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Detrimental Effects of Rising Global Temperatures and Atmospheric Levels of Carbon Dioxide on Coral Reef Ecosystems

The three major types of coral reefs are fringing reefs, barrier reefs, and atolls. Fringing reefs typically “form borders near volcanic islands”, barrier reefs are usually found “further off shore near continental landmasses”, and atolls usually “[surround] low islands” (Snyderman 15). The major calcifying organisms associated with coral reefs are corals, calcifying macro algae, benthic foraminifera, mollusks, and echinoderms (Kleypas 21). Examples of these organisms include plankton, shellfish, sea stars, sea urchins, and coral polyps. Coral reefs are made of the limestone skeletons that coral polyps build to protect their soft bodies. Coral polyps are part of the phylum Cnidaria, and feed by stunning their prey with tentacles called cnidae that surround their mouth opening. The polyp could be described as a “bag enclosing a coelenteric cavity or gut open to the surrounding seawater by a mouth” (Kleypas 25). The organism takes in carbonate from the surrounding seawater and secretes a protective calcium carbonate skeleton to encase it. The coral reefs that many are familiar with are actually the limestone skeletons of many generations of coral polyp colonies built up over hundreds of years. Corals partake in a symbiotic relationship with zooxanthellae, photosynthetic algae. The zooxanthellae give corals their vibrant colors and provide them with oxygen as a byproduct from photosynthesis. In turn, corals provide the zooanthellae with a place to live as well as nutrients and carbon dioxide from their waste (Snyderman 15).

One consequence of the increasing carbon dioxide emissions into our atmosphere due to human activity and natural events consists of a dramatic alteration of the oceans chemistry. Studies have shown that at least one third of all carbon dioxide released into the atmosphere ends up in the oceans (Acid in the Oceans). This creates a detrimental problem for the vast majority of marine organisms that rely on calcification as a means of building their outer skeletons for protection. These organisms use carbonate found in seawater to build their shells, and increasing the levels of carbon dioxide in the water reduces the amount of carbonate available to the organisms. Due to reduced carbonate, organisms such as shellfish are not able to produce sufficiently thick shells. As seen in the pacific oyster industry, "by 2009 [they were] reporting 80% mortality for oyster larvae due to the corrosive nature of the water" (Jamail). Carbon dioxide reacts with water to form carbonic acid. In the ocean, the "carbonic acid dissociates to form bicarbonate ions and protons, which in turn react with carbonate ions to produce more bicarbonate ions" (Hoegh-Guldberg 1737). When the carbonate in the water reacts to form bicarbonate ions, which are useless to marine calcifiers, there is less carbonate available in the water to them. This reduces the rate of calcification and favors erosion on their shells.

Levels of carbon dioxide are currently at a record high. In the atmosphere, concentration levels "now exceed 380 [parts per million], which is 80 ppm above the maximum values of the past 740,000 years" (Hoegh-Guldberg 1737). In order to counter the decreasing levels of carbonate in seawater, corals are likely to respond in one of three possible ways. First, corals may exhibit a "decreased linear extension rate and skeletal density" (1738). This would contribute to a decreasing habitat size for the many organisms that inhabit the reefs, as well as a more fragile coral reef. Second, the corals may respond by "[maintaining] their physical extension or growth rate by reducing skeletal density" (1738). This response would prove the corals to be especially brittle and very susceptible to storm damage and other damages including "activities of grazing animals". Third, corals may maintain "both [their] skeletal growth and density under reduced carbonate saturation by investing greater energy in calcifying" (1738). This response would ultimately lead to less energy invested in other necessary processes such as reproduction, and in turn eventually reduce the total population of the coral colony. All of these possible responses to reduced levels of carbonate predict disastrous consequences for the coral reef ecosystems.

