Climate Change and the Ocean: The Disruption of the Coral Reef

Fabio-Massimo Battaglia

Abstract

Even though coral reefs represent a negligible percentage of the ocean floor, they are wardens of incredible biodiversity. They provide support for at least 500 million people with food security and livelihoods, mostly in poor or developing countries.

Despite their importance, coral reefs are also extremely fragile. They are among the most damaged and threatened ecosystem due to unprecedented global warming, ocean acidification and climate changes, combined with increasing local pressures. These incredible ecosystems are calling us into action towards more efficient protection to ensure their conservation and restoration.

Keywords

Biodiversity · Biomimicry · Climate change · Coral reefs · Community-based approach · Restoration

1 Introduction

If we listen to the David Bowie song 'Space Oddity', Major Tom tells ground control that "Planet Earth is blue and there is nothing I can do". Fortunately, this is not the case for us. We can do something, and we should.

Oceans cover almost 70% of the Earth's surface. They are the most productive ecosystem, housing the vast majority of all known species. This unequalled habitat plays a crucial role in regulating global temperature and controlling our climate and weather patterns. The oceans are the primary producer of oxygen, and they also absorb large amounts of carbon dioxide.

Even though coral reefs represent a negligible percentage of the ocean floor—less than 1%—they are wardens of great biodiversity, more so than any other habitat. These reefs harbour a quarter of all marine life, and they provide support for at least 500 million people with food security and livelihoods, mostly in poor or developing countries. Furthermore, at a time when rising sea levels suggest that there is a real risk of small islands and atolls disappearing, it is essential to highlight how coral reefs play a pivotal role in protecting the coastline from floods and additional harm. These reefs protect shorelines by dissipating the force of the waves and floods, thereby helping to preventing loss of life, property damage and erosion.

Unfortunately, despite their importance, coral reefs are also extremely fragile. They are among the most damaged and threatened ecosystem due to unprecedented global warming, ocean acidification and climate changes, combined with increasing local pressures.

F.-M. Battaglia (✉)
Catholic University of Portugal, Global School of Law, Lisbon, Portugal
e-mail: s-fbattaglia@ucp.pt

M. d. G. Garcia, A. Cortês (eds.), *Blue Planet Law*, Sustainable Development Goals Series,
https://doi.org/10.1007/978-3-031-24888-7_10

Coral reefs are seriously threatened by climate change, and we cannot ignore this. In recent years, due to the mounting anthropogenic pressure from pollution and over exploitation alongside the rise in the global temperature, coral reefs around the world have suffered mass coral bleaching events that increase their vulnerability. Coral reefs are dying, and if we continue to act as normal, the vast majority of coral reefs will cease to exist by the end of this century.

The only way to avoid this scenario and ensure the survival of coral reefs is to maintain the global average temperature well below 2 °C above pre-industrial levels. Doing so would make it possible to improve coral reef living conditions in addition to introducing other measures to preserve, rescue and restore them. Such other measures alone would not be sufficient, as they cannot save coral reefs unless GHG emissions are also limited.

These incredible ecosystems are calling us into action towards more efficient protection to ensure their conservation and restoration.

What consequences would the loss of coral reefs have? What can be done to protect this heritage for which we are responsible? By answering these questions, this chapter also aims to analyse how the international environmental legal framework is acting to support and improve the conservation of coral reef ecosystems. We will also consider whether the current environmental treaty rules are sufficient to meet this challenge or whether it is necessary to change the paradigm and our perspective on nature and biodiversity. Moreover, it will also be essential to reflect on creative solutions that embrace a new perspective, based on sustainability and the coexistence of man with the environment. It is impossible to think about safeguarding our planet's biodiversity without considering economic, social and technological development and the dynamics of this.

2 An Incredible Ecosystem

The oceans are already interesting and productive ecosystems, which host, within them, incredible wonders, and a large amount of biodiversity. They are often identified as the blue lung of the Earth; they cover much of our planet and represent our greatest resource. As mentioned before, the Oceans play a notable role in regulating global temperature and governing our climate and weather patterns. Furthermore, they are the primary producer of oxygen, and they also absorb large quantities of carbon dioxide. None of this, however, conveys the full extent of their importance. In this vast ocean environment, the smallest but surprisingly crucial asset is coral reefs.

