GCRMN
GLOBAL CORAL REEF MONITORING NETWORK

Status of Coral Reefs in East Asian Seas Region: 2014

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Ministry of the Environment
Government of Japan

JWRC

Front Cover: Shallow coral reef in Sekisei Lagoon, Okinawa, Japan (©Mitsuhiro Ueno, 2014)
Back Cover: Acanthaster predation in Kamise, Kagoshima, Japan (©Naoko Dewa, 2014)

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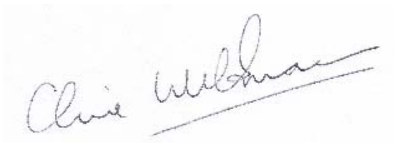
FOREWORD

This regional report is a direct response to the International Coral Reef Initiative (ICRI) strategy on research and monitoring determined in the 'Call to Action' developed in Dumaguete City, The Philippines in 1995 which promotes cooperation among national research programs and monitoring networks.

Responding to the 'Call to Action', the Ministry of the Environment of Japan and the Japan Wildlife Research Center, in association with the regional coordinators on coral monitoring for Northeast and Southeast Asia worked with national coral reef monitoring coordinators to produce a regional status of coral reefs that was launched at the 10th International Coral Reef Symposium in Okinawa, Japan in 2004 and which was subsequently summarised in the GCRMN global report released in December 2004. This 2014 report contains updated information from East Asian countries and is intended to provide the latest information on coral reef threats, problems and solutions to governments, natural resource managers, NGOs and communities, along with a series of practical recommendations to improve the health of these reefs. While the Northeast and Southeast Asian regions support the highest coral reef biodiversity, it also contains large populations of people depending directly or indirectly on coral reefs for their livelihood. An encouraging feature of this report is that this region also contains a wealth of trained and committed coral reef scientists assessing the status of the reefs and managing them for long-term sustainability. A major objective for governments of the region is to make full use of this human capacity to conserve these valuable resources and their diversity for the peoples of the region and the world. This is possible, but it will require the formation of partnerships among all key stakeholders.

I particularly welcome this book that brings together the national status of coral reef from Southeast and Southeast Asian countries into one volume. The GCRMN is specifically tasked with providing information on the status of coral reefs to assist in their effective conservation and management. The global reports can only provide a brief summary of data and information from individual countries; therefore it is essential to provide more comprehensive data and information for national governments and regional organisations to assist them in their efforts to conserve coral reefs for use by their peoples into the future. I particularly wish to congratulate the national and regional authors and the people who have pulled this material together: the Ministry of the Environment and Japan Wildlife Research Center for an excellent and useful product.



Clive Wilkinson

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PREFACE

The Global Coral Reef Monitoring Network (GCRMN) was launched in 1996 with the purpose of collecting information on the state of coral reefs and raising awareness about coral reef conservation. This was in response to the "Call to Action" by the International Coral Reef Initiative (ICRI) in 1995 at its Dumaguete meeting, which encouraged the 1) promotion of linkages between regional and global research and monitoring networks, and 2) use of regional networks to achieve better coordination and cooperation among national research programmes. In response to the first point, a series of reports 'The Status of Coral Reefs of the World' edited by Clive Wilkinson was published in 1998, 2000, 2002, 2004, 2008 and they represented a massive global effort at documenting the condition of the world's reefs based on national monitoring initiatives. In response to the second point, Japan's Ministry of Environment and the Japan Wildlife Research Center took the lead for the East Asian Seas region and published the 'Status of Coral Reefs in East Asian Seas Region' in 2004, 2010 and this latest edition. The aim is to provide more detailed information on the coral reef condition in a region that has the world's richest coral reef biodiversity and also the highest threats.

A decade has passed since the first regional report was published and we are grateful to Clive Wilkinson for sharing his valuable experience with the GCRMN and the East Asian Regional network. An accurate recollection of the original intention of the reef monitoring network will help to prevent institutional memory from waning. This is also the first time that the regional network received a report from Myanmar, which helps to complete a gap apparent in previous reports. The national reports indicated a mix of reef loss due to coastal development, degradation due to human stressors and bleaching, and reef recovery from impacts ranging from crown-of-thorns outbreak to heavy storms. Management responses vary between countries but are important for experience sharing. Two reports are included of coral species migrating to higher latitudes in response to sea temperature rise related to climate change and more scleractinian species are establishing in the southern octocoral-dominated reefs of Jeju, South Korea.

One of the immediate future goals of the East Asian Seas regional network is to analyze reef status trends in response to threats and management over the long-term. Continued monitoring and reporting are necessary as they provide the basis for such an analysis and it is our hope that national coordinators, all operating on a voluntary basis will maintain their interest and passion for this significant regional cause.

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EXECUTIVE SUMMARY

◆ GCRMN HISTORY IN EAST ASIA

1. Coral Reef Monitoring in Southeast and East Asia

- From the mid 1980s to 1990s, the ASEAN-Australia Living Coastal Resources (LCR) project and the ASEAN-US Coastal Resources Management Project (CRMP) were key projects that built the capacity and developed a strong network for coral reef research and monitoring in the Southeast Asian region.
- The concept of GCRMN 'Nodes' was adopted with 17 Node regions developed including Southeast Asia and East Asia. The Southeast Asia Node covered the ASEAN countries with coordination provided by coral reef researchers at the National University of Singapore, headed by Chou Loke Ming and subsequently Karenne Tun. The East Asian Node included China, Japan, Korea, and Taiwan and was coordinated by marine scientists based in Okinawa and assisted by Japanese Government environment agencies.
- The first reports on the status of reefs in Southeast and East Asia were published in 1998 following presentations in 1996 at the 8th International Coral Reef Symposium in Panama City. These reports based on the authors' extensive reef experience were written prior to the advent of active GCRMN monitoring. Subsequent reports based on GCRMN monitoring appeared soon after.
- GCRMN leaders in Southeast and East Asia have continued to support the production of 'Status of Coral Reefs of the World' reports in 2000, 2002, 2004 and 2008 (edited by Clive Wilkinson through the comprehensive regional chapters with increasing data quality and quantity.
- A particularly important feature of these two Nodes is their participation and coordination of the Asia-Pacific Coral Reef Symposia, the first of which was held in Hong Kong (2006), the second in Phuket Thailand (2010) and thethird in Pingtung Taiwan (2014).

2. Progress of the regional network on coral reef monitoring in East Asia

- The earliest regional coral reef status assessment of Southeast was published in 1998 as part of the GCRMN global report. It covered past reef monitoring efforts and was based extensively on the contribution of the ASEAN-Australia LCRP. There was no assessment for Northeast Asia in the report.
- The next global assessment in 2000 included chapters for Southeast Asia and for the first time, Northeast Asia that dealt with China, Japan and Taiwan. The Southeast Asia chapter now included the reefs of Cambodia and Vietnam.
- The 2002 assessment showed that Southeast Asia's coral reefs including Brunei Darussalam and Myanmar remained under threat mainly from anthropogenic impacts and weak management capacity but with isolated instances of effective management and protection. The coral reefs of Northeast Asia, this time including South Korea, were reportedly recovering from the 1998 bleaching but a 2001 bleaching in Japan resulted in up to 69% mortality in southern Ryukyus.
- The assessment of 2004 indicated an overall decline in Southeast Asia's coral reefs although small improvements were registered for Indonesian reefs. Coral reefs of North Asia, now with

the inclusion of Hong Kong remained under anthropogenic stress and reef conservation and management programmes have been implemented and developed in all countries.

- The 2004 Indian Ocean tsunami resulted in severe localised damage of some reefs in Indonesia, Thailand and Malaysia but most reefs suffered minimal impact. Recovery is expected to take 5 to 10 years for most of the affected reefs and up to 20 years for those that were severely damaged.
- Coral reef condition improved in Philippines, Thailand, Singapore and Vietnam by 2008. Overall decline of North Asian reefs continued under the combined influence of human and natural (bleaching, COTs, typhoons) impacts. The database on 'Coral Reef MPAs of East Asia and Micronesia' was developed in 2007 and showed an increase of MPAs with coral reefs from 178 in 2003 to 403 in 2007.
- A Southeast Asia regional overview of the 2010 coral bleaching impact appeared in a regional status report. Although widespread bleaching was noted, the impact varied greatly. In Northeast Asia, serious bleaching impact was observed at Ishigaki but reefs throughout the region were subjected to human impacts. Localised COTs outbreaks were recorded. These induced ecological phase shifts from coral to algae dominated reefs in some areas. Interestingly, migration of hard coral species to higher latitudes in response to sea warming was observed in Japan and South Korea.

◆ CORAL MIGRATION TO HIGHER LATITUDES IN EAST AND NORTH ASIA

1. Migration of corals in Taiwan

- Taiwan, situated between 21.90°N and 25.30°N, constitutes a unique biogeographical overlap of marine taxa from tropical, subtropical and temperate regions.
- SSTs around Taiwan have however already increased by 1.55°C since 1957, and may rise further by 2.0-2.5 °C by the end of the century resulting in a homogenization of the marine communities around the island.
- Species range shifts are likely to be particularly obvious as it may cause considerable tropicalization of the marine assemblages and a loss of species less tolerant of high temperature.
- Recent regional surveys of the benthic community structure/composition suggested that major degradation of Taiwanese benthic communities may imperil connectivity between tropical and temperate latitudes.
- This could represent a strong limitation to the poleward migration (if any) and highlights the importance of protecting the source of propagules if we are to allow high latitude refugia for the survival of tropical taxa.

2. Migrating coral community in Shikoku, Japan

- The poleward range expansion of modern corals is based on 80 years of national records from temperate areas of Japan, where century-long measurements of in situ sea-surface temperature have shown statistically significant rise. In terms of general decadal trends in Kochi, SST in the 1980's were cooler than in the 1970s, but those in the 1990s and 2000s were warmer than the 1970s.
- A total of 139 species of scleractinian corals have been recorded from Shikoku and among these, the following 8 species; *Acropora cytherea*, *Acropora nana*, *Millepora exaesa*, *Acropora* sp.

having cochleariform radial corallites, *Acropora digitifera*, *Acropora robusta*, *Acropora subulata* and *Millepora platyphylla*, were not reported in previous records and considered rare in high-latitude but are now increasingly common in tropical and sub-tropical coral reef regions in southwestern Kochi since 2000.

- *Acropora nana* was first recorded in 2004 in southwestern Kochi and a number of colonies gradually increased in southwestern Kochi. It may be evident that *A. nana*, which is a tropical species in Kochi, has been reproductively active and potentially contributing to the proliferation of regional populations.

- *Acropora pruinosa* is a common species in high-latitude, Japan and small colonies not reported in previous studies were found in temperate sargassum and kelp beds in southwestern Ehime prefecture in 2013. This suggests that reef-building corals in Shikoku are gradually expanding their ranges northward not only by the appearance of tropical species but also of temperate species, and further suggests that the winter seawater temperature may be the main factor limiting the distribution expansion of reef-building corals to high-latitudes.

◆ CONSERVATION OF MARINE AREA WITH MULTIPLE DEMANDS

1. Managing Singapore's coral reefs

- Singapore Strait is one of the world's busiest waterway and also where coral reefs, seagrass beds and mangroves are present. Prior to July 2014 none of the islands is designated as an MPA or MMA and do not come under the jurisdiction of a nature conservation agency. Without an MPA framework, marine biodiversity has remained rich despite overall loss of habitats to land reclamation and exposure to elevated sediment levels. Access restriction and strong enforcement of existing regulation have created a situation that is similar to a network of de facto protected areas. As Singapore is implementing an Integrated Urban Coastal Management (IUCM) framework, it will provide an integrated governance and management structure for the Southern offshore islands and the rich marine biodiversity that they support.

- As a city state, Singapore's governance hierarchy consists of only one (national) level and the benefits to all citizens are considered in the planning and management of these marine areas. Returns from the facilities and activities in these areas accrue to the agency holding the mandate over them. Singapore has long moved away from traditional livelihoods to services and industry. Local communities have thus ceased to rely on natural resources to generate incomes but they continue to benefit from the services that the coastal and marine areas provide.

- The indirect benefits to marine biodiversity afforded by access restriction and maritime-related legislation imposed by the agencies responsible for the development and management of the southern islands include reduced extractive activities, reduced water pollution, and reduced and better managed development-related impacts. All these indirect benefits are highlighted by the fact that despite losing almost 90% of sub-tidal coral reef area, the hard coral biodiversity has been maintained with only two reported local species extinction from a recorded diversity of 255.

- As Singapore's coastal development landscape changes, the number and location of the de facto protected areas may be affected. The recently published "Population White Paper: A Sustainable Population for a Dynamic Singapore" (NPTD, 2013) provided an overview of the likely profile of Singapore and possible land use allocation beyond 2030 (map accessible at http://www.mnd.gov.sg/landuseplan/e-book/files/assets/basic-html/page14.html). It highlights the continued maintenance of the southern military prohibited areas, which further implies the continued de facto protection to the coral reefs within the area.

- Unlike legally gazetted MPAs where success can be qualified and quantified using one of the numerous available MPAs assessment tools, there are no established tools for measuring the success of the de facto protected areas. Current research initiatives are looking at developing locally relevant metrics to qualify and quantify the success of the de facto protected areas not only in achieving habitat conservation and but also in providing opportunities for recreation, research, and education.

- The Southern Offshore Islands serve a diverse range of stakeholders whose derived benefits are largely independent of the ecosystem goods and services provided by coastal biodiversity. It is difficult to identify a specific beneficiary from a natural resource usage perspective, but from a conservation perspective the obvious beneficiary is the natural environment itself. Conserving biodiversity for its own sake can be a contentious issue within a multi-stakeholder environment, but it can be made to work within Singapore's environmental management framework if benefits, either direct or derived, can be identified for all stakeholder groups.

◆ STATUS OF CORAL REEFS IN EAST AND NORTH ASIA

1. Mainland China

- The degradation trend of the coral communities and coral reefs in mainland China seems to have slowed in the past 3 to 5 years, but habitat loss is still inevitable due to coastal development and engineering. Major stressors driving the degradation of reefs were direct reef damage from coral mining and collection for the ornamental trade and destructive fishing activities before the 1980s. After the 1980s, especially in the last two decades of rapid economic and development growth, the main threats are mariculture in coral reef areas, over-fishing, water quality deterioration caused by eutrophication, coastal development, sedimentation, sewage pollution, and outbreaks of crown-of-thorns starfish. These stressors can drive coral community and reef degradation directly through increased coral mortality, or indirectly by increasing competitive species (algae) and decreasing coral recruitment.

- The degradation of the coral ecosystem is manifested by a decrease in area of scleractinian coral distribution, reduction in percent cover and biodiversity of coral reefs with a concurrent increase in the percent cover of soft corals or macro algae, and by ecosystem phase shifts from coral-dominated to algal or soft coral-dominated reefs. An extraction activity, which is the digging of buried giant clam shells for shellcraft making has been a popular practice of fishers in Hainan Island for the past 3 to 5 years. This is very destructive and a serious threat to China's coral reefs. Many reefs of Xisha and Nansha Islands were directly damaged by this activity.

2. Taiwan

- The status of coral reefs and non-reefal coral communities in Taiwan were synthesized based on the 4-year dataset (2010-2013) using the ReefCheck method from 6 regions including, northeastern coast, eastern coast, Lutao, Lanyu, Hsiaoliuchiu, and Penghu Islands. In addition, an analysis of the long-term ecological research (LTER) data was obtained from the Kenting National Park, southern Taiwan. Mean live coral cover (LCC) of the 37 sites varied from 3.06±0.958% to 72.81±10.263%, but high variation was found among the years in some regions depending on the site selected for the surveys.

- Based on the LCC, coral communities in "poor" condition (LCC<25%) were found in northeastern coast, Taitung, Hsiaoliuchiu, Kenting, Lanyu, whereas those in Penghu and Lutao were in "fair" and “good” conditions. The abundance of fish and invertebrate indicators at most of the sites was very low suggesting that coral reefs and non-reefal coral communities in Taiwan suffered from overfishing.

- All of these data suggested that most reefs and coral communities in Taiwan were under relatively high impact of anthropogenic stresses. Most reefs and coral communities are located within national scenic areas or national parks in Taiwan, but their management is not effective. Nevertheless, the recent development of marine protected area demonstration sites and sewage treatment facilities in the Kenting National Park, the listing of humphead wrasse and bumphead parrotfish as “endangered species” under the Wildlife Conservation Law, and the NGO-lead ReefCheck operation, are encouraging. These activities have raised public awareness and their effectiveness on conservation.

3. Japan

- An overview of coral status from 2004 to 2012 showed average coral cover decreasing from 37% in 2004 to 29% in 2007 with no recovery yet in 2012. Coral growth was affected by Acanthaster predation in Amami, Kerama and Miyako Islands and Yabiji reefs, and damage from typhoon and bleaching by high water temperature in Ishigaki Island and Sekisei Lagoon in 2007. The outbreak of Acanthaster ended in Amami and Kerama Islands from 2006 to 2007. However, the outbreak continued around Miyako Island and Yabiji reefs and expanded to Ishigaki Island and Sekisei lagoon. Typhoon also damaged coral reefs around the Okinawa Island in 2011.

- Average coral cover of all the non-reef area sites was 30% in 2004 with fluctuations of 1 % decrease to 3 % increase until 2012 caused by disturbances and recovery. The major disturbances in this period were typhoons, Acanthaster predation and bleaching from higher/lower sea temperature. The average coral cover showed a degradation trend from 2010 to 2012 because of Acanthaster predation in Shikoku southern west coast and Kagoshima Southern coast, typhoon damage around Iki and Tsushima Islands and Kagoshima Southern coast. However, Acanthaster numbers observed showed a slight decrease recently in Shikoku southern west coast and Amakusa sites.

4. South Korea

- Corals of Korea are concentrated in the southern part of the country, particularly within the South Sea and around Jeju Island. Most species are octocorals, and scleractinian corals represent only a minor portion of the regional species composition. However, the number of scleractinian corals appears to be increasing in response to climate change. Recent studies and survey efforts revealed three additional scleractinian coral and 25 subtropical and tropical fish and invertebrate species from Jeju Island. The new records are concentrated in the southern part of Jeju Island.

◆ STATUS OF CORAL REEFS IN SOUTHEAST ASIA

1. Cambodia

- Data were collected over four years from 2010 to 2014 throughout the Koh Rong Archipelago, with surveys carried out year-round. A total of 24 fish species from 17 families were recorded in addition to 22 invertebrate species in 7 classes, 27 genera of corals and 14 classifications of substrate. To gain an understanding of localised stressors on reefs within the Koh Rong Archipelago, 5 physical impacts were also recorded.

- In comparison to reefs in other countries of Southeast Asia, commercial fish abundance in the Koh Rong Archipelago ranks first for parrotfish, second for grouper, and third for snapper and sweetlips. This could be an important indicator of reef health, demonstrating that certain commercial species are not specifically targeted for food. Invertebrate population abundance appears to be similar to other Southeast Asian countries.

2. Indonesia

- According to the data collected from 2006 to 2011, Cendrawasih NP had the highest coral cover and Wakatobi NP the lowest among the protected areas. Bunaken NP showed a relatively stable coral cover between 2006 and 2009. Coral cover decreased in 3 national parks in 2011, probably related to the mass bleaching event in 2010.

- Monitoring data from the West of Indonesia show an increasing trend of coral cover except for Lingga Regency. This is especially for islands at Tambelan sub-district, Bintan Regency. Hard coral cover kept increasing from 61.43 % in 2004 to 67.11 % in 2009, and 72.63 % in 2010. Meanwhile, the percentage of dead coral with algae decreased from 25.78% and in 2004 to 22.51% in 2009 and 17.28 % in 2010.

- In East of Indonesia, coral cover in Biak and Padaido Islands declined, in contrast to Selayar, which showed an increasing trend, while LMMA Wakatobi tended to be stable. The combination of a strong storm (2009), blast fishing, and coral bleaching (2010) caused the major decline in Biak. In 2006, average coral cover in East of Biak and Padaido Islands was 22.97%. In 2009, the cover increased slightly to 26.14% but plummeted to 20.08% in 2010 and dropped further to 17.6% in 2011.

- In December 2013, MMAF and local governments had initiated the development and management of about 11 million ha of MPAs while 4.6 million ha of MPAs are managed by the Forestry Ministry, including 7 national parks. In January 2014, the Government released act no. 1/2014, a revision of UU 27/2007, to hand over the management of the 7 national parks from Forestry to MMAF. Indonesia has now in total established 15,764,210 ha in 131 MPAs. The Government is aiming to establish 20 million ha of MPAs in 2020. In the face of the changing climate, MMAF has just set up guidelines of MPA network development that takes resilience as one of the main consideration factors (MMAF regulation 13/2014).

- In total there are at least 13 government agencies at national level, which are involved in marine/coral reef management in Indonesia. The national level agencies will set programs at national level that provide guidelines or standard operational framework and policy to manage coral reefs at provincial level. In general, operational aspects of local coral reef management are set by agencies at provincial and regency government levels, except for areas that are considered of national strategic importance. Act 32/2004 delineates provincial marine territory as 12 nautical miles from coastline to open sea, while the regency marine territory is a third from provincial marine territory.

3. Malaysia

- The status of Malaysian coral reefs in 2013 was primarily based on the results of Reef Check Malaysia surveys at 196 reef sites. The mean live coral cover for Malaysia was ‘Fair’ at 48.3% with a range from 17.4% to 75.7%. The surveys divided Malaysian reefs into their three marine eco-regions and found that the reefs in Sunda Shelf eco-region was at 57.6% (Good), Straits of Malacca 44.6% (Fair) and North Borneo 39.5% (Fair).

- The results suggested that all reefs in Malaysia are under high anthropogenic threats. It is encouraging that support is given by relevant authorities to the reef monitoring efforts by an

NGO such as Reef Check Malaysia. Nevertheless the number of monitoring sites is still inadequate and must be increased inclusive of permanent transects or quadrats at crucial reef sites to be able to monitor accurate changes.

- After the mass coral bleaching event in 2010, a coral bleaching response plan for Malaysia has been developed and is hoped to be used effectively in the next mass coral bleaching event. In addition, new management plans for three marine park areas in Peninsular Malaysia have just been finalised and should enhance their management and effectiveness in conserving the marine resources, which will be useful for other marine protected areas to emulate.

4. Myanmar

- Corals can be found mainly in the Myeik archipelago as coral communities and fringing reefs developing on sandy bottom, limestone rock and granite rock. Some islands situated in the southern part of Rakhine coastal region and Cocos Islands situated in Deltaic coastal region have corals. Different species of corals can be found from the shallow water to about 30 meters depth based on surveys by Fauna and Flora International-Myanmar Programme team. Most of coral species can be found in the outer islands and branching corals are the most dominant in the turbid waters of the inner islands. Corals can be found in the sheltered parts of the islands and this is common in the Myeik archipelago.

- Regular monitoring programme on coral reefs started in 2012. Coral monitoring areas cover the entire Myeik archipelago starting from the islands situated in the northern part. Random surveys have been done at all of the main island groups in the Myeik archipelago. Myanmar scientists are surveying coral condition of the islands using Reef Check survey method. Their surveys showed that corals can be found around most of the islands even in very turbid waters at the river mouth region to very clear water in the outer islands.

