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Impact of Global Climate Change and Ocean Acidification on Coral Reefs

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Coral reefs represent one of the largest diverse ecosystems in the world. There are over 800 species of corals and provide homes to over 4,000 species of fishes. They provide resources for over 500 million people and are critical to the economy for many reef dependent countries. Currently coral reefs are in jeopardy of becoming extinct with the impact of global climate change and ocean acidification. This has led to coral bleaching, erosion, a decrease in carbonate ion concentration, increasing water levels, etc. Currently levels of atmospheric carbon dioxide are at 389.95 ppm and if levels were to reach 450 ppm we could see the extinction of coral reefs. Coral reefs provide many benefits that will put millions of people at risk if extinct such as commercial fishing, tourism, construction materials, coastal protection, and medicine.

Home to more than a quarter of all marine bio-life, coral reefs represent one of the most diverse ecosystems in the world ("Where are corals found?," n.d.). Currently there are over 800 species of reef building coral recognized with new coral species constantly being discovered with advances in technology ("Coral: Plant, animal, or mineral?," n.d.). The economic and ecological impact from coral reefs is substantial. They represent important resources for over 500 million people (Hoegh-Guldberg, 2011). Coral reefs provide services for commercial fishing, tourism, construction materials, coastal protection, medicine, etc. (Hoegh-Guldberg, 2011). That being said, coral reefs are currently threatened and have already declined in coverage by as much as 50% (Hoegh-Guldberg, 2011). There are many factors that contribute to the decline in coral reefs but this paper will discuss two of the largest attributing global issues which include global climate change and ocean acidification (Hoegh-Guldberg, 2011).

Recognizing the impact from these global issues requires an understanding of the environment in which coral reefs grow in. One of the main reasons why these global issues are impacting coral reefs is because of their environmental limitations (Hoegh-Guldberg, 2011). The environment in which they thrive in is extremely specific and they are therefore sensitive to any variations within it. There are three main factors in the environment that must be present in water conditions for coral to survive in: sunlight, temperature, and carbonate ions (Hoegh-Guldberg, 2011). Coral reefs require sunlight to be able to provide energy to deposit calcium carbonate giving it its structure while providing habitats to over a million species (Hoegh-Guldberg, 2011). Although it sounds like coral reefs are plants, they are surprisingly recognized as animals and are classified as under the class *Anthozoa* ("Coral: Plant, animal, or mineral?," n.d.). Coral reefs have actually formed a symbiotic relationship with a photosynthetic organism known as dinoflagellates which basically provides energy for the corals (Hoegh-Guldberg,

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2011). Lastly, corals thrive in saturated levels of carbonate ions which is essential in the calcification process. Carbonate ion concentrations are also typically higher in warmer temperatures. (Hoegh-Guldberg, 2011) For all these reasons, coral reefs are found in shallow waters and coupled with the fact that they can only live in warm waters where temperature will not go below 18 degrees Celsius, they only grow in regions near the equator (Hoegh-Guldberg, 2011).

Knowing the environmental conditions coral reefs live in, the effect of global change has been detrimental to them. Increasing water temperatures has placed a large amount of stress on coral reefs which has resulted in bleached corals (Hoegh-Guldberg, 2011). Coral bleaching essentially refers to the process in which corals lose their photosynthetic organisms, dinoflagellates, due to stressful conditions which results in the corals turning white (Baker, Glynn, & Riegl, 2008). As explained earlier, corals depend on this organism for energy and calcification. The process of bleaching is actually reversible depending on the degree of bleaching (Hoegh-Guldberg, 2011). In mild conditions where the temperature quickly returns back to normal, dinoflagellates can repopulate and the coral can recover (Hoegh-Guldberg, 2011). However, in severe cases where temperature changes happen for an extended period of time, bleaching becomes fatal and results in mortality (Hoegh-Guldberg, 2011). In the summer of 2006, temperatures in the Great Barrier Reef reached fatal conditions and resulted in almost 100% of the corals being bleached which led to 40% of the corals dying off (Hoegh-Guldberg, 2011). There is strong evidence that correlates high temperatures with mass coral bleaching in which scientists are able to use satellites to predict mass coral bleaching events based on water temperatures with an accuracy greater than 95% (Hoegh-Guldberg, 2011).

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Other factors associated with global change that affect corals include rising sea levels and storm intensity (Hoegh-Guldberg, 2011). Globally sea levels have been increasing at a rate of 3.3 mm per year; however, this rate is expected to be accelerating when taking into consideration the rate at which glacial ice has been melting in the past 5 years (Hoegh-Guldberg, 2011). It has been estimated that if sea levels were continue to accelerate, coral reefs will be unable to keep up with rising sea levels and will essentially drown, which has been indicated historically (Hoegh-Guldberg, 2011). In addition to rising sea levels, higher sea temperatures are likely to cause more intense storms which cause physical damage to coral reefs (Hoegh-Guldberg, 2011). With sea levels rising and storms increasing in intensity these factors are intensified with the effect of ocean acidification (Hoegh-Guldberg, 2011).

