

REPORT

CORAL BLEACHING

By Aashni Parikh

CORAL REEFS

¹Coral reefs are some of the most diverse ecosystems in the world, second only to rainforests. They contain 25% of the world's marine species but occupy only 0.2% of the ocean bed. They reefs are found in circumtropical shallow tropical waters along the shores of islands and continents. Their environment includes very nutrient poor waters and they have certain zones of tolerance to water temperature, salinity, UV radiation, opacity, and nutrient quantities. Coral reefs are composed of calcium carbonate exoskeletons that are excreted by coral colonies. These coral colonies consist of thousands of individual corals or polyps, making polyps the simplest unit of a coral reef. Polyps are marine invertebrates, classified in the phylum Coelenterata and class Anthozoa. They are mostly composed of a stomach and top tentacles to ingest and digest plankton and other small marine organisms that constitute their diet.

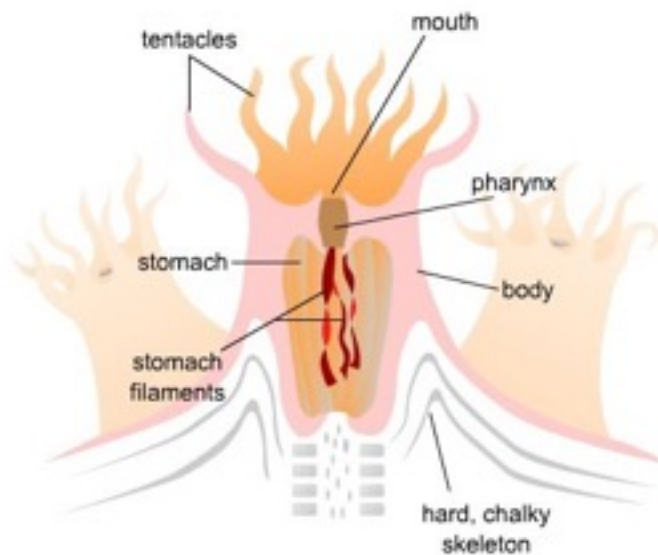


Figure 1: A labelled diagram of a polyp



Figure 2: An accumulation of polyps forming a coral colony

Importance of Coral Reefs

²Coral reefs are critical to the survival of life under and over the water. Firstly, they are depended on by marine organisms for a habitat and shelter, in fact, about one-third of all saltwater fish species live at least part of their lives on coral reefs. Additionally, corals facilitate carbon and nitrogen fixation, are a source of nitrogen and other nutrients essential to marine ecosystems, and assist nutrient cycling. Secondly, they sustain balance on land by protecting coastlines from the damaging effects of wave action and tropical storms. Furthermore, they are vital to the economy in terms of the fishing industry and tourism. The

¹ "Basic Facts About Coral Reefs." *Defenders of Wildlife*. N.p., 16 Sept. 2014. Web. 26 July 2017.

² Bauer, Adriana. "Importance of Coral Reefs - Biodiscovery and the Great Barrier Reef." *Queensland Museum*. N.p., n.d. Web. 26 July 2017

Great Barrier Reef, as a result, annually generates over 1.5 billion dollars for the Australian economy. Lastly, due to the diversity that coral reefs attract, coral reefs promote a larger gene pool, which presents natural communities survival options when environmental conditions and climates change. Evolution occurs on the basis of natural selection, which favours the characteristic that best helps an individual to survive. With a larger gene pool the number options of surviving characteristics increases, decreasing the threat of extinction for that species.

The Decline of Coral Reefs

³Over the past 50 years, however, the health of coral reefs have begun declining. According to *Reefs at Risk Revisited*, a recent report by the World Resources Institute (WRI), 75% of the world's coral reefs are at risk from local and global stresses. Ten percent of coral reefs have already been damaged beyond repair, and if we continue with business as usual, WRI projects that 90% of coral reefs will be in danger by 2030, and all of them by 2050. The reasons for their decline include anthropogenic and natural events. More specifically, overfishing, unsustainable tourism, destructive fishing methods, coastal development, pollution, invasive fish species, coral disease, climate change and a few more. Under climate change some particular examples include rising sea levels, ocean acidification and, coral bleaching. This report will lay emphasis on the process of coral bleaching and its effect on coral reefs in different parts of the world.