5. Philippines

- A brief background on the nationwide surveys initiated at the end of the 1970’s to the mid-1980 highlighted the urgency to respond to the declining state of coral reefs in the Philippines. Using quadrats laid perpendicular to shore, estimates of the percent live coral cover of hard and soft corals in reef surveys categorized quartile categories reported by Gomez and Alcala (1979), Gomez et al. (1981).They reported that a considerable proportion (around >30% of the sites) were in poor condition (i.e. having less than 25% live coral) while only around 30% were in good (50-75% live coral cover) and excellent condition (75-100% cover).

- Despite a change in methodology to line intercept transects and point intercepts transects laid parallel to shore, these % categories were carried over the next decades (1985-2005). Concern was raised by the considerably lower proportion, i.e. around 20% were in good to excellent category and around 50% were in a poor state. The prevalent threats to reefs from overexploitation, siltation and poor land uses were re-echoed to increase protection measures.

- These multiple concerns provided the impetus for the increase in efforts for establishing more functional and effective Marine Protected Areas (MPA), learning from the good practices of Alcala and colleagues. In addition, the focus in MPA monitoring of reef benthos and their associated fish benthos inside and outside the no-take marine reserves/sanctuaries showed improvements in most of the sites surveyed. While protection through MPAs served as sentinels that showed promising positive impacts, more concerted and accelerated actions are necessary to meet the future.

5. Thailand

- Manta tow survey and observation on permanent transects and quadrats were carried out in 133 study sites. Average live cover in Thai waters decreased after the 2012 coral bleaching event until the present day.

- Many coral reef sites in Thai waters are good for tourism use. High percentage of monitoring reef sites in several provinces has been intensively visited by local and foreign tourists. Most anthropogenic stress and damage for coral reefs in Thai waters were caused by sediment from coastal development activities, tourism and fishery impacts, marine debris and land-based wastewater.

- Anomalous seawater temperatures were recorded in Thai waters during the summer months of 2014. Coral bleaching was obvious at Mu Ko Angthong (Western Gulf of Thailand) and Mu Ko Surin (Andaman Sea). It was also reported from Mu Ko Lan (Inner Gulf of Thailand), Mu Ko Samed and Mu Ko Chang (Eastern Gulf of Thailand), Ko Tao and Ko Losin (Western Gulf of Thailand) and Mu Ko Phi Phi (Andaman Sea). The coral species susceptible to bleaching varied among study sites.

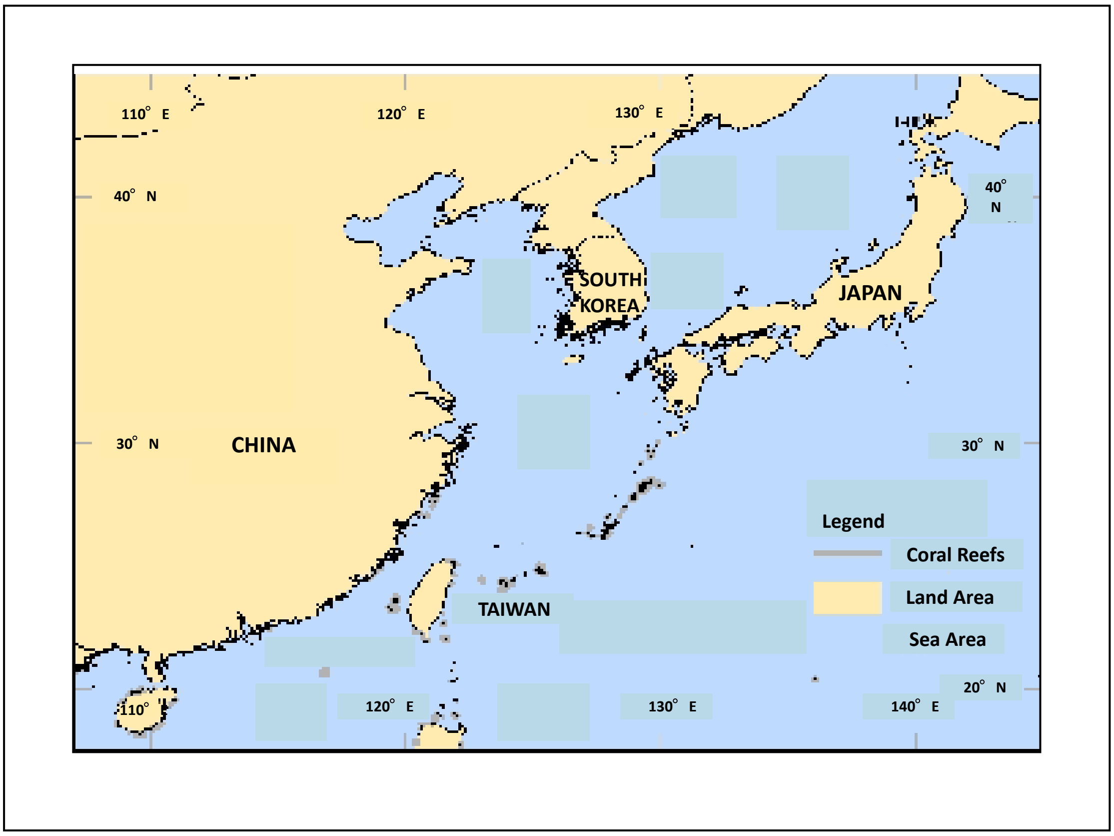
6. Vietnam

- Overall status of coral reef benthos surveyed at 89 sites from 10 key areas during 2010-2011 showed a low overall average live coral cover. No reefs were in excellent condition (> 75% cover), only 2.2% were in good condition (range 51-75 % cover), 34.4% in fair condition (26-50% cover) and 63.5% of reefs in poor condition (< 25% cover). Comparison with monitoring data between time periods from 1994 to 2012 indicate that overall mean cover of hard corals declined notably from 34.6% in 1994 to 25.6% in 2006 and 21.1% in 2012. Among them, reefs that are improving between 1994 and 2012 averaged 10.8% whereas reefs that are declining or remained unchanged were 55.4% and 30.0% respectively.

- There are 16 MPAs approved by the Prime Minister in May 2010 with a total planned area of the whole system of 270,271 ha and 169,617 ha of marine area. All of the MPAs planned support coral reefs and more than 57% of the area of known coral reefs in the coastal waters is represented within the declared MPAs. Up till middle of 2014, only 6 MPAs have been declared including Nha Trang Bay (established in 2001), Cu Lao Cham (2004), Phu Quoc (2007), Nui Chua (2008), Con Co (2010) and Hon Cau (2011). Of these, 16.7% of MPAs had good management (Cu Lao Cham), 50.0% moderate (Nha Trang, Nui Chua/Ninh Hai and Phu Quoc) and 33.3% poor (Con Co and Hon Cau).

- Results from monitoring activities have positively contributed to the enhancement of management of coral reefs. Keeping these activities ongoing should be a major need and requirement at present and in the future. A total of 80 sites are proposed for monitoring at 10 key areas for the future including 8 sites at Ha Long-Cat Ba, Con Co (8), Cu Lao Cham (8), Van Phong Bay (8), Nha Trang Bay (8), Nui Chua/Ninh Hai coast (8), Hon Cau (8), Phu Quy (8), Con Dao (8) and Phu Quoc (8). Reefcheck indicators combined with additional local indicators should be used for monitoring at all proposed areas. Development of a monitoring network through training on monitoring methods for staff of MPAs together with appropriate support for infrastructure and funding should be considered as important for successful monitoring programmes in Vietnam in the future.

. A map of Southeast Asian countries.



A map of East and North Asian countries.

1. GCRMN HISTORY IN EAST ASIA

1.1. CORAL REEF MONITORING IN SOUTHEAST AND EAST ASIA: A PERSONAL PERSPECTIVE

Clive Wilkinson

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A former coordinator Global Coral Reef Monitoring Network

I was invited to write this paper on the Global Coral Reef Monitoring Network and its role in coral reef activities in Southeast and East Asia. This will follow a historical view through a focus on my involvement in the region over almost 25 years and why this region is so important in the world of coral reefs, and also as a major component of the International Coral Reef Initiative.

EARLY CORAL REEF MONITORING IN SOUTHEAST AND EAST ASIA

Coral reef monitoring, and indeed much of the activity of global monitoring, can be traced back to events in Southeast and East Asia. In the mid-1970s, Professor Edgardo Gomez and his team at the University of the Philippines, Marine Science Institute became alarmed at the reported decline of coral reefs throughout the Philippine archipelago. However, they had no coherent data set to quantify reef status and alert the national government to the problem that required action to conserve these resources. Their initial estimation was that the Philippines had 25,000 km^2 of reef area, approximately equal to 10% of the total land area. These reefs provided fishery resources for many thousand people engaged in subsistence fishing; but fishing yields were dropping from about 36 tons/ km^2 to about 10% of this figure. They launched the ‘Investigation of the coral resources of the Philippines’ project with assistance from the government (Gomez et al. 1994).

The UP MSI team surveyed more than 800 sites throughout the archipelago using random 1 m^2 quadrats with the focus on coral cover. They reported the data using a basic metric: 0 – 25% cover = poor; 25 - 50% = fair; 50 – 75% = good; and 75 – 100% = excellent; basic categories specifically selected for political decision makers. However, there were few reefs in the upper categories, although anecdotal reports indicated that coral cover had previously been ‘excellent’ on many reefs.

The significance of this 1970s monitoring should not be underestimated. This was the first large-scale attempt at assessing coral reef status and the data collected constituted a baseline (although after significant anthropogenic prior damage) that few other countries in the world could match. The ICRP project was later incorporated into the ASEAN-Australia Living Coastal Resources project (LCR) that started in 1985 and also the ASEAN-US Coastal Resources Management Project.

In the early 1980s, leading marine scientists from the ASEAN countries approached the Australian government aid agency and the Australian Institute of Marine Science (AIMS) for assistance in training young scientists in methods to assess and monitor coastal marine resources of Indonesia, Malaysia, Philippines, Singapore and Thailand. Instrumental in that early project development and training were Don Kinsey and Kevin Boto of AIMS who became the first Chief Technical Advisors of the project. Phase I of the ASEAN-Australia Living Coastal Resources (LCR) project ran from 1984 to 1989 with a major focus on developing appropriate monitoring methods and training to assess coral reefs, mangrove forests, seagrass resources, soft bottom communities and fisheries. Joint workshops were held at AIMS in Townsville in late 1985 with 3 groups of ASEAN participants: senior leaders to agree on the scope of the project and operations; a group of coral reef researchers to define these methods; and another group with more technical knowledge on mangroves, seagrasses and soft bottom communities. This cooperation between the 5 ASEAN countries and AIMS resulted in the production of the first collated collection of monitoring methods: the Survey Manual for Tropical Coastal Resources (English et al. 1994 & 1997). The coral reef methods in this 'Manual' are still employed widely throughout the world and formed the basis for much of the Indo-Pacific activities of the Global Coral Reef Monitoring Network.

The LCR project was extended into Phase II from 1989 to 1994; making it a rare 10 year project. The extension was catalysed through particularly strong lobbying to Australia from senior ASEAN scientists, notably Suraphol Sudara, Chou Loke Ming and Edgardo Gomez, as well as others involved in the Project Management Committee. I was fortunate to become the Chief Technical Advisor in 1990 after Phase II had been initiated, and until the project ended in June 1994 with the final conference in Bangkok. That conference produced 3 major volumes of 41 collated summaries of the status of resources in the ASEAN countries and a compilation of 126 research papers from 45 participants in the LCR project (Wilkinson et al. 1994; Sudara et al. 1994).

The LCR project also produced a book for decision makers: 'The Living Coastal Resources of Southeast Asia: Status and Management' that summarised the findings of the 2 collated paper volumes above into 24 essays aimed at informing senior managers and politicians in the Southeast Asian region of the status of coastal resources, the threats they are experiencing and potential management actions to aid in natural resource conservation (Wilkinson 1994).

The ASEAN-Australia LCR project was regarded as being particularly successful during its operation and especially since it ended in 1994. Many factors contributed to this success:

- The project was originally requested from ASEAN by science and natural resource management leaders in the region, based on their needs for assistance;
- The project was developed collaboratively by ASEAN scientists and those from Australia, especially AIMS;

- The initial focus was on developing effective monitoring and assessment methods that would be applied throughout the region. This resulted in publication of the widely used 'Manual' mentioned above;
- The LCR project focussed on training many young scientists from these 5 countries. Many of these went on to be leaders throughout the region, often through support to complete post-graduate degrees;
- The project also facilitated joint research between ASEAN and Australia scientists. These collaborations continued long after the project formally ended in 1994;
- Throughout the project, emphasis was on ensuring that the results were freely available throughout the region by publishing many scientific papers and reviews;
- Management of the project was driven by the ASEAN countries, such that the Project Management Committee consisted of 2 members from each of the 5 participating countries with the Chief Technical Advisor and the Project Manager sitting on this committee as invited observers. The Chair of the Committee was selected from these 10 ASEAN scientists and managers, with the late Dr Suraphol Sudara being a particularly enthusiastic and effective leader; and
- The LCR project was funded by the Australian aid agency (firstly ADAB and then AusAID) for 2 Phases of 5 years each. Few projects are funded beyond 5 to 7 years.

Several of these factors should be highlighted. The original themes were selected by ASEAN senior personnel who were witnessing damage to their coastal resources; they sought help from Australia and Australian scientists. The management of the project was by ASEAN science and natural resource managers, such that the problems being addressed derived from their experience and decisions about spending money were made for the benefit of the region. Thus most of the money was spent on projects within Southeast Asia. And finally, the project was funded adequately by Australia for 10 years; this permitted the project to reach 'maturity'.

I reported earlier that I was fortunate to be appointed as the Chief Technical Advisor in 1990 after the project had been in operation for 6 years (from mid-1984). In late 1990, there was a well-established network of ASEAN scientists and natural resource management leaders who were in active collaboration with a large degree of mutual trust and understanding; they welcomed a new CTA into the network and continued active research and monitoring. The fact that the project was initiated and managed from within the region must be stressed as a major factor. This structure was also adopted by the ASEAN-US Coastal Resources Management Project; whereas another funded project in ASEAN used management from external consulting companies, who instigated projects on their assessment of the problems and possible solutions. Frequently these assumptions were contradictory to the direct experiences of ASEAN scientists and natural resource managers; such that this project did not achieve its full potential.

FURTHER DEVELOPMENTS IN SOUTHEAST AND EAST ASIA:

Many subsequent activities and projects may be regarded as flowing (at least partially) from these two collaborations with Australia and USA. The ASEAN-US CRMP project was headed by Chua Thia Eng and the very successful PEMSEA (Partnerships in Environmental Management for the Seas of East Asia) network and projects followed, with initial leadership of Dr Chua. This project has just celebrated 20 years of operation in Cambodia, China, Indonesia, Lao PDR, Philippines, Thailand, Timor-Leste, Vietnam, Japan, Singapore and Republic of Korea, with a focus on improved management of coastal resources, especially around port cities, and includes assessments of coral reefs. One theme of particular mention is the State of the Coasts Reporting project that will use data based from previous projects using methods frequently drawn from the 'Manual' (English et al. 1997).

The "Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand" project under the direction of UNEP and GEF was focussed on assessing and managing coral reefs, mangroves, seagrasses and wetlands in countries of the South China Sea (Cambodia, China, Indonesia, Malaysia, Philippines, Thailand, and Vietnam). This project built on the monitoring and research conducted under the LCR project from 2002 to 2009 with direction from a mix of external and Asian scientists.

It can also be claimed that the ASEAN-Australia LCR project played a critical role in the formation of the International Coral Reef Initiative (ICRI) and the Global Coral Reef Monitoring Network (GCRMN), as discussed in the next section.

The methods developed during the ASEAN-Australia LCR project were adopted as recommended protocols by the UNEP-IOC (UNESCO)-WMO-IUCN Global Task Team on the Implications of Global Climate Change on Coral Reefs in 1991 which was a precursor to the Global Coral Reef Monitoring Network. My involvement in the ASEAN-Australia LCR project and the Global Task Team lead to an invitation to give one of two plenary addresses at the 7th International Coral Reef Symposium in Guam, June 1992. This address drew largely from the experiences gained in the ASEAN countries through the advice and information from senior ASEAN scientists and natural resource managers and viewing first-hand the degradation of coral reefs in this, the region of highest biodiversity (Wilkinson, 1993). Following that 1992 symposium, a meeting called in 1993 by Robert Ginsburg in Miami, USA was able to confirm many anecdotal and a few data-rich reports of coral reef decline throughout the world, but there was insufficient reliable monitoring data to draw firm conclusions (Ginsburg, 1994). The most extensive and data-rich report came from Southeast Asia (Wilkinson et al. 1993). Participants at that meeting in 1993 called for a greater focus on coral reefs around the world supported by effective monitoring. The formation of the GCRMN in 1996 and Reef Check in 1997 (Hodgson and Liebeler 2002) followed from this Miami meeting in 1993.

ICRI, GCRMN AND SOUTHEAST AND EAST ASIA

The increased focus on coral reefs that originated predominantly from events in Southeast Asia was heard in the USA with the US Department of State and the

National Oceanic and Atmospheric Administration (NOAA) noting the recommendations from the Miami meeting and suggesting a 'Year of the Reef' for 1996 (later postponed to 1998). The USA also proposed the formation of a US Coral Reef Initiative at the 1st Small Islands Developing States Conference in Barbados in October 1994. A counter-proposal was suggested by the Australian Ambassador for the Environment, Penny Wensley who negotiated with France, Jamaica, Japan, the Philippines, Sweden, the UK, the Intergovernmental Oceanographic Commission of UNESCO, UN Environment Programme, the IUCN, the World Bank and others to join with the USA and Australia in forming the International Coral Reef Initiative. The formation of ICRI was endorsed at the 1st Conference of the Parties of the Convention on Biological Diversity in December 1994, in the Bahamas. At that meeting, the Philippine Secretary for the Environment and Natural Resources, Angel Alcala (and a particularly active coral reef researcher, who had been on the ASEAN-Australia LCR Project Management Committee, with Edgardo Gomez) and his co-chair Wensley, invited participants to Siliman University in Dumaguete City in May 1995, where ICRI was formally initiated with a Call to Action and a Framework for Action (www.ICRIForum.org). This meeting focussed on 4 main themes: **Coastal Management**, with calls for integrated coastal management and the designation of marine protected areas; **Capacity Building** to improve information flow and exchanges on coral reef issues and management mechanisms; **Research and Monitoring** to develop regional networks to enhance reef research and improve reef assessments through the formation of a global coral reef monitoring network; and **Review** to periodically assess progress in achieving the Call to Action and the Framework for Action. The **Research and Monitoring** theme specifically called for the formation of the Global Coral Reef Monitoring Network, with the Government of the USA providing catalytic financial support.

ICRI has since developed as the major body providing advice to the UN General Assembly and other UN agencies such as Convention on Biological Diversity and UNEP on coral reefs, with the initial core countries accepting the role of coordinating ICRI for two year periods usually in association with a developing partner country. The full history and outputs are on www.ICRIForum.org.

The initial (and continuing) funding from the USA for the formation of the GCRMN was provided to IOC-UNESCO and then UNEP to lead the process; I was appointed as the Global Coordinator in early 1996, principally as a result of my experience as CTA of the ASEAN-Australia LCR project and being Chair of the UN Global Task Team on the Implications of Global Climate Change on Coral Reefs.

The GCRMN was originally advised by the Scientific and Technical Advisory Committee (GCRMN-STAC). Two key participants on that committee were immediate past-Chairs, Edgardo Gomez and Chou Loke Ming.

THE CORAL REEFS OF SOUTHEAST AND EAST ASIA:

The catalyst for ICRI and the GCRMN arose out of activities in Southeast and East Asia with the formal designation made at a meeting in Dumaguete City, the Philippines in 1995. This region is particularly important for many critical reasons:

1. The centre of coral reef biodiversity is within the region, and most of the reefs have high diversity in both species and structural complexity. Similarly the mangrove forests and seagrass beds contain very high biodiversity (Fig. 1.1.1);
2. The largest areas of coral reefs are within this region, with approximately 28 to 32% of the world's reefs in Southeast and East Asia. Indonesia is listed as the country with the 2nd largest area of reefs (16.5%), with the Philippines as 3rd (5%). Only Australia and its offshore territories have a larger proportion with (18.8%). These calculated data from Burke et al. 2011 report the area of reefs in the Philippines as 22 484 km^2 which is very close to the estimates in the mid-1970s by Gomez et al. 1994 of 25 000 km^2;
3. A large proportion of these reefs are between 7^o North and South parallels; that is outside the damaging cyclone storm belt, such that these reefs can achieve very high levels of natural coral cover (Fig. 1.1.2);
4. The Southeast and East Asian region, however, is most at risk of coral reef over-exploitation and consequent degradation with very large populations using these reefs for subsistence, luxury products, tourism and as dumping grounds for pollution (Fig. 1.1.3; Burke et al. 2011);
5. Finally the region is the most rapidly developing economic region of the world with the greatest expansion in education and as a result offers the greatest hope for finding solutions to the increasing global rate of reef decline.

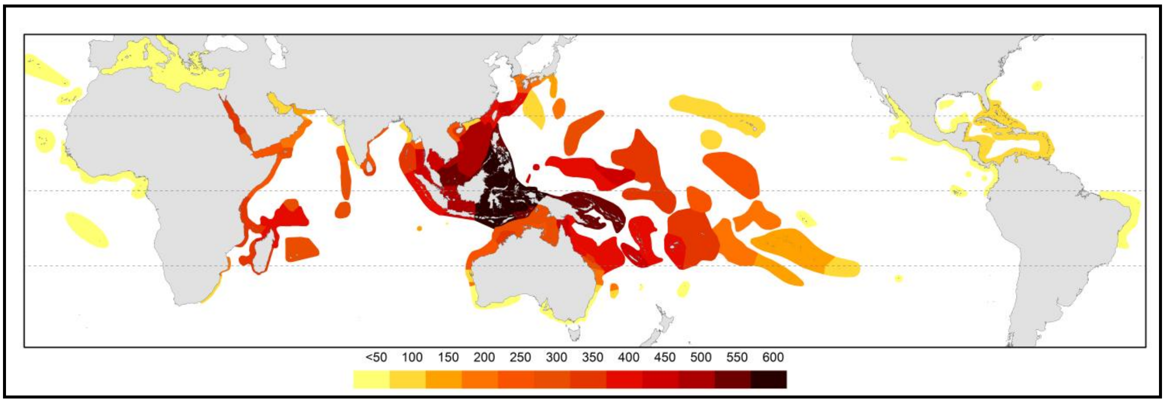

Fig. 1.1.1: The distribution of hard coral species throughout the world, showing that the greatest diversity of corals is within Southeast and East Asia. From Veron JEN, Stafford-Smith MG, DeVantier, LM and Turak E (in prep.) An overview of coral distribution.