Without going too far into matters that are beyond the scope of this work, it is, however, interesting to note how coral reefs are composed. Coral reefs are complex structures that have been formed over thousands of years due to the deposition of calcium carbonate skeletons of coral species that form the reef. The coral is an organism belonging to the Anthozoans, small polyps of a few millimetres in size grouped in colonies that can belong to over five thousand different species. These polyps live in symbiosis with the underlying unicellular algae, which give the coral formation its characteristic colour. It is these algae that have the function of carrying out photosynthesis and producing nourishment for the coral polyps (Creary 2013).

There are several species and different kinds of corals; they can be found in deep water and also in the shallow waters surrounding the ocean environment. However, it is essential to distinguish between corals in cold or warm water (Goodwin 2006). For this study, we will focus only on warm water corals, which are common in the coastal tropical areas, and which make up the reefs covered by this chapter.

Finally, it is critical to highlight that while it is difficult for this type of coral to persist in low temperatures, coral reef-building in shallow tropical marine areas is only possible where the water temperature is between 18 and 30 degrees centigrade (Hoegh-Guldberg 1999). Therefore, the temperature of the water is a crucial aspect for the survival of the entire coral reef ecosystem.

Why are coral reefs important, and what is the issue? As mentioned before, coral reefs represent one of the richest ecosystems in terms of

biodiversity. Although they occupy only a very small portion of the ocean surface, coral reefs are home to more than a quarter of all fish species and marine animals. Furthermore, coral reefs provide a wide variety of ecosystem services and benefits for the populations living close to them. They are indeed not only a source of subsistence food but also protect coastal areas from floods, as well as supporting the fishing and tourism industries.

Coral reefs are considered to directly support more than 500 million people by giving them the minimum subsistence for survival (IUCN 2017). This figure is even more important if we consider that most of these people live in poorer or developing countries. Thus, given this huge number of people from different cultures who rely on coral reefs, it is easy to understand how the disappearance of this type of ecosystem would have a severe impact not only in environmental terms but also at the economic, social and cultural level.

It may also be useful to point out that coral reefs are seen as a prime indicator of the health of the global environment. Since they are a very sensitive ecosystem, they react very quickly to climate change, pollution and anthropogenic stress. For this reason, they are considered an alarm bell, showing us what could happen to other less sensitive systems. If climate change is not urgently addressed, the deterioration of other systems could unfold more rapidly and irreversibly (IUCN 2017).

3 A Critical Issue

Coral reefs around the world are suffering. Recently there has been much discussion about the risks and dangers for the future of coral reefs. We are witnessing increasingly frequent coral bleaching events; but what do these events mean and what are the causes?

Anthropogenic climate change is putting coral reefs under pressure; greenhouse gas emissions have caused a rise in the global surface temperature and increased acidification of the oceans.

These facts, in addition to growing local pressure, have led to unprecedented mass coral bleaching events, which have made coral reefs one of the most endangered ecosystems on the planet.

Coral bleaching occurs when the water temperature is too high and this has a negative effect on the symbiosis between polyps and algae. The latter are expelled, and the polyps are deprived of their nourishment. When these conditions last for an extended period, the polyps die, and the absence of algae turns the coral structures white. Coral bleaching events often lead to the death of large numbers of corals. Moreover, other types of algae can take over a damaged reef and create a different new environment where the growth of new corals is more difficult.

Dead corals are rapidly destroyed by marine erosion, which is no longer retarded by the production of new calcium carbonate. Furthermore, the death of polyps damages the food chain, with repercussions for the marine fauna of the entire coral ecosystem (Heron et al. 2017).

The consequences for the human population and the economy can also be devastating. As we have seen, in many areas of the world, especially in poor and developing countries, subsistence activities such as fishing or tourism depend heavily on coral reefs. Furthermore, the loss of these structures reduces the natural defence against coastal erosion from floods and destructive storms associated with extreme weather events.

The first cases of bleaching were observed in the 1990s along the Australian Great Barrier Reef, after a warming of the Pacific waters due to the periodic climatic phenomenon known as El Niño.