CORAL BLEACHING

Symbiotic Relationship Between Corals and Zooxanthellae

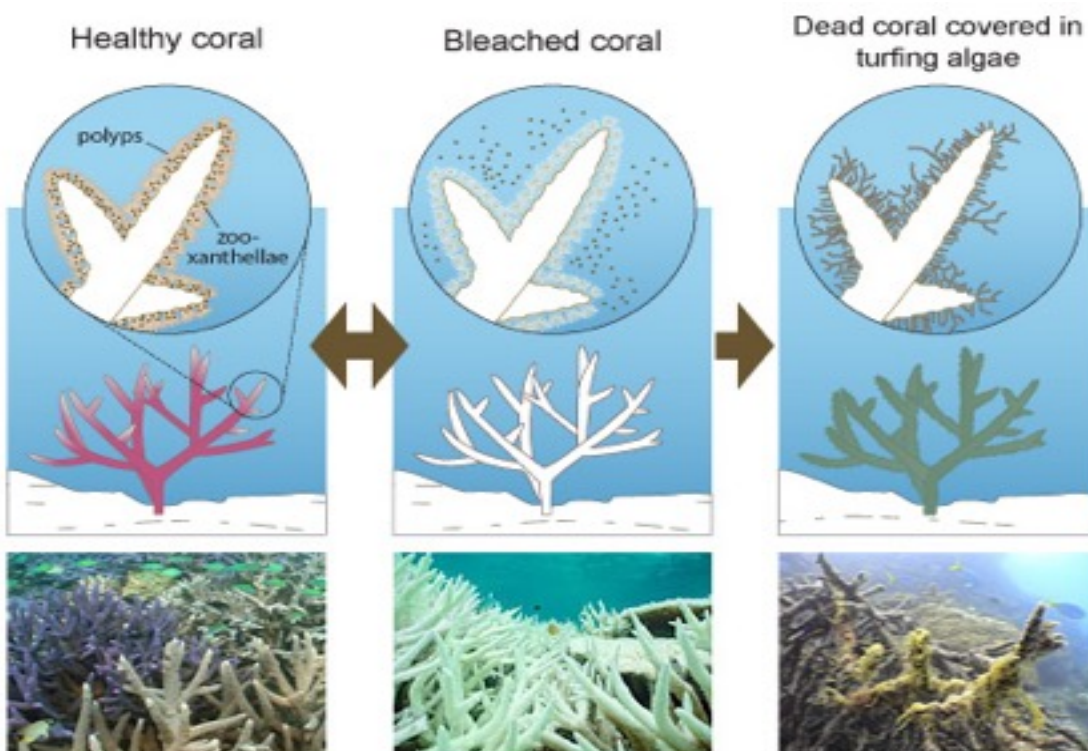
⁴To understand coral bleaching, one must first understand the symbiotic relationship between the polyps of corals and the zooxanthellae. Zooxanthellae are invertebrates that live in the tissues of coral polyps and assist the coral with its nutrient production through photosynthetic processes. These include, enhancing calcification, providing the coral with fixed carbon compounds for energy, and moderating elemental nutrient flux. In turn, the host coral provides the zooxanthellae with a secure habitat and a regular supply of carbon dioxide for its photosynthetic activity. This relationship also allows slow-growing coral to compete with rapid-growing algae for resources by feeding via photosynthesis in the day and predation through tentacles at night. Additionally, the zooxanthellae provides the otherwise clear coral with vibrant colours, giving them their distinct appearance.

³ Report: 75% of Coral Reefs Threatened." CNN. Cable News Network, 23 Mar. 2011. Web. 26 July 2017.