In addition to reducing the available amount of carbonate in the ocean water to marine calcifiers, increased levels of carbon dioxide entering the ocean and forming carbonic acid decreases the oceans pH, making it more acidic. "The range of tolerable pH changes [in the ocean] is as yet unknown for many marine organisms", although studies show that "a decrease of 0.2 to 0.3 units in seawater pH inhibits or slows calcification in many marine organisms, including corals, foraminifera, and some calcareous plankton" (Zeebe 52). Compared with preindustrial times, the "average surface ocean pH has already decreased by 0.1 units" (52), based on such studies, another drop of 0.1 units in pH could inhibit the calcifying process and drastically change ocean ecosystems as we know them.

Also, the increase of global temperatures is proving to be detrimental to coral reefs, causing coral bleaching. Coral bleaching occurs when ocean temperatures rise so high that corals lose the zooxanthellae living on them. The loss of the symbiotic relationship with these algae is due to the fact that “[photosynthetic] pathways in zooxanthellae are impaired at temperatures above 30 degrees [Celsius]” (Buchheim). This dysfunction in the photosynthetic pathways of zooxanthellae causes death to the algae, as well as no oxygen being provided to the coral. Corals under moderate thermal stress with a reduced number of zooxanthellae “typically show reduced growth, calcification, and fecundity” (Hoegh-Guldberg 1740). Although recovery from high water temperatures is possible if the coral regains its zooxanthellae, if the loss of zooxanthellae is prolonged, “the coral host will eventually die” (Buchheim). The decrease in ocean pH combined with decreasing carbonate levels and effects of coral bleaching may prove to be too much for calcifying organisms to handle. Compared to the “relatively long generation times and low genetic diversity” found in many reef-building corals, the rapid rate of global temperature increase and carbon dioxide emission increase is estimated to be too fast for the corals to adapt (Hoegh-Guldberg 1741).

With the destruction of coral reefs, the disruption of many important marine habitats, resources used by humans, and food chains around the world will also result. Coral reef ecosystems are very delicately balanced, with each organism depending on each other. The basis relationship between the coral itself and the zooanthellae provides the main habitat and shelter for a variety of vertebrates, plants, and invertebrates alike. Although reefs make up only about 0.1% of the world’s oceans, they provide a home to about 25% of all marine species. As acidification and rising water temperatures progress further, “the density and diversity of coral on reefs are likely to decline, leading to vastly reduced habitat complexity and loss of biodiversity” (Hoegh-Guldberg 1740). Rising acidity combined with depleted carbonate supplies and coral bleaching are “pushing reef ecosystems from coral- to algal- dominated states”, since many alga are more resistant to these harsh conditions. Coral associated fish and other coral reef dependant organisms are expected to die off, as these organisms “do not appear to have the capacity to adapt fast enough to sudden environmental change” (1738). Major socioeconomic effects are also possible due to the changing coral ecosystems. Coastal communities are very heavily dependent on coral reefs in multiple ways, “in Asia alone, coral reefs provide about one fourth of the annual total fish catch, and [provide] food to about one billion people” (1742). Humans are not only dependant on coral reefs to provide food, but also coastal protection, tourism income, aquarium trade, and possible cures for diseases.

Human efforts and actions focused toward rebuilding, re-establishing, and sustaining coral reefs must be taken in order to avoid drastic, detrimental, changes in ocean ecosystems and marine species. Coral reefs are naturally resilient, and if given the chance, will restore themselves to full health. In order to promote natural restoration of the reefs, humans must “reduce the influence of local stressors such as declining water quality, coastal pollution, and over-exploitation of key functional groups such as herbivores” (Hoegh-Guldberg 1742). Putting an end to over-fishing and destructive tourism helps to sustain current populations of fish situated in the reef ecosystem, maintaining the food chain and ecosystem diversity. Also, educating local communities about the importance of coral reefs and promoting organizations that support coral reef protection raise awareness to what needs to be done in order to sustain these fragile ecosystems. Since no new studies or tests have been conducted concerning the ocean pH and temperature tolerance of specific shelled organisms, we cannot set any targets for a safe carbon dioxide emission level. Studies have proven though, that in order to prevent the ocean pH from declining more than 0.2 units, emission targets would have to range from about ~700 petagrams of carbon (PgC) over 200 years to about ~1200 PgC over 1000 years (Zeebe 52).

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