How to Kill a Killer: Controlling the Effects of the Murderous Crown-of-Thorns Starfish on Reef-Building Coral Communities

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March 22, 2022

Despite being naturally beautiful and aesthetically pleasing, coral reefs are fundamental ecosystems that not only provide numerous economic and cultural functions for humans, but also play imperative roles throughout the ocean. The coral reef structure serves as the basis for one of the highest and most productive ecosystems in the world, and accordingly, must be preserved in order to protect tropical marine life around the globe (Maragos, 1996). Unfortunately, coral reefs have been progressively declining as the result of multiple anthropogenic factors, including water pollution from terrestrial run-off, overfishing and coastal development. However, there is an even more prominent villain to account for roughly forty-two percent of coral mortality in the Great Barrier Reef, known as the Crown-of-Thorns starfish (De'ath et al., 2012). Luckily, there are accessible models that have been proven to manage and reduce the outbreaks of these killer predators.

But first, what really are coral reefs? With amazing productivity, high species diversity and a variety of functions, coral reefs represent ecosystems that maintain beaches, provide protection from heavy wave action and offer opportunities for recreation and jobs for local communities (Maragos, 1996). Accordingly, it is important to understand the viability of coral reefs, along with their intricate biological processes.

Reef building corals are geographically limited to clear, warm and sunlit tropical waters. They form entire chains of islands across the Indo-Pacific and western Atlantic oceans, resulting in three major classifications of coral reefs (Goreau et al., 1979). While Fringing reefs grow in shallow waters and closely border the coast, Barrier reefs are located further from the coast and are larger in size, continuing for great distances. The Great Barrier Reef in particular is the world's largest coral reef ecosystem, and is subject to severe disturbances including multiple mass outbreaks of Crown-of-Thorns starfish (Maragos, 1996). Meanwhile, Atoll reefs consist of rings of coral islands that enclose a central lagoon and are typically formed on ancient volcanic rock. Nonetheless, these reef building corals are responsible for harboring more plant and animal species than any other ecosystem on earth (Goreau et al., 1979)!

Reef building corals are considered "hermatypic," and their structures typically accumulate over the remains of already-existing coral reefs through the accretion of calcium carbonate (Maragos, 1996). While the skeleton of corals is composed solely of aragonite, coral growth is achieved through an increase in calcareous mass and also includes the living tissue that overlies the skeleton (Goreau et al., 1979). Thus, although corals are sessile and each reef is incredibly unique, they are actually considered living organisms, as they are made up of soft polyps that vary in size (Goreau et al., 1979). Polyps gain their energy through stunning prey with their specialized stinging cells called nematocysts.

Furthermore, polyps live in symbiosis with a unicellular algae called zooxanthellae. As the zooxanthellae conduct photosynthesis, they provide organic material and oxygen to the polyps. The coral host capitalizes from this energy, while zooxanthellae actively take up inorganic waste products and carbon dioxide from the polyps, gaining their own energy. Therefore, as the algae produce oxygen for the coral polyps to respire, the carbon dioxide that was produced by the polyps are fixed by the zooxanthellae into organic matter (Goreau et al., 1979). Zooxanthellae also enhance the calcification rate of corals, meaning that intense coral growth and sunlight dependence is only observed when the algae are present (Goreau et al., 1979). Hence, corals are able to actively feed on plankton with their nematocysts, take up dissolved organic matter and nutrients across their body wall, and use the chemicals released by zooxanthellae to respire, gain energy and maintain a symbiotic relationship with them (Goreau et al., 1979). Consequently, corals play multiple ecological roles throughout the ocean. Since they are primary producers, primary consumers, detritus feeders and carnivores, coral reef environments have the highest rates of photosynthetic carbon fixation and limestone deposition compared to any other ecosystem (Goreau et al., 1979)!

Evidently, corals are essential oceanic ecosystems that maintain multiple functions. However, there is increasing concern about the degradation of the earths coral reefs, and the main drivers of coral mortality are dynamic (De'ath et al., 2012). Surprisingly, coral loss isn't solely due to anthropogenic factors, although they are certainly responsible for large scale coral disturbances (De'ath et al., 2012). So, what's worse than human threat?

Coral predation, which is actively eating and killing corals, is actually increasing in frequency and intensity as a result of human activities (De'ath et al., 2012). But first, who are the killers? The Crown-of-Thorns starfish, who are scientifically classified as Acanthaster planci, are predatory invertebrate seastars that feed on reef building corals and often lead to widespread mortality of coral populations (Kayal et al., 2012). The outbreaks of these predators constitute significant disturbances throughout the Indo-Pacific oceans as they propagate the entire reef system through aggregative migrations. They are classified as ordered, diffusive and relatively slow biological disturbances (Kayal et al., 2012). Although the magnitude in coral decline varies according to the outbreak events of the Crown-of-Thorns starfish, it is important to understand what exactly initiates the drastic eruption of these organisms. Some argue that they are a natural phenomenon, yet outbreak frequencies have increased substantially throughout history as a result of human activity (Brodie et al., 2005).

