Climate change and coral reefs – key issues and risks for the Maldives

PROJECT REGENERATE – AN IUCN AND USAID INITIATIVE

Climate change is happening now
The earth’s climate is changing. Around the world people are noticing shifts in weather patterns, and scientists are recording impacts on temperatures, sea level, rainfall and frequency of severe weather events.

Increased concentrations of greenhouse gases, especially carbon dioxide, are not just altering conditions on land. They are also altering conditions in the world’s oceans. Increasing air temperatures are causing the seas to warm, while the extra carbon dioxide absorbed by the oceans is causing chemical reactions leading to increased ocean acidity.

These changes are occurring on a global scale. But they have very local implications – especially for coral reefs. Climate change and ocean acidification are now regarded as the most serious threats to the future of coral reefs and related marine ecosystems. This means that they are also serious issues for coastal communities, reef-based industries (such as tourism and fishing), and for the economies that depend on the goods and services that come from healthy marine ecosystems.

Coral reefs are in the firing line
Coral reefs are especially vulnerable to climate change because of the high sensitivity of corals to small changes in environmental conditions. Minor increases in water temperature (as little as 1-2°C over the

Maldives: an island nation of natural treasures
The Maldives is renowned for its abundant and globally significant marine biodiversity. It contains the largest group of coral reefs in the Indian Ocean, with over 3,500km² of coral reef spanning 21,000 km² of diverse and rich marine habitat. Its biodiversity includes:

- Over 1,100 species of reef fishes
- Over 250 species of corals
- Green and hawksbill turtles (globally threatened)

The Maldivian atoll ecosystems also include a variety of other important habitats, including extensive shallow and deep lagoons, deep slopes, sandy beaches, and mangrove and seagrass areas.
normal maximum) can stress corals, leading to coral bleaching. If unusually high temperatures persist, mass death of corals can occur over scales of tens to thousands of kilometers.

The stress caused by elevated water temperatures also leads to increased risk of disease in corals and many other species that comprise coral reefs. Through the direct impacts on corals, through the direct and indirect effects on other species, climate change is compromising the health of entire ecosystems.

Coral reefs under pressure are less able to provide the services that support human communities, such as food and fisheries income, recreational opportunities and commercial tourism, and protection of vulnerable shorelines. Climate change is therefore a major concern not just for coral reefs, but also for food security, economic prosperity and social wellbeing of communities that depend on them.

The Maldives is a nation of people with strong links to coral reefs and related marine and coastal ecosystems. Understanding the implications of climate change is fundamental to effective adaptation; and adaptation is essential for maximizing the prospects of sustainable development in this nation of remote tropical islands.

What is climate change?
Gases in the atmosphere trap some of the heat radiated from earth, keeping the earth at a temperature suitable for life. This is known as the greenhouse effect.

The enhanced greenhouse effect results from increased levels of greenhouse gases (mostly carbon dioxide) in the atmosphere, meaning that more heat is trapped, which is leading to increases in earth’s temperature. This is also known as global warming.

The term climate change is generally used to refer to the changes in the earth’s climate resulting from the enhanced greenhouse effect. It encompasses a range of climate characteristics, including temperature, rainfall, storm intensity, etc.

In technical terms, climate change is defined as sustained shifts in climate characteristics that are statistically significant, and which indicate a departure from normal variations in climate.
What is climate change doing to coral reefs?  
Climate change is affecting coral reefs in many ways. While coral bleaching is one of the most dramatic and worrying consequences, disease, sea level rise, increased storm intensity, changes in ocean currents and ocean acidification are all expected to impact coral reefs. Information on each of these effects is provided in the following sections.

Coral bleaching
Corals live throughout the world’s tropical seas, where they create the largest living structures on earth and provide habitat for millions of species. The secret to their success is the symbiotic relationship corals have with microscopic algae. These zooxanthellae, which live within the coral’s tissue, provide much of the energy required by corals. They are also responsible for the brown/green color that characterizes most corals (corals in shallow water can be bright colors, which is the result of blue, pink or yellow pigments that mask the more drab color of the zooxanthellae). Through this partnership, corals can thrive and grow even in clear water that is relatively low in nutrients, all the while forming calcium carbonate skeletons that accumulate over time to create coral reefs (the process of accretion).