Thus, the Southeast and East Asian region is of critical importance for the world and the expertise and lessons gained in this region will be essential for the long-term conservation and sustainable use of coral reefs, both here and elsewhere.

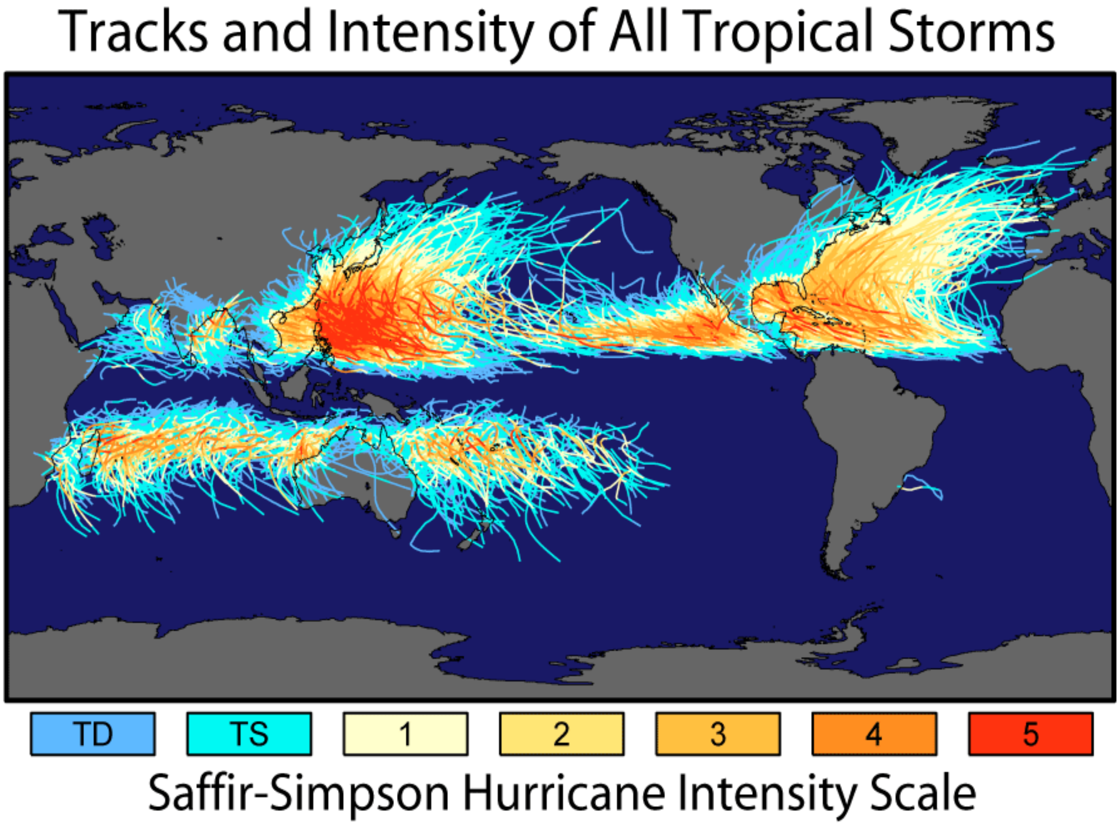

Fig.1.1.2: Tropical cyclones (and typhoons) predominantly originate in tropical waters, often around the equator, but do not reach damaging strength until they have migrated out of the 'doldrum' band 7o North and South of the Equator. Thus a large proportion of the high biodiversity reefs in Southeast Asia are rarely damaged by damaging storms (courtesy of NASA, USA).

Countries of Southeast and East Asia have also been particularly supportive of ICRI. One of the major objectives of those leaders who formulated the ICRI at Dumaguete City in 1995 and detailed in the 'Call to Action' and the 'Framework for Action' (www.ICRIForum.org), and reaffirmed and revised several times since then, was that leading countries and agencies should conduct regular regional meetings to review progress and ensure that all countries are able to participate in ICRI initiatives (the 4^{th} arm of ICRI – the **Review** progress focus). All regions held these meetings in 1995-96; but only the Southeast and East Asian region has maintained a continual review process with 7 regional meetings held throughout the participating countries; the latest being the 7^{th} ICRI East Asia Regional Workshop, held in Siem Reap, Cambodia in October 2011. These meetings have been largely supported by the Government of Japan and featured detailed GCRMN meetings to ensure a free flow of information on reefs across all participating countries.

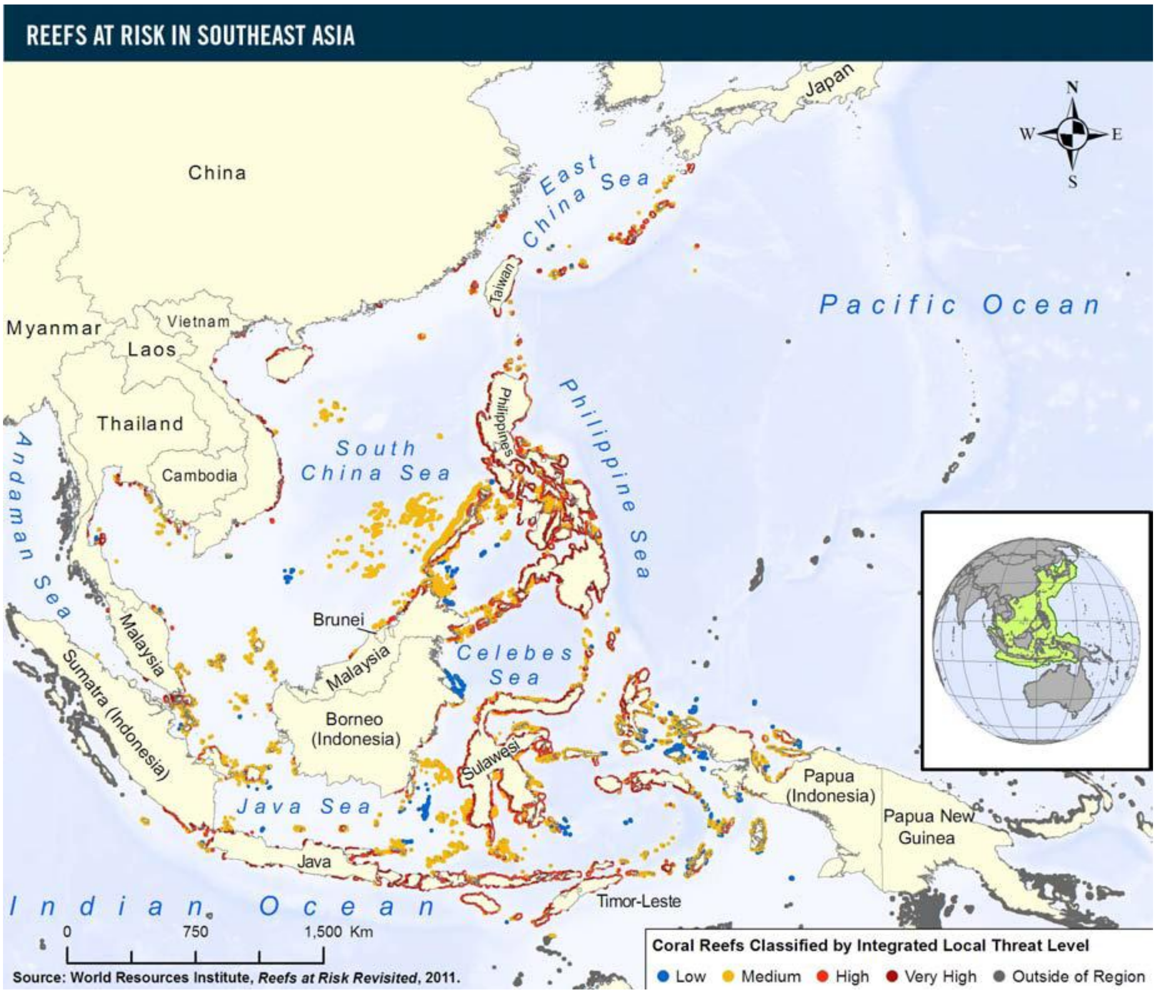

Fig.1.1.3: Southeast Asia features as the centre of coral reef decline in the world, based on this analysis by the World Resources Institute in the Reefs at Risk Revisited series (Burke et al. 2011). The large areas of red and orange over reefs in Indonesia and the Philippines strongly emphasises this analysis.

THE GCRMN AND SOUTHEAST AND EAST ASIA

One of the first logistic arrangements of the GCRMN was to divide the reef regions of the world into suitable sized management units. Thus, the concept of GCRMN 'Nodes' was adopted with 17 Node regions originally developed. Decisions on country membership of each Node were made during the regional meetings of ICRI starting in late 1995 in Jamaica for the wider Caribbean. The Southeast and East Asian region met in Bali in March 1996 through assistance from the Japanese Government. This meeting decided that Southeast Asia and East Asia would constitute Nodes of the GCRMN with membership of Southeast Asian Node containing the ASEAN countries with coordination through the coral reef researchers at the National University of Singapore, headed by Chou Loke Ming, and the East Asian Node for China, Japan, Korea, and Taiwan with coordination from marine scientists in Okinawa and assisted by Japanese Government environment agencies.

The decisions on country membership of Nodes were essentially pragmatic; what combination of countries could collaborate together around a major centre of coral reef research, management or monitoring, and for which there was a possibility of funding. The initial catalyst came for the South Asian region when the Government of the UK agreed to fund coral reef activities in India, Maldives and Sri Lanka with the potential to expand to Bangladesh and maybe Pakistan if reefs were found. Thus the first Node was determined on a 'political' basis through a funding agency willing to support a number of countries and employ a young British scientist to coordinate through the Regional Seas Node (SACEP) in Sri Lanka. After that, Node formation was predominantly on finding a group of countries that could be funded for monitoring and were willing to collaborate.

The first chapters covering the status of reefs in Southeast and East Asia were written in 1998 following presentations in 1996 at the 8th International Coral Reef Symposium in Panama City. These chapters were the basis for future GCRMN status reports. However these reports were based on extensive reef experience of the authors and written prior to the advent of active GCRMN monitoring (Chou 1998; Maragos et al. 1998; Wilkinson 1998). The first reports based on GCRMN monitoring appeared soon after (Chou 2000; Fujiwara et al. 2000).

The two Nodes 'South-East Asia' and 'East and North Asia' have continued to be better organised, and particularly effective and responsive partners within the GCRMN. This effectiveness is due to several factors including: having node coordinators in Singapore and Japan who have been effective communicators with their member states; being supported by their home institutions in Singapore and Japan, along with continued financial support from the Government of Japan; having a very sound base throughout the region in marine science, monitoring and management; and through being a strong network of people who share common objectives and a sense of cooperation. This network is particularly evident in these two Nodes continuing to function as effectively one large Node.

GCRMN leaders in Southeast and East Asia have continued to support the production of 'Status of Coral Reefs of the World' reports in 2000, 2002, 2004 and 2008 (Wilkinson (editor) in 2000, 2002, 2004, 2008) through the production of comprehensive and authoritative chapters on their reefs with ever increasing data quality and quantity.

A particularly important feature of these two Nodes is through their participation and coordination of the Asia-Pacific Coral Reef Symposia held in Hong Kong 2006 (1st), in Phuket Thailand (2nd) in 2010 and this the 3rd Symposium in June 2014 in Pingtung Taiwan.

SOUTHEAST AND EAST ASIA – CONCLUSION

It has been a pleasure to write this chapter for the "Status of Coral Reefs in East Asian Seas Region: 2014" as it has given me the opportunity of thanking my many colleagues and friends throughout the region who have assisted me greatly during the ASEAN-Australia Living Coastal Resources project and particularly during my role with the Global Coral Reef Monitoring Network. It has also been a pleasure to reminisce over my interactions with these colleagues throughout 24 years – I thank you all.

Most importantly, however, is that the Southeast and East Asian region has collectively been the most effective partners in ICRI and the GCRMN since they were formed almost 20 years ago. This is particularly pertinent as this expanded region is at the 'heart' of the coral reef world (Fig.1.1.1), with the greatest diversity and area of coral reefs, the largest human populations surrounding those reefs and often dependent on them, and the greatest potential resources in marine science management enthusiasm and capacity to find the critical solutions needed to reverse the decline in the status of coral reefs around the world. There are many threats facing coral reefs, with global climate change being particularly prominent; this Southeast and East Asian region will be the future source of responses to these threats to ensure that coral reefs continue to provide goods and services to people of the world, and especially to amaze us with their complexity and beauty.

ACKNOWLEDGEMENTS

I wish to thank all my colleagues and friends in the ASEAN-Australia Living Coastal Resources project, the UN Global Task Team and more recently in the GCRMN. Special mention is to those who served on the LCR Project Management Committee, lead particularly effectively by the late Suraphol Sudara of Thailand. More recently the GCRMN has been very enthusiastically supported by the Node Coordinators Karenne Tun and Tadashi Kimura. The Government of Japan is warmly thanked for funding this regional report and many previous workshops, meetings and activities throughout the region. It is now fitting that Japan and Thailand are the co-Chairs of the International Coral Reef Initiative, putting Southeast and East Asia at the centre of the 'coral reef world'.

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1.2. PROGRESS OF THE REGIONAL NETWORK ON CORAL REEF MONITORING IN EAST ASIA

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INTRODUCTION

Coral reef monitoring at a regional scale began in the late 1980s with the implementation of the ASEAN-Australia Living Coastal Resources Project (LCRP) from 1986 to 1994. The five participating ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, Thailand) at that time agreed to adopt common reef survey methods that would facilitate regional analysis (Chou, 2010). As ASEAN membership expanded, new member countries (Brunei Darussalam, Cambodia, Vietnam) incorporated the same reef survey methods in their reef capacity development supported by bilateral arrangements. This enabled the Southeast Asian region to not only monitor the status of coral reefs in the separate countries but also to analyse trends across the region. Chou Loke Ming served as the regional coordinator for Southeast Asia until 1994, after which, Karenne Tun took over the role. The network for the East and Northeast Asian region was initiated by Shuichi Fujiwara when he compiled the status of coral reefs in China, Hong Kong, Taiwan, Japan and Korea in 2000 (Fujiwara et al, 2000). This work has since 2002 been carried on by Tadashi Kimura, serving as regional coordinator for East and Northeast Asia (Kimura, 2010), which will be referred to simply as Northeast Asia in the rest of this paper.

The regional network on coral reef monitoring for both regions, Southeast and Northeast Asia, remains as an informal group of reef scientists and managers. These individuals stay unified by the common purpose of authenticating the health of the coral reef ecosystem and providing the scientific basis for management. The advantages and disadvantages of an informal arrangement were highlighted by Chou (2010). While network participants have changed, the group has been able to organize itself and contribute to the coral reef status reports of the Global Coral Reef Monitoring Network (GCRMN) since 1998 (Chou, 1998, 2000; Fujiwara et al, 2000; Dai et al, 2002; Chou et al, 2002; Tun et al, 2004, 2008; Kimura, 2008).

CONTRIBUTION OF REGIONAL ASSESSMENTS

The earliest regional coral reef status assessment of Southeast was published in 1998 (Wilkinson, 1998). It covered past reef monitoring efforts and was based heavily on the contribution of the ASEAN-Australia LCRP and earlier assessment by Wilkinson et al (1993). Of the 49 reef sites in the five ASEAN countries that participated in the ASEAN-Australia LCRP, less than 20% supported live coral cover exceeding 75%. There was no assessment for Northeast Asia in Wilkinson (1998).

The next assessment in 2000 (Wilkinson, 2000) included chapters for Southeast Asia (Chou, 2002) and for the first time, Northeast Asia (Fujiwara et al, 2000) dealing with China, Japan and Taiwan. The Southeast Asia chapter now included the reefs of Cambodia and Vietnam. Human pressure persisted and reefs continued to decline with the 1998 bleaching contributing further to the decline. Monitoring efforts expanded together with increasing rehabilitation initiatives while reefs that were once considered remote no longer escaping the impact of destructive fishing. The 1998 bleaching also affected reefs in Northeast Asia with serious damage in southern Japan and Taiwan. Mortality as high as 90% in some places resulted in localised extinctions of prominent species. Reef management measures increased in both regions.

The 2002 assessment showed that Southeast Asia's coral reefs (including Brunei Darussalam and Myanmar) remained under threat mainly from anthropogenic impacts and weak management capacity but with isolated instances of effective management and protection (Chou et al, 2002). This was confirmed by Burke et al (2002), which drew most of the data from the same group of researchers in the region. The coral reefs of Northeast Asia, this time including South Korea were recovering from the 1998 bleaching but a 2001 bleaching in Japan resulted in up to 69% mortality in southern Ryukyus (Dai et al, 2002). Crown-of-Thorns (COTs) outbreaks were reported and the major widespread anthropogenic threat was identified as sedimentation from terrestrial runoff. The Japanese Government established an International Coral Reef Center on Ishigaki Island in 2000 to act as a Node for the GCRMN and to facilitate coral reef monitoring and conservation.

The assessment of 2004 showed that Southeast Asia's coral reefs showed an overall decline in reef condition although Indonesian reefs improved slightly (Tun et al, 2004). Myanmar remained the only country without a reef monitoring programme. More active reef management initiatives throughout the region were documented. Coral reefs of North Asia, now with the inclusion of Hong Kong remained under anthropogenic stress (Kimura et al, 2004) and reef conservation and management programmes have been implemented and developed in all countries.

The 2004 Indian Ocean tsunami produced severe localised damage of some reefs in Indonesia, Thailand and Malaysia but most reefs suffered minimal impact (MOE, 2005). Recovery is expected to take 5 to 10 years for most of the affected reefs and up to 20 years for those that were severely damaged (Tun, 2008).

Coral reef condition improved in Philippines, Thailand, Singapore and Vietnam by 2008 (Tun et al, 2008). Information on Timor Leste's reef condition, although limited, was included for the first time. Overall decline of North Asian reefs continued under the combined influence of human and natural (bleaching, COTs, typhoons) impacts (Kimura et al, 2008). Reef monitoring was well established in Japan, Hong Kong, Taiwan and China's Hainan Island. The database on 'Coral Reef MPAs of East Asia and Micronesia' was developed in 2007 (Kimura et al, 2008) and showed an increase of MPAs with coral reefs from 178 in 2003 to 403 in 2007 (Tun et al, 2008).

A Southeast Asia regional overview of the 2010 coral bleaching impact appeared in MOE (2010). Although widespread bleaching was noted, the impact varied greatly. Some sites like Manado and Raja Ampat had no occurrence of bleaching but in others like Peninsular Malaysia and Thailand, the bleaching was so severe that dive sites in marine parks had to be closed in an unprecedented move to minimise visitor stress. In Northeast Asia, serious bleaching impact was observed at Ishigaki but reefs throughout the region were subjected to human impacts. Localised COTs outbreaks were recorded. These induced ecological phase shifts from coral to algae dominated reefs in some areas. Interestingly, migration of hard coral species to higher latitudes was observed in Japan and South Korea.

PROGRESS

Support from Japan's Ministry of the Environment (MOE) has to be acknowledged for maintaining the associated activities of the informal group. Japan has supported the International Coral Reef Initiative (ICRI) as a member since the Initiative's formation in 1994 and hosted the Secretariat in its capacity as a developed country with a developing country partner in 2005-2007 (with Palau) and 2014-2016 (with Thailand). The MOE has been actively organising regional ICRI meetings on an annual basis and these provided support to the GCRMN of both regions for regional reef status reporting. At a regional meeting in 2004 in conjunction with the 10^{th} International Coral Reef Symposium in Okinawa, it was agreed that the two regional networks merge in order to strengthen and facilitate information flow and sharing on coral reef research and conservation (Kimura, 2008; 2010). Since then the MOE has supported activities consistently, which allowed network members to meet annually to contribute not only to GCRMN but also to ICRI activities. Special acknowledgement has to be given to Clive Wilkinson who coordinated GCRMN all these years and helped to make reef status reporting an integral component of reef conservation and management, and for the solid and consistent support he gave to the network of both regions.

The First Asia Pacific Coral Reef Symposium (APCRS) was organised in Hong Kong in 2006, spearheaded by the GCRMN Nodes of East Asia and Southeast Asia. Spurred by its success, the equally-successful Second APCRS was organised in Phuket in 2010, with the Third APCRS taking place in 2014 in Pingtung (Taiwan). These Symposiums attract large numbers of coral reef scientists and managers from the region and have become an important forum for coral reef information sharing. The informal GCRMN groups of both regions have contributed much to the regional ICRI activities, having participated in the development of the MPA database from 2005 to 2007 and in regional workshops on MPA networking between 2008 and 2010 that were designed to achieve WSSD 2012 goals of enhanced MPA networks (Kimura, 2010).

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2. CORAL MIGRATION TO THE HIGH LATITUDE AREA IN EAST AND NORTH ASIA

2.1. MIGRATION OF CORALS IN TAIWAN

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INTRODUCTION

Aside from their acclimating and adaptive abilities, living organisms can migrate to safe localities in order to survive current environmental changes (see Burrows et al. 2011, Walther et al. 2002). Whereas our capacity to limit global temperature increase to <2°C by the end of the century seems already seriously compromised (Rogelj et al. 2011), the shift in the geographical distribution of marine species could therefore strongly reconfigure worldwide marine ecosystems in the coming decades (Doney et al. 2012, Poloczanska et al. 2013). In this context, high-latitude areas have recently risen as potential refugia for coral reef habitat (Pandolfi et al. 2011, Pandolfi & Kiessling 2014) and some studies have already suggested prioritizing conservation in some areas to facilitate coral range expansions as Sea Surface Temperature (SST) rises (Makino et al. 2014).

Fossil records suggest that reefs in some high latitudes locations have been indeed much more prolific in the past when SSTs were higher than at present (see for example Veron 1992, Woodroffe 2011). However, different from paleontological examples that involve warming over hundreds if not thousands of years, the current situation is characterized by abrupt changes in environmental conditions and may have contrasting outcomes (Hoegh-Guldberg 2014). Reefs experience in parallel, changes in pCO_2, pH or carbonate ion concentrations (Hoegh-Gulberg 2007, Hoegh-Guldberg 2009), which could additionally limit temperature-induced poleward shift to a limited number of species and locations (Woodroffe 2011, Yara et al. 2012, but also see Kleypas et al. 1999 and Guinotte et al. 2003 for environmental limitation). In this context, it is therefore unlikely that coral reefs can maintain their complexity by moving poleward (Hoegh-Guldberg 2014) and that high latitude areas can provide suitable and functional refugia for coral reef habitat. Up to date, poleward range expansion has been reported for several marine organisms including fish (Figueira & Booth 2010, Last et al. 2011), sea urchin (Ling et al. 2009), seaweed (Wernberg et al. 2011), coral dwelling crab (Yamano et al. 2012) and intertidal fauna (Pitt et al. 2010). It has been further recorded for several scleractinian corals in Japan (Yamano et al. 2011), in the Caribbean (Precht & Aronson 2004), and in Australia (Baird et al. 2012, Hughes et al. 2012). As part of our limitation to detect species range shift, regions and taxonomic groups concerned may have been the object of reliable historical surveys for the comparison with current situation. While there is today undeniable sign of tropicalization of temperate waters, the amount of species concerned by this scenario worldwide remains unclear. Individuals involved must however demonstrate high tolerance characteristics to colonize high latitude areas (see Hoegh-Guldberg 2014), and an increasing number of studies have been therefore focusing on the physiological potential of marine organisms to colonize these latitudes, especially in response to SST variation. Low temperature tolerance in the larvae of two scleractinian corals (Woosley et al. 2013), the tropical sand dollar urchin *Arachnoides placenta* (Hardy et al. 2014), and also the coral eating crown-of-thorns starfish *Acanthaster plancii* (Kamya et al. 2014), for example, highlighted the potential of these organisms to disperse into subtropical locations.

