



Introduction and Background

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Abstract

Coral reefs are important ecosystems, especially in regions like the Western and South-Western Pacific, where they play vital roles in food provision, resource production and coastal protection. They are, however, under severe pressure from human and climate change. The importance of reefs is recognised globally, and substantial research efforts are being made to improve our understanding of the chemical, ecological, geological and physical processes occurring in and around reefs. This research will, in turn, provide information essential for the improved and more sustainable management of reefs. Success in such research often requires multidisciplinary/multinational teams. One such grouping was the Coral Reefs under Climate and Anthropogenic Perturbations (CorReCAP) Project established through the UNESCO-IOC-WESTPAC office in 2008. This monograph presents the outcomes of the CorReCAP Project, and this chapter outlines the aims, objectives and activities of the project.

Keywords

Coral reefs · Western Pacific · Climate change · Human impacts, CorReCAP Project · Aims · Background

Coral reefs are one of the most important ecosystems found on the Earth's surface. They are found in tropical and subtropical oceanic waters, and have evolved to form structures that are home to an enormous number of organisms. Coral reefs facilitate the very efficient production of organic matter, particularly notable as they operate in waters that would otherwise be considered relatively infertile. Surrounding communities use coral reef areas as a major source of foodstuffs, pharmaceuticals and building materials, as well as coastal protection sites. If the resource use activities are well managed, the coral reef can be a major community asset for many years. The balance is a delicate one and can be disturbed by population increase (locally driven by improved living conditions, e.g. better health standards, or by migration, or internal drift of people from inland to the coast).

The importance of reefs as resource providers has been known to humans for a long time, but as they became more of a focus for global exploration and inquisitive scientists, interest in understanding and managing reefs expanded. This is especially true in the twentieth century, when it was observed that reefs were an important contributor to ocean-atmosphere interactions and the global carbon budgets. Thus, coral reefs, being dominated by carbon, are being impacted by human activities altering oceanic processes, and also by human actions changing atmospheric conditions. As one of these atmospheric changes is carbon dioxide concentration, a significant contributor to global climate change, it can be considered that coral reefs are clearly impacted by both anthropogenic and climate forcings.

The tropical and subtropical Western Pacific Ocean Region (see Fig. 1.1) possesses an enormous marine biodiversity but suffers impacts from a combination of high population density and rapid economic development that result in

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high material inputs from land-based sources (i.e. rivers). Furthermore, this region is exposed to frequent climatic and oceanic perturbations, e.g. monsoons with episodic typhoons—ca. 10–20 events or even more frequent in a year. This region is, therefore, particularly vulnerable to the combined effects of land-based human activities and ocean-/atmosphere-based climate events.

In the Western Pacific Region, humans are critically dependent on the coral reefs and related food webs because of the goods and services they provide, such as fishery resources and tourism. The region is well recognised for its biodiversity richness in both the terrestrial and marine zones (the Wallace and Huxley lines discussion in the nineteenth century), and considered to contain “hot spots” for biogeochemical and ecosystem studies, such as in the connecting area between the Indian and Pacific Oceans at low latitudes. Despite their recognition of the vital role of reefs, humans have significantly damaged coral reef systems through overfishing and destructive fishing practices (e.g. dynamite and cyanide fishing), coastal engineering, land-source pollutant discharge and marine aquaculture which have considerably changed the structure and function of fringing coral reefs, to such an extent that they have caused the extinction of important marine species (Huang et al. 2000). As a result, increased knowledge of the status and functions of coral reefs, as well as better understanding of the connectivity between individual coastal habitats, is required for sustainable management of these ecosystems. Climate change and natural disasters (e.g. typhoons, high tectonic activity and tsunamis) are other threats to coastal ecosystems with the potential to cause severe damage (Burke et al. 2011).

Anthropogenic perturbations both from terrestrial and from marine sources impact the functioning of reef ecosystems; this, in turn, regulates the nature of the sustainability of the ecosystems and thus affects the services that can be provided to reef users (see Fig. 1.2). Freshwater, sediment and nutrient inputs from land-based sources have changed and are continuing to change, often with adverse consequences for the technical, social and economic functions of the coral reef ecosystems, including tourism, sewage disposal, illegal fisheries and direct exploitation of resource materials from coral reefs (Brodie and Fabricius 2019).