Another critical phase occurred in 2010, but it was between 2014 and 2017 that these events began not only to last longer but also to be more extensive, as they affected over 70% of the world's coral reefs (Heron et al. 2017).

The vast majority of the reefs around the world have suffered from mass bleaching events with devastating effects. Overall, it is estimated that almost 50% of the world's corals have been lost in the last thirty years. Some authors fear that only 10% of those still existing in the world will survive beyond 2050, and by the end of this century

we could permanently lose this incredible ecosystem (Obura 2017).

These catastrophic data indicate that we are no longer facing only periodic fluctuations in ocean temperatures linked to El Niño, but slow and inevitable rises in seawater temperatures, produced by global warming.

The bleaching of corals and their ultimate death due to heat stress that has been observed over the past three decades is expected to continue and intensify over the next few decades unless GHG emissions are dramatically reduced (Heron et al. 2017). Unfortunately, corals cannot survive the frequency of current bleaching events, and ocean acidification due to the high level of GHG emissions is continuing to increase. The first global scientific assessment of climate change impacts on World Heritage coral reefs—published in 2017 by UNESCO—highlights that if humans continue to act under a business-as-usual scenario bleaching events will increase in intensity and frequency. The consequence will be that almost all coral reefs in the World Heritage sites would cease to exist as functioning coral reef ecosystems by the end of this century (IUCN 2017).

4 What Are We Doing?

Fighting coral bleaching is one of the priorities on the international agenda. In order to contain the increase in global average temperature between 1.5 and 2 °C compared to pre-industrial levels, the path is to drastically reduce GHG emissions by the second half of the century, as set out in 2015 by the Paris Agreement. On one hand, achieving this goal is crucial since it provides the only chance for the survival of coral reefs globally. On the other hand, the same goal is now considered unattainable by many scientists, for several reasons. The first of these is that time is not on our side and we are still far from reaching our goal. We need to act immediately and with more ambitious measures. Secondly, the current rules of the world market are in stark contrast to a sustainable view of the economy, and even at the local level, this is a severe problem. The increase in local populations, resource consumption and economic activities, such as fishing or tourism, will inevitably damage the state of the ecosystem. A radical change in the economic vision would be needed (Aldred 2019).

Suppose the goal of the Paris Agreement is fully reached. In that case, we will obtain a decrease in atmospheric carbon concentrations that will lead to better conditions for the survival of coral reefs and enable other measures to rescue them to be successful. It is evident that a single solution is not enough; on the contrary, we need a synergy of measures and policies aimed at the conservation and safeguarding of coral reefs. For this reason, some research centres are trying to intervene directly on corals, with various measures of repopulation or restoration of the reefs.

These techniques, however, have some limitations. In addition to being expensive, they can only be applied on a tiny scale, while the risk to coral reefs concerns large areas of the oceans. Furthermore, it is essential to highlight that none of these techniques is currently able to recreate the ecological functions of a coral reef. Thus, even if the corals can be recreated, it is not possible to reactivate the ecosystem (Aldred 2019).

Support and restoration of coral reefs should be treated as a complementary measure to the achievement of the objectives of drastically reducing emissions and changing the economic paradigm. Long-term investments should, therefore, be made to support research for the restoration of barriers to overcome the current difficulties (IUCN 2017).

The Paris Agreement is not the only tool that the international community has adopted to tackle climate change and its adverse effects. The whole international agenda aims to create a more sustainable society, a new economic perspective that involves all human activities. Human development, which must be achieved through the goals of sustainable development, should take into account an integral ecology that cannot separate human and social development, through the eradication of poverty, from the protection and safeguarding of the environment.

So, the objectives established with the Paris Agreement are also present and reinforced in other international and regional agreements, in local policies and other instruments such as the UN Sustainable Development Goals (SDGs).

Among the SDGs, there are some that—at least partially—cover the theme addressed in this chapter.