⁴ Content Contact Ellen Ray Ellen@theoceanagency.org +61, and Media Contact Lorna Parry Lorna@theoceanagency.org +61. "Ellen Ray." *Global Coral Bleaching*. N.p., n.d. Web. 26 July 2017

The Process of Bleaching

⁵Coral bleaching is the paling of zooxanthellae resulting in a coral appearing white. It is a symptom of stress on the coral, mainly in the form of warm ocean temperatures. Bleaching has been observed to occur due to an increase in ocean temperature by merely 1.5°C. In extreme light and temperature conditions, the zooxanthellae become extremely toxic and deactivate the protective sunscreen layers of corals. Corals exposed to extreme levels of solar radiation in general and ultra-violet light in particular, together with high water temperatures, zooxanthellae produce oxygen 4-8 times faster than the coral host can use. In this circumstance, part of the excess oxygen molecules become chemically active as oxygen 'radicals' causing cellular distress to an otherwise unprotected coral. The coral then expels the zooxanthellae to counteract this distress, unknowingly causing more harm. Expulsion most commonly takes place by sloughing-off the gastrodermal cells in which the algae live, however there are also other mechanisms like resorption and tissue death. Concrete reasons and evidence for the mechanism of expulsion and toxification of zooxanthellae are still unknown.



⁵ Content Contact Ellen Ray Ellen@theoceanagency.org +61, and Media Contact Lorna Parry Lorna@theoceanagency.org +61. "Ellen Ray." *Global Coral Bleaching*. N.p., n.d. Web. 26 July 2017

Post Coral Bleaching

⁶A healthy coral reef contains approximately $1-5 \times 10^6$ zooxanthellae per cm^2 of live surface tissue and 2-10 pg. of chlorophyll-a per zooxanthella. After bleaching, the coral will lose 60-90% of its zooxanthellae and 50-80% of its photosynthetic pigments. The pale appearance of bleached scleractinian corals and hydrocorals is due to the cnidarian's calcareous skeleton showing through the translucent tissues (that are nearly devoid of pigmented zooxanthellae). At this stage (post bleaching), the coral is white in colour and its growth rate has significantly decreased, however, it is not yet classified as a 'dead' coral. If the stress (temperature mostly) causing the bleaching is not acute and decreases with time, bleached corals can regain their symbiotic algae in several weeks or a couple of months. However, if the stress is severe, zooxanthellae populations will not recover and the coral will eventually die.

⁷Other Possible Causes of Coral Bleaching

- El Niño: These conditions increase sea temperatures in the Indian and central to eastern Pacific Oceans. La Niña may increase temperatures in the western Pacific.
- Coral diseases like Aspergillosis
- Cloud Cover: low cloud cover increase surface water temperatures while mildly-high cloud covers act as a shade and decrease temperatures.
- Tidal currents: strong tidal currents coincident with spring tides increase mixing and reduce water temperatures.
- Changes in salinity: corals occur in a salinity range of 32 and 40 PSU. Salinity levels beyond this range can be detrimental to corals.
- Sedimentation from undersea activities like dredging
- Pollution like fertilizers and pesticides from urban or agricultural run-off
- Other harmful chemicals that enter the water due to human activity

Coral Bleaching Trends Over Time

⁸Extensive data regarding coral bleaching has been collected from 1997 onwards and thus has only recently become a pressing issue. Some organisations who conduct research in this field include The National Oceanic and Atmospheric Association (NOAA), Cooperative Research Centre for the Great Barrier Reef (CRC Reef), and the Australian Institute for Marine Science (AIMS). ⁹Though the general increase in air and water temperatures due to global warming heightens the issue of bleaching indefinitely, there have been specific