The global changes outlined above also affect physical, biogeochemical and ecological processes in coastal coral reef ecosystems; these can be considered as added stresses on an already over-stressed environment. These will further reduce the ability of coral reef systems to provide goods and services. Some of the impacts that have been noted include loss of habitat and shifts in community structure, which have

consequences for food web dynamics. These changes can be severe, particularly in areas of rapid economic development and population growth, such as in the Western Pacific Region (Holbrook et al. 2015).

The obvious need for increased/improved understanding of coral reef systems has led to the initiation by many agencies of numerous research and training activities to further investigate the complex reef biogeochemistry and ecosystem behaviour. One such international collaborative research group was established in 2008, by the IOC/WESTPAC Sub-Commission when a new initiative study of “Coral Reefs under Climate and Anthropogenic Perturbations” (i.e. IOC/WESTPAC-CorReCAP Project) was adopted.

The terms of the reference (TORs) of the IOC/WESTPAC-CorReCAP Project were as follows:

- To understand the biogeochemical and ecological nature of coral reefs in WESTPAC (i.e. the Western Pacific Ocean) in different geographic, physical and environmental settings, as well as different types of human interventions;
- To evaluate the consequences of impacts of climate change and other human activities on the health of coral reefs and their sustainable use; and
- To promote capacity building in areas related to research on coral reefs through sharing scientific knowledge and training activities, as well as collaboration within research networks in WESTPAC.

These TORs were in accordance with the IOC Medium-Term Strategy (2008–2013), which has highlighted the prevention and reduction of harm from natural hazards to coral reef ecosystems as a matter of urgency. In addition, the mitigation of impacts from climate variability and human impacts is a major challenge for the IOC/WESTPAC Sub-Commission, given that coral reefs form substantial but sensitive ecosystems for most of its member countries in the region. Linkage to the IOC/WESTPAC Sub-Commission would also facilitate meetings with other marine environmental research groups to compare results for tropical and sub-tropical zones of the region.

The project had initially a steering group of regional researchers; more than 15 researchers (from the nine IOC/WESTPAC countries) contributed to the project planning. After the launch of the IOC/WESTPAC-CorReCAP Project in May 2008, the following activities were organised to facilitate greater regional cooperation among research programmes, training of young marine researchers and international workshops.