East Asia encompasses among the most warming seas in the world, with SST rising 7 to 12 times faster than the global rate (Belkin et al. 2009). The warm Kuroshio Current, the world's strongest continental boundary current (Veron 2011), largely influences the ecology of the bioregion. It allows corals to colonize more northerly locations compared to other regions at similar latitudes (Veron 2000), and ensures a high connectivity from south to north for many marine organisms following a stepping stone model (Adjeroud & Tsuchiya 1999, Takabayashi 2000, Rodriguez-Lanetty & Hoegh-Guldberg 2002). Yabe & Sugiyama (1931, 1935) and Sugiyama (1937) performed extensive coral surveys in the region at the early 20th century. Although diving limitations could have been an obstacle to underwater survey at that time, their work provides the most reliable historical data in the region to describe past scleractinian distribution, particularly for shallow-water species. Therefore, based on the comparison of this data with current coral species distribution along the coastline of Japan, Yamano et al. (2011) recorded 4 species, including 3 *Acropora* spp. and 1 *Pavona* sp. migrating poleward. When considering the marine community as a whole, however, it seems to concern only a few taxa of scleractinians, fish, and algae. Rare species, present up to date as a background in the ecosystem, could benefit from recent environmental changes in some cases, and further studies suggest an alternative of local expansion of native tropical species (Denis et al. 2013a). Regional differences tend to support that this could be, at first, the most common scenario. Nevertheless, this could be to the detriment of temperate assemblages (see examples in Tanaka et al. 2012, Denis et al. 2013b) and reconfigure rapidly marine ecosystems in the northern part of the Kuroshio region.

Impact of seawater temperature increase on subtropical marine communities remains relatively poorly documented in North-East Asia, especially the cascading effects that it may have on temperate ecosystems. It could strongly reconfigure existing assemblages and endanger species with restricted distribution. Given the uncertainty over which species will arrive or depart and lack of knowledge about the history of most subtropical reef development, Beger et al. (2014) suggested that active management is presently not the best use of management resources in these areas. As a source of propagules for the replenishment of degraded communities or their role in the dispersion of tropical species, low latitude reefs should remain a priority for conservation and management actions. Increasing attention on high latitude locations is necessary to establish the baseline upon which, we can assess impact of climate changes on these areas. Here, we provide an update of the situation in Japan, Korea and Taiwan by describing recent changes in the marine communities of these regions.

SITUATION IN TAIWAN

Ranged between 21.90°N and 25.30°N, Taiwan constitutes a unique biogeographical overlap of marine taxa from tropical, subtropical and temperate regions. SSTs around Taiwan have however already increased by 1.55°C since 1957 (Belkin 2009), and may further rise by 2.0-2.5 °C by the end of the century (Liu et al. submitted) resulting in a homogenization of the marine communities around the island. More than 3000 fishes, 2500 molluscs, 700 crustaceans, 600 macroalgae , 300 scleractinian corals, 150 echinoderms and 100 octocorals have to date been recorded around Taiwan (see Taiwan Biodiversity National Information Network: http://taibnet.sinica.edu.tw) and an obvious decreasing gradient of biodiversity is thought to be present from South to North (example for corals in Dai & Horng 2009). Therefore, species range shifts are likely to be particularly obvious as it may cause considerable tropicalization of the marine assemblages and a loss of the less tolerant species to high temperature.

So far, there is however no evidence suggesting that any taxa, including corals, could move poleward or benefit from the recent change in environmental conditions in this area. However, a recent regional survey of the benthic community structure/composition has suggested that major degradation of Taiwanese benthic communities may imperil connectivity between tropical and temperate latitudes (Ribas-Deulofeu 2013). This could represent a strong limitation to the poleward migration (if any) and highlights the importance of protecting the source of propagules if we are to allow high latitude refugia for the survival of tropical taxa.

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2.2. MIGRATING CORAL COMMUNITY IN SHIKOKU, JAPAN

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INTRODUCTION

Shikoku, which includes four prefectures; Kochi, Ehime, Tokushima, Kagawa, is the smallest of Japan's four main Islands. Reef-building corals are most abundant on the west coast of Shikoku, predominantly in southwestern Kochi Prefecture (Ministry of the Environment and Japanese Coral Reef Society, 2004) due to the influence of the Kuroshio Current, and form a patchy community directly growing on the upper part of the rocky substrata.

SITUATION OF CORAL MIGRATION IN SHIKOKU

The poleward range expansion of modern corals is based on 80 years of national records from temperate areas of Japan, where century-long measurements of *in situ* sea-surface temperature have shown statistically significant rises (Yamano *et al*., 2011). In terms of general decadal trends in Kochi, SST in the 1980's were cooler than in the 1970s, but those in the 1990s and 2000s were warmer than 1970s (Tanaka *et al*., 2012).

A total of 139 species of scleractinian corals have been recorded from Shikoku (unpublished data). Among these, the following 8 species; *Acropora cytherea*, *Acropora nana*, *Millepora exaesa* (Nomura and Mezaki, 2005), *Acropora* sp. having cochleariform radial corallites (Mezaki, 2012), *Acropora digitifera*, *Acropora robusta*, *Acropora subulata* and *Millepora platyphylla* (unpublished data), not reported in previous records and rare in high-latitude but common in tropical and sub-tropical coral reef regions have been recorded in southwestern Kochi since the year 2000.

Acropora nana was first recorded in 2004 in southwestern Kochi (Nomura and Mezaki, 2005). A number of *A. nana* colonies gradually increased in southwestern Kochi, and one small colony of *A. nana* was found in Tei (33°30' N), center of Kochi in 2011 (Mezaki and Kubota, 2012). Spawning of more than one *A. nana* colony at Nishidomari (southwestern Kochi) was observed many times *in situ*, occurring synchronously in summer (July to August) from 2007 to 2010 and 2012 (unpublished data). It may be evident that, *A. nana* which is a tropical species in Kochi, has been reproductively active and potentially contributing to the proliferation of regional populations.

Fig. 2.2.1 *Acropora pruinosa* in temperate Sargassum and Kelp beds in Ehime Prefecture.

Acropora pruinosa is a common species in high-latitude, Japan (Nishihira and Veron, 1995). Small colonies of *A. pruinosa* not reported in previous studies were found in temperate Sargassum and Kelp beds in Ooshima (33°22’ N), southwestern Ehime in 2013 (Fig. 2.2.1). This suggests that reef-building corals in Shikoku are gradually expanding their ranges northward not only by the appearance of tropical species such as *A. nana* but also temperate species such as *A. pruinosa*. However, *Acropora* sp. (having cochleariform radial corallites) as a tropical species monitored at odd intervals between 2009 and 2011 died in winter of 2011 from a sudden drop in seawater temperature (minimum 13.4℃; Mezaki, 2012). This suggests that the winter seawater temperature may be the main factor limiting reef-building corals in expanding their distribution to high-latitude and it is important to continue monitoring a future shift in their distribution in Shikoku.

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3. CONSERVATION OF MARINE AREA WITH MULTIPLE DEMANDS

3.1. MANAGING SINGAPORE'S CORAL REEFS

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INTRODUCTION

The island state of Singapore with a land area of 714km^2 and a population density of 7,283 per km^2, is the third most populous nation in the world after Macau and Monaco (UNFPA, 2011). Managing Singapore's natural environment within the context of its limited land and sea area and competing demands from various land-use stakeholders has always been challenging. Although legislation related to the environment is currently present in at least two dozen Acts (Ong, 2010), they do not specifically include the establishment of Marine Managed Areas (MMAs). While there were no Marine Protected Areas (MPAs) or MMAs, some legislation and regulations relevant to the management of marine areas do exist, and they indirectly provide some protective function. Particularly, the Parks and Trees Act, which is administered by the National Parks Board, makes provisions for the establishment of national parks and nature reserves. In July 2014, the 40ha Sisters' Islands Marine Park was established and is the first offshore marine area in Singapore that has been brought under the management of the National Parks Board. This paper focuses on the status of marine habitat protection in Singapore prior to the formation of the Marine Park.

Despite the fact that MPAs are one of the most effective tools to conserve and manage marine and coastal ecosystems and resources, many MPAs exist only as "paper parks" where there is a lack of legislation enforcement or effective management plans (UNEP-WCMC, 2008). A compilation of 8000 assessments of protected area management effectiveness shows that while most of MPAs have strong establishment elements (such as design, legislation and boundary marking), management planning and processes remain weak (Leverington et al., 2010). Furthermore, isolated MPAs or MMAs can be impractical to deal with issues that are beyond the boundaries of the protected areas (Cicin-Sain and Belfiore, 2005). An integrated management framework, such as Integrated Coastal Management (ICM), offers a closely integrated and coherent management mechanism especially in areas that are challenged by competing land uses and multiple stakeholders. In the absence of MPAs, enforcement of existing legislation and implementation of an ICM programme that is oriented toward biodiversity conservation are the more pragmatic approach to protecting coastal and marine resources and environment.

SINGAPORE'S CORAL REEFS

A 2012 GIS assessment revealed 44 offshore islands in Singapore (Tun, 2012), which represented a 30% reduction from the 63 islands in 1997 (MOC, 1997) and a 37% reduction from the 70 islands reported for 1922 (Chou et al., 1998). Of the present 44 islands, 30 are located within the country's southern waters better known as the Singapore Strait, which is among the world's busiest waterway extending 14km south and across 30km from east to west. This part of the sea supports the passage of about 140,000 seagoing vessels per year, with much of the shallower areas demarcated for vessel anchorage. These 30 islands serve the needs of various sectors such as industry, transport, military and recreation, and their management remains with the respective agency responsible for each island's development. This is also where coral reefs, seagrass beds and mangroves are present. Prior to July 2014 none of the islands is designated as an MPA or MMA and do not come under the jurisdiction of a nature conservation agency.

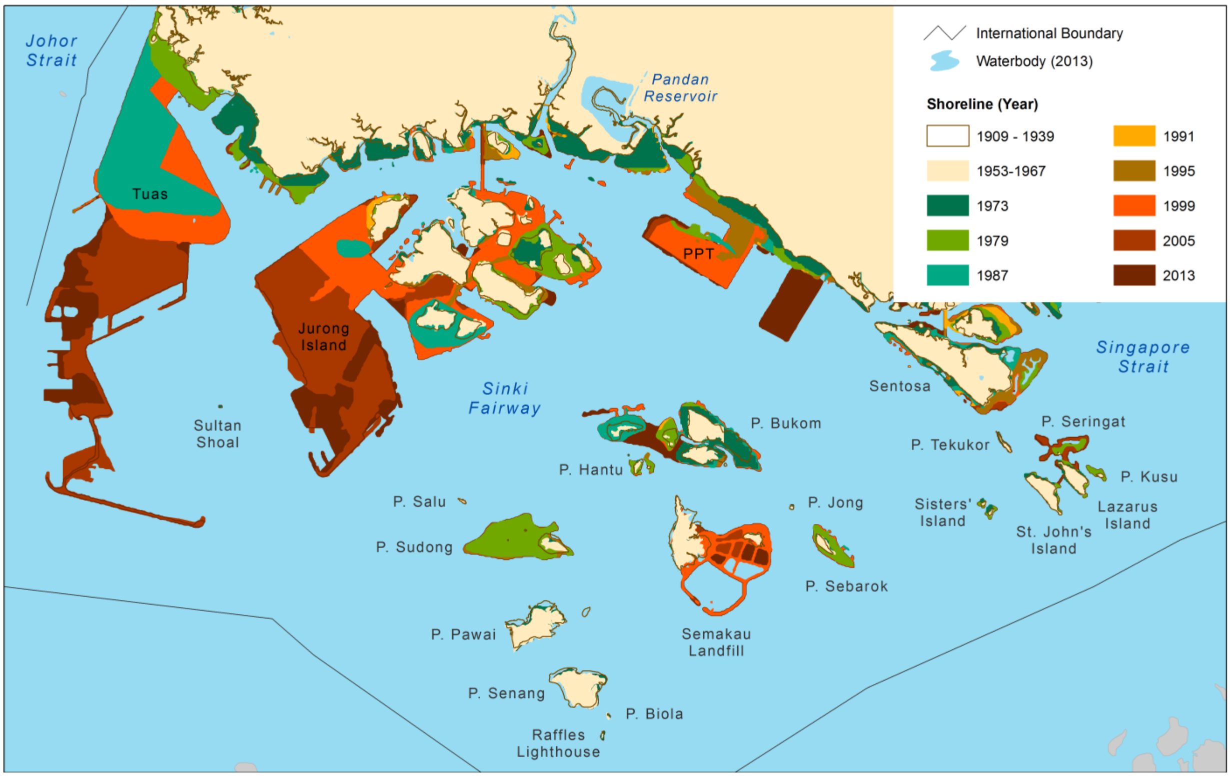

Fig. 3.1.1: Shoreline modification in Singapore since the 1960s (derived from a series of Landsat imageries by Nguyen et al., 2013)

However, due to the nature of the facilities and activities, many of the southern islands remain strictly out of bounds to visitors. While not designated as MPAs or MMAs, there are legal mechanisms to manage these islands, which indirectly provide some safeguard to the marine habitats.

An inevitable consequence of Singapore's acute land scarcity and high population density is the continuing conversion of natural and semi-natural natural areas for housing, infrastructure and industry, an activity that intensified in the post-independence era after 1965 (Fig. 3.1.1). Under the Urban Redevelopment Authority's (URA) Concept Plan 2001 and Master Plan 2008 (URA 2001; 2008), much of the petrochemical industry infrastructure was transferred from the mainland (or main island) to the offshore islands in the south, requiring in-filling of the sea channels between neighboring islands to create larger island masses that can accommodate these industries.

Together with a container terminal complex along a large stretch of the southwestern coast, Singapore's largest petrochemical complex on Jurong Island and the Shell petrochemical complex form the major offshore industrial cluster closest to the mainland. South of this cluster lies the Semakau offshore landfill and the islands used for live-firing practice by the military are flanking the southern-most coastal waters. To the east are the islands forming the St. John's recreational island-group. In addition, several marine aquaculture facilities also operate within these waters, and recreational activities like boating, scuba diving and fishing are permitted within non-restricted areas away from the main shipping channels.

With the limited areal extent and high activity profile of the southern coastal waters, almost every coastal habitat lies within several hundred meters to less than 2km from one or more coastal activity or facility. In the real sense, there are no "pristine" coastal habitats and all have shown anthropogenic influences across an apparent near to offshore environmental gradient. Despite being juxtaposed with urban centers and industrial activities, these areas serve as important refugia for marine biodiversity in the whole of Singapore. Over 255 hard coral species or about 32 per cent of the world's 800 species (Huang *et al.*, 2009), 111 reef fish species (REST, ND), 12 species of seagrass, 200 species of algae and 200 species of sponges (Lim *et al*., 2008) have been found in Singapore.

Without an MPA framework, marine biodiversity has remained rich despite overall loss of habitats to land reclamation and exposure to elevated sediment levels. Access restriction and strong enforcement of existing regulation have created a situation that is similar to a network of *de facto* protected areas. As Singapore is implementing an Integrated Urban Coastal Management (IUCM) framework, it is envisaged to provide an integrated governance and management structure for the Southern offshore islands and the rich marine biodiversity that they support.

GOVERNANCE AND MANAGEMENT

The islands south of the Singapore mainland and the surrounding waters host rich marine biodiversity but there is only a small portion of it identified as Marine Nature Area[1] (Figure 3.1.3). Not until July 2014 when about four islands were included to

[1] Areas contain some nature areas which have been identified for their biodiversity. They will be kept

form the Sisters' Islands Marine Park, have the islands come under the jurisdiction of a conservation agency. However, prior to the Marine Park, these southern islands are well managed with access restrictions and for some are out-of-bounds to the public and thus "protected" from unauthorised activities. These islands are utilised for different purposes and are managed by different government agencies. The following elaborates the management and governance of these islands with respect to their assigned function.

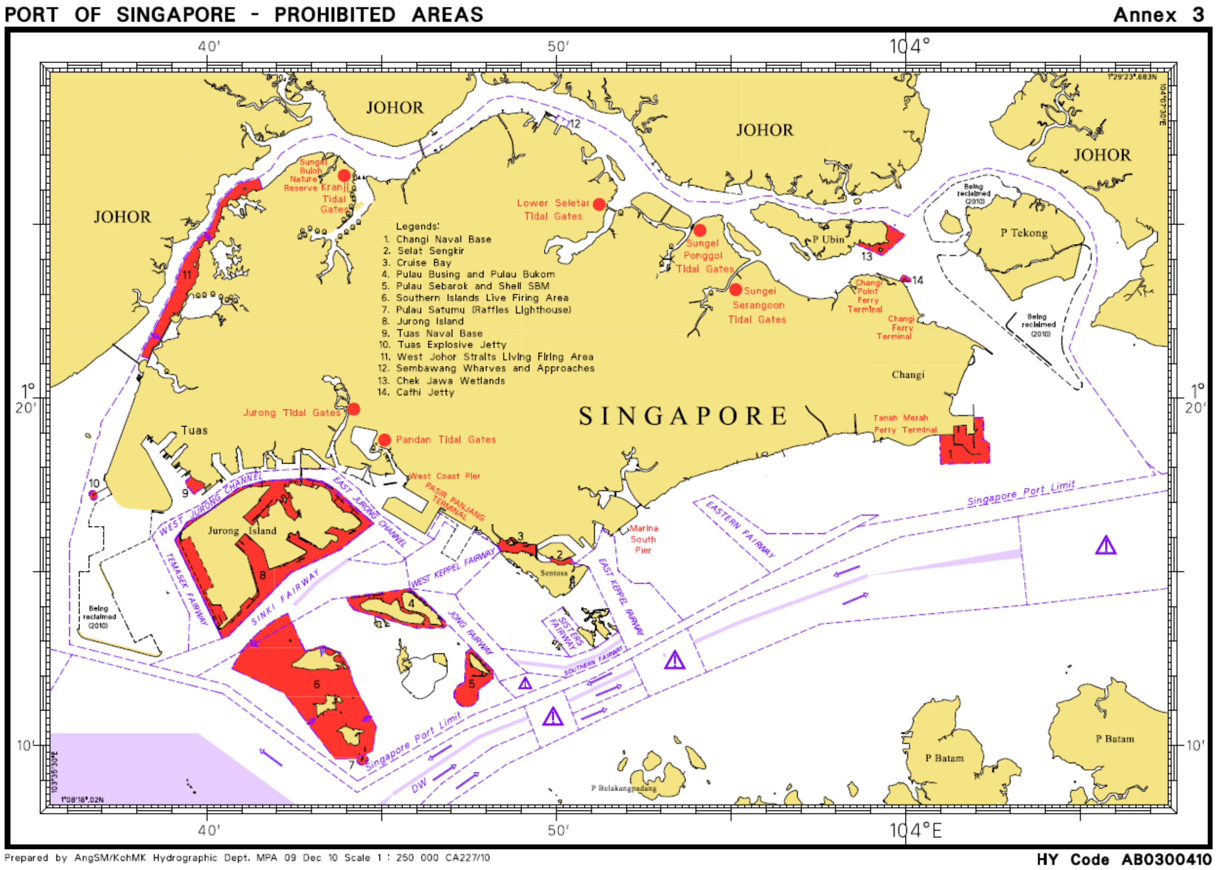

Fig. 3.1.2: Prohibited areas regulated by the Maritime and Port Authority of Singapore

Source: http://www.mpa.gov.sg/sites/circulars_and_notices/pdfs/port_marine_circulars/pc11-11.pdf

Military: A number of offshore islands have been designated for military training. The entire area is reserved for use as live-firing zones for military practices, and the coastal waters off the military land is a restricted area. Although these islands are managed by the Singapore Armed Forces (SAF) under the Ministry of Defence (MINDEF) for defence training, they are sites of high marine biodiversity. By virtue of restricted access by MINDEF, they hence remain 'protected' for defence purposes and permitted research.

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for as long as possible until required for development. If development falls within or in the vicinity of the demarcated areas, ecological studies may be required as advised by the relevant authority before any development proceeds. From http://www.ura.gov.sg/maps/index.html?service=PWB

Recreational and Residential use: A cluster of islands in the south, including Sentosa Island and the St. Johns cluster, is designated for housing and recreation and is managed by Sentosa Development Corporation (SDC), a statutory board under the Ministry of Trade and Industry. Sentosa Island is a globally recognised resort receiving 19 million visitors in 2011, and supports a luxury seafront residential area. To the southeast of the mainland is a group of smaller islands, known as the St Johns' island cluster, utilised for recreational purposes. This cluster supports rich marine biodiversity and is accessible to the public. However, approval from SDC is needed to access these islands for permitted recreational activities such as camping, scuba diving, snorkelling, and fishing.

Environmental service: Semakau Island is an offshore landfill for solid waste disposal commissioned in April 1999. Ash from incineration plants and also non-combustible construction waste are disposed of at this sanitary landfill. The waters surrounding the landfill host rich marine biodiversity. The main habitats found include grass and shrub, mangrove, seagrass, intertidal reef flat and coral reef. In July 2005, Semakau Landfill was officially opened for recreational and nature activities allowing visitors to enjoy and explore its many habitats. Since then, it has become increasingly popular and to date has received more than 62,500 visitors who come for a wide range of activities including educational tours, intertidal walks, bird watching, stargazing and sport fishing.

Marine navigation: A sizable area of reefs in Singapore is well secluded since they lie within the restricted area for safe navigation (Fig. 3.1.2). Under the jurisdiction of the Maritime and Port Authority, access is strictly controlled through a permit granting system.

Although these islands are managed by different agencies, issues which are cross-cutting are coordinated through a whole-of-government mechanism, allowing agencies to work together and mobilise each other's resources. For example, there is an internal process of agency consultation for issues like coastal development, which may have an impact on marine biodiversity, environment, aquaculture, and navigation. Singapore is implementing an Integrated Urban Coastal Management framework, a proactive planning and management structure for sustainable development of the marine and coastal area. This framework recognises and encourages close and active partnerships amongst stakeholders and interested parties to create greater synergies to optimise the use of coastal resources and to ensure conservation of sensitive coastal habitats together with their biodiversity and natural resources amidst active coastal development.