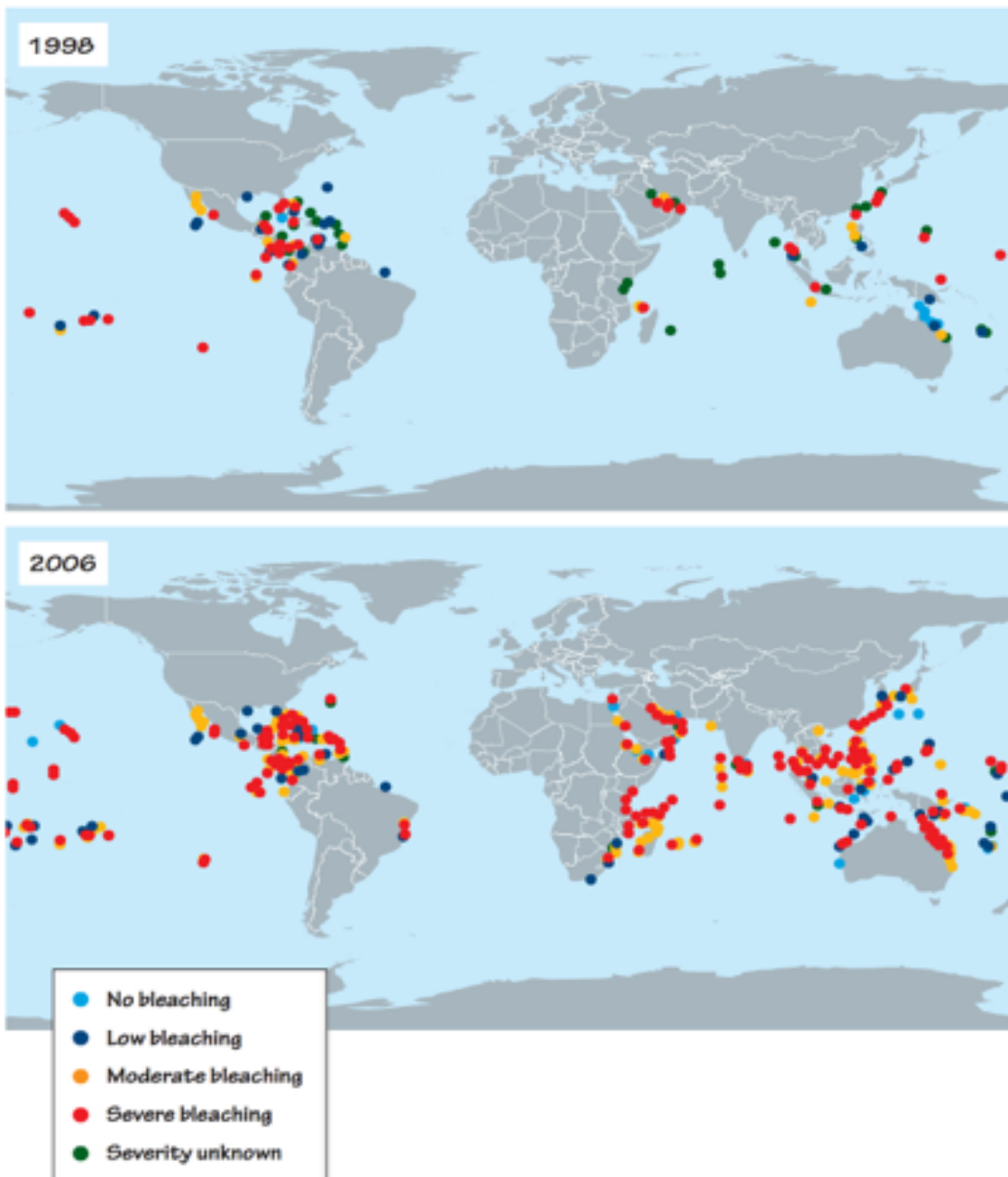
⁶ *Coral Reef Bleaching*. N.p., n.d. Web. 26 July 2017.