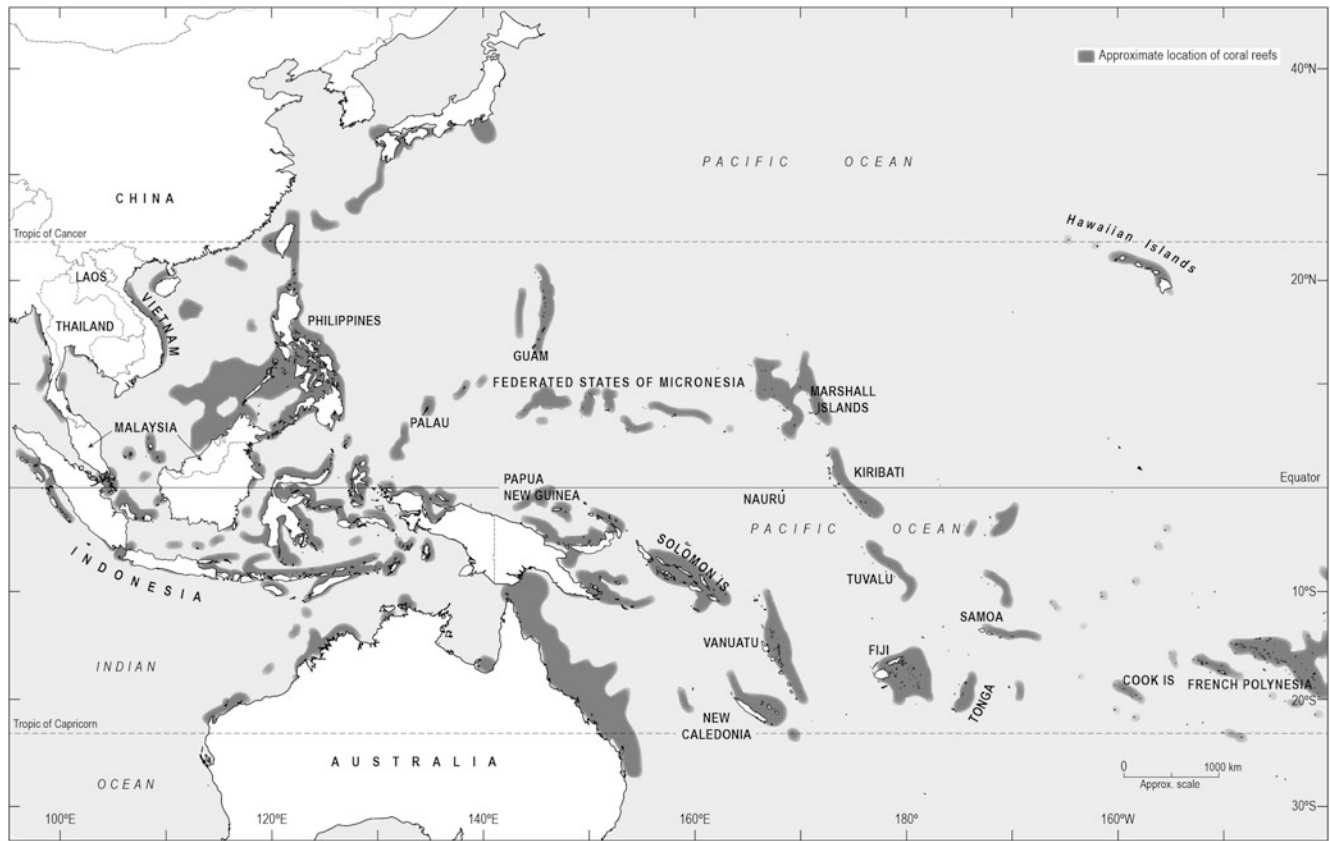


Fig. 1.1 The tropical and subtropical Western Pacific Region—the geographic focus of the IOC/WESTPAC-CorReCAP Project. Note the extensive distribution of coral reefs in the tropical and subtropical latitudes. In the figure, shadow areas represent coral reef locations.

The Western Pacific Region is the largest area of coral reefs with biodiversity richness on this planet. In this region, major external forcings and feedback loops are illustrated in Fig. 1.2

1.1 International Workshops

- Shanghai, China (26–29 May, 2009): meeting of about 25 researchers to establish a work programme, determine priorities, discuss paper writing and identify support funding options.
- Phuket, Thailand (22–24 June, 2010): meeting of about 12 scientists to receive progress reports, identify common issues and provide advice as required to various research projects.
- Busan, Republic of Korea (28–31 March, 2011): meeting of about 35 researchers with ten CorReCAP collaborators. Meeting was in three parts: first, some presentations; second, discussion of writing papers; and third, drafting some short items for implementation.
- Shanghai, China (31 July–4 August, 2012): co-funded by the Asia-Pacific Network (APN); *Capacity Building in Marine Research*—this meeting was attended by 20 researchers, government officials and representatives from international funding agencies.

The outputs of this workshop included an Asia-Pacific Network Report:

Fang Luo, Liuming Hu and Jing Zhang (2014) Capacity building assessment for integrated marine biogeochemistry and ecosystem research in the Asia-Pacific region. *APN Science Bulletin*, 4(1) 35–39.

A refereed international research journal paper from the Shanghai workshop (31 July–4 August, 2012) as below:

R.J. Morrison, et al. (2013). Developing human capital for successful implementation of international marine scientific research projects. *Marine Pollution Bulletin*, 77, 11–22.

It was also agreed that attempts would be made to publish a special volume of an international and peer-reviewed journal in 2013, focusing on the IOC/WESTPAC-CorReCAP Project.