It could be useful to consider two different groups of SDGs. The first group is composed of Goals 8 and 12. Both of these goals concern the transformation of the economic system, to promote a circular economy that fosters inclusive and sustainable growth as well as sustainable consumption and production patterns. In the last part of this work, we will deal with the aspect of the economic system and its transformation to a system that rapidly reduces greenhouse gas emissions to ensure global temperature decrease, and a new economic perspective that takes into account the benefits and the services provided by the ocean and the coral reefs (United Nations General Assembly 2015, goals 8–12).

The second group is based on Goals 13 and 14. Goal 13 is a general goal aimed at fighting climate change. It seeks to promote action, at all levels, from local to global, to combat climate change. It highlights how climate change is a global issue that knows no national borders, but at the same time, that not all countries are affected in the same way and with the same intensity. This point is interesting because the countries most directly affected by the coral reef crisis are often the poorest or the developing countries. These countries have contributed minimally to anthropogenic climate change, and yet they are the most affected by it. The resources of these countries are limited; there is a need to promote common actions, in a shared effort by all the players on the international stage. Goal 14 is directly focused on the ocean ecosystem. It concerns the conservation and sustainable use of the oceans, seas and marine resources for sustainable development. Therefore, it is obvious how important the protection of coral reefs is for this SDG since—as mentioned in the previous part of this work—they represent the most outstanding heritage within the ocean ecosystem.

Among all the objectives proposed by SDG 14, there is one in particular that aims to increase the economic benefits to small island developing states by 2030, by resorting to more sustainable use of marine resources, including sustainable management of fisheries and tourism (United Nations General Assembly 2015, goals 13–14). To do this and to preserve the coral reef, these countries need to receive technological support from developed countries. This kind of alliance between states can overcome local difficulties in the move towards a more sustainable economy.

Another exciting tool within the international community is the UN Decade on Ecosystem Restoration. This programme, established by the UN General Assembly in 2019, aims to dramatically increase the restoration of degraded and destroyed ecosystems through targeted and agreed actions at global, regional and local levels. The aim of these measures is to fight the climate crisis and improve food security, water supply and biodiversity and, at the same time, ensure human development and the sustainable exploitation of natural resources. The programme will help countries to take action against the harmful effects of climate change and biodiversity loss, promoting rapid and effective restoration policies that build resilience, reduce vulnerability and increase the ability of ecosystems to adapt to daily threats and extreme events (Eisele and Hwang 2019).

The Sixth Status of Corals of the World Report—recently published on 5th October 2021 by the Global Coral Reef Monitoring Network (GCRMN)—highlights the current status of coral reefs worldwide, analysing their trends and potential future scenarios. One claim among the Report's key findings is crucial and straightforward: coral reefs are still in trouble, and we need to act now. The report points out that 14% of the world's coral reefs have been lost in the last decade. Many reefs are diminishing instead of flourishing, and coral bleaching is becoming a regular event rather than a rare damaging episode (GCRMN et al. 2021).

As previously described in this chapter, increasing coral bleaching events, higher ocean temperatures, and other climate change-related

impacts can drastically affect coral reefs, with severe and irreparable consequences.

Luckily, the report also points out some positive hopes and possibilities.

Indeed, given the right conditions, coral reefs can recover. There are already some good examples of resilience and natural resistance in dealing with increasing water temperatures. Thus, since healthy corals are more likely to adapt to climate change, the action needed for coral protection should focus on creating the proper conditions to help the natural recovery of the reefs. This could be, for example, by minimising human impacts, such as water pollution and overfishing, and slowing climate change. It is essential to work together with local communities to identify proper measures and good practices to keep coral reefs in good and healthy condition.

In order to increase awareness of this issue and to spread action among international actors and local communities, the GCRMN and the International Coral Reef Initiative (ICRI) published this report before the UN Climate Change Conference (COP26) held in Glasgow in November 2021.

Indeed, the ocean was one of the most important themes during COP26. World leaders, international organisations, civil society and NGOs demonstrated considerable interest in ocean challenges and opportunities, at both official meetings and side events. As is evident from the COP26 outcomes, there are intangible and complex links between the ocean, climate and biodiversity, and the need to address them jointly is on the international agenda.

This high level of mobilisation crystallised the importance of the ocean in the climate negotiations, and the importance of paying increasing attention to the maritime ecosystem and its protection.