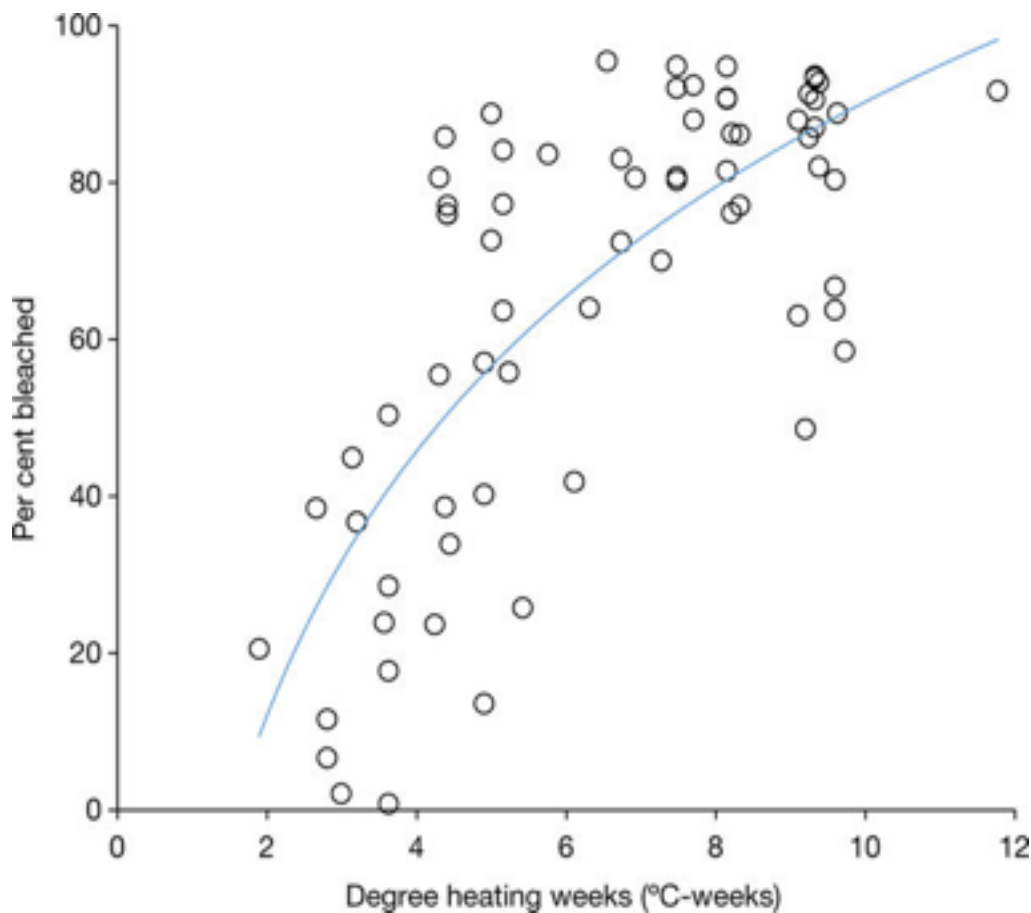
⁷ "Oceans and Coasts." *Coral Reefs: Coral Bleaching What You Need to Know* | The Nature Conservancy. N.p., n.d. Web. 26 July 2017.

⁸ *Losing Our Coral Reefs*. "State of the Planet Losing Our Coral Reefs Comments." N.p., n.d. Web. 26 July 2017.

⁹ Jurisdiction=Commonwealth of Australia; CorporateName=Australian Institute of Marine Science. "About the Australian Institute of Marine Science." *Bleaching Events - AIMS*. Jurisdiction=Commonwealth of Australia; CorporateName=Australian Institute of Marine Science, 24 July 2000. Web. 26 July 2017.

periods of time when bleaching cases were more significant. Starting from the summer of 1997-1998, when the hottest temperatures were recorded, 70% of the coral in Palm Islands area died (the area most affected). Similarly, in 2001-2002, a mass bleaching event took place where 70% of corals in the Bowen area died (most affected) and in 2005-2006 where the Keppel Islands were most affected. In the summers of 2008-2011, extremely high rainfall in Queensland led to flooding and the discharge of large amounts of freshwater to nearshore reefs resulting in freshwater bleaching. This was the first recorded coral bleaching for several sites ranging affecting reefs across 12°N of latitude along the Western Australian coast. Currently, ocean temperatures are rising at a higher rate, the major causes being global warming and El Niño. El Niño is an irregularly occurring and complex series of climatic changes, characterised by the appearance of unusually warm, nutrient-poor water. From In the 1990s El Niño first hit and was responsible for mass bleaching. A similar El Niño event occurred in 2014 and according to the National Oceanic and Atmospheric Association (NOAA), it continued till 2016. Below are graphic representations of bleaching over the years and across the world, as well as its correlation with temperature.





Due to the number of possible reasons for coral bleaching and the variability of each cause in different places of the world, corals in some places are more susceptible to the phenomena of bleaching as compared to others. This report will focus on the health of coral reefs in the South Ari Atoll of The Maldives and the West coast of Bali and possible reasons for the difference between the reefs.

