Coral Reef Carnage

Beauty, beauty, beauty everywhere, on the sea, on land, in the sky, and down beneath the ocean's breast as well; for spread out on these coral reefs and sandy shoals are the most wonderful submarine gardens that eye ever beheld.
– Gordon Stables, Jack Locke: A Tale of the War and the Wave

If we don't manage this resource, we will be left with a diet of jellyfish and plankton stew.
– Daniel Pauly

The canary, a member of the finch family, is very sensitive to carbon monoxide, which is a colorless, odorless and tasteless gas. This deadly gas would be frequently found in coal mines after fires and explosions. At one time, miners and rescue workers used the canary to test the mine atmosphere, and when the bird showed signs of distress the workers knew there was a problem with the air.[1]

> *A canary in a small portable cage is an almost indispensable adjunct to rescue work after a mine explosion or during a mine fire... The symptoms manifested underground by a canary in the presence of carbon monoxide are an increased rate of breathing, often accompanied by opening of the mouth, fluttering and unsteadiness on perch, and last – sometimes almost instantly – unconsciousness and death.*[2]

Coral reefs are like desert oases in the vast, largely nutrient-devoid tropical oceans. They provide the shelter and nourishing framework that allow the reefs to teem with an extraordinary variety of life. Coral reefs have one of the most incredibly diverse, yet vulnerable, ecosystems on our planet that are second only to tropical rainforests in biodiversity. As many as 100,000 species may have been identified inhabiting coral reefs, but the total number may be anywhere between 500,000 to 2,000,000 or more.[3] The world's reefs measure a total of 284,300 square kilometers (109,768 square miles), slightly less than the size of Italy. Coral reefs account for less than 1.2% of the world's continental shelf area and less than 0.1% of the world's oceans[4] yet they account for 25% of all marine life. For this reason, coral reefs are often referred to as the "rainforests of the sea".[5]

> *The beauty of color and form and the overwhelming variety of life on coral reefs are both legendary and real. Nowhere else in the seas is there such a bewildering range of living things, and perhaps nowhere else is the physical and biological pattern so uniform, characteristic, and widespread as in the coral reef.*[6]

Coral reefs are built by and made up of thousands of tiny animals, called polyps, which live in large colonies. The polyp uses calcium and carbonate ions from seawater to build itself a hard, cup-shaped skeleton made of calcium carbonate (also known as limestone) which protects the soft, delicate body of the polyp. Most coral polyps have clear bodies and the skeletons they build are bone white. The coral's brilliant colors come from tiny plants (microscopic marine algae called zooxanthellae) living inside their tissues. The animal and plant components live together, where the animal provides protection and raw materials for photosynthesis and the plant produces food. The symbiosis (a mutually beneficial relationship) between the polyps and zooxanthellae provides the abundant nutrient-dense habitat that supports the amazing assortment of life on the reef.

The coral reef ecosystem has existed for at least 200 million years.[7] Corals have built the primary structure of entire reefs, islands and such massive oceanic structures that they can even be seen from outer space. One such structure that can be seen and monitored from space is off the coast of Australia – the Great Barrier Reef (GBR). It is the largest living structure on the planet.[8]

Coral reefs grow very slowly. It may take up to a hundred years for a coral reef to grow about one meter (three feet).[9] Reefs thrive in highly stable environments with approximately 500 million people depending on coral reefs for food, coastal protection, building materials, and income from tourism.[10]

Research by Associate Professor John Pandolfi, a Chief Investigator in the ARC Centre of Excellence for Coral Reef Studies (CoECRS) and The University of Queensland, warns that the world's reefs are now experiencing transformations that they have never experienced before. Recent human activity has greatly degraded the Caribbean coral reefs that were remarkably stable over many tens of thousands of years measuring up to 220,000 years ago.[11]

> *"In the past, you would have seen an overwhelming dominance of Elkhorn coral. It was one of the most beautiful and striking features of the Caribbean reefs. Now, [that species] has virtually disappeared and the same reefs are dominated by algae and seaweed. There are precious few large fish, turtles, dugongs, or sharks. It is totally different to the past."*[12]