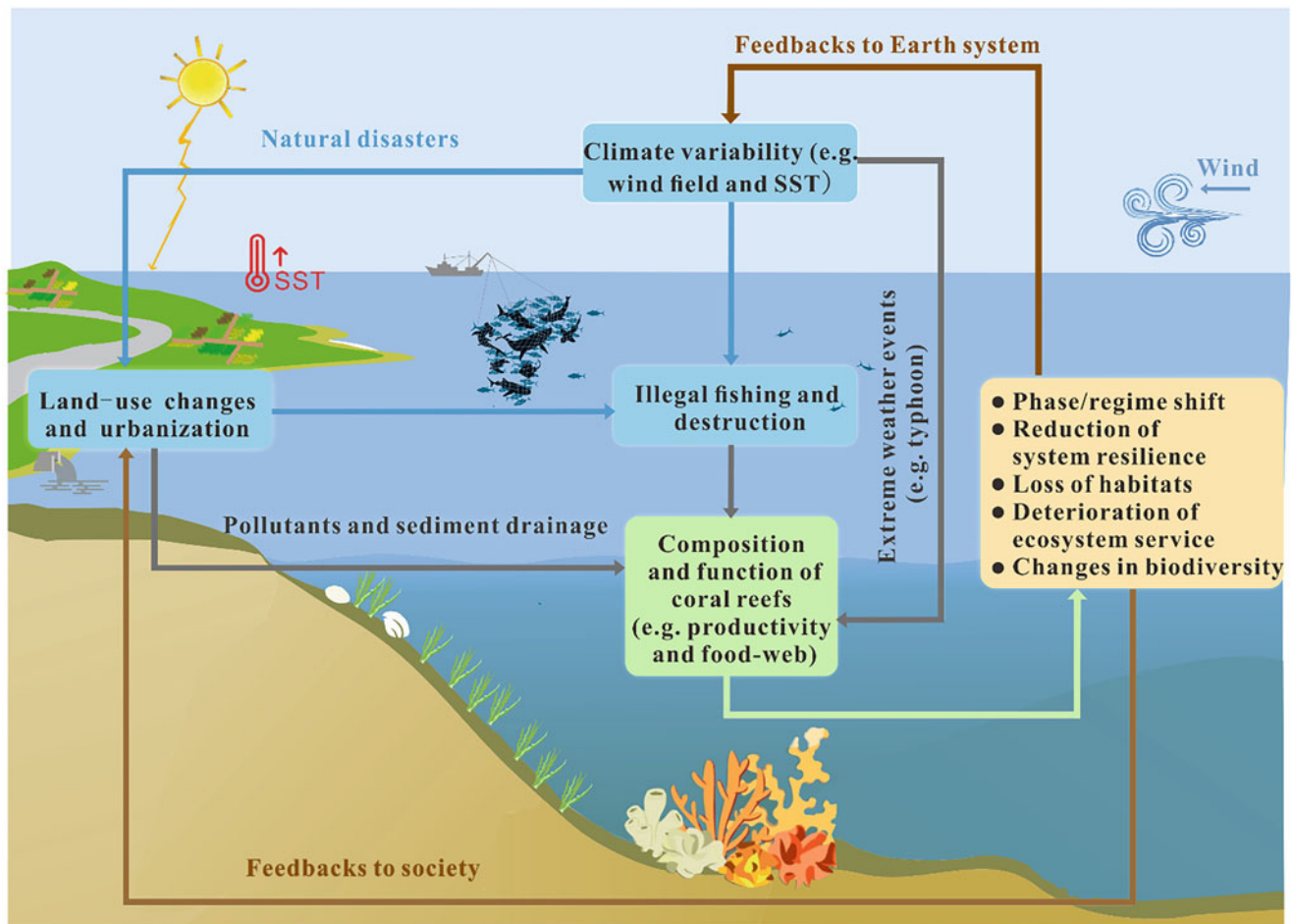


Fig. 1.2 Illustration of external forcings and feedback loops of coral reefs under the impacts of climate variability and anthropogenic activities for the Western Pacific Ocean. The light blue boxes indicate external forcings, the green box denotes the ecosystem response, the

yellow box shows the consequences to the marine ecosystem (i.e. coral reefs) in terms of sustainability, while the illustration next to the coloured line with arrow highlights the example of known mechanisms through which the impacts can produce a result

Deep Sea Research II agreed to publish such an issue; *Volume 96 (2013)* contained 11 research articles from scientists in the IOC/WESTPAC Region. The papers, in a collective way, give snapshots of various aspects of the biogeochemistry, ecology and environmental sciences of coral reefs of the Western Pacific Ocean, and examine the response of coral reef ecosystems to the external driving forces from change in climate and anthropogenic activities in various hydrodynamic as well as geographic situations.