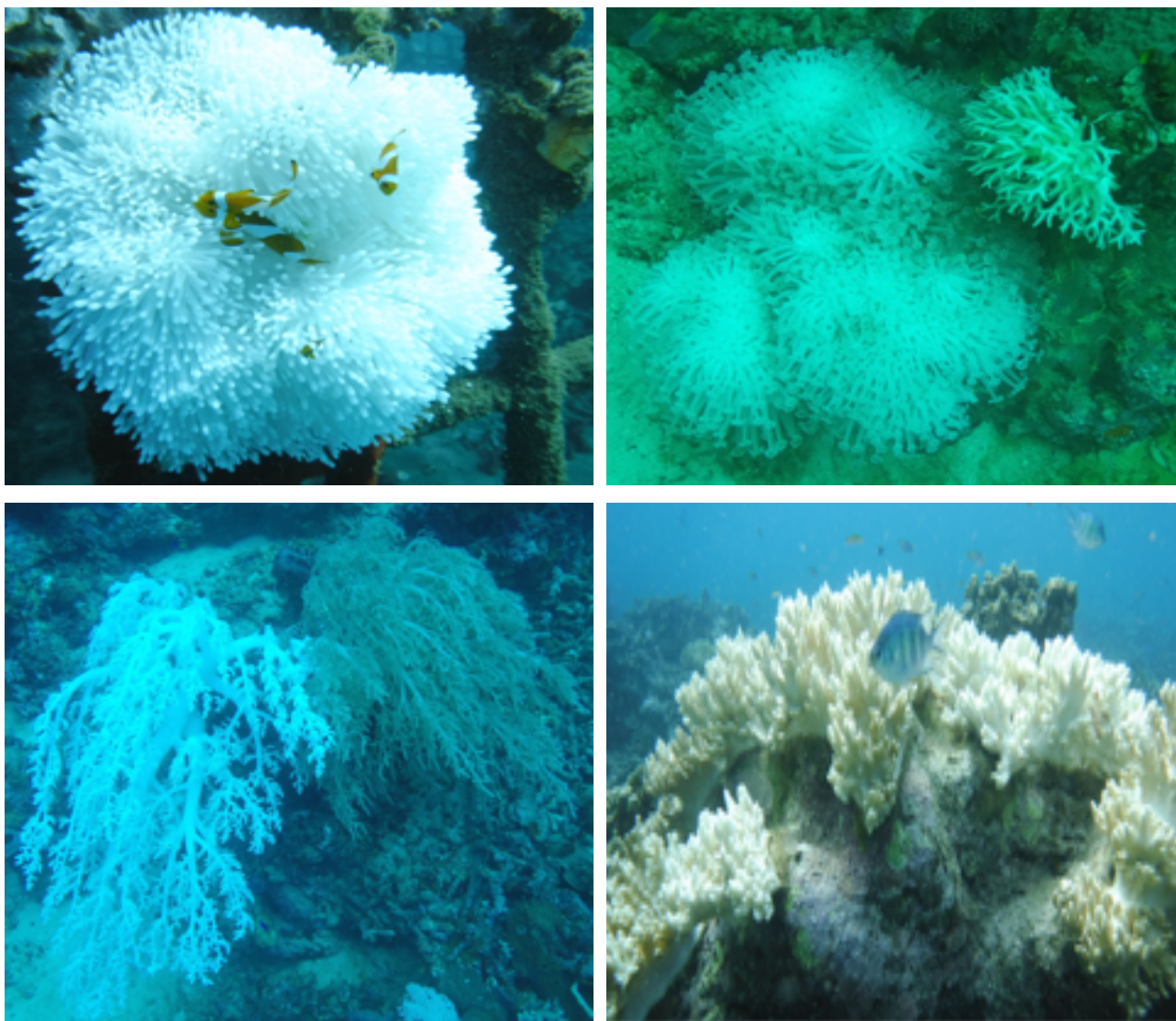
Bali

¹⁰Bali is an Indonesian Island located in the westernmost end of the Lesser Sunda Islands, lying between Java to the west and Lombok to the east. Indonesia, with a coastline of some 57,000 km (35,420 miles), has at least 2.6 million hectares (6.425 million acres) of coral reefs, or about 25 percent of coral reefs in the region and 8 percent of the world's coral reefs, according to the World Bank. Tulamben, Pemuteran, Amed are a few of the many areas that lie on the coast of Bali and are adjacent to the coral reefs in Bali.