Given this context, it is worth mentioning another interesting initiative in the international arena: the UN Decade of Ocean Science and Development 2021–2030. This initiative aims to bring together institutions, researchers, stakeholders and other actors in the ocean community to design and deliver proper solutions and development projects to support the Agenda 2030 in its path for a healthier Ocean.

Finally, the decision to hold COP27 in Egypt is also a good opportunity. The Egyptian government launched one of the earliest conservation initiatives in 1983 (Kleinhaus et al. 2020) and it has repeatedly reiterated the importance of protecting coral reefs. Hosting COP27 right on the shores of the Red Sea could represent an opportunity to encourage action in this sense.

5 What Can Be Done?

Despite the vast range of potential tools and the objectives that have been set, there is still a risk that we will fail to achieve the goals, or fail to do so within the necessary timeframe. According to an opinion shared among much of the scientific community, the emissions target set in the Paris Agreement is not ambitious enough, and even if we reach that goal, there will still be temperature increases by 2030. That could mean the end for the coral reefs. Another note concerns Goal 14 of the SDGs, which, it is suggested, should deal more specifically with the human impacts causing the destruction of coral reefs and their current situation, in order to consider faster and more efficient strategies between states (Manfrino 2017).

More aggressive and robust actions are required to face this issue, not only by states and the governments but also by other actors, such as local institutions, NGOs or the private sector. This paragraph will address the current situation in developing countries in order to identify some good practice and potential solutions.

While it is evident in any international agreement that there must be significant financial aid to help developing countries, it is also true that relying too heavily on this kind of help could be problematic for them.

Nowadays, it is becoming clear that climate adaptation costs will be higher than previously expected. This fact will probably lead to a lack of funding support and weakening international aid in the future.

Thus, governments in developing countries should act to prepare for this situation, and they

should be ready to decrease their dependence on foreign support (Clissold et al. 2020).

Obviously, the Principle of Common but Differentiated Responsibilities places western and developed countries in a position to help and, in some way, pay for their pollution. They should support poorer countries in achieving social and economic development and also in tackling the impacts of climate change. Financial aid and technological support are crucial in this challenge, but other factors must also be taken into account. For instance, the ability to act and to choose what is best for one's country also depends on cultural and social factors which differ from state to state. These factors can also influence adaptation policies. This explains why it is important to maintain an appropriate level of independence.

An analysis of the climate adaptation strategies used to date reveals that these have often been a failure, or at least inefficient or inadequate. This is primarily the case when the people living in a particular context have not been involved in the planning of the adaptation measure. A case in point is the building of sea walls and barriers in the Pacific region to protect low-lying states from floods and sea-level rise or to prevent coastal erosion. This could be a feasible solution in rich developed countries where appropriate technology and funding can be found. However, it may not be sustainable in small island developing states. Moreover, this solution does not take into account any cultural factors. These nations have been living alone in the oceans for centuries, and their traditional technologies might provide more suitable solutions. For instance, some nature-based measures, such as replanting coastal mangroves, can be more sustainable for the local society (Nunn and Kuman 2020).

Following on from this last point, it is worth mentioning the Community-Based Approach, a strategy to empower communities to prevent and face climate challenges. The aim of the strategy is to facilitate adaptation measures, creating inclusive, community-driven and sustainable actions that take into account the cultures and the tradition of the local community (Kirkby et al. 2015). The idea is to enable local communities to understand and foresee climate change impacts in advance and to plan and decide how to intervene. The local communities will choose their own strategies and methods to respond to the harmful effects of climate change, and they can independently plan their adaptation goals. This kind of programme is thoroughly planned and led by the local communities, without any external imposition. Hence, any social and cultural factors will not be neglected.

Taking—once again—the small island states of the Pacific as an example, it is easy to imagine that they have longstanding traditional knowledge of the ocean environment and also a generous legacy from their ancestors regarding the implementation of cashless adaptation actions. These rural communities could develop measures and solutions to tackle the impact of climate change that cost nothing and that are consistent with their cultures. This means starting from the bottom, through policies of education and involvement of the whole society.

