience and promote thermal tolerance within the population.

Palumbi, Barshis, Traylor-Knowles, and Bay (2014) also looked at the thermal tolerance of corals, specifically *Acropora hyacinthus*. They argued that corals living in naturally warmer temperatures (i.e. highly variable areas where temperatures often reached above the local critical bleaching temperature of 30°C) are more resistant to thermal stress and can survive bleaching temperatures in comparison to their conspecifics living in cooler temperatures (i.e. moderately

variable areas where temperatures rarely reached above the local critical bleaching temperature). Corals in the highly variable areas were found to have higher survivorship and higher photosynthetic efficiency with their zooxanthellae than corals in moderately variable areas. They tested this by taking corals of highly variable and moderately variable areas and experimentally exposing them to bleaching temperatures. They also performed a swap to see how corals acclimatize in different thermal environments. Highly variable corals were moved to moderately variable areas, and moderately variable corals were moved to highly variable areas. They found that moderately variable corals developed some thermal tolerance in the highly variable areas (greater retention for chlorophyll a) but not to the same degree as the highly variable corals' thermal tolerance. In contrast, highly variable corals placed in moderately variable areas lost their high retention for chlorophyll a and became less sensitive to heat, matching the moderately variable corals' level of thermal tolerance. They also determined that heat shock and chaperonin proteins, as well as tumour necrosis factor receptors, cytochrome p450, and fluorochromes played a role in heat acclimation. Furthermore, tumour necrosis factor receptors had higher gene expression in the highly variable corals, which is important as these receptors are involved in immune functioning and apoptosis. This study suggests that corals have the capacity to acclimate to their environment, however, the issue lies in how the corals adapt. Is there a certain range where corals could potentially acclimate to high temperatures and any temperatures above that range would cause bleaching? Future research should look in to special environmental conditions that allow acclimatization in corals. Research should also look more in to the transplantation of corals once they are able to acclimate and how stable and successful the corals are afterwards.

Palumbi and colleagues (2014), as well as Ainsworth and colleagues (2016) showed that the corals they studied had the ability to acclimate to temperatures higher than what they are used to. Future research should look into the acquisition of thermal tolerance in different coral populations in the GBR as a way to help build resilience in reefs and help corals acclimate to higher ocean temperatures. It may be the case that how well coral populations adapt to high ocean temperatures will predict the survival of coral reefs in the future (Palumbi et al., 2014). It is also a question of whether coral populations can evolve fast enough to adapt to the increasing ocean temperatures caused by climate change (Pandolfi & Kiessling, 2014). Building resilient reefs by promoting thermal tolerance is one way to prevent coral death from coral bleaching induced by climate change.

References

- About the Great Barrier Reef. (n.d.). Retrieved from <http://www.greatbarrierreef.org/about-the-reef>
- Ainsworth, T. D., Heron, S. F., Ortiz, J. C., Mumby, P. J., Grech, A., Ogawa, D., . . . Leggat, W. (2016). Climate change disables coral bleaching protection on the Great Barrier Reef. *Science*, 352(6283), 338-342. doi:10.1126/science.aac7125
- Australia's Great Natural Wonder. (n.d.). Retrieved from <http://www.greatbarrierreef.org/>