It is generally known that climate change stressors have complicated effects on ecosystems and may directly or indirectly impact oceanic organisms (Kamya et al., 2017). Accordingly, one of the main climate stressors on marine ecosystems is increasing levels of ocean acidification, which can alter the interactions between herbivores and plants. As plants alter their nutritional values, herbivores increase their consumption of less nutritious plants to compensate for a lack of protein in their diet (Kamya et al., 2017). Since the Crown-of-Thorns starfish are herbivorous throughout their juvenile stage of life, they rely on crustose coralline algal food (CCA) for survival. Therefore, as ocean acidification conditions increase, the juvenile Crown-of-Thorns starfish increase their feeding rates on the CCA as they become more palatable and highly nutritious. As the juvenile stages of the seastars are highly dependent on the CCA, increased feeding rates result in a boost in the coral-eating life stage recruitment, posing as a concerning threat for coral reef viability (Kamya et al., 2017). Unfortunately, these starfish are subject to similar outbreaks due to increased nutrient inputs from terrestrial run-off.

Nutrient input from rivers in the Great Barrier Reef have increased over four-fold within the last century (Brodie et al., 2005). This results in a higher proportion of larger phytoplankton compared to normal. Since Crown-of -Thorns larvae feed predominantly on these organisms, there is more food availability in nutrient-enriched waters, including diatoms, dinoflagellates and chlorophytes (Brodie et al., 2005). Therefore, the Crown-of-Thorns larvae survive, grow and reach competency earlier and in larger numbers where there are elevated amounts of large phytoplankton in the water column (Brodie et al., 2005). Accordingly, greatly increased nutrient discharge results in phytoplankton blooms, which coincides with the initiation of Crown-of-Thorns spawning. As the seastar larval survival is enhanced, the outbreak of populations will drive even more coral-eating and result in immense coral decline (Brodie et al., 2005).

Without intervention, coral covers within the Great Barrier Reef will likely fall to ten percent within the next ten years (De'ath et al., 2012). Therefore, actions to reduce Crown-of-Thorns starfish populations must be taken so that corals are able to maintain their ecological integrity and biodiversity. Luckily, as there is an urgent need for mitigation, there have been a multitude of trials and efforts to combat the outbreaks of these organisms in an efficient manner (Boström-Einarsson, 2018).

According to the Australian Government guidelines, the best method for undertaking control of Crown-of-Thorns starfish in the Great barrier Reef is through using a modified drench gun to inject the starfish with poison (2017). This can be achieved through a single-shot method with bile salts or household vinegar, or a multi-shot method with sodium bisulphate. By injecting the predator, the risk of breaking corals and spiking are minimized and there is no residual environmental impact from the poisonous solutions (GBRMP, 2017). The equipment that is typically used to inject the organisms includes an applicator, a five-litre plastic bottle containing the poisonous solution, and a hook, which are typically used by Marine Park Tourism Operators to protect the local coral community (GBRMP, 2017). Since single shot methods are far more time efficient compared to multi-shot methods, trials have been conducted to test the efficacy of using solutions such as household vinegar and citric acid to control the seastar outbreaks.

Although injections with bile salts are greatly effective at culling Crown-of-Thorns starfish, access can be difficult in developing countries and non-government entities. The chemical is also expensive and has a limited shelf life, which poses greater complications for localized control efforts (Boström-Einarsson, 2018). However, vinegar, which is widely available and cost-effective, provides an efficient alternative as an injection solution, since it triggers acidosis in the starfish and leads to death. Studies indicate that when taking into account coral viability and other organisms, there is evidence that injection of Crown-of-Thorns starfish with household vinegar has no harmful effects on organisms in the surrounding environment (Boström-Einarsson, 2018). Therefore, with a refined delivery method, complete mortality of the seastars can consistently be achieved by using household vinegar. Accordingly, there are no signs of increased coral mortality or disease when this control method is used, indicating that vinegar can become a powerful new tool to defend coral reefs from Crown-of-Thorns predators (Boström-Einarsson, 2018). Furthermore, powdered citric acid is a widely available and cost effective method of control, although the starfish require two to four shots to reach full mortality (Buck et al., 2016). Thus, four injections halve the time of death compared to two, since the acidic solution is more evenly spread throughout the organisms bodies. Additionally, when a higher concentration of the acid is used, the Crown-of-Thorns starfish became immobile at a quicker rate, although some seastars still survive for up to ten days after injection (Buck et al., 2016). Nonetheless, citric acid and household vinegar are effective, economical and widely available control methods for Crown-of-Thorns starfish outbreaks with no impact on other marine organisms. Additionally, they can be mixed on site with seawater, making it easily transportable and unlikely to accumulate in sediment (Buck et al., 2016).

At the end of the day, coral reefs are the foundation of oceanic health and are essential to both marine and earthly life. As anthropogenic factors are increasing Crown-of-Thorns starfish predation, it becomes human responsibility to control the outbreaks and protect the ocean's biodiversity. With consistent efforts to minimize these killers, the Great Barrier Reef and other coral communities can not only survive, but continue to flourish.

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