BENEFITS

As a city state, Singapore's governance hierarchy consists of only one (national) level and the benefits to all citizens are considered in the planning and management of these marine areas. Returns from the facilities and activities in these areas accrue to the agency holding the mandate over them. Singapore has long moved away from traditional livelihoods to services and industry. Local communities have thus ceased to rely on natural resources to generate incomes but they continue to benefit from the services that the coastal and marine areas provide.

With the natural environment identified as the only direct beneficiary of Singapore's *de facto* protected areas, the derived benefits from their existence are therefore intrinsically linked to biodiversity conservation, with the distribution of biodiversity in return linked to the hydrodynamic regime. Major shoreline modification through decades of coastal development and land reclamation has permanently altered the coastal hydrodynamics. Recent research indicated that the hydrodynamic pattern has a significant influence on the movement and connectivity of marine larvae between Singapore's coastal habitats, with the possibility of a large proportion of hard coral larvae (and possibly other marine taxa) confined within Singapore waters (Tay, 2012) . The continued maintenance of Singapore's remaining natural coastal habitats, much of which are found within the *de facto* protected areas, is therefore an important precursor for ensuring long-term larval supply and biodiversity conservation.

The indirect benefits to marine biodiversity afforded by access restriction and maritime-related legislation imposed by the agencies responsible for the development and management of the southern islands include reduced extractive activities (e.g., recreational fishing, reef gleaning), reduced water pollution, and reduced and better managed development-related impacts. All these indirect benefits are highlighted by the fact that despite losing almost 90% of sub-tidal coral reef area (Tun, 2012), the hard coral biodiversity has been maintained with only one reported local species extinction from a recorded diversity of 255 (Huang *et al.*, 2009). All these species are found within the southernmost, military islands that make up less than 30% of Singapore's total remaining coral reef area.

STATUS

Currently, the significant coral reefs are located within the southernmost cluster of the military-managed islands, including the adjacent reefs at Pulau Satumu, which have the best coral reefs in terms of quality and biodiversity. Conservation strategies, which focus on safeguarding, restoring and rehabilitating marine habitats and species, have been implemented in these marine areas. The National Parks Board collaborates with research institutions on studies relating to connectivity of coral and mangrove habitats in order to optimize their roles as larval sources or sinks for better recruitment. Fragile reefs are being rehabilitated through transplanting of coral fragments, sexually-reared corals, and reintroducing marine invertebrate such as giant clams.

Singapore's *de facto* protected areas have existed for as long as the areas have been afforded legal protection with strict restrictions on visitor entry. While the protection is not centered on the conservation of natural habitats, access restriction indirectly helps with habitat protection.

All of Singapore's *de facto* protected areas currently lie within ***gazetted prohibited areas*** (Fig. 3.1.2), which prohibit the entry, transit, anchorage and mooring of all vessels within the areas unless specific approval has been obtained from the Port Master. Some are further safeguarded as they have been designated as Marine Nature Area under the Parks & Waterbodies Plan, Special and Detailed Controls Plan by the Urban Redevelopment Authority. Such prohibition and designation reduces impacts from coastal development and damaging activities such as reef gleaning, anchor dropping and unmanaged fishing. The establishment of the Marine Park is a major step towards legal protection of the biodiversity resources. However, unlike of conservation by deterrence as seen earlier, the Marine Park provides opportunities for outreach, educational, conservation and research activities related to the native marine biodiversity.

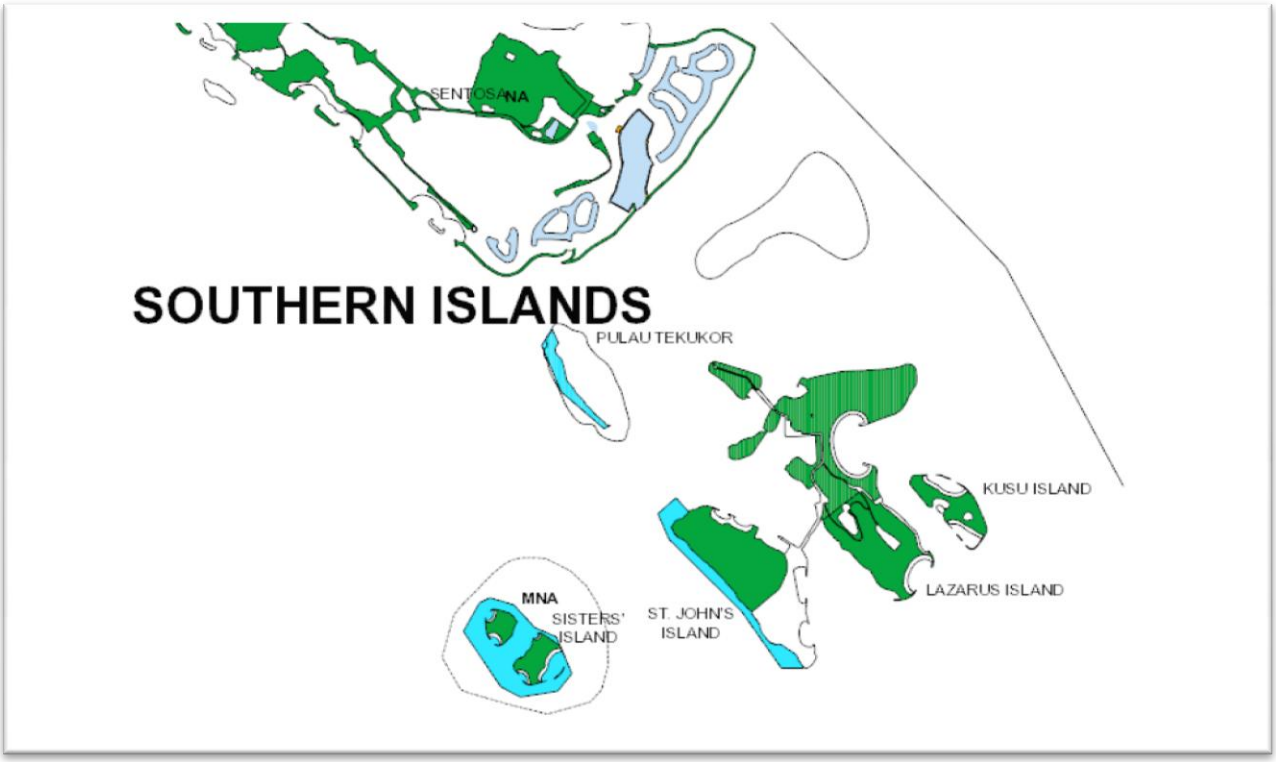

Fig.3.1.3: Example of Nature Area (NA) and Marine Nature Area (MNA) in the 2014 Master Plan.
Source: https://www.ura.gov.sg/maps/

As Singapore's coastal development landscape changes, the number and location of the *de facto* protected areas may be affected. The recently published "Population White Paper: A Sustainable Population for a Dynamic Singapore" (NPTD, 2013) provided an overview of the likely profile of Singapore and possible land use allocation beyond 2030 (map accessible at http://www.mnd.gov.sg/landuseplan/e-book/files/assets/basic-html/page14.html). It highlights the continued maintenance of the southern military prohibited areas, which further implies the continued *de facto* protection to the coral reefs within the area.

REMARKS

Unlike legally gazetted MPAs whose success can be qualified and quantified using one of the numerous available MPAs assessment tools, there are no established tools for measuring the success of the *de facto* protected areas. Even though similar metrics can be used to evaluate the management success of these areas, the metrics will need to be weighted differently to take into account the multitude and complexity of uses and stakeholders. Current research initiatives are looking at developing locally relevant metrics to qualify and quantify the success of the *de facto* protected areas not only in achieving habitat conservation and but also in providing opportunities for recreation, research, and education.

The Southern Offshore Islands serve a diverse range of stakeholders whose derived benefits are largely independent of the ecosystem goods and services provided by coastal biodiversity. There are however, a handful of recreational and subsistence fishermen who fish off the coral reef, but there is no evidence of complete resource dependency by any single user group. It is therefore difficult to identify a specific beneficiary from a natural resource usage perspective, but from a conservation perspective the obvious beneficiary is the natural environment itself. Conserving biodiversity for its own sake can be a contentious issue within a multi-stakeholder environment, but it can be made to work within Singapore's environmental management framework if benefits, either direct or derived, can be identified for all stakeholder groups.

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4. STATUS OF CORAL REEFS IN EAST AND NORTH ASIA

4.1. MAINLAND CHINA

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SUMMARY

The total area of coral reefs in China including underwater reef support formations up to 300m depth is about 50,000 km^2. The area of fringing reefs is 266.6 km^2 and the emergent reefs (including only reef flats and coral cays) of atolls and platform reefs is 5,287 km^2. These two total 5,554 km^2 (excluding coral communities).

The number of identifiable species of reef-building corals reported from our surveys is 210 species. Recently published checklists of China's marine biodiversity recorded about 260 scleractinian coral species (Chen 2003, Huang et al 2007, Liu et al 2008), which included species from Dongsha (Pratas) Islands and Taiping Island, Nansha Islands. The most remarkable event for coral reefs in China was the outbreak of crown-of-thorns starfish in Xisha Islands that denuded reefs during 2007-2009. The recent survey in 2012 found that some local shallow areas recovered well with live coral cover more than 40%, but for most other areas the recovery speed was slow due to recruitment limitation.

In the six monitoring sites, the live coral cover has not changed much in the past 5 to 8 years for Dongshan (Fujian province), Weizhoudao (Guangxi), Daya Bay and Xuwen (Guangdong province), and Sanya, Hainan Island, but at Yongxing Island a large variation was observed. There were few reports of coral bleaching in China. Mass bleaching events were observed and informally recorded at both, Weizhoudao (Guangxi) and Nansha Islands in 1997-1998, and moderate bleaching was observed and recorded in Sanya and Xisha Islands in 2010.

The degradation trend of the coral communities and coral reefs in mainland China seems to have slowed in the past 3 to 5 years, but habitat loss is still inevitable due to coastal development and engineering. Major stressors driving the degradation of reefs were direct reef damage from coral collection for mining or decoration, and destructive fishing activities before 1980s. After 1980s, especially in the last two decades of rapid economic and development growth, the main threats are mariculture in coral reef areas, over-fishing, water quality deterioration caused by eutrophication, coastal development, sedimentation, sewage pollution, and outbreaks of crown-of-thorns starfish. These stressors can drive coral community and reef degradation directly through increased coral mortality, or indirectly, by

increasing competitive species (algae) and decreasing coral recruitment. The degradation of the coral ecosystem is manifested by a decrease in area of scleractinian coral distribution, reduction in percent cover and biodiversity of coral reefs with a concurrent increase in the percent cover of soft corals or macro algae, and by phase shifts of ecosystem from coral-dominated to algal or soft coral-dominated reefs. It should be noted that a fishing activity, which is digging out buried giant clam shells for shellcraft making, was practiced popularly by fishers of Hainan Island for the past 3 or 5 years. This is a very destructive and a serious threat to China's coral reefs and many reefs of Xisha and Nansha Islands were directly damaged by the practice.

INTRODUCTION

The coral communities and coral reefs in mainland China are mainly distributed along the coast of southern China, and the tropical islands and atolls in the South China Sea. Due to the lack of the mainstream Kuroshio warm-water currents, the northern most coral communities occur in Dongshan county (23°45′N) of Fujian Province. A typical coral community occurs in Daya Bay (22°40′N), Guangdong Province, which is neighbors Hong Kong waters. China's coral reefs occur from Xuwen (20°15′N), Guangdong Province to the South China Sea's Dongsha (Pratas) Islands (20°40′N), Xisha (Paracel) Islands (17°08′~15°46′N), Zhongsha Islands (Macclesfield Bank) (19°33′~13°57′N), and Nansha Islands (Spratly Archipelago) (11°55′~3°35′N).

Only a few coral reef surveys were carried out in mainland China when the 'Status Report 2004' report was prepared, and the 'Status Report 2008' was based mainly on extensive surveys carried out by our study group only. After the 'Status Report 2008', more surveys have been reported by different study groups and this report is based on all these sources of data. An estimate of China's total reef area is presented in the next section.

The number of identifiable species of reef-building corals reported from our surveys is 210 species. Recently published checklists of China's marine biodiversity recorded about 260 scleractinian coral species (Chen 2003, Huang et al 2007, Liu et al 2008), which included species from Dongsha (Pratas) Islands and Taiping Island, Nansha Islands.

China's fast economic growth, heavy population and intensive land-use have brought severe negative impacts on the marine ecosystems, especially on coral communities and coral reefs. Hughes et al (2013) reported that 80-100% of the coral cover of the coastal fringe reefs in southern China has been destroyed. The outbreak of coral predators, crown-of-thorns starfish (*Acanthaster planci*) in Xisha and Nansha Islands during the years 2006 to 2009 was the most remarkable event after the preparation of the 'Status Report 2008'. The recent survey in 2012 found much variation in recovery between reefs of the Xisha Islands. Some local shallow areas recovered very well with live coral cover more than 40%, but for most other areas, the recovery speed was slow due to recruitment limitation.

A highly destructive fishing practice, which involves digging out buried giant clam shell valves for shellcraft making, became popular with the fishers of Hainan Island in the past 3 to 5 years. Many reefs of Xisha and Nansha Islands were directly damaged by such destructive fishing practice.

In this report, we selected 6 representative sites (monitoring sites) with distribution of scleractinian coral communities or coral reefs to demonstrate the present status of reefs in China. The 6 sites (Fig. 4.1.1) are: (1) Dongshan Island (23°45′N), in southeast China's Fujian Province, (2) Daya Bay (22°40′N), in southern China's Guangdong Province, (3) Xuwen (western coast of Leizhou Peninsula, 20°15′N) also in Guangdong Province, (4) offshore Weizhou Island (21°03′N) in Guangxi Zhuang Autonomous Region. (5) Saya Bay (18°14′N), in mainland China's southmost Hainan Province, (6) offshore Yongxing (Woody) Island, Xisha Islands (16°50′N) of the South China Sea in Hainan Province.

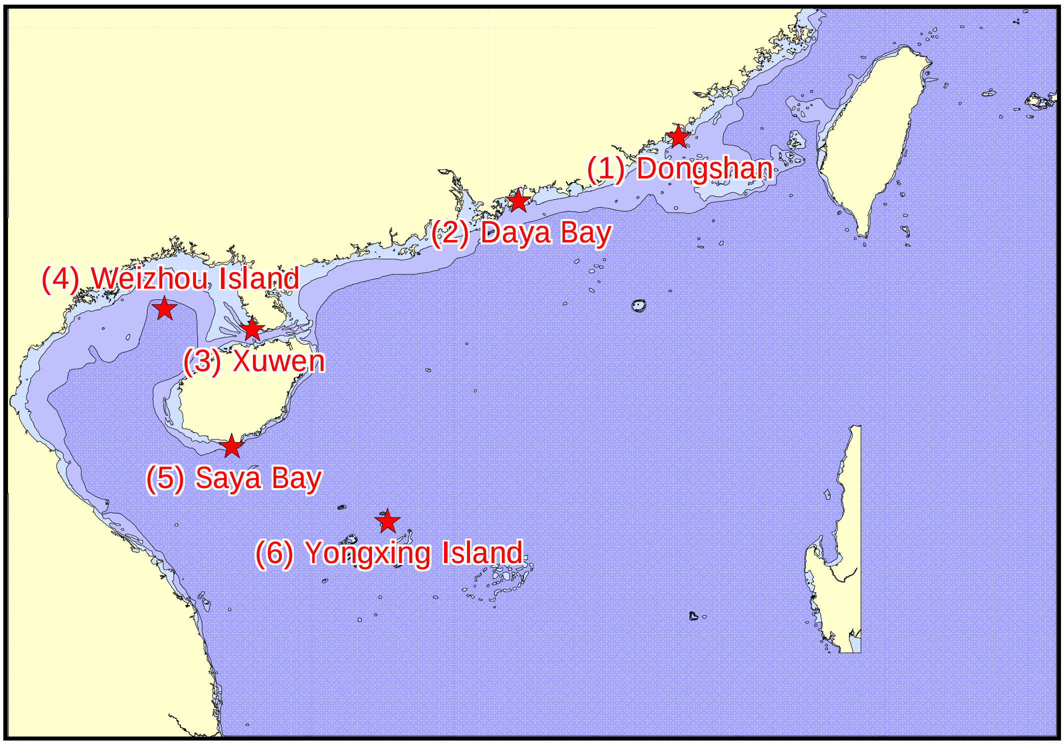

Fig. 4.1.1: Map of the 6 selected sites of representative scleractinian coral communities or coral reefs.

COUNTRY STATISTICS AND CORAL REEF RESOURCES IN 2014

Coral communities and coral reefs occur mainly along the coast of southern China and the tropical islands and atolls in the South China Sea. There is no exact estimate of the total area of China's coral reefs including fringing reefs, atolls and platform reefs, and reports range from 30,000 km^2 (Zhang, 2000, 2001; Chen 2011), 8000 km^2 (Wang et al 2009) to 5000 km^2 (Hughes et al 2013). From all available information (Table 4.1.1) we estimated that the area of China's fringing reefs is 266.6 km^2 and the emergent area (including only reef flats and coral cays) of atolls and platform reefs is 5,287 km^2 (the same as Zhao 1999 and Chen 2011). We calculated the whole reef ecosystem area, including underwater reef support formations to depths of 300m to be about 50,000 km^2. We estimated the total area of living coral reefs in China (area of coral communities not included) to be about 5,554 km^2, which is the fringing reef area of 266.6 km^2 plus the emergent area of atolls and platform reefs of 5287 km^2. And the total area of coral reefs in China, including living coral reefs, and dead or fossil coral reefs is about 50,000 km^2.

Table 4.1.1: Area of China's Coral Reefs (coral communities not included)

Location	Latitude	Longitude	Area (km^2) (Fringing Reef)	Emergent Area* (km^2) (Atolls and platform reefs)	Area including underwater habitat† (km^2) (Atolls and platform reefs)	Reference
Southern China	21°03′ - 20°15' N	107°33' - 109°56' E	44.6			Song (2007)
Hainan Island	20°10' - 18°10' N	108°37' - 111°05' E	222 (500, before 1960s)			Zhou 2004, Chen 1997
Dongsha Islands	20°40′ N	116°45′ E		417	600	Zhao (1999), Dai (2006)
Xisha Islands	17°08′ - 15°46′ N	111°11′ - 112°54′ E		1836	15795（to 300m depth）	Zhao (1999, 2008)
Zhongsha Islands	19°33′ - 13°57′ N	113°02′ - 118°45′ E		130	7554 （to 300m depth）	Zhao (1999, 2008)
Nansha Islands	11°55′ - 3°35′ N	109°30′ - 117°50′ E		2904	26059（to 200m depth）	Zhao (1999, 2008)
Subtotal			266.6	5287	50008	

*Note: *The emergent area is only the area of reef flats and coral cays.*
†Area including underwater habitat is calculated as the whole area of water depth shallower than 300m (Xisha Islands and Zhongsha Islands) or 200m (Nansha Islands).

NUMBER OF SPECIES OF MAJOR TAXA RECORDED

Zou (2001) described a total of 54 genera and 174 scleractinian coral species in mainland China. Among them, 21 genera and 45 species of shallow water reef-building corals are found offshore in Guangdong Province and Guangxi Zhuang Autonomous Region; 34 genera and 110 species occur in Hainan Island; 38 genera and 127 species occur in the Xisha (Paracel) Islands; 33 genera and 94 species and subspecies occur in the Nansha (Spratly) Islands.

The number of newly reported identifiable species of reef-building corals recorded from our surveys is 210 species (Huang et al 2006, 2009, 2011a, 2011b, 2012a, 2012b, 2012c; Lian et al 2010). Recently published checklists of whole of China's marine biodiversity recorded about 260 scleractinian coral species (Chen 2003, Huang et al 2007, Liu et al 2008), which included species from Dongsha Island and Taiping Island, Nansha Islands.

The newest and most comprehensive and taxonomically authoritative species checklist book, *Checklist of Marine Biota of China Seas,* edited by RY Liu (2008) recorded a total of 22,629 marine species. According to this book, some 260 scleractinian coral species and their distribution were recorded (Table 4.1.2; Liu [2011]).

Table 4.1.2 Scleractinian coral diversity and distribution in China

Location	Number of Genus	Number of Species
Nansha Islands	50	200
Xisha Islands	38	127
Dongsha Island	27	70
Huangyan Isle, Zhongsha Islands	19	46
Hainan Island	34	110
Taiwan	58	230
Hong Kong	21	50
Guangdong & Guangxi	21	45
Fujian	13	13

A total of 2700 marine species were recorded from the Xisha Islands (Liu 2011) and 6500 marine species from the Nansha Islands (Chen 2003). In 1994, the first compilation of marine species for all of China's seas, *Marine Species and Their Distribution in China's Seas* (Huang 1994), recorded a total of 20,278 species, which was updated to 22,561 species in the 2nd edition published in 2007 (Huang et al 2007). In the 1st edition, Huang (1994) compared the species richness of major taxa in the South China Sea and other seas and concluded that the South China Sea is richest for corals and all taxa in total (Table 4.1.3).

Table 4.1.3: Species number of some taxa groups recorded in the China seas

taxa group	China Sea	The Huanghai & Bohai Sea	The East China Sea	The South China Sea
Pyrrophyta	255	74(16)	117(33)	182(50)
Rhodophyta	443	112(49)	217(94)	264(166)
Hydromedusae	435	101(25)	288(73)	307(106)
Reef-building corals	195	0	27(0)	193(160)
Snails	1115	130(57)	565(142)	686(279)
Opisthobranchia	450	108(36)	228(58)	343(179)
Cephalopod	101	14(2)	76(14)	82(24)
Copepoda	523	125(23)	317(25)	458(172)
Shrimps	476	49(4)	138(20)	316(212)
Crabs	734	90(23)	305(75)	578(349)
Echinoderms	474	57(30)	139(44)	379(291)
Fishes	3032	280(48)	1750(573)	1825(687)
Total	8133	1140(313)	4167(1151)	5613(2675)

Note: The numbers in parentheses are the number of species recorded only in the local seas.

CORAL REEF MONITORING SITES AND CHANGES IN HARD CORAL COVER

The selected six representative sites with distribution of scleractinian coral communities or coral reefs are the most studied and monitored. They are all in the relatively fast developing and economic growth areas. Their status is demonstrative of the current status and trends of coral communities and coral reefs in China.

The first 2 sites (Fig. 4.1.1) are representative of China's coral communities. Coral communities are scattered along southern China's coastal waters, mainly in Guangdong and Fujian Province, typically in Daya Bay and Dongshan (Fig. 4.1.1). The coral community in Dongshan (23°45′N) of Fujian is the northern most limit of hermatypic coral distribution in mainland China. The other 4 sites are representative of China's coral reefs. Coral reefs in China include fringing reefs along the south most Guangdong (Leizhou Peninsula), offshore island of Guangxi (Weizhou Island and Xieyang Island), around most part of Hainan Island and atolls of South China Sea (including Xisha Islands, Zhongsha Islands and Nansha Islands).