¹⁰ "Breaking News, Top News & Latest News Headlines." *Reuters*. Thomson Reuters, n.d. Web. 26 July 2017.

¹¹According to *Reef Check Foundation Indonesia*, upto 40% of corals in Bali are bleached and their surveys recorded the average temperature of the water to be between 29-30°C. The worst bleaching event in Bali took place between 1997-98, the global bleaching incident, due to El Niño where more than 50% of hard corals were bleached. At that time, the mortality level of the bleaching coral was up to 50-60% (Irdez et al. 1998). However, reports in 2010 have stated that the status of the corals are, for the first time, worse than what they were in 1998. Besides temperature, these severe bleaching incidents in Bali have been specifically related to El Niño and crown-of-thorns starfish outbreak. This along with blast fishing, anchor damage, and diver damage have contributed to coral degradation.

The *Reef Check Foundation Indonesia* also observed that the hard coral species *Seriotopora*, *Pocillopora*, *Stylophora*, and *Pavona* in Indonesia, are more susceptible to bleaching as compared *Porites*, which are hardly or not at all bleached. The soft coral species *arcophyton* and *Sinularia*, anemones, and zooanthids are also susceptible to bleaching. The following images are of bleached corals of the Menjengen Islands in Pemuteran (West Coast of Bali), taken by the author of this report.



¹¹ "About Us." About Us | International Coral Reef Initiative. N.p., n.d. Web. 26 July 2017.

The South Ari-Atoll of The Maldives

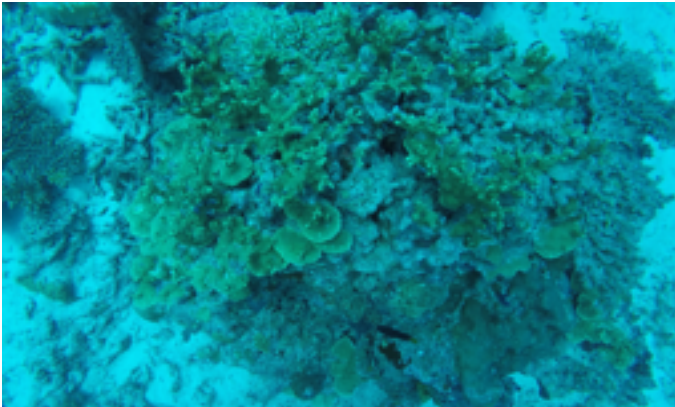
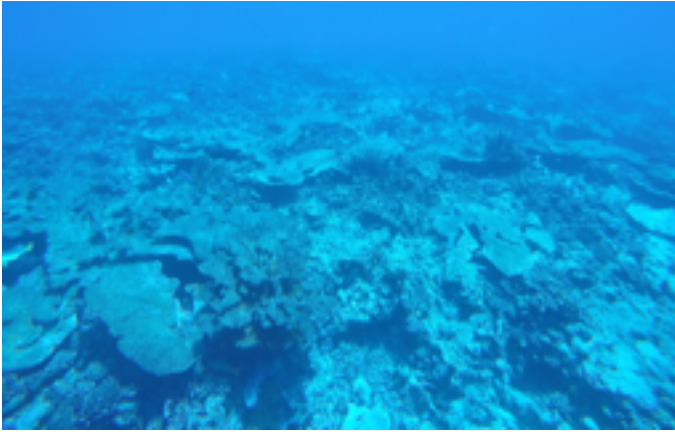
¹²The Republic of Maldives is located south-west of Sri Lanka and India. It comprises some 1190 coral islands grouped in a double chain of 26 atolls and spread out in the north-south direction, covering an area of 90,000 square kilometres in the Indian Ocean. The Maldives contains 3% of the world's coral reefs, which are also under threat. According to a report by Maldives Marine Research Centre and the Environmental Protection Agency, in partnership with the International Union for Conservation of Nature (IUCN) in 2016, 60% of Maldives' coral reefs are bleached, dead, or under threat. They conducted research on the Alifu Alifu Atoll-North Ari Atoll- and chose it as the island representative of the Maldives. However, the bleaching is not evenly spread out across the North and South atolls thus the statistics cannot be generalised.