Human impacts have been the most influential driving force in coral reef decline over the last several hundred years.[13] Large branching coral species that once were common have been decimated all over the Caribbean. In 1918 there were reports of expansive tracts of Elkhorn coral near the island of Barbados. By 1960 this species was only a minor part of the reef. By 1987 this coral comprised less than 1% of coral cover. The substantial degradation in many coral reefs actually began before the year 1900. This pre-1900 decline was probably mainly due to overfishing, pollution and other human activities.[14]

> *The greatest impacts on Barbados are probably related to increased turbidity resulting from land clearing and the development of sugar cane agriculture in the mid-17th century.* [15]

Comparison of early British nautical charts to modern coral habitat maps demonstrates that entire sections of the Florida reef that were present before European settlement are now largely gone. An estimated 88% of Florida Bay corals have been lost, which suggests a massive cumulative loss of reef coral in the Florida Keys over the last 240 years.[16]

Coral reefs are extremely sensitive to environmental disturbances. Reefs are greatly influenced by increased seawater temperature, overfishing, alterations in reef fish populations, eutrophication (excessive nutrient enrichment),[17] disease, and heavy metal pollution.[18]

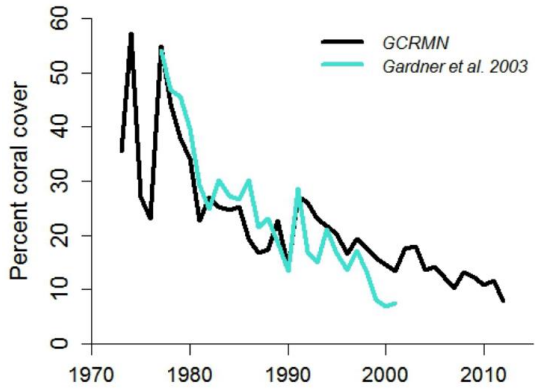
> *Overfishing has become so widespread that there are few, if any, reefs in the world which are not threatened. This, combined with such destructive practices as blast fishing, is shifting the patterns and balances of life in many reef ecosystems. From onshore a much greater suite of damaging activities is taking place. Often remote from reefs, deforestation, urban development*

> *and intensive agriculture are now producing vast quantities of sediments and pollutants which are pouring into the sea and rapidly degrading coral reefs in close proximity to many shores.*[19]

When corals experience stressful conditions, such as high temperatures, it causes them to expel their symbiotic algae which are the source of their brilliant colors. Once the algae are gone only the bone white skeletons of the polyps remain, giving the coral a bleached look. Prolonged bleaching events lead to coral deaths because the plant part of the coral is no longer present to provide food for the animal component of the coral. The coral can die from starvation, or become so weakened by a lack of food, that it succumbs to harmful bacteria and seaweeds. Coral can also be made more susceptible to bleaching by excessive sewage and fertilizers that are associated with increasing coastal populations.[20,21]

Coral deaths resulting from bleaching encourage seaweed (macroalgae) to inhabit the area quickly and take over even the few remaining patches of live coral reefs. This radically transforms the area from a coral to a seaweed dominant environment. Major coral bleaching events occur during high sea surface temperatures associated with El Niño, which is an extreme warm weather pattern. But other factors such as cold conditions, elevated solar radiations and pollution have been found to cause minor local coral bleaching. Not all bleaching events result in coral deaths. If the bleaching is mild, coral reef systems can recover by surviving long enough to reacquire new algal partners.

Since the 1970s the coral reef degradation has accelerated, and many reefs have suffered enormous, long-term decline in abundance, diversity, and habitat structure due to a number of negative human generated factors. These losses were more recently compounded by substantial mortality due to disease and coral bleaching. By 2003 the reefs in the Caribbean had already experienced a huge decline which continues to the present day.



Decline in percent coral cover on Caribbean coral reefs from 1963 to 2012. Data is from a 2003 study (Gardner) and from the Global Coral Reef Monitoring Network (GCRMN) in 2012.