These solutions might involve direct intervention on the environment using a small amount of money and little technology. Hence, there is no need to rely too heavily on the developed countries. Examples include actions related to traditional methods of planting and restoring the mangroves—as mentioned above—or similar solutions relying on resources available locally.

It is not only an issue of reducing costs but also a means of enabling rural communities to enhance their heritage and act directly on the environment that surrounds them (Nunn and Kuman 2020). It is essential to understand that the two different levels of action must be complementary. It is vital that we act internationally to change the way we live, produce and consume. However, it is also important to specifically engage the communities of developing countries, increasing their autonomy without creating dependence on foreign funding, which could run out quite quickly.

6 Blue Economy: A Sustainable Future for the Ocean

As we have seen, all the solutions and the objectives identified to tackle climate change and to save the coral reefs are related to economic and business interests. To meet the requirements of the Paris Agreement, and also to achieve the SDGs of the UN Agenda 2030, it is vital that we change our economic system, or—at least—understand that the benefit of preserving the coral reef ecosystem is not anti-economic. Indeed, we have seen how the coral reef is crucial for the economy of many countries.

At first glance, saving the environment runs contrary to the rules of our economy and mainstream trade and finance. It is easier to find business activities following the principles of the linear economy than those of the circular economy. This is no longer sustainable. Switching our economic system to become sustainable and circular must be the priority. It is the only way to achieve the goals we have set ourselves. It will dramatically decrease waste and emissions, and will involve governments finding policies and practices that follow the economic aims of the SDGs (Aldred 2019).

The first action might be to thoroughly understand the vast range of benefits that humanity gains from coral reefs. This chapter has shown how reefs play a crucial role in the economies of tropical countries. Coral reefs are one of the greatest assets for these nations, and governments should treat them as such, increasing the investment to preserve, sustain and restore them and the entire ecosystem (Obura 2017).

Related to this issue, in recent years, we have long heard of the blue economy—a model of an economic system that aims to revolutionise the world economy through a sustainable approach. The Belgian economist Gunter Pauli introduced the term blue economy (Pauli 2010) for the first time in 2010. As can easily be guessed, the term alludes to water—and the oceans represent its core—but it goes beyond this element. Pauli introduces a new type of sustainable economy, similar to the green economy but with a new crucial aspect: *biomimicry*. It is concerned with studying, and possibly imitating, nature in order to seek solutions to apply to human activities.

According to the Belgian economist, by studying how nature works, it is possible to improve production and processing techniques, thus creating new jobs, revitalising the economy and safeguarding the environment (IIED 2019). In short, it is possible to say that the blue economy seeks to eliminate emissions that harm the planet and to revolutionise production systems through biomimicry. Hence, this model of sustainable development has been continually promoted, in recent years.

As this chapter shows, coral reefs are an essential part of the blue economy, and we must therefore act and invest in preserving their productivity. If we do so, with proper investments and solutions, it will be possible to create a sustainable economy that enables both human development and environmental protection, preserving the heritage and the biodiversity of the coral reefs and preventing the harmful loss of this incredible ecosystem.

7 Conclusions

One important conclusion is that, in addition to states and international programmes, other actors can play a crucial role. As this study shows, developing countries need to stop relying totally on foreign support. Funds and financing projects often do not consider the cultures and traditions of indigenous peoples, who have a privileged relationship with the nature that surrounds them. NGOs and local actors can therefore be the missing link in the chain that protects this delicate ecosystem. Even if we assume that the objectives of the Paris Agreement will be achieved, it has been shown that without an ambitious change, even they may not be enough. That is where other actors come into play. Local adaptation and resilience policies can give an extra boost. Synergy between actions is needed, with different components of action against climate change complementing each other.

As mentioned above, coral reefs—and their conditions in the short term—are a clear indicator of our ability to revolutionise our lifestyle, promoting and implementing good practices to preserve the environment.

Collective action is needed because, as this chapter has shown us, even though coral reefs cover a tiny part of the ocean surface, they could change the fate of the entire planet and all humanity will benefit from their protection. Ultimately, we cannot think of living in a world that does not contemplate sustainable development. It is an indissoluble binomial; human and technological development cannot ignore the protection of the environment and its biodiversity.