- Berkelmans, R., & Willis, B. L. (1999). Seasonal and local spatial patterns in the upper thermal limits of corals on the inshore Central Great Barrier Reef. *Coral Reefs*, 18(3), 219-228. doi:10.1007/s003380050186
- Britannica. (2014, October 22). Polyp. Retrieved from <https://www.britannica.com/science/polyp-zoology>
- Goreau, T., Mcclanahan, T., Hayes, R., & Strong, A. (2000). Conservation of Coral Reefs after the 1998 Global Bleaching Event. *Conservation Biology*, 14(1), 5-15. doi:10.1046/j.1523-1739.2000.00011.x
- Hoegh-Guldberg, O. (2010). Coral reef ecosystems and anthropogenic climate change. *Regional Environmental Change*, 11(S1), 215-227. doi:10.1007/s10113-010-0189-2
- Hohn, S., & Merico, A. (2012). Modelling coral polyp calcification in relation to ocean acidification. *Biogeosciences*, 9(11), 4441-4454. doi:10.5194/bg-9-4441-2012
- Kennedy, E. V., Ordoñez, A., & Diaz-Pulido, G. (2018). Coral bleaching in the southern inshore Great Barrier Reef: A case study from the Keppel Islands. *Marine and Freshwater Research*, 69(1), 191. doi:10.1071/mf16317
- Linares, C., Pratchett, M., & Coker, D. (2011). Recolonisation of *Acropora hyacinthus* following climate-induced coral bleaching on the Great Barrier Reef. *Marine Ecology Progress Series*, 438, 97-104. doi:10.3354/meps09272
- Noaa. (n.d.). NOAA Coral Reef Watch Coral Bleaching Thermal Stress Outlook (Experimental product). Retrieved from https://coralreefwatch.noaa.gov/satellite/bleachingoutlook/descriptions/demo_introduction.php
- Palumbi, S. R., Barshis, D. J., Traylor-Knowles, N., & Bay, R. A. (2014). Mechanisms of reef coral resistance to future climate change. *Science*, 344(6186), 895-898. doi:10.1126/science.1251336
- Pandolfi, J. M., & Kiessling, W. (2014). Gaining insights from past reefs to inform understanding of coral reef response to global climate change. *Current Opinion in Environmental Sustainability*, 7, 52-58. doi:10.1016/j.cosust.2013.11.020
- Peixoto, R. S., Rosado, P. M., Leite, D. C., Rosado, A. S., & Bourne, D. G. (2017). Beneficial Microorganisms for Corals (BMC): Proposed Mechanisms for Coral Health and Resilience. *Frontiers in Microbiology*, 8. doi:10.3389/fmicb.2017.00341
- Veron, J., Hoegh-Guldberg, O., Lenton, T., Lough, J., Obura, D., Pearce-Kelly, P., . . . Rogers, A. (2009). The coral reef crisis: The critical importance of. *Marine Pollution Bulletin*, 58(10), 1428-1436. doi:10.1016/j.marpolbul.2009.09.009

Figures

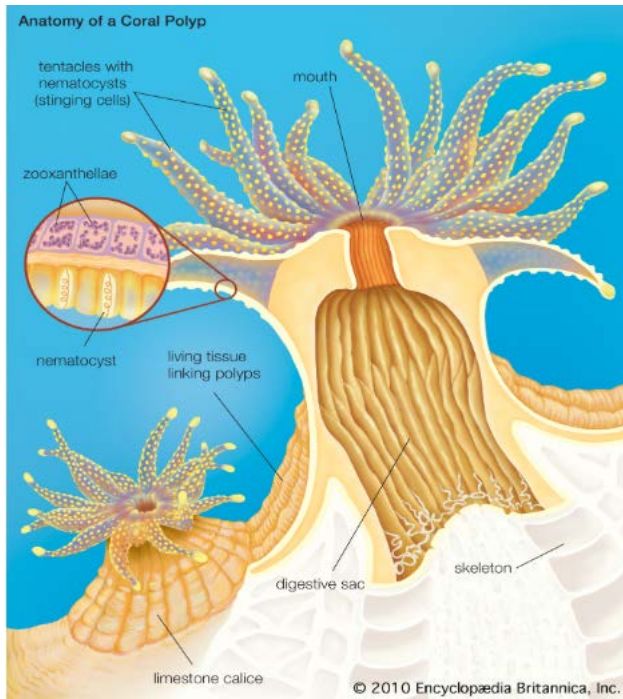


Figure 2. the anatomy of a coral polyp. Corals are composed of coral polyps (Source: Britannica, 2014)



Figure 3 a photograph of bleached corals (Source: NOAA, n. d.)