However, under times of stress the relationship between coral and zooxanthellae breaks down. Temperatures only 1-2°C above the normal maximum result in loss of the algae. Without the algae, much of the coral tissue becomes transparent, and the bright white of the underlying coral skeleton gives the appearance of the coral being bleached. More serious, however, is the impact on coral health. Without the energy supplied by the zooxanthellae, many corals will starve to death or succumb to disease. In many locations around the world, high temperatures have caused severe mass bleaching events leading to widespread death of corals and long lasting reef damage.

Mass coral bleaching is a major threat to coral reefs. Much of the information in this section is drawn from The Reef Resilience Toolkit, which is a comprehensive online resource for coral reef managers maintained by the Reef Resilience Program, an initiative led by The Nature Conservancy. www.reefresilience.org

I like hot weather, but corals don’t. If it gets too warm the corals bleach and start to die. That is bad because all the fish lose their homes and the reef loses its color. Colorful, healthy reefs are nicer to visit and they give people fish to eat.

Savanna, age 9.
threat to coral reefs with the potential to impact hundreds of kilometers of reefs simultaneously. It affects not only reefs close to human development, but also those in remote, nearly pristine settings.

Smaller-scale or patchy coral bleaching is often associated with short-term changes in the reef environment: cold snaps, unusually high levels of solar irradiance, sedimentation, freshwater, and disease. However, large-scale bleaching events (often called mass bleaching) are tied to increased ocean temperatures.

Projections of future ocean warming under global climate change indicate that stressful temperatures can be expected to occur with increasing frequency over coming decades. As a result, climate change is widely regarded as the most serious long term threat to coral reefs at both national and global scales.

The largest mass bleaching events occurred during the 1998 El Niño and subsequent La Niña, when corals died on 16% of the world’s coral reefs. Along with the Seychelles and Chagos, the Maldives was hit especially hard. Over 80 percent of corals were killed in many areas when sea temperatures reached unusually high levels, especially in locations with historically stable temperatures. Further bleaching was recorded in 2001, 2005 and most recently in 2010.

Although these bleaching events have had a devastating effect on the coral reefs of the Indian Ocean, there have also been many examples of impressive resilience. Some of the best examples of rapid recovery can be seen in the Maldives, where there are instances of reefs in recovering to coral cover exceeding the pre 1998 levels.

The extent of bleaching depends on environmental factors such as overall ecosystem health, water quality, water depth, location and species of corals. When stressful conditions abate, most bleached corals recover their symbiotic algae and return to normal state; however, if stressful conditions persist then eventually bleached corals will die.

**Coral disease**

Just as in humans, corals are regularly exposed to diseases. Bacteria, viruses, protozoa, or fungi can cause coral diseases, but generally disease is isolated, patchy or not deadly in healthy coral reef systems. However, under certain conditions disease can spread through entire populations or reef communities,

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2 McClanahan & Muthiga 2014
causing widespread damage. There have been alarming increases in the frequency, intensity, and geographic range of coral disease over the last several decades. While there appear to be a range of causes, there is increasing concern that climate change is significantly increasing disease risk in corals.

**Sea-Level Rise**

Rising seas linked to climate change may not pose a major threat to coral reefs, as long as sea-level rises slowly enough for coral reef accretion (the rate of accumulation of coral skeleton) to keep pace. However, sea-level rise is a serious issue for coasts and low lying land, such as many of the islands of the Maldives. As the flattest country on earth, the Maldives is highly vulnerable to rising sea levels and increased coastal flooding associated with climate change. At a current rate of approximately 3 mm increase in sea level per year, there are grave concerns for the future of low lying islands everywhere. The government of the Maldives has identified potential measures to help the country adapt to rising seas. These include protecting groundwater and increasing rainwater harvesting, as well as increasing the elevation of critical infrastructure.