> *We report a massive region-wide decline of corals across the entire Caribbean basin, with the average hard coral cover on reefs being reduced by 80%, from about 50% to 10% cover, in three decades... Although the rate of coral loss has slowed in the past decade compared to the 1980s, significant declines are persisting. The ability of Caribbean coral reefs to cope with future local and global environmental change may be irretrievably compromised.*[22]

In the Florida Keys coral reefs were already severely degraded in the early 1970s.[23] Total coral cover in the Florida Keys, US Virgin Islands and Puerto Rico has progressively declined from 25% to 35% in 1970 to less than 15% today. In the US Virgin Islands and Belize, there was a gradual decline in coral in the 1970s and 1980s followed by a catastrophic collapse in the 1980s and 1990s.[24]

Carysfort Reef is located east of Key Largo, Florida. Analysis has shown that between 1974 and 1999 living coral cover on the Carysfort Reef declined by 92%.[25] Images of the reef from 1975 to 2014 show the devastating breakdown in this reef. A once thriving reef now looks little more than ocean bottom rubble.

Off the coast of Galveston Texas sits the Flower Garden Banks National Marine Sanctuary which is home to spectacular coral formations. In 2016 divers saw hazy water, lifeless sea urchins with their spines falling out, and other dead crustaceans. In the most severely impacted area, as much as 70% of the corals were dead. It was termed a "hot zone" because the corals' skeletons were exposed, almost as if the corals had been incinerated.[26] Emma Hickerson, the research coordinator of the sanctuary, had for years felt confident that Flower Garden Banks was relatively safe.

> *What she saw stunned her: dead and dying corals, many of them tens of centuries old, some the size of SUVs. And it was more than corals that were affected. Sponges and clams were dead and dying too. And there were no fish to be seen, which is unusual around a coral reef. "It was just shock, disbelief," Hickerson says.*

Carysfort Reef, Florida Keys 1975 (top) to 2014 (bottom).

One of the major reasons for reef deterioration is the decline of grazing animals such as parrotfish and urchins. Grazers are important in the marine ecosystem as they eat the algae that can smother corals. Disease led to a mass death of the sea urchin in the 1980s, and overfishing throughout the 20th century has brought the parrotfish population to the brink of extinction in some regions.[27] A 2014 report by Global Coral Reef Monitoring Network (GCRMN) indicated that unless this problem is addressed, most Caribbean coral reefs will disappear within the next 20 years. Jeremy Jackson, lead author of the report, noted that:

> *"Even if we could somehow make climate change disappear tomorrow, these reefs would continue their decline. We must immediately address the grazing problem for the reefs to stand any chance of surviving future climate shifts."*[28]

Blast fishing is the most damaging method of fishing on the reefs. Explosives are usually homemade from fertilizers, although dynamite is occasionally employed. The explosive is usually thrown near the reef and detonates on the surface of the water. The shock wave from the blast kills or stuns most fish. The small percentage of fish that float to the surface are easily collected by the fisherman while

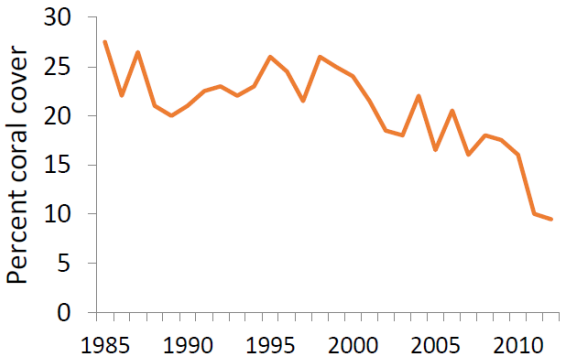
the majority sinks to the bottom. This type of fishing is non-selective killing and causes massive damage to the reef itself.[29] The Mergui archipelago on the Thai-Myanmar border has been damaged by this destructive fishing.

> *The region was once famous for its coral reefs; these have been ravaged by dynamite-fishing and climate-change induced bleaching.*[30]

A large-scale survey in 2015 of East Africa's coral reefs showed places where destructive fishing practices have wreaked havoc on the reefs.