1.2 IOC/WESTPAC Summer Training Courses Were Organised

- Koh Samui, Thailand (15–18 June, 2010) on the “Impact of Sedimentary Dynamics and Biogeochemistry on Coral Reefs”
- Sanya, Hainan, China (8–12 June, 2011) on the “Water Quality and Its Impact on Coral Reefs”

- Nha Trang, Vietnam (18–21 April, 2015) “Resilience of Coral Reefs to Climate Change and Anthropogenic Disturbances”

Each of the above-mentioned training activities had 25–30 participants who were postgraduate students (e.g. Ph.D. candidates) and young scientists from IOC/WESTPAC countries. Mentors at the courses were experts or senior scientists from IOC/WESTPAC countries.

A workshop on “IOC/WESTPAC-CorReCAP” outreaches was convened in Shanghai, March 2016, with participants from China, Australia, Korea, the Philippines and Thailand, to review the project. During the meeting, participants noted that some completed work had been published independently, while outputs from other completed projects had not been published. It was proposed that a synthesis be prepared by IOC/WESTPAC-CorReCAP collaborators focussing on the research progress of this project with consensus on publication of a monograph on coral

reefs of the Western Pacific Region. The book has several advantages and could be used for follow-up training activities of the IOC/WESTPAC-CorReCAP Project for young scientists and graduate students. Suggested chapter titles at the time were ambitious and composed of various aspects of coral reefs for the Western Pacific Region, which were as follows: hydrodynamics in coral reef ecosystems, anthropogenic environmental impacts on coral reefs in the Western Pacific Region, advances in coral biology, reef ecology in the Western Pacific Ocean for adaptation to global change, biogeochemical cycles of coral reef ecosystems, climate change and records from coral reefs, environmental and climate proxies embedded in coral skeletons, social and economic dimensions of coral reefs as well as change of coral communities and implications. Leading scientists, co-authors, potential additional contributors and reviewers were assigned and invited at that meeting.

1.3 This Monograph Is an Output from These Activities!

In conclusion, the IOC/WESTPAC-CorReCAP Project has implemented a well-coordinated and multidisciplinary range of activities contributing to a better understanding of the evolution of coral reefs under the external forcings from the climate change and anthropogenic activities. The critical importance of strong partnerships within the research network at the regional scale to guide the joint research activities has been noted, and the implementation of the IOC/WESTPAC-CorReCAP Project has provided a platform on which people from different countries and backgrounds can share knowledge and research techniques, and contribute to the development of the capacity to sustainably manage the coral reefs in the Western Pacific Region.

In this monograph, Chap. 2 provides information about the current environmental conditions of the Western Pacific

Ocean, with focus on the climate and anthropogenic issues that are impacting coral reefs in terms of sustainability. Chapter 3 provides an up-to-date summary of the knowledge on coral biology, from genetics to life cycles, with an emphasis on the situation in the West Pacific Region. In Chap. 4, reef ecology is examined in light of the current view of ecosystem sustainability, from individual organisms to the system behaviour. In Chap. 5, the recent progress on the biogeochemical studies for coral reefs is summarised, with focus on carbon and nutrient cycling. In Chap. 6, a critical review of the application of proxies, such as radioisotopes and other tracers, is elaborated based on the recent findings. In Chap. 7, we review the achievements and success of coral reef studies and synthesise major knowledge in this Western Pacific Region, and then provide thoughts for the research in the near future. Finally, in the postscript, the chronology and major activities of the IOC/WESTPAC-CorReCAP Project are listed for a better understanding of the scientific research and capacity development activities needed in this region in the next decade or so.

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