Sea level rise can have indirect impacts on coral reef healthy through coastal erosion. Erosion can lead to increased sedimentation of nearshore reef areas, while also affecting mangroves and sea turtle nesting beaches.

**Changes in Storm Intensity**

Global climate change is likely to drive changes in tropical storm patterns. Although it is not possible to predict the timing or severity of individual storms, future projections based on sophisticated climate models suggest that the frequency of intense storms may increase substantially in some areas. In addition to the risks to lives and infrastructure on exposed islands like the Maldives, intense tropical storms can cause extensive damage to coral reefs through direct impacts on reef structure and increases in sedimentation and freshwater runoff from land.

**Altered Oceanic Currents**

The ocean moves large amounts of heat around the planet through global ocean currents (e.g., through upwelling, downwelling, and thermohaline circulation).

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3 IPCC Fourth and Fifth Assessment Reports
Ocean currents will be affected by changes in wind, precipitation, temperature, and salinity due to global climate change. Changes in ocean currents can affect the transport or retention of pollutants, movement of larvae, and temperature regimes that may impact thermally sensitive species such as corals. Many climate models predict a weakening of the thermohaline circulation due to climate change, changing large-scale circulation and climate patterns. For the Maldives, this could mean changes in the timing or strength of currents that bring nutrients or cool water to the islands, and potential flow-on effects for fisheries productivity or the intensity and duration of episodes of stressful water temperatures.

**Ocean Acidification**

A simple chemical reaction links the levels of carbon dioxide in the atmosphere with the acidity of the oceans. As carbon dioxide increases in air, more is dissolved into the oceans, where it reacts with water molecules to create carbonic acid and lower pH (increase acidity). Already, so much extra carbon dioxide has been absorbed by the world’s oceans that changes in pH have been measured throughout all corners of the ‘blue planet’: from the north to south pole, from the surface shallows to the deepest abyss.

The ability of the ocean to absorb CO2 has meant that concentrations in the atmosphere have not increased as quickly as they might have. While this has been good for the ecosystems on land, it is leading to worrying changes in the oceans. Acidification of the oceans reduces the amount of calcium carbonate available for corals and other calcifying marine organisms to build their skeletons and shells. There is very real concern that corals will grow more slowly, or produce more fragile skeletons, due to ocean acidification. While the impacts may take a decade or more to be fully evident, there is little that can be done to reverse the process once it is underway. The only way to reduce ocean acidification globally is to reduce CO2 concentrations in the atmosphere.

**What does the future hold for the coral reefs of The Maldives?**

Coral reefs all around the world are under unprecedented pressure from a combination of local stresses (such as pollution and overfishing) and climate change. Sadly, coral bleaching events are almost certain to occur more frequently in the Maldives over coming decades as ocean temperatures continue to warm. However, previous bleaching events may have removed many of the more sensitive species, resulting in future bleaching events appearing less severe in the future.

In most places around the world, repeated coral bleaching events have led to changes in the composition of coral communities. Usually, this has lead to reductions in structural complexity, which translates to less habitat for fish and...
other species. This can adversely affect predatory fish species, such as groupers and snappers. Coral eating fish, such as butterfly fishes, can also decrease in numbers as coral cover dwindles. Conversely, reduced coral cover is usually accompanied by increased algal abundance, which can lead to increases in the abundance of herbivorous species, such as rabbitfishes and surgeon fishes. Depending on dietary preferences, this change in fish composition can impact both commercial and recreational fishing opportunities.

From a tourism perspective, the damaging effects of repeated coral bleaching events in combination with other impacts such as severe storms can severely reduce the visual appeal of coral reef sites. The Maldives have already experienced a significant loss of visual amenity in many reef areas. Fortunately, the Maldives is adorned with alternative tourism offerings in the form of superlative beaches and clear water which have been able to offset the deterioration in coral reef condition in the tourism market.