> *On more than one occasion we dived up against massive monofilament gill nets, un-fondly referred to as 'hanging walls of death.' In addition, the destructive effects of dynamite fishing have devastated the corals in many areas, an illegal practice entered into more boldly than one might expect... The destruction is total and devastating, leaving behind eerie uninhabited craters of coral rubble.*[31]

Large outbreaks of coral-eating crown-of-thorns starfish (CoTS) also severely threaten some reefs. On healthy coral reefs, the coral-eating starfish plays an important role, as it tends to feed on the fastest growing corals allowing slower growing coral species to form colonies, helping increase coral diversity. However, due to a number of factors, including terrestrial runoff that increases phytoplankton that the larvae of CoTS feed on and the loss of CoTS predators, major outbreaks of CoTS have increased.



Decline in percentage of reef surface covered by live coral across the Great Barrier Reef, Australia, 1985-2012.

Like the Caribbean reefs other of the world's reefs show decline. The Great Barrier Reef has been classified as the world's least threatened coral reef due to its distance from the relatively small human population centers and strong legal protection. However, the GBR has been subject to severe disturbances, including CoTS outbreaks, mass coral bleaching and declining growth rates of coral due to increasing seawater temperatures, terrestrial runoff, tropical cyclones, and coral diseases. The runoff of soils, fertilizers and pesticides from agricultural and coastal development has significantly affected inshore coral reefs.[32] Due to these various factors, live coral cover on the Great Barrier Reef off the coast of Australia has decreased from approximately 50% from the 1980s to 2012, with CoTS outbreaks making up 42% of this decline.[33]

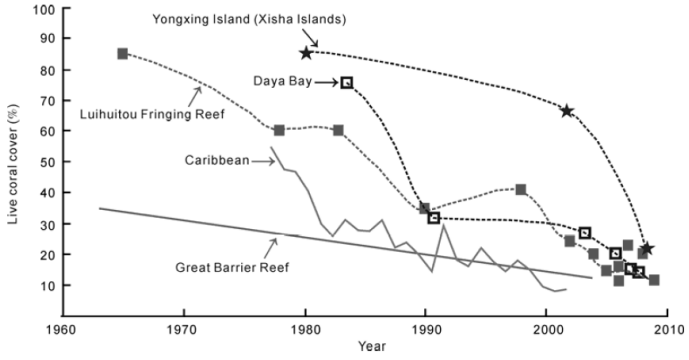
> *...coral cover has declined considerably, seagrass health in the central GBR is in poor shape, dugong numbers have declined precipitously, shark populations are in serious decline (although perhaps recent management has reduced the rate of decline), many other large fish on the GBR have had large population declines (although data on many are incomplete) and the fourth wave of CoTS outbreaks has commenced. Most notably coral bleaching has become more*

frequent, widespread and damaging and coral calcification has started to decline due to ocean acidification.[34]

Coral reefs are widespread in the South China Sea (SCS) but have also declined dramatically over last 50 years. According to a 2013 study, China's unrestrained economic development has caused a devastating decline of 80% in China's coral reefs over the last 30 years.[35] Coastal development, pollution, overfishing, and destructive fishing practices have been the primary factors causing this decline. Professor Terry Hughes who conducted this research noted that:

"Typically, when a coral reef degrades it is taken over by seaweeds – and from there, experience has shown, it is very hard to return it to its natural coral cover. The window of opportunity to recover the reefs of the South China Sea is closing rapidly, given the state of degradation revealed in this study."[36]

Long-term monitoring suggests that the coral reefs of the SCS [South China Sea] have suffered a dramatic decline over the past 50 years, reflected in the decrease of live coral cover. Live coral cover in Daya Bay (northern SCS) declined from 76.6% to only 15.3% between 1983/1984 and 2008; Luhuitou fringing reef (Hainan Island, northern SCS) coral cover decreased from ~80%–90% to ~12% between 1960 and 2009; and that in Yongxing Island (the Xisha Islands, central SCS) decreased from 90% to ~10% between 1980 and 2008.[37]



Live coral cover declines in the South China Sea in comparison to long-term trends in the Great Barrier Reef and the Caribbean.

The live coral cover in the Caribbean, Great Barrier Reef and locations in the South China Sea all show significant declines.