¹³The South, in general, experiences less bleaching as compared to the north and this difference in bleaching is due to many reasons, the first being levels of rainfall. The south experiences much heavier rainfall (2,200-2,300 mm per year) as compared to the north (1,700-1,800 mm per year). The level of rainfall is inversely proportionate to temperature. As a result, more rainfall results in lower temperatures and thus less bleaching. Second, the south is less populated and with less tourism than the north. As a result, the corals are subjected to less damage from divers, snorkelers and stressors like diesel from incoming and outgoing boats. Lastly, The Maldives can be occasionally reached by tropical cyclones, which usually pass at higher latitudes, in the northern Indian Ocean. The southernmost atolls are protected from them, since they are located near the Equator, where cyclones cannot form nor survive. The North, however, experiences them causing additional stress on corals, which can also lead to coral bleaching. Therefore, the coral reefs in the South of Maldives appear quite healthy compared to most reefs. Some images of relatively healthy reefs in the Gaafu Alifu Atoll -South Ari Atoll- have been displayed below, taken by the author of the report.

In the Maldives, the fast growing corals are the most susceptible to bleaching. The juvenile corals and boulders are no as affected but are still susceptible. The bleaching in Maldives is mainly attributed to El Niño and temperature.

¹² Association, Press. "More than 60% of Maldives' Coral Reefs Hit by Bleaching." *The Guardian*. Guardian News and Media, 08 Aug. 2016. Web. 26 July 2017.

¹³ "Climates for Travellers: Climate, When to Go, What to Pack." *Climates to Travel - World Climate Guide*. N.p., n.d. Web. 26 July 2017



Response of Corals to Bleaching

¹⁴Many studies have suggested that it is possible for corals to genetically adapt to warming that has occurred over 40 to 60 years, given that the level of carbon emissions decrease. Researchers have predicted that this adaptation could reduce the currently projected rate of temperature-induced bleaching by 20 to 80 percent of levels expected by the year 2100.

This adaptation is a fluorescent pigment that acts as a sun-block, protecting the zooxanthellae from the harmful effects of sunlight. The pigments convert the harmful UV rays and blue wavelength light to lower energy wavelengths like green and yellow. As a result, the zooxanthellae produce normal levels of oxygen and are not expelled by the corals.

All corals, however, are not capable of this adaptation. Therefore, those with the adaptation are more resistant to bleaching. Over time, fluorescent corals may be favoured over ones that don't have these fluorescent pigments, resulting in evolutionary changes in coral species through natural selection. Charles Darwin stated that natural selection is the process whereby organisms better adapted to their environment tend to survive and produce more offspring. In this context, corals with the adaptation have favourable characteristics that will

¹⁴ Rowan, R. "Coral Bleaching: Thermal Adaptation in Reef Coral Symbionts." *Nature*. U.S. National Library of Medicine, 12 Aug. 2004. Web. 26 July 2017.

help them survive. When these surviving species reproduce, they create offsprings with the adaptation inborn, resulting in an array of corals, which can resist bleaching.

However, this process is largely dependent on the ability of humans to decrease carbon emissions in the atmosphere. Currently, the rates of carbon-dioxide release are accelerating, preventing this adaptation to function appropriately.

Possible Solutions

The only way to prevent coral bleaching is to decrease the amount of stress placed on corals in terms of temperature, chemicals and physical damage.

- Global warming: avoid travelling by car when possible, prevent deforestation, minimise release of untreated gasses from factories, financially aid local tree-protecting organisations.
- Chemicals: avoid fertiliser and pesticide run-off into water bodies as they can change acidity levels in the water to non-optimum parameters.
- Water pollution: should be limited as the placement of dark substances with high absorbance tends to promote water temperature increases.
- Refrain from creating live rock aquariums as the coral is being depleted from the ocean. Additionally, join or start local projects which make bio-rock structures on fish nurseries. Assistance can be provided financially or actively.
- Avoid overfishing and the use of fish nets as they lead to drops in the levels of zooplankton and thus starvation of corals. Reducing the amount of fish in one's diet can help this.
- Activities like cloud seeding over coral reefs will form clouds which act as a blanket to help reduce temperatures across waters.