In some ways the Maldives has an advantage over most coral reef areas around the world. The remote location, lack of major rivers and relatively small population mean that there is less stress from local pressures, or at least that any significant sources of local stress are amenable to management interventions. The health of a reef ecosystem (its lack of exposure to local stress) can influence the amount of damage suffered during a coral bleaching event, and it is a major determinant of the speed of recovery after a destructive episode. The Maldives is in the enviable position of being able to take meaningful measures to protect the resilience of its reefs, and thereby position is coral reef ecosystem to cope better with climate change than most locations. In many other countries, the large spatial scale and extensive history of pollution, overfishing and habitat destruction mean there have been severe, and largely irreversible, losses of ecosystem resilience.

Coral reefs & people: ecosystem services

Coral reefs provide many goods and services that are essential to local communities, as well as delivering economic and cultural benefits to society more broadly. These include fish for consumption, fish and other products to sell for income, destinations that support tourism businesses, shoreline protection and assimilation of wastes. These many and varied benefits that people obtain from ecosystems are known as ecosystem services.
In 2005, the Millennium Ecosystem Assessment identified and categorised ecosystems and their resulting services into four categories: (i) provisioning services, which are the products or goods such as fish; (ii) regulating services, which are the ecosystem functions that benefit people such as shoreline protection; (iii) cultural services, which are the non-material benefits such as recreational and aesthetic benefits; and (iv) supporting services, which are the fundamental natural processes that support the other three categories (see figure).

![Diagram showing different types of ecosystem services provided by coral reefs.](http://www.millenniumassessment.org)

**Figure 1** Different types of ecosystem services provided by coral reefs, based on categories developed for the Millennium Ecosystem Assessment (http://www.millenniumassessment.org). (Source: The Outlook for the Pitons and Soufriere Marine Management Areas 2014; http://climateandreefs.org/outlook-reporting/)

In combination, the services provided by healthy marine ecosystems are extremely valuable. Although it can be challenging to put a dollar value on many of the non-market benefits (such as cultural services or shoreline protection), economic analyses provide an indication of what it would cost if coral reefs or other systems stopped providing ecosystem services.

Global analyses have estimated the full economic value of coral reefs at between $36,794 and $2,129,122 per hectare per year (USD; de Groot et al 2012). Based on these global average figures, the reefs of the Maldives are valued at $16-$96 trillion.

Of course, different reefs have different values, and the extent to which values are converted to benefits varies enormously, even within a relatively small reef region like the Maldives. However, even highly conservative calculations using actual market value data illustrate the importance of coral reefs to the Maldivian economy. Government figures show that the tourism sector contributed USD$1.9 billion to the national economy in 2012. Together with fishing, ecosystem
services from coral reefs directly provide the foundations for at least 31% of the national GDP of the Maldives.

These vital economic sectors are highly dependent on sustained provision of ecosystem services from the Maldives’ natural capital, much of which rests in coral reefs. Therefore, much of the fate of the Maldivian economy is tied to the health of these ecosystems. Understanding this dependency is crucial to recognising the threats that climate change presents not just to coral reefs, but to the health of Maldivian economy and the wellbeing of its people. This creates a clear incentive for strong leadership and effective management of the marine environment in the Maldives, and for ardent support of global efforts to reduce the rate and extent of climate change.

**Reef Resilience**

While future coral bleaching events, and further reef degradation, are inevitable as the earth continues to warm, there is much that can be done at local and regional scales to improve the outlook for these precious ecosystems. Healthy corals are less likely to bleach, while reefs in areas protected from pollution, overfishing and sedimentation can recover faster if corals do succumb to high temperatures. The rapid recovery of reefs in the Maldives highlights the value of ensuring that reef ecosystems are managed carefully to prevent or reverse any impacts on ecosystem health.

Understanding the links between ecosystem health and the fate of coral reefs in a warming climate is the basis for the growing focus on resilience as a basis for coral reef management. It is also the subject of a related fact sheet on *Resilience-based management*.

For relevant references and additional reading, please see:

*Climate change, coral reefs and Resilience-based management in the Maldives: Information Resources*