Although many factors can result in coral reef bleaching, higher Sea Surface Temperature (SST) and stronger El Niño have been accepted as the primary causes of large-scale coral reef bleaching events. SST increased dramatically in recent times, with the 1990s being 2.2°C (4°F) warmer than 1,500 years ago. This is significant in that it suggests that recent human-caused global warming is a major factor in reef bleaching. The extremely high SST in the 1998 El Niño year resulted in 16% of global coral reef degradation. It impacted almost all coral reef sites around the world, especially on the GBR where several well-established and mature coral colonies of up to 1,000 years old were killed.[38]

...the 1997-1998 global coral bleaching event caused mortalities of up to 80% in some of Tanzania's reefs. This worldwide bleaching event was caused by elevated sea surface temperature due to El Nino. Sea surface temperatures were 2°C higher than average (over 30°C). The Misali and Tutia reefs in Pemba and Mafia Islands were the most affected with about 90% of these reefs suffering coral mortality.[39]

Mass coral reef bleaching episodes that resulted in large-scale coral mortality were first recorded in the early 1980s. Prior to that, reports of coral bleaching were scattered or almost nonexistent in the scientific literature. However, analysis of dated corals from the SCS has shown that coral deaths within the last 200 years correlated with historic El Niño events. These coral deaths were probably caused by temperature-induced bleaching, indicating that this is not a new phenomenon produced by more recent global warming.[40] However, historical analysis also has shown that there has been a drastic change in coral community composition from long-term stability in recent declines. This indicates that the extent of mass bleaching events is much worse today than it has been in the past.[41]

Scientists noted another devastating loss of coral due to a spike in sea temperatures in 2015 and 2016. A recent *Environment Ministry* survey of the Sekiseishoko coral reef, just off the coast of Okinawa, Japan, found 70% of the coral dead due to an inflow of red soil into the ocean, seawater contamination, as well as higher water temperatures. The water temperature was 1-2 °C (1.8-3.6°F) higher than normal.[42] A 2018 government survey of Sekisei Lagoon found that only 1.4% of the coral reef was healthy.[43] At the Dongsha Atoll in the South China Sea 40% of coral has died. According to experts, nothing this severe has happened on Dongsha Atoll for at least 40 years. Anne Cohen of Woods Hole Oceanographic Institution in Massachusetts said:

> *"The 2015/2016 El Nino was devastating for reef systems in other parts of the world as well, including Dongsha Atoll and reefs in the central Pacific, where some of the most pristine coral reefs are located and of course, the US Pacific Remote Marine National Monument. We observed devastating bleaching in that area as well."*[44]

In 2016, two thirds of corals in the northern sector of the GBR died after severe bleaching from unusually warm waters. This was followed by another major bleaching event in 2017. With these back to back bleaching events, nine hundred miles long on the GBR have now experienced severe bleaching at some point during the past two years.[45] Terry Hughes, director at ARC Centre of Excellence for Coral Reef Studies at James Cook University in Queensland, noted that:

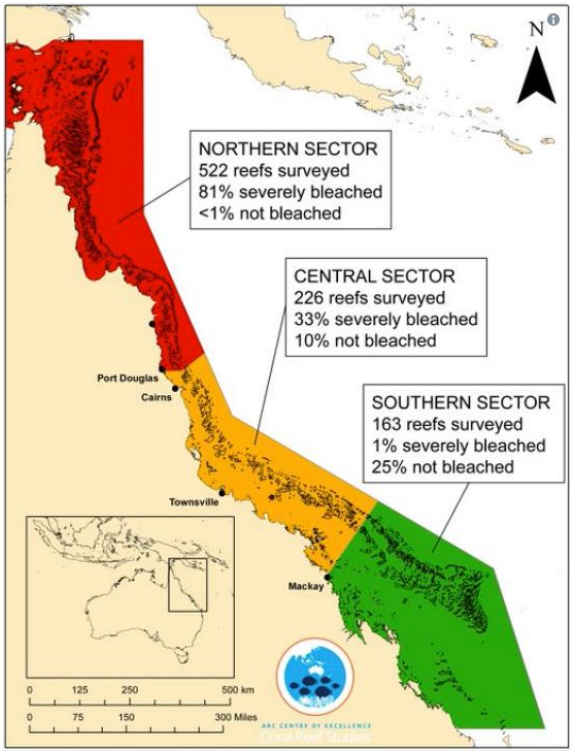
> *"Last year [2016] we lost 67 percent on average of the corals in the northern 700 kilometers (430 miles) of the barrier reef, between March and October. That's obviously an enormous loss over two-thirds of the Great Barrier Reef. I wouldn't say the barrier reef is dying. But clearly, we're measuring serious losses here. And the reason it's happening is global warming."*