In 2005 to 2006, extensive surveys using line intercept transect method were conducted to evaluate the status of coral reefs. After this time, different sites were added from different monitoring or survey sources. The 2005 to 2006 data provided the baseline condition that can be used for future analysis. Figure 4.1.2 shows the species richness of scleractinian corals in the six representative sites, and Figure 4.1.3 shows the average percent cover of live scleractinian corals of the six sites recorded in 2005 to 2006. These results indicated the low biodiversity and low live coral cover condition in general. The average percent cover of live scleractinians was less than 30% except in the offshore atolls of Xisha Islands.

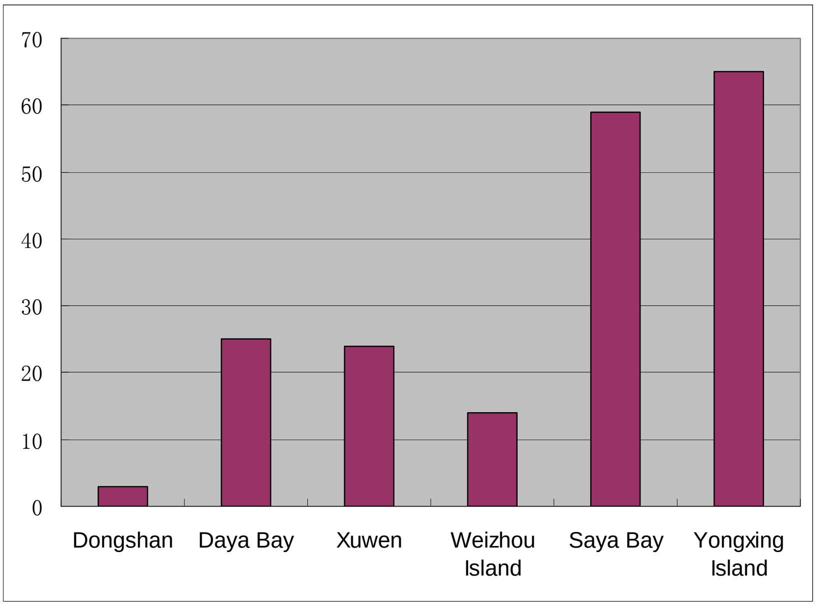

Fig. 4.1.2: Number of reef-building coral species of the selected 6 representative sites in 2005 to 2006

The distribution area of stony corals was also reduced greatly because many places of coral habitats had been lost, such as in Dongshan, Daya Bay, Xuwen, Weizhou Island, and Sanya. The reef community structure underwent phase shifts and change of dominant species from branching to massive corals in most of these areas. The degradation trends of coral reefs in China are continuing. The economic and population growth, particularly in coastal areas, are the major contributors to the degradation of coral reefs.

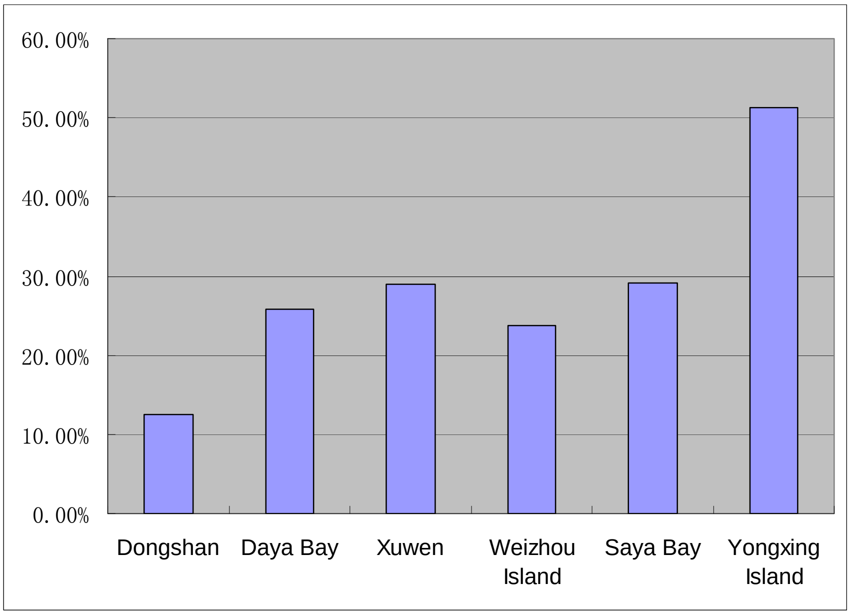

Fig. 4.1.3: Percent cover of live reef-building corals of the selected six representative sites in 2005 to 2006

(1) Dongshan Island

Dongshan Island (23°45′N), in southeast China's Fujian Province, is the north most range of reef-building coral communities in mainland China.

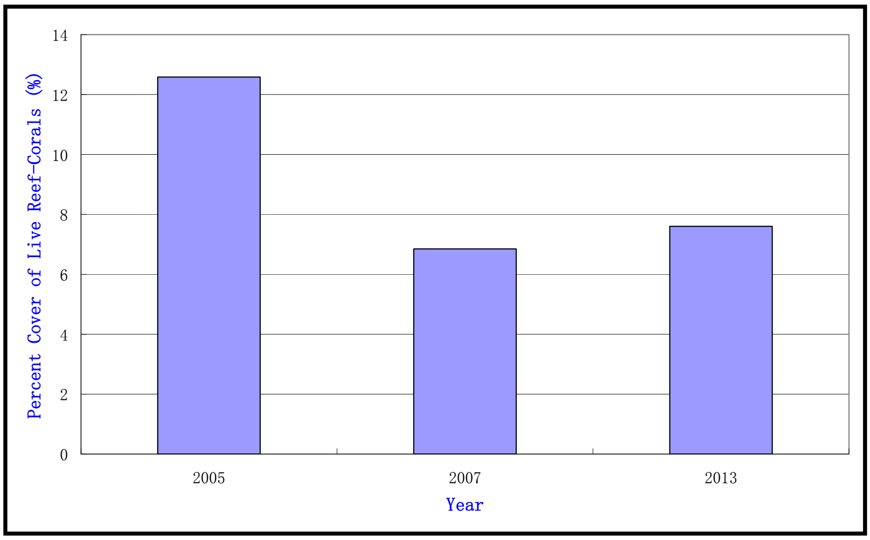

Fig. 4.1.4: Percent cover change of live reef-corals at the Dongshan site, Fujian Province.

This site had lost some coral habitat to mariculture, coastal development and poor water quality in the past 8 years. The percentage of live coral cover declined (Fig. 4.1.4) but species number of the reef-building coral communities increased from 6 to 9, species number of scleractinian coral increased from 8 to 13, with enhanced survey effort.

(2) Daya Bay

Daya Bay (22°40′N), in southern China's Guangdong Province and neighboring Hong Kong and Shenzhen, is a typical subtropical semi-enclosed bay with two nuclear power plants located in its middle-west side since 1990s. Daya Bay is a relatively well managed marine ecosystem in China. With the great economic development, especially the fast growing petro-chemical industry in the north and tourist industry around the bay, some coral habitats were lost due to port construction and coastal development. Coral transplantation had been practiced four times to relocate the reef-building coral communities. The percent cover remained almost unchanged at 30% after 1990s (Fig. 4.1.5). Chen et al (2009) reported about 20% live coral cover in 2008 and 2009 in Dalajia area, but they surveyed only one station in Dalajia and did not include Samendao area, which we surveyed and accounted for in the above. The species number of the reef-building coral communities is about 40.

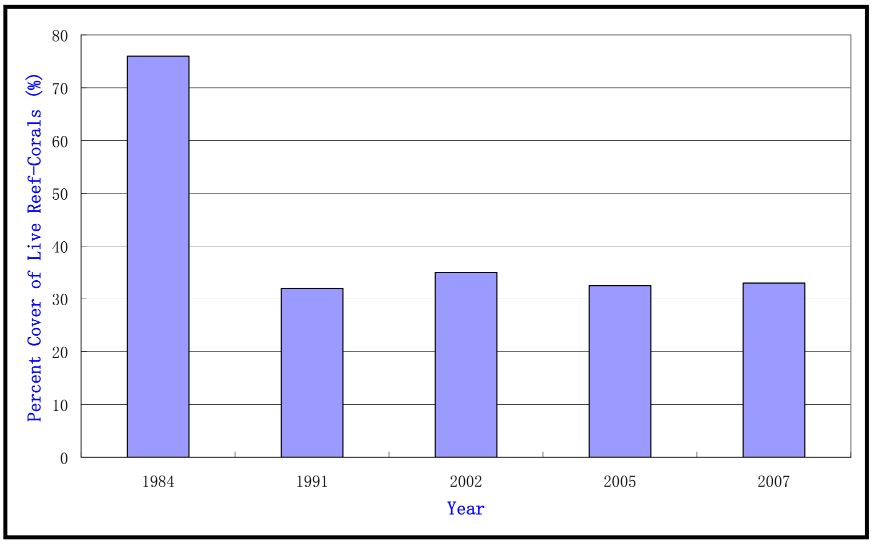

Fig. 4.1.5: Percent cover change of live reef-corals at the Daya Bay site, Guangdong Province

(3) Xuwen

Xuwen (western coast of Leizhou Peninsula, 20°15′N) also in Guangdong Province, is famous for its north most presence of coral reefs in mainland China's coast. This site is located in an undeveloped area with very few industry around. The major threats to these coral reef comes from the poor water quality, local fishers, mariculture and coastal development. In the past 8 years, the percent cover experienced a rapid decline in 2008 and 2009 (Fig. 4.1.6) due maybe to the impact of typhoons. The species number of the reef-building coral is about 60.

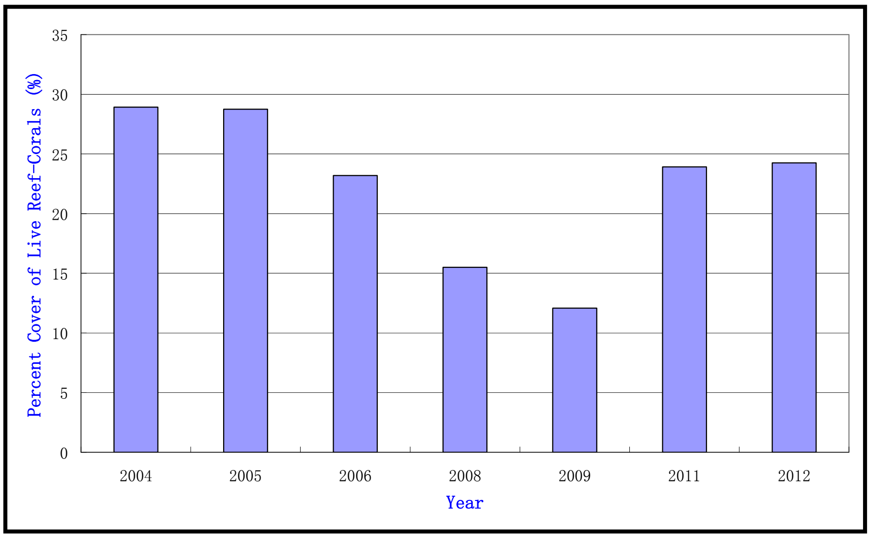

Fig. 4.1.6: Percent cover change of live reef-corals at the Xuwen site, Guangdong Province

(4) Weizhoudao

Weizhoudao Island (21°03′N) in Guangxi Zhuang Autonomous Region, is an offshore island with a well-developed fringing reef and become a marine park since 2011. A marine park is a special kind of MPA in China's regulations. Weizhoudao Island is a famous tourist destination. Some coral reef habitats were lost due to mariculture and coastal development in the past 8 years. The percent cover has not changed much (Fig. 4.1.7). The species number of the reef-building coral is about 40.

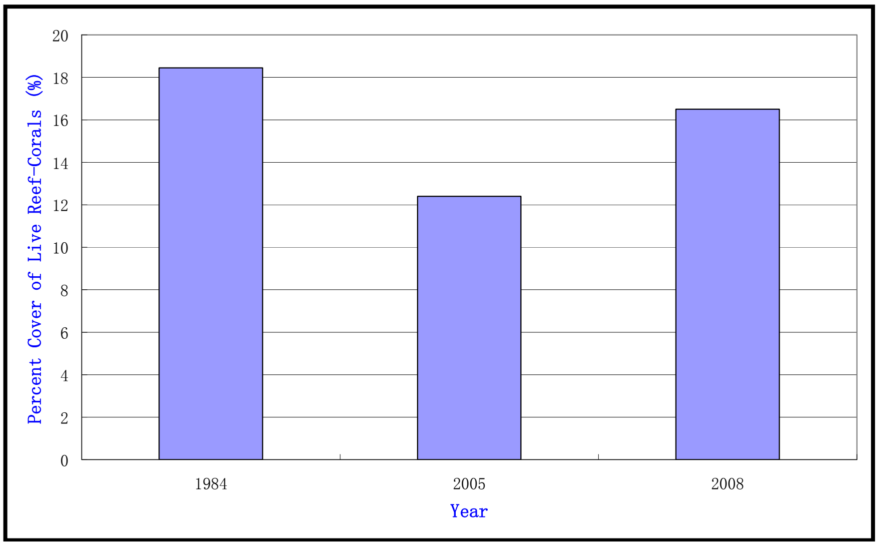

Fig. 4.1.7: Percent cover change of live reef-corals at the Weizhoudao site, Guangxi

(5) Sanya

Sanya city is (18°14′N) located at the south-most tip of mainland China's Hainan Province. The coral reefs in Sanya have the longest history of studies since the 1950s. The first national level MPA of coral reef in China was established in Sanya in 1990. Sanya city is one of China's most famous tourist destinations and one of the fastest economic-growing city. Luhuitou and Yalong Bay are two typical coral reef areas being monitored.

Coral reef habitat loss is almost inevitable due mainly to coastal development. The coral reef in Xiaodonghai, Dadonghai and some areas of Yulin Bay are almost totally damaged. The species number of the reef-building coral for whole of Sanya is about 100.

Luhuitou of Sanya Bay, is the longest studied coral reef since 1950s. The percent cover increased slightly (Fig. 4.1.8a), which may be because of improving water quality as more of the city's waste water is being collected and processed over the past 8 years. However the coral reef habitat in Luhuitou may be lost to port construction for the Volvo sailing yacht Sanya (Sanya station).

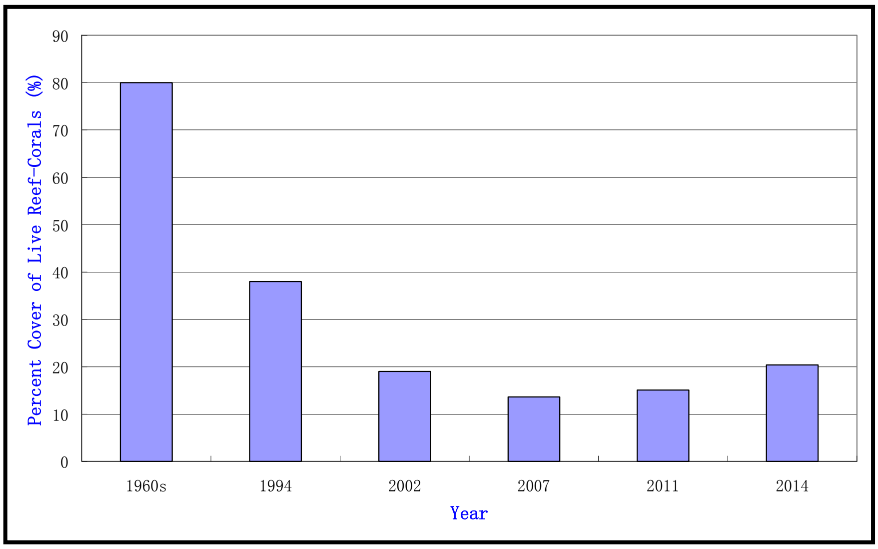

Fig.4.1.8a: Percent cover change of live reef-corals at the Sanya Luhuitou site, Hainan Province

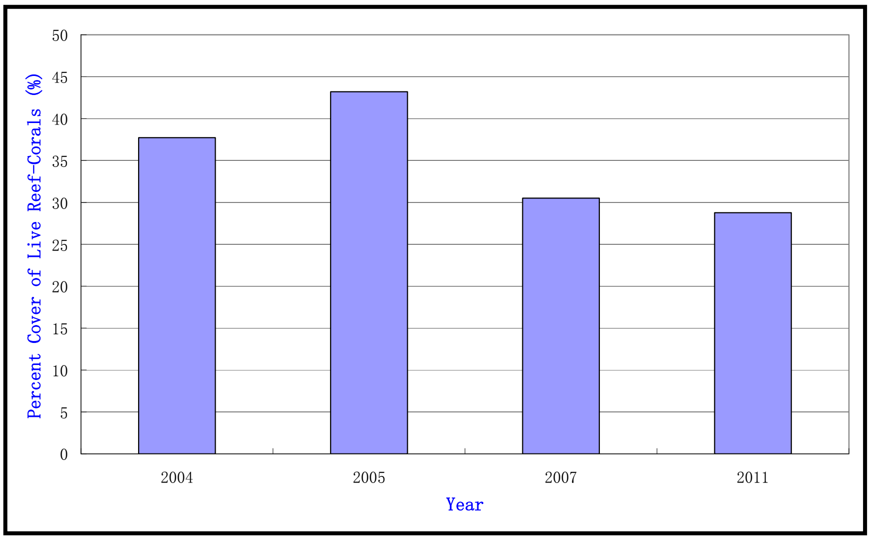

Fig. 4.1.8b: Percent cover change of live reef-corals at the Sanya Yalong Bay site, Hainan Province

Yalong Bay, in the east of Sanya city, has the best water quality and best environment and landscape in Sanya. Before 2000, the best coral reef was in Yalong Bay's Xipai Reef, but it was almost totally damaged by some nearby engineering and outbreak of crown-of-thorns starfish during 2001-2004 with resulting community phase shift. It is puzzling that Xipai Reef has not shown any recovery. In general, the percent cover in Yalong Bay decreased slightly (Fig. 4.1.8b) in the past 8 years.

(6) Yongxing Island

Yongxing (Woody) Island about 2 km^2 in area, is a biggest island of Xisha Islands (16°50′N) in the South China Sea belonging to Hainan Province. After the infestations of crown-of-thorns starfish during 2007-2009 in most areas of Xisha Islands, the percent cover of the live stony corals declined from 70％ before 1980s to about 50％ in 2006, and dropped to about 3% and 1% in 2008 and 2009. In recent years, slow recovery was observed and the percent cover of the live stony corals was about 5% in 2012 (Fig. 4.1.9). A big port was constructed and coral reef habitat loss occurred in the past 5 years.

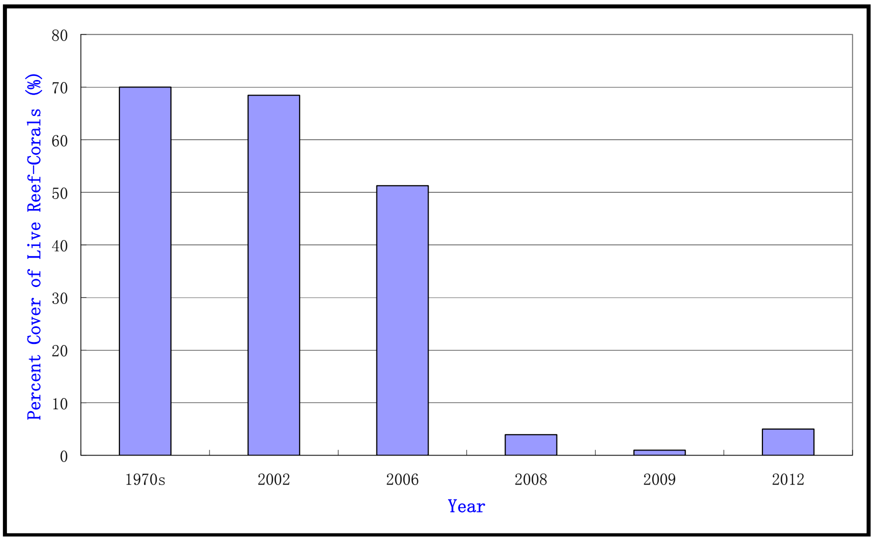

Fig. 4.1.9: Percent cover change of live reef-corals at the Yongxing Island site, Xisha Islands

Yongxing Island is representative of the Xisha Islands (15 ° 45'N - 17 ° 15'N, 111 ° E - 113 ° E) in terms of coral cover change. Xisha Islands consist of about 44 islands, and most belong to a number of large atolls. The biodiversity in Xisha Islands is quite abundant. Some 210 species of the reef corals were recorded so far, but the coral reef ecosystem has been degrading in the past 20 years. In terms of live coral cover, the reefs were in good condition before 2002 with >70% coral cover in many areas of the Xisha Islands. Basically healthy reefs were observed in 2006, and the average live coral cover was about 50~60%. Following the mass coral death after 2007 due to outbreak of the crown-of-thorns starfish, live coral cover declined to less than 1% after 2009. The recent survey in 2012 found that some local shallow areas were recovering well with live coral cover of more than 40%, but in most of the other areas, the recovery speed was very slow due to recruitment limitation.

Compared to the historical record of corals in all six sites, coral communities and coral reefs have degraded over the last 30 to 50 years at a fast pace. Coral reefs were in good condition before 1984, where coral cover was >70% in many areas, such as 76% in Daya Bay, >70% in Weizhou Island, Sanya and Xisha Island. In the 1990s, reef condition declined at great pace due to the fast social-economic growth. Coral percent cover was 32% in Daya Bay in 1991, and 38% in Luhuitou, Sanya, in 1994. The surveys in 2005-2006 showed the mean live coral cover down to 30% in Daya Bay, 24% in Weizhou Island 29% in Sanya, and 68% and 51% in Yongxing Island, Xisha Island in 2002 and 2006 respectively.

The distribution area of stony corals was also reduced greatly because many places of coral habitats had been lost, such as in Dongshan, Daya Bay, Xuwen, Weizhou Island, and Sanya. The community structure underwent phase shifts and a change of dominant species from branching to massive corals occurred in most of these areas. The degradation trends of coral reefs in China are continuing mainly due to habitat loss, although the live coral cover seems not much changed. The economic and population growth, particularly in coastal areas, are the major contributors to the degradation of coral reefs.

STRESS AND DAMAGE TO CORAL REEFS

The heavy population and fast economic growth bring much stress to the coral reefs in mainland China. Loss of reef habitat and reduced biodiversity of coral reefs have occurred over a long period and especially in the recent 30 years.

One example for loss of coral habitat from coastal development in Daya Bay, Mabianzhou Island and the north bank of Daya Bay occurred when reefs were blasted or reclaimed for the oil industry in late 1990s. Although coral reef transplantation has been carried out to reduce the impact of reef destruction, the damage to coral reefs is still great.

Climate change is still not considered as a critical threat to China's coral reefs. There were a few reports about coral bleaching due to the extreme high temperature in China: mass bleaching events were observed at Weizhoudao (Guangxi), and Nansha Islands, and informally recorded in 1997-1998; and medium sized bleaching events were observed and recorded in Sanya and Xisha Islands in 2010 (Li et al 2012, 2013).