Acknowledgments First of all, I would like to express my special thanks to the editors of this book, Professor António Cortês and Professor Maria da Gloria Garcia who gave me the opportunity to participate in this wonderful project. From the very beginning, Professor Cortês was interested in my topic, and he helped me to identify the proper angle to develop my research. Secondly, I would like to thank Professor Armando Rocha—who is the supervisor of my PhD thesis—for always being available to discuss my ideas, giving me the chance to see my research from a different perspective and fostering constant debate that helps my PhD path. This project was a stimulating and challenging journey which also helped me in developing my doctoral research increasing my knowledge of relevant topics related with the area of my PhD thesis.

References

Aldred J (2019, March 28) Dialogue with David Obura: 'We are not doing enough to combat the decline of coral reefs'. China Dialogue Ocean. https://chinadialogueocean.net/7338-david-obura-coral-reefs/

Clissold R, Piggott-McKellar A, McNamara KE, Nunn PD, Kumar R, Westoby R (2020, June 29) Their fate isn't sealed: Pacific nations can survive climate change – if locals take the lead. The Conversation. https://theconversation.com/their-fate-isnt-sealed-pacific-nations-can-survive-climate-change-if-locals-take-the-lead-136709. Accessed 15 Nov 2022

Creary M (2013) Impacts of climate change on coral reefs and the marine environment. UN Chron 50:24–27

Eisele F, Hwang BS (2019, March 1) New UN decade on ecosystem restoration offers unparalleled opportunity for job creation, food security and addressing climate change. UNEP Press Release. https://www.unep.org/news-and-stories/press-release/new-un-decade-ecosystem-restoration-offers-unparalleled-opportunity. Accessed 15 Nov 2022

GCRMN, ICRI, Australia Institute of Marine Science, UNEP (2021) The status of corals of the world report 2020

Goodwin EJ (2006) International law and the promotion of marine protected areas for the conservation of coral reef ecosystems. PhD thesis, University of Nottingham

Heron SF, Eakin CM, Douvere F, Anderson K, Day JC, Geiger E, Hoegh-Guldberg O, Van Hooidonk R, Hughes T, Marshall P, Obura D (2017) Impacts of climate change on World Heritage coral reefs: a first global scientific assessment, CLT-2017/WS/12. UNESCO, Istanbul

Hoegh-Guldberg O (1999) Climate change, coral bleaching and the future of the world's coral reefs. Mar Freshw Res 50:839–866

IIED (2019) Introduction to an inclusive blue economy (IIED, February 2019). https://www.iied.org/introduction-inclusive-blue-economy. Accessed 15 Nov 2022

IUCN (2017) Coral reef and climate change, Issues brief (IUCN, November 2017). https://www.iucn.org/resources/issues-briefs/coral-reefs-and-climatechange. Accessed 20 May 2020

Kirkby P, Williams C, Huq S (2015) A brief overview of community-based adaptation. ICCCD, Dhaka

Kleinhaus K, Al-Sawalmih A, Barshis DJ, Genin A, Grace LN, Hoegh-Guldberg O, Loya Y, Meibom A, Osman EO, Ruch JD, Shaked Y, Voolstra CR, Zvuloni A, Fine M (2020) Science, diplomacy, and the Red sea's unique coral reef: it's time for action. Front Mar Sci 7. https://doi.org/10.3389/fmars.2020.00090

Manfrino C (2017) Can we save coral reefs? UN Chron 54: 28–31

Nunn PD, Kuman R (2020, July 31) Pacific Islands must stop relying on foreign aid to adapt to climate change, because the money won't last. The Conversation. https://theconversation.com/pacific-islands-must-stop-relying-on-foreign-aid-to-adapt-to-climate-change-because-the-money-wont-last-132095. Accessed 15 Nov 2022

Obura D (2017) Refilling the coral reef glass. Science 357: 1215

Pauli G (2010) The blue economy: 10 years, 100 innovations, 100 million jobs. Paradigm Publications, New Mexico

United Nations General Assembly (2015) Transforming our world: the 2030 agenda for sustainable development, A/RES/70/1. United Nations, New York