The 2016 bleaching was tied with El Niño, however, the lack of El Niño in 2017 indicates that warming ocean temperatures from global warming are likely the major reason for the bleaching. The GBR has experienced bleaching events in 1998, 2002, 2016, and now in 2017. Typically, these events have been localized in scale and if bleaching is mild, the coral can survive long enough to reacquire new algal companions. Bleaching in itself is not something new, but the observation of mass coral bleaching on the huge scale certainly appears to be, and it represents a whole new level of coral reef decline. An analysis published in the journal Nature noted reefs that suffered this severe heat exposure had undergone a "catastrophic die-off" and an "unprecedented ecological collapse" in the upper third of the GBR.[46]

The die-off of corals drove a radical shift in the composition and functional traits of coral assemblages on hundreds of individual reefs, transforming large swaths of the Great Barrier Reef from mature and diverse assemblages to a highly altered, degraded system.

Unfortunately, it takes over a decade for reefs to recover from a bleaching event. With two sequential years of bleaching the chances of significant recovery become severely limited. Kim Cobb, a coral reef expert at Georgia Tech, stated that this event "may very well mark the beginning of the end for many iconic reefs as we know them today, at least for the foreseeable future."[47] Some ecologists and marine biologists fear that the GBR is in terminal decline.[48]

"I don't think the Great Barrier Reef will ever again be as great as it used to be — at least not in our lifetimes," said C. Mark Eakin with the National Oceanic and Atmospheric Administration.



Results of aerial surveys of bleaching of the Great Barrier Reef.

In 2017 a study also implicated ocean dead zones (low or reduced oxygen concentration areas) in coral die-offs. Land-based sewage and agricultural runoff spurs the growth of algae. When the algae die they decay, consuming oxygen faster than it can be brought down from the surface. As a result sea life, including corals in the area that can't move away, can suffocate and die.

"Based on our analyses, we think dead zones may be underreported by an order of magnitude." said Nancy Knowlton of the Smithsonian's National Museum of Natural History and study co-author. "For every one dead zone in the tropics, there are probably 10 — nine of which have yet to be identified," she said.[49]

The massive amount of plastics polluting the ocean is another serious threat that corals are facing. Plastic particles, with their irregular and pitted surface, absorb not only pollutants such as PCBs (polychlorinated biphenyls) to levels up to 1,000,000 times the surrounding sea water,[50] but also can be home to bacteria and other microbes. Scientists examined 125,000 corals across the Asia-Pacific region and found 89% of those contaminated by plastic were suffering disease. On plastic-free reefs, only 4% of the corals were diseased.[51]

"Corals are animals just like me and you – they become wounded and then infected," said Joleah Lamb, at Cornell University in the US, "Plastics are ideal vessels for microorganisms, with pits and pores, so it's like cutting yourself with a really dirty knife. It's like getting gangrene on your

> *toe and watching it eat your body. There's not much you can do to stop it. If a piece of plastic happens to entangle on a coral it has a pretty bad chance of survival."*

Since 2014, the reefs off the Florida coast have been suffering from an unknown condition that appears as white patches that spreads until it consumes and kills the entire coral.[52] The disease appears to have affected brain and star coral species the most. Without the cause of the condition unknown to scientists, it has been described as "the largest and longest reef infection on record." In some areas almost all of those corals are dead, which scientist William Precht noted is "essentially equivalent to a local extinction."[53]

A toxic ingredient commonly found in sunscreen, oxybenzone, is also killing corals around the world. Oxybenzone has been found in bird eggs, fish, coral, humans, and other marine mammals. It is a widespread environmental contaminant found in streams, rivers, lakes, and in marine environments from the Arctic Circle to the beaches and coral reefs along the equator.[54] The chemical oxybenzone breaks coral down by leaching it of nutrients and eventually turning it white. Not only does it harm coral, but has also been shown to disrupt the development of fish and other marine life. [55] Each year between 6,000 and 14,000 tons of mostly oxybenzone-laden sunscreen lotion ends up in coral reefs around the world.[56]