Major stressors driving the degradation of China's reefs were direct reef damage by coral collection for mining or decoration, and destructive fishing activities before the 1980s. Coral reefs can provide raw materials for building construction. The use of stony coral for limestone has been practiced for several decades in Xuwen, Guangdong province and Hainan Island.

After 1980s, especially in the last two decades with the rapid growth of economy and development, the main threats are mariculture in coral reef areas, over-fishing, and water quality deterioration caused by eutrophication, coastal development, sedimentation, sewage pollution, and outbreaks of crown-of-thorns starfish. These stressors can drive coral communities and coral reef degradation directly through increased coral mortality, or indirectly, by increasing competitive species (algae) and decreasing coral recruitment.

Overfishing and destructive fishing practices have badly damaged coral communities around southern China's coastal area and Xisha islands. Valuable edible fish and mollusc species are the target, causing most high-value fish species to become locally extinct. Illegal fishing activities and the sale of live corals for the aquarium trade are also problems. Blast fishing and use of cyanide are very destructive to coral reefs. Blasting has been often observed in Daya Bay, around Hainan Island or even in remote islands such as Nansha Islands. Cyanide-fishing is carried out by large-scale commercial operators who take fish from remote areas such as Xisha islands and Nansha islands. Cyanide is also used for collecting aquarium fishes.

Human activities on land such as coastal development, aquaculture and agriculture cause sediments and nutrients to flow onto coral reefs. Sedimentation and sewage outflows have adversely impacted China's reefs, particularly near the mainland. Typical example is Sanya's coral reef. The 2007-2008 biodiversity survey in Sanya showed that sewage and river discharges to Sanya Bay and Yulin Bay caused significant damage to the surrounding coral reefs compared to Yalong Bay, which has little runoff and where the biodiversity is high and coral reefs are more healthy.

Outbreaks of the coral predator, crown-of-thorns starfish occurred in Sanya in 2003 to 2004 and in Xisha Islands in 2006 to 2009. The population of COTs is still high in Sanya and Xisha. Many places were almost denuded by COTs in the recent years. The corallivorous snail (*Drupella* sp. or *Cronia* sp.) was found in most of China's coral area, however, damage by the snails seems to be not a serious problem. Special attention should be paid to the crown-of-thorns starfish, which can develop large-scale outbreaks and need physical removal regularly and long-term monitoring.

Table 4.1.4: Major threats to coral reefs in mainland China (Y = yes, N = no)

Region/ Province	Site	Past Direct Damage	Destructive Fishing	Mariculture	Over-Fishing	Development	Sedimentation	Pollution
Fujian	Dongshan	Y	Y	Y	Y	Y	Y	Y
Guangdong	Daya Bay	Y	Y	Y	Y	Y	Y	Y
	Xuwen	Y	Y	Y	Y	Y	Y	Y
Guangxi	Weizhou Island	Y	Y	Y	Y	Y	Y	Y
Hainan	Sanya Bay	Y	Y	N	Y	Y	Y	Y
Xisha Islands	Yongxing Island	Y	Y	N	Y	Y	N	N

The incidence of coral disease seems not serious. However, outbreaks of "black disease" of reef-building corals, which may be caused by cyanobacteriosponge, *Terpios hoshinota* (Suberitidae; Hadromerida) were recorded in Xisha Islands. The incidence of "black disease" was also reported in Guam (Bryan, 1973) and in Taiwan (Liao, et al 2007; Soong et al 2009).

Reef-related tourism is rapidly developing in China, especially in Sanya. In the last decade the natural beauty and uniqueness of coral reefs have attracted millions of tourists both domestic and international. Places like Yalong Bay, Xipai Island, West Island, Dadonghai, Xiaodonghai have become major tourist destinations in the country. Tourism may be a big potential threat to China's coral reefs. The major threats to coral reefs in mainland China are summarized in Table 4.1.4.

CONCLUSIONS AND RECOMMENDATIONS

The coral communities and coral reefs in the mainland China are being unprecedentedly degraded over the last 30 to 50 years, overwhelmingly by anthropogenic stressors. This situation in China is to some extent different from other countries with coral reefs, where global climate change is more threatening to coral reefs than other factors. However, in recent years, the degradation trend of the coral communities and coral reefs in mainland China is continuing but seems to have slowed down in the past 3 to 5 years. Much habitat loss is still inevitable due to coastal development and engineering but the live coral cover has not changed much in the past 5 to 8 years for Dongshan (Fujian province), Weizhoudao (Guangxi), Daya Bay and Xuwen (Guangdong province), and Sanya, Hainan Island.

The most remarkable event for coral reefs in China was the outbreak of crown-of-thorns starfish in Xisha Islands (and may be in the whole South China Sea) and the reefs were almost denuded during 2007-2009. The recent survey in 2012 found that some local shallow area recovered well with live coral cover more than 40%, but the recovery speed of most other areas was slow due to recruitment limitation. Few reports of coral bleaching in China include the mass bleaching events that were observed and informally recorded in both Weizhoudao (Guangxi), and Nansha Islands in 1997-1998, and moderate bleaching events in Sanya and Xisha Islands in 2010.

Major stressors driving the degradation of reefs in China were direct reef damage from coral collection for mining or decoration, and destructive fishing activities before 1980s. After 1980s, especially in the last two decades with the rapid growth of the economy and development, the main threats are mariculture in coral reef areas, over-fishing, water quality deterioration caused by eutrophication, coastal development, sedimentation, sewage pollution, and outbreaks of crown-of-thorns starfish. These stressors can drive coral community and reef degradation directly through increased coral mortality, or indirectly, by increasing competitive species (algae) and decreasing coral recruitment. The degradation of the coral ecosystem is manifested by a decrease in area of scleractinian coral distribution, reduction in percent cover and biodiversity of coral reefs with a concurrent increase in the percent cover of soft corals or macro algae, and by phase shifts of the ecosystem from coral-dominated to algal or soft coral-dominated reefs.

A fishing activity, which is digging of buried giant clam shells for shell craft making, is practiced commonly by fishermen of Hainan Island for the past 3 to 5 years. This destructive fishing practice is a serious threat to China's coral reefs. Many reefs of

Xisha and Nansha Islands are directly damaged by this practice.

Table 4.1.5: Degradation status of the coral reefs in mainland China in recent years (Y = yes, N = no)

Region/ Province	Sites	Area decrease	Percent cover decrease	Mass bleaching	COTs	Phase shift
Fujian	Dongshan	Y	N	N	N	
Guangdong	Daya Bay	Y	N	N	N	
	Xuwen	Y	N	N	N	Y
Guangxi	Weizhou Island	Y	N	In 1998	N	
Hainan	Sanya Bay	Y	N	2010	Y	Y
Xisha Islands	Yongxing Island	N	Y	2010	Y	?

In the last twenty years, coral reefs in China faced many pressures and problems. Special coordinating efforts from government, local communities and scientists are needed. The major challenge for coral reef conservation and management of China is to balance the need of its growing maritime economics (e.g. fishing, aquaculture and tourism) that depend on coral reef resources with the need to protect and manage the reefs in a way that sustains its value. The government and society should consider a subtle balance between short-term economic benefits and the long-term sustainable use of environmental and ecological resources, although it is always difficult and sensitive for government and society. More efforts should be taken for development of ecologically and sociologically sound models for management, and for effective education of people on the value of biological conservation. The perspectives on coral reefs in China should be better in the near future. However, it is a changing perspective, depending on how much effort is made. If no strong measures are taken to protect the coral reefs, then the degradation status may exacerbate in the future due to the combined effects of natural factors such as global warming, ocean acidification, outbreak of crown-of-thorns starfish, and various anthropogenic factors such as eutrophication, urbanization, mariculture, and overfishing.

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4.2. TAIWAN

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SUMMARY

The status of coral reefs and non-reefal coral communities in Taiwan were synthesized based on the 4-year data (2010-2013) of the ReefCheck method from 6 regions including, northeastern coast, eastern coast, Lutao, Lanyu, Hsiaoliuchiu, and Penghu Islands. In addition, an analysis of the long-term ecological research (LTER) data was obtained from the Kenting National Park, southern Taiwan. Mean living coral cover (LCC) of the 37 sites varied from 3.06±0.958% to 72.81±10.263%, however, high variation was found among the years in some regions depending on the site selected for the surveys. Based on the LCC, coral communities under “poor” condition (LCC<25%) were found in northeastern coast, Taitung, Hsiaoliuchiu, Kenting, Lanyu, whereas those in Penghu and Lutao were in “fair” and “good” conditions. The abundance of fish and invertebrate indicators at most of the sites was very low suggesting that coral reefs and non-reefal coral communities in Taiwan suffered from overfishing. All of these data suggested that most reefs and coral communities in Taiwan were under relatively high impact of anthropogenic stresses. Most reefs and coral communities are located within national scenic areas or national parks in Taiwan, but their management is not effective. Nevertheless, the recent development of marine protected area demonstration sites and sewage treatment facilities in the Kenting National Park, the listing of humphead wrasse and bumphead parrotfish as “endangered species” under the Wildlife Conservation Law, and the NGO-lead ReefCheck operation, are encouraging. These activities have raised public awareness and their effectiveness on conservation. In addition, adequate laws and action should be established or revised for the authorities to enforce management policies and to protect the coral reefs and communities in Taiwan.

COUNTRY STATISTICS AND CORAL REEF RESOURCES IN 2014

Taiwan lies on the northern edge of the Coral Triangle and the marine environment is mainly influenced by the Kuroshio Current, which flows from the Philippines to southern Japan (reviewed in Chen, 1999; Chen and Keshavmurthy 2009). Corals are found in southern, eastern, northern Taiwan, and most offshore islands around

Taiwan (Fig. 4.2.1). The main coral reef area is located on the coast around the southern tip of Taiwan, Lutao (Green Island), Lanyu (Orchid Island) off southeastern Taiwan, and Hsiaoliuchiu off southwestern Taiwan, where well-developed fringing reefs can be found. The northern, northeastern rocky coasts, and Penghu Islands (the Pescadores) in the Taiwan Strait have flourishing or patchy coral communities with scattered reef development (Chen and Keshavmurthy 2009). These areas are characterized by diverse and abundant scleractinians and alcyonaceans (Dai, 1991; Dai and Horng 2009). The status of coral reefs in eight reef regions around Taiwan has been monitored by the ReefCheck method from 1997 to the present, and a long-term ecological research (LTER) from 2000 to the present in the Kenting National Park, southern Taiwan (Kuo et al. 2012).

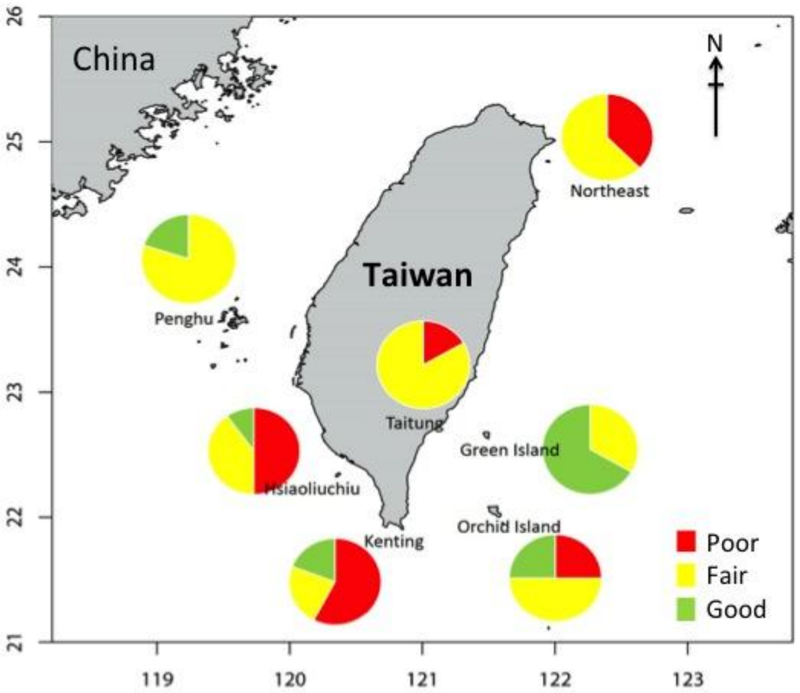

Fig. 4.2.1: Map of Taiwan showing regions of coral reef monitoring and condition of reefs based on living coral cover (LCC). Poor: LCC <25%; Fair: LCC between 25% and 50%; Good: LCC>50%.

NUMBER OF SPECIES OF MAJOR TAXA RECORDED

Species diversity of reef organisms on the coral reefs around Taiwan is relatively high and new species of corals and reef-associated organisms are continuously being discovered (Dai and Horng 2009; Lin et al. 2012; Pichon et al. 2012; Chan et al. 2014; Tsang et al. 2014). Approximately 300 species of scleractinian corals, 50 species of alcyonaceans, 20 species of gorgonians, 130 species of decapod crustaceans, 90 species of echinoderms, 1200 species of reef fishes and 150 species of algae have been recorded from coral reefs in southern Taiwan, Lutao and Lanyu (Shao 1994). About 200 species of scleractinian corals and 1000 species of fishes have been reported from Hsiaoliuchiu and Penghu islands (Chen et al. 1992, Shao et al. 1994). Approximately 100 species of scleractinian corals and 800 species of fishes have been reported from the coastal areas in the northeastern coast of Taiwan. A total of 229 species of scleractinians, 47 species of alcyonaceans, and 577 species of reef fishes have been recorded from Dongsha Atoll (Jeng et al. 2008). A total of 190 species of scleractinians, 16 species of alcyonaceans, and 515 species of reef fishes have been recorded from Taiping Island in the South China Sea (Shao et al. 2009). Due to limited surveys conducted on most reefs, the species diversity of reef organisms is still underestimated.

CORAL REEF AND NON-REEFAL COMMUNITY MONITORING SITES

Based on species diversity and formation of aragonite reefs, "tropical coral reefs" and subtropical "non-reefal" coral communities can be found around waters in Taiwan (Chen 1999; Chen and Keshavmurthy 2009). Tropical coral reefs, mainly fringing reefs, are formed in the south and southeastern, eastern Taiwan, and three offshore islands including, Lutao, Lanyu, and Hsiaoliuchiu (Fig. 4.2.2A, 4.2.2B).

Fig. 4.2.2: Tropical coral reefs (A, B) and nonreefal coral communities (C, D) in Taiwan. A: Kenting National Park; B: Lutao; C: Yeiliu, north coast; D: Mudou Yu, Penghu Island.

Corals grow on top of volcanic rocks in the Penghu islands, Keelung Islets, north and northeastern coast, and non-reefal coral communities are formed and mixed with algal reefs (Fig. 4.2.2C, 4.2.2D). Monitoring of these coral communities has been conducted sporadically based on short-term ecological impact assessments since late 1980s. Volunteer-based ReefCheck monitoring on 6 regions was started by the Taiwan Coral Reef Society (TCRS) since 1997, and by the Taiwan Environmental Information Association (TEIA) since 2009 (Fig. 4.2.1). A long-term ecological research (LTER) was funded by the National Science Council (NSC) and the Kenting National Park (KNP) specifically on 9 monitoring sites since 2000 (Kuo et al. 2012).

CHANGES IN PERCENT HARD CORAL COVER AT DIFFERENT SITES - YEARLY COMPARISON BETWEEN 2010 AND 2013

Living coral cover (LCC) in the 7 monitoring regions from 2010 and 2013 are listed in Table 4.2.1. LCCs were variable among sites within a region and between years, probably due to the different transect lines laid out by different volunteer teams of ReefCheck during monitoring surveys. For example, in Yeliu, northeastern Taiwan LCC was 16.09% in 2010, but ranged from 30.94% to 49.06% in surveys conducted between 2011 and 2013. This did not appear at the LTER monitoring in the Kenting National Park (KNP), where surveys were conducted by trained researchers and results showed a consistent trend among years. Nevertheless, the high variability of LCCs found in different sites within and between regions suggested heterogeneity of human disturbances in combination with natural disturbance, such as typhoons (see below), occurring in different regions of Taiwan.

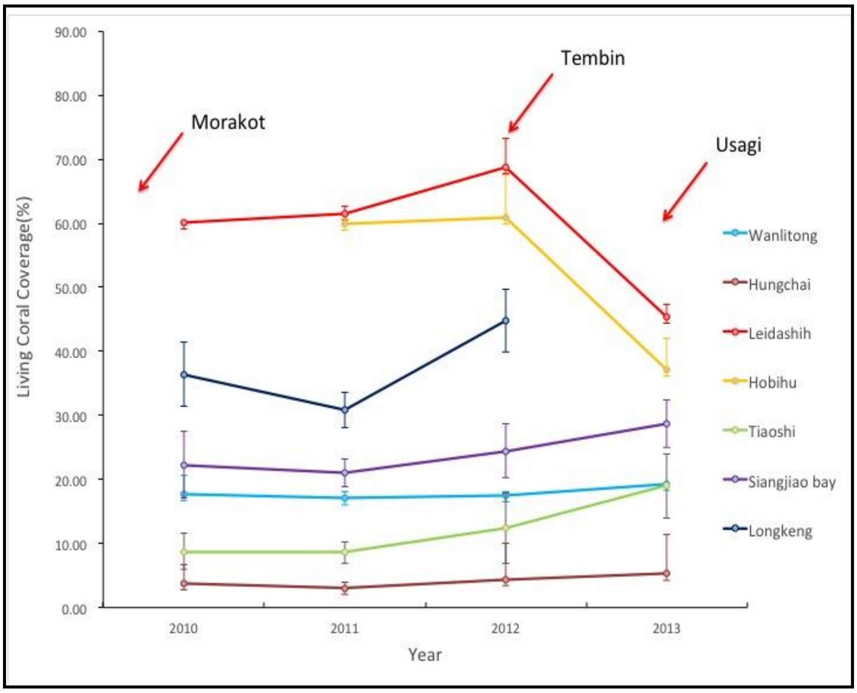

Fig. 4.2.3: Living coral cover (%) of the 7 monitoring sites of reefs in the Kenting National Park between 2010 and 2013. Arrow indicated the year that major typhoons hit.

Overall, the lowest LCC was found at Hungchai, KNP ranging from 3.06% to 5.25%, and the highest was recorded at Shiliang, Lutao in 2011 (72.81%). Physical damage caused by large wave action resulted in significant loss of LCCs in the regions hit by typhoons between 2010 and 2013 (Figure 4.2.3). For example, coral reefs in Wanlitong, Honchai, Tiaoshi, and Shianjiao Bay of the KNP were severely damaged by Typhoon Morakot in 2009 (Kuo et al. 2011), resulting in significant reduction of LCC in 2010 (Table 4.2.1).

Table 4.2.1: Living coral cover (mean%±SE) from the ReefCheck monitoring in 6 regions and a long-term ecological research in the Kenting National Park of Taiwan between 2010 and 2013.

Region	Site	Living Coral Cover			
		2010	2011	2012	2013
Northeast	Fanziauo	15.94±4.481	24.63±15.153	27.81±3.727	19.53±14.659
	Bitou	16.25±4.689	13.50±11.414	26.25±3.24	-
	Yehliu	16.09±5.944	42.34±13.923	49.06±4.192	30.94±3.098
	Longdong	31.91±12.662	36±9.15	-	-
	Hemei elementary school	-	47.75±16.165	34.22±3.425	37.81±11.322
Taitung	Shanyuan	38.13±6.816	39.00±16.004	40.63±10.582	
	Kihaw		29.38±11.169	38.75±5.962	20.31±6.445
Kenting	Wanlitong	17.70±2.928	17.03±2.993	17.49±0.182	19.34±2.01
	Hungchai	3.73±1.044	3.06±0.958	4.43±1.002	5.25±0.814
	Leidashih	60.05±0.688	61.56±5.611	68.68±4.617	45.38±6.699
	Hobihu	-	59.90±6.247	60.84±1.969	37.10±4.986
	Tiaoshi	8.76±2.776	8.62±1.701	12.42±5.547	19.00±5.068
	Siangjiao bay	22.29±5.163	21.01±2.2	24.47±4.179	28.74±3.727
	Longkeng	36.36±5.005	30.78±2.731	44.77±4.852	
Hsiaoliuchiu	Geban bay	6.88±0.957	-	-	-
	Beauty cave	10.31±1.051	-	-	-
	Houshi	19.06±3.889	44.06±4.719	49.38±1.541	-
	Yufu harbor	-	52.19±13.419	32.50±3.182	45.00±14.407
	Duozaiping	-	22.50±5.078	15.31±3.058	-
Penghu	Seven yule door	50±4.005	-	-	-
	East yuping	-	28±4.536	41.25±6.235	55.63±5.504
	West yuping	-	41±7.395	-	-
Green Island	General rock	47.50±3.089	-	49.81±7.897	51.88±1.909
	Gongguanbi	47.19±2.184	-	56.56±10.377	52.19±1.652
	Chaikou	44.06±4.211	-	55.63±6.229	52.5±2.843
	Dabaisha	-	67.81±13.302	-	-
	Shihlang	-	72.81±10.263	-	-
	Turtle bay	-	71.25±14.170	-	-
Orchid Island	Yeyin harbour	53.13±8.133	-	-	-
	Twin lions rock	46.25±8.339	36.88±3.146	-	70±1.926
	Maiden rock	52.81±7.543	-	-	-
	Hen rock	-	52.5±6.524	-	-
	Water purification station	-	25.94±5.579	-	-
	Tank rock	-	-	44.69±6.437	-
	Tudigong temple	-	21.88±3.069	15.63±1.399	-
	Yayo harbour	-	-	17.81±1.887	-
	Battleship rock	-	-	-	67.5±2.517

Subsequently, disturbances caused by Typhoon Tembin in 2012 and Usagi in 2013 also damaged reefs in Leidashih and Hobihu, where LCC was quoted as good (>50%), but changed to fair (25%-50%) after typhoon damage (Figure 4.2.3). Severe damage by typhoons was also observed in Tudigong temple and Yayo harbour of Lanyu in 2012 and 2013.

INDEX SCORES OF MAJOR FISH, BENTHIC TAXA, AND TRENDS IN CORAL REEF RESOURCE USAGE

Abundance estimates of keystone fishes are listed in Table 4.2.2.