Ocean acidification is directly related to increased levels of carbon dioxide from human influences such as greenhouse gas emissions (Hoegh-Guldberg, 2011). Roughly 33% of the carbon dioxide emitted by humans has directly affected the ocean by reacting with water to form carbonic acid (Hoegh-Guldberg, 2011). As a result, carbonic acid dissociates into a proton which reacts with the carbonate ions in the water to form bicarbonate ions (Hoegh-Guldberg, 2011). This process essentially lowers the amount of carbonate ions in the water and decreases the pH (Hoegh-Guldberg, 2011). As reported previously, corals are dependent on carbonate ions in the water to go through calcification. At the rate of which carbonate ion levels have been decreasing, concentrations may be cut by 50% by the end of the century (Hoegh-Guldberg, 2011). Studies have shown that if levels of atmospheric carbon dioxide continue to rise, coral reefs will begin to dissolve (Hoegh-Guldberg, 2011). This is evident in the Great Barrier Reef which has seen a decrease in calcification of corals by 15% since 1990 (Hoegh-Guldberg, 2011). Rising sea levels combined with less carbonate ions present will make it difficult for corals to

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keep up with growth (Hoegh-Guldberg, 2011). This also affects the equilibrium between erosion and calcification in which coral reefs are constantly experiencing erosion through physical and biological means and calcification is continuously occurring for maintenance. (Hoegh-Guldberg, 2011) As reported previously, the physical erosion experienced from intensifying storms coupled with ocean acidification will increase the stress placed on corals.

Specifically looking at carbon dioxide levels, as of August 2012, globally we are at 389.95 ppm (parts per million) ("Trends in carbon Dioxide," n.d.). If we are to reach 450 ppm of atmospheric carbon dioxide levels, this would mean that concentration levels of carbonate ions in the ocean would drop to 200 micromoles per kilogram or less (Hoegh-Guldberg, 2011). At these rates, concentration levels would be too low to sustain the carbonate coral reef system and would therefore lead to their extinction. There has also been evidence that reaching 400 ppm would lead to accelerating melting rates of Artic ice (Hinrichsen, 2010). Scientists also have evidence that when carbon dioxide levels were over 400 ppm 20 million years ago, sea levels were almost 40 meters higher (Hinrichsen, 2010).

The consequences of the neglecting the conservation and restoration of coral reefs are significant. In terms of economic impact from coral reefs, it is hard to quantify a total number taking into account tourism, fisheries, and protection (Hoegh-Guldberg, 2011). That being said, there are serious economic implications for reef dependent countries. $90 billion represents the Caribbean economy that is directly related to fishing and tourism (Hoegh-Guldberg, 2011). For these reef dependent countries up to 80% of their economy is driven by tourism. (Hoegh-Guldberg, 2011) Countries in Southeast Asia represent 85% of the aquarium fish trade with a total value of over $1 billion a year ("Fisheries," n.d.). The US itself represents over $100 million in the aquarium fish trading. Another important role that coral reefs have a part in is

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protection, coral reefs are responsible for dissipating 90% of the energy from waves and each meter of coral reef protects almost $50,000 of property ("Coral reefs protect coastlines," n.d.).

Other benefits that the coral reef brings results from just the sheer volume of bio diversify it contains. The extinction of coral reefs will jeopardize habitats for over 4,000 species of fishes ("Biodiversity," n.d.). It has been estimated that there may be up to nine millions species that are undiscovered in the coral reefs. Another advantage from having a large biodiversity is that coral reefs and its inhabitants are useful for medicine development. For example the anticancer agent Ara-C was developed from sponges found in coral reefs and neurotoxins from the cone snail has the potential to be used as a painkiller ("Medicine," n.d.).

Coral reefs have already started declining across the world with 50% less coral coverage than they were 30 years ago (Hoegh-Guldberg, 2011). Because of the specialized conditions corals have to live in, they are even more susceptible to changes in the environment than other marine bio-life. Factors such as global change and ocean acidification have added stress factors to coral reefs and which have caused bleaching, erosion, a decrease in carbonate ion concentration, etc. (Hoegh-Guldberg, 2011). If the future does not emphasize the importance on the controlling greenhouse gas emissions, it can be said with certainty that the global impact from coral reef loss puts millions of people at risk (Hoegh-Guldberg, 2011).

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