> *Coral reef contamination of oxybenzone in the U.S. Virgin Islands ranged from 75 µg/L [micrograms/liter] to 1.4 mg/L [milligrams/liter], whereas Hawaiian sites were contaminated between 0.8 and 19.2 µg/L.*

The majority of coral reefs around the world are threatened by human activities, and many show signs of degradation. While some coral reefs have not been harmed, less than half of the world's reefs are regarded as being relatively healthy and not under any immediate threat of destruction.[57]

There are certain well-established no-take zones where some reefs are in near pristine condition. These have high fish diversity and well-developed coral communities with large and old corals. Yet, these ever increasing perils from pollution, disease and coral bleaching indicate that coral reef ecosystems will not survive for more than a few decades, unless they are promptly and massively protected from human activity fallout. There has been some global attention to the ongoing degradation of coral reefs due to overfishing, pollution and climate change, nevertheless the deterioration of the reefs continues.

> *Without significant changes to the rates of disturbance and coral growth, coral cover in the central and southern regions of the GBR is likely to decline to 5–10% by 2022.*[58]

Coral reefs are deteriorating not from a single cause but from multiple factors. With the focus almost singularly on global warming as the cause of the decline of coral reefs around the world, it obscures the other numerous manmade factors that have caused their large scale devastation over many decades. Reefs are exposed to a combination of stresses including destructive fishing practices; overfishing or loss of herbivorous fish and other grazing organisms; increased discharge from the land of sediment, nutrients, and pesticides; coral predator outbreaks; increased bleaching associated

with global climate change; chemical assaults; and increased incidence of and severity of coral diseases magnified by oceanic plastic pollution.

The world has lost roughly half its coral reefs in the last 30 years, and even if global warming stopped now, scientists still expect that more than 90% of corals will die by 2050. Biologist Ove Hoegh-Guldberg, director of the Global Change Institute at Australia's University of Queensland, noted:

> *"Whether you're living in North America or Europe or Australia, you should be concerned. This is not just some distant dive destination, a holiday destination. This is the fabric of the ecosystem that supports us. You couldn't be more dumb... to erode the very thing that life depends on – the ecosystem – and hope that you'll get away with it."*[59]

The continued loss of coral reefs is much more than losing a beautiful work of nature. Coral reefs provide food and resources for over 500 million people in 94 countries and territories. The decline of the structurally complex corals means the reef will be much flatter, with a decreased habitat for the hundreds of thousands of species that live in the coral reefs.[60] Reefs also create a shoreline barrier to guard against incoming storms and mitigate the damage done by surging seas.[61]

The coral reefs are experiencing nothing less than a full-blown ecological catastrophe. Over the centuries, reefs have suffered massive deterioration due to human activity and have in some cases been entirely annihilated.

As reefs, which are a storehouse of biodiversity, continue to degrade, they will be replaced with seaweed dominated ocean bottom. There will be fewer and fewer fish but increases in jellyfish.[62] Almost no large animals will survive in the poor water quality that ensues as the dead or dying large corals are replaced by soft corals and seaweed. The oceans will likely eventually turn into little more than rubble, seaweed and slime.[63] Like the canary in the coal mine, the environmentally sensitive reefs are a warning for the health of the rest of the oceans and the world. We ignore this aquatic canary at our own peril.

Pictures:

Decline in percent coral cover on Caribbean coral reefs from 1963 to 2012 – Jeremy Jackson, et al., "Tropical Americas Coral Reef Resilience Workshop," Global Coral Reef Monitoring Network (GCRMN), April-May 2012, p. 8.

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This is one chapter from an upcoming book – Moving Back from Midnight – A World in Peril.

If you have feedback or you would like to help with working on this book in any way please contact us at movingbackfrommidnight@gmail.com. Our planet is under major threats and it will take all of us taking action to reverse course and make it a sustainable world.

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