Table 4.2.2: Abundance estimates (no./100m^2) of keystone fishes from the ReefCheck monitoring in 6 regions of Taiwan between 2010 and 2013

Region	Keystone fish	Density (no./100m^2)			
Year		2010	2011	2012	2013
Northeast	Butterflyfish	2.25	4.45	2.86	4.52
	Haemulidae	0.07	0.03	0.23	0.25
	Snapper	0.13	0.07	0.04	0.48
	Barramundi cod	0.03	0.07	0.04	0.13
	Humphead wrasse	0	0	0	0
	Bumphead parrot	0	0	0	0
	Parrotfish	0.57	0.32	0.2	0.02
	Moray eel	0.10	0.12	0.14	0.04
Taitung	Butterflyfish	1	1.38	0.19	1.63
	Haemulidae	0	0	0	0
	Snapper	0	0.19	0.06	2.88
	Barramundi cod	0	0	0	0
	Humphead wrasse	0	0	0	0
	Bumphead parrot	0	0	0	0
	Parrotfish	0	0	0	0.63
	Moray eel	0	0	0	0
Hsiaoliuchiu	Butterflyfish	2.25	6.13	1.54	7.13
	Haemulidae	0.04	0.08	0.04	0
	Snapper	0.63	0.04	0	0
	Barramundi cod	0	0	0	0
	Humphead wrasse	0	0	0	0
	Bumphead parrot	0	0	0	0
	Parrotfish	0.29	2.29	0	5.63
	Moray eel	0.08	0.04	0.04	0
Penghu	Butterflyfish	3.63	4.75	1.17	4.5
	Haemulidae	0	0	0.17	0
	Snapper	0	0.88	0	2.63
	Barramundi cod	0	0	0	0.13
	Humphead wrasse	0	0	0	0
	Bumphead parrot	0	0	0	0
	Parrotfish	1	0.13	2.17	0
	Moray eel	0.13	0	0.08	0.25
Green Island	Butterflyfish	4.38	4	1.33	1.65
	Haemulidae	0.08	0	0	0.05
	Snapper	0.42	0.08	0.79	0
	Barramundi cod	0	0	0	0
	Humphead wrasse	0	0	0	0
	Bumphead parrot	0	0	0	0
	Parrotfish	0.67	0.46	0.17	0.15
	Moray eel	0.08	0.04	0.13	0
Orchid Island	Butterflyfish	3.08	2.83	2.63	0.67
	Haemulidae	0	0	0.17	0.13
	Snapper	1.96	0.50	0.13	0.08
	Barramundi cod	0	0	0	0
	Humphead wrasse	0	0	0	0
	Bumphead parrot	0	0	0	0
	Parrotfish	0.5	0.63	0.17	0
	Moray eel	0.08	0.13	0	0

The relative abundance of fishes were consistently low among the regions and years with several targeted taxa such as, humphead wrasse and bumphead parrotfish, not observed throughout the entire extent of coral reefs and non-reefal communities in Taiwan. Similar patterns were also observed in key macro-invertebrates (Table 4.2.3) that extremely low abundances were recorded from the hard substrates around Taiwan. These data suggested that coral reefs and non-reefal coral communities in Taiwan suffer from long-lasting and severe overfishing.

Table 4.2.3: Abundance estimates (no./100m^2) of key macro-invertebrates from the ReefCheck monitoring in 6 regions of Taiwan between 2010 and 2013

Region		Density			
Year	Key marcro-invertebrates	2010	2011	2012	2013
Northeast	Banded coral shrimp	0.65	0.08	0.25	0.54
	Diadema urchin	0.6	1.98	0.84	1.02
	Pencil urchin	0.03	0	0	0
	Collector urchin	0.08	0.20	0.25	0.27
	Sea cucumber	0	0	0	0
	Crown-of-thorns	0	0	0	0
	Triton	0.07	0	0	0.04
	Lobster	0.12	0.07	0.04	0.02
	Giant clam	0.03	0.02	0.04	0.02
Taitung	Banded coral shrimp	0	0.06	0	0
	Diadema urchin	3.5	0.25	0.06	1.0
	Pencil urchin	0	0	0	0
	Collector urchin	0.25	0	0	0
	Sea cucumber	0	0	0	0
	Crown-of-thorns	0	0.06	0	0
	Triton	0	0	0	0
	Lobster	0	0	0.06	0
	Giant clam	0.13	0.06	0.44	0.13
Hsiaoliuchiu	Banded coral shrimp	0.08	0	0	0.5
	Diadema urchin	1.92	2.96	1.04	2.75
	Pencil urchin	0	0	0	0
	Collector urchin	0.08	0.21	0	0
	Sea cucumber	0.04	0	0	0
	Crown-of-thorns	0	0	0	0
	Triton	0	0	0	0
	Lobster	0	0	0.04	0
	Giant clam	0.25	0.46	0.21	0.13
Penghu	Banded coral shrimp	0	0	0	0
	Diadema urchin	7.13	0.50	1.17	0.63
	Pencil urchin	0	0	0	0
	Collector urchin	0	0.13	0	0.38
	Sea cucumber	11.13	0	0	0
	Crown-of-thorns	0	0.13	0	0
	Triton	0	0	0	0
	Lobster	0	0	0	0
	Giant clam	0	0.13	0.25	0.13
Green Island	Banded coral shrimp	0	0	0	0.15
	Diadema urchin	4	1.08	2.38	0.2
	Pencil urchin	0.21	0	0	0
	Collector urchin	0	0	0	0
	Sea cucumber	0	0.04	0	0
	Crown-of-thorns	0.04	0.04	0.42	0
	Triton	0	0	0	0
	Lobster	0	0	0	0
	Giant clam	1.13	1.04	1.67	1.15
Orchid Island	Banded coral shrimp	0.04	0.04	0.08	0.13
	Diadema urchin	0.08	1.71	14.75	0.38
	Pencil urchin	0.04	0	0	0
	Collector urchin	0.08	0	0	0.04
	Sea cucumber	0.08	0	0	0
	Crown-of-thorns	0.04	0	0	0
	Triton	0	0	0	0
	Lobster	0	0	0.04	0
	Giant clam	0.75	0.71	1.13	0.25

INDEX SCORES FOR CURRENT STRESS AND DAMAGE FOR CORAL REEFS

Using the living coral cover percentage as the expression of coral reef condition, i. e., “poor” (<25%), “fair” (25%-50%), “good” (50-75%), and “excellent” (>75%), it is clear that none of monitoring sites around Taiwan showed reefs with excellent condition. Fifty percent of monitored reefs in Hsiaoliuchu, and 55% of monitored reefs in the Kenting National Park were in poor condition. Reefs or non-reefal communities in poor condition were also found in Penghu, northeast coast, and Lanyu while 75% of monitoring sites in Lutao showed good condition (Fig. 4.2.1).

MEASURABLE STRESS AND DAMAGE SUMMARIES AT REGIONAL/NATIONAL LEVEL

Overfishing, habitat destruction, and pollution are three major threats to the survival of coral reefs and non-reefal coral communities in Taiwan. Our multi-year data on keystone fish species and macro-invertebrates clearly indicated severe overfishing on every reef that we surveyed (Table 4.2.2, 4.2.3). Habitat destruction caused by hotel and housing development projects, fishing port/ harbor construction, and coastal protection using concrete tetrapods have increased sediment runoff and destruction of reefs. Modification of watershed and catchment with increase in sewage runoff has caused eutrophication in most reefs. Physical damage by strong typhoons also cause localized destruction of coral reefs in Kenting and Lanyu. Outbreak of coral-killing cyanobacteriosponge, *Terpios hohinota*, reported from Lutao and Lanyu in 2007, has gradually decreased its coverage in our monitoring surveys between 2010 and 2013. Other coral predators, such as crown-of-thorns (COT) starfish and *Drupella* gastropods, were reported from southern Penghu and caused damage of coral communities in several islands (Justin Hsieh, per. com.)

MPA ATTRIBUTES AND MANAGEMENT EFFECTIVENESS SCORES

Coral reefs and non-reefal communities in Taiwan are within the jurisdiction of national parks and national scenic areas. The management authorities include the Kenting National Park in south Taiwan, Dongsha Atoll National Park, the Northeastern Coast National Scenic Area, the East Coast National Scenic Area, Tapengwan National Scenic Area, and Penghu National Scenic Area. All of these areas could be recognised as marine protected areas. However, the management effectiveness of these areas is still weak, due to either lack of adequate law implementation or lack of enforcement even when the law is implemented. The revision of laws and establishment of MPAs with effective management are being planned and discussed by governmental administrations.

Coastal resources in Taiwan are protected under the National Park Law, the Wildlife Conservation Law, Fisheries Act and the Coastal Environmental Protection Plan, which are administered by the Ministry of Interior and the Council of Agriculture. However, these laws are not competent to protect marine ecosystems and biodiversity. The Coastal Area Protection Act, which is focused on conservation and sustainable management of coastal areas, is under revision by legislators.

Nevertheless, the Wetland Act, which was recently passed by legislators, provides an encouraging direction for future law implementation not only on coral reef conservation but also other shallow-water marine habitats around Taiwan.

RECOMMENDATIONS AND CHALLENGES ON CORAL REEF CONSERVATION AND SUSTAINABLE RESOURCE USE

ReefCheck and LTER monitoring data between 2010 and 2013 showed that nearly every site of coral reefs and non-reefal coral communities surveyed is under strong impacts of the synergetic effects derived from overfishing, habitat destruction, and pollution. The intensified typhoons, probably due to climate change, causing physical damage to the structure of coral communities might provide an additive effect to the anthropogenic stress.

Nevertheless, recent developments on conservation actions showed a positive trend in sustaining coral reef resource use. First, establishment of MPA demonstration sites in the Kenting National Park has showed a significant increase of fish populations. This has brought attention from several neighborhood villages requesting similar implementation of MPAs from national park. Local environmental NGOs and tour operators in Hsiaoliuchiu have started to work with local villages to stop gillnet fishery and poaching of marine life from the intertidal zone. These changes provide an alternative livelihood to local fishermen by increasing incomes from snorkel and SCUBA diving tourists. Second, implementation of sewage treatment systems along the urban areas of Kenting National Park has improved the control of eutrophication. Third, humphead wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) have been listed as “endangered species” under the Wildlife Conservation Law, making a big step in improving reef-associated keystone species. Lastly, an education program involving NGOs, such as ReefCheck, has brought public awareness on the importance of conserving coral reefs for the future generations in Taiwan.

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4.3. JAPAN

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Japan Coral Reef Monitoring Network (JCRMN)

SUMMARY

An overview of coral status in coral reef areas from 2004 to 2012 showed average coral cover decreasing from 37% in 2004 to 29% in 2007 with no recovery yet in 2012. Coral growth was affected by *Acanthaster* predation in Amami, Kerama and Miyako Islands and Yabiji reefs, and damage from typhoon and bleaching by high water temperature in Ishigaki Island and Sekisei Lagoon in 2007. The outbreak of *Acanthaster* ended in Amami and Kerama Islands from 2006 to 2007. However, the outbreak continued around Miyako Island and Yabiji reefs and expanded to Ishigaki Island and Sekisei lagoon. Typhoon also damaged coral reefs around the Okinawa Island in 2011.

Average coral cover of all the non-reef area sites was 30% in 2004 with fluctuations of 1 % decrease to 3 % increase until 2012 caused by disturbances and recovery. The major disturbances in this period were typhoons, *Acanthaster* predation and bleaching from higher/lower sea temperature. The average coral cover showed a degradation trend from 2010 to 2012 because of *Acanthaster* predation in Shikoku southern west coast and Kagoshima Southern coast, typhoon damage around Iki and Tsushima Islands and Kagoshima Southern coast. However, *Acanthaster* numbers observed showed a slight decrease recently in Shikoku southern west coast and Amakusa sites.

INTRODUCTION

The Ministry of the Environment started a national coral reef monitoring program in 2003 with a preliminaly survey to develop a methodology and select monitoring sites to assess the status of coral reefs around Japan. The official monitoring began in 2004 at 24 sites with a spot check (timed swim) method. Coral percent cover as a primary indicator of coral health is estimated by observers through 15 minutes of snorkeling who also recorded indicators of disturbances such as numbers of *Acanthaster planci*, (Crown-of-thorns (COTs) starfish) percent cover of bleached corals, and *Drupella* infestations etc. Seven non-reef area sites of from Yaku and Tanegashima Islands northward and 17 coral reef area sites from the Tokara Islands southward were selected (Fig. 4.3.1). Monitoring survey was conducted every 5 years at 2 remote sites in the Tokara Islands and Daito Islands, while the other 22 regular sites were surveyed annually.

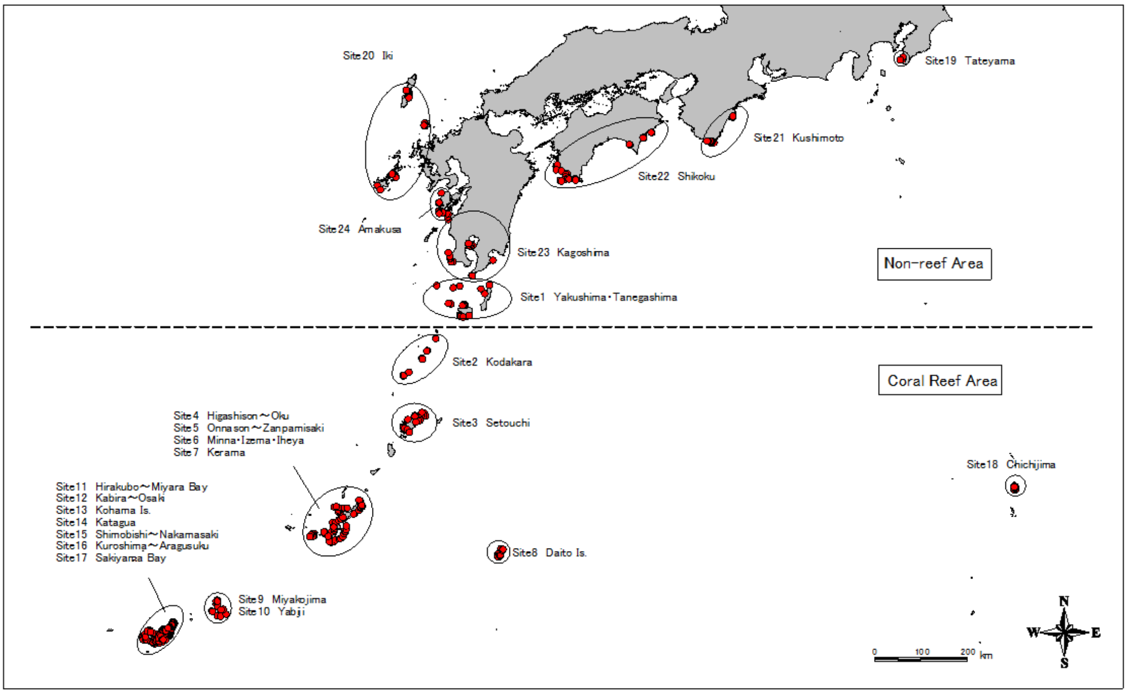

Fig. 4.3.1: Location of the monitoring sites of the national coral monitoring program by the Ministry of the Environment (red circles).

The surveys are conducted by coral reef scientists, research agencies, local consultants and dive operators (Table 4.3.1) with corabollation of volunteers from NGO/NPOs in some sites. A total 70 stakeholders were involved in the monitoring program in 2012.

Table 4.3.1: Members of Japan Coral Reef Monitoring Network and monitoring sites of national monitoring program

Monitoring Area (prefecture) Site no.: site name		member	Monitoring Area (prefecture) Site no.: site name		Member
Non Reef Area	Tateyama (Chiba) Site 19: Tateyama	Masahito KIYOMOTO	Coral Reef Area	Tokara Islands (Kagoshima) Site 2: Kodakara	Tadashi KIMURA
				Amami Is (Kagosima) Site 3: Setouchi	Katsuki OKI
		Tomoki SUNOBE		Okinawa Is (Okinawa)	Tomohumi NAGATA
	Kushimoto (Wakayama) Site 21: Kushimoto	Keiichi NOMURA		Kerama Is (Okinawa)	Kenji IWAO
	Ootuki Chou (Kochi) Site 22: Shikoku	Humihito IWASE		Miyako Is (Okinawa)	Kenji KAJIWARA
		Takuma MEZAKI			Hisashi MATSUMOTO
	Southern Kagoshima Site 23: Kagoshima	Shinichi DEWA		Ishigaki Is (Okinawa)	Minoru YOSHIDA
	Amakusa (Kumamoto) Site 24: Amakusa	Satoshi NOJIMA		Sekisei Lagoon (Okinawa)	Tadashi KIMURA
	Suou Chou (Yamaguchi) (no national monitoring)	Masaaki HUJIMOTO			Mitsuhiro UENO
	Yakushima (Kagoshima) Site 1: Yakushima-Tanegashima	Takeshi MATSUMOTO		Ogasawara (Tokyo)	Tetsuro SASAKI
	Iki & Tsushima (Nagasaki) Site 20: Iki	Kaoru SUGIHARA			

The results of the first 10 years were analyzed by the Ministry of the Environment in 2013 to determine the trend and status of Japan's coral reefs and a summary of the results is presented in this chapter.

STATUS OF CORAL REEFS

Overview of Coral Reef Area

Average coral cover of all coral reef area sites (Fig. 4.3.2) declined gradually from 37% in 2004 to 30% in 2012 under various stresses of typhoon damage, bleaching by high/low temperature, COTs predation, etc.

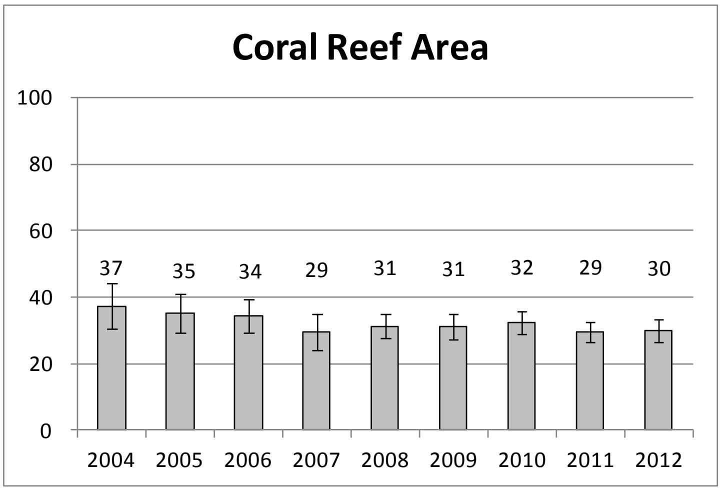

Fig. 4.3.2: Mean live coral cover (%) in coral reef area from 2004 to 2012. Error bar on each column indicates standard error of the mean coral cover.

COTs predation was a major disturbance in coral reef areas since 2000 when the outbreak started in Amami Islands (site 3: Setouchi), continued and ended in 2007 causing large scale of destruction of corals. The outbreak also started in the Yaeyama Islands (consisting of Ishigaki (site 11-12), Iriomote (site 17) Islands and Sekisei Lagoon (site 13-16)) in 2001 and the number of individuals increased rapidly from 2009 with large aggregations around Ishigaki, Iriomote Islands and Sekisei Lagoon until 2012. COTs aggregations were also found around Miyako Island (site 9) and Yabiji reefs (site 10) in 2002 with the outbreak continuing until 2012. An outbreak also appeared in Kerama (site 7) Islands in 2004 and ended in 2007.

Coral bleaching by high water temperature was another major disturbance. Mass bleaching was observed in Yaeyama Islands in 2007 with 30 to 60% of corals affected by the high water temperature. Corals were also damaged by typhoon that hit this area right after the bleaching event leading to degradation of coral cover in 2007. Bleaching caused by low water temperature was also observed around Yabiji reefs in 2008 and 2009.

Average coral cover showed a slight recovery after the decline from bleaching in 2007 until 2010. However, COTs predation was still a major problem in Miyako (site 9), Ishigaki (site 11-12), Iriomote (site 17) Islands and Sekisei Lagoon (site 13-16) and typhoons were another regular disturbance adding further damage to corals. Coral cover decline in 2011 was caused by COTs predation in Miyako Island and Yabiji reefs, and typhoon damage around Okinawa Island (site 4-5).

Besides these major disturbances, there were some site-specific impacts such as lower temperature in winter time, soil discharge by heavy rain during typhoons and storms, coral diseases, etc.

Site descriptions of Coral Reef Area

Tokara Islands, Okinawa Islands, Daito Islands and other outer islands (Fig. 4.3.3)

Tokara Islands (site 2: Kodakara) are located on the border between non reef and coral reef areas. The monitoring stations of this site are spread among the islands from north to south and the coral communities vary from small patchy communities on rocky shore to high cover *Acropora* communities on small fringing reefs in the southern islands. The average coral cover of the Tokara Islands was about 20% in 2005 and it gradually increased to 30% in 2010.

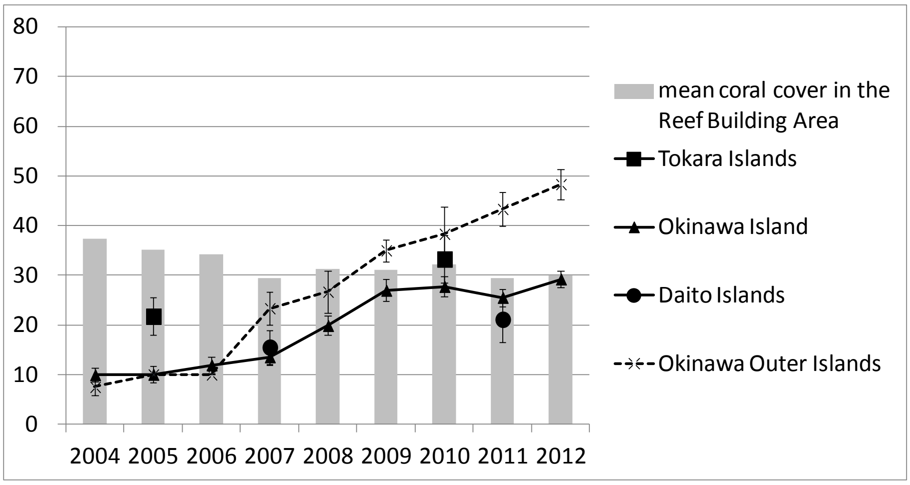

Fig. 4.3.3: Mean live coral cover (%) at Tokara Islands site, Okinawa Island site, Daito Islands site and Okinawa Outer Islands site from 2004 to 2012. The vertical bars of the each line indicate standard error in mean coral cover.

Okinawa Island (site 4: Higashison-Oku and site 5: Onnason-Zanpamisaki) is located in the sub tropical area with fringing reefs along the coast line. Rapid development in 1970's to 80's affected soil erosion and coastal pollution that damaged the coral population around the island. The outbreak of COTs in 1980s hampered coral recovery. Monitoring showed an increase in coral cover from 10% in 2004 to 30% in 2012 with a minor drop in 2011 caused by typhoon. This may indicate a potential for recovery. Coral cover of the outer islands (site 6: Minna-Izena-Iheya) increased more rapidly than on Okinawa Island since 2007 and reached to 50% in 2012.

Daito Islands (site 8) consist of 3 islands located 360 km off east of Okinawa Island. These are isolated oceanic islands uplifted from the deep sea bottom over 1,000 m depth. Corals around the Daito Islands showed a relatively lower coverage than fringing reefs in Okinawa because of the exposure to strong wave action that damaged coral colonies in the shallow water. Average coral cover of Daito Islands was 15% in 2007 and 20% in 2011. Although aggregations of COTs were observed in the *Acropora* communities at the deeper shelf about 20 m in depth during the first survey in 2007, neither COTs nor predation was observed during the second survey in 2011 and coral growth was slow under the strong wave condition.

Amami Islands and Kerama Islands (Fig. 4.3.4)

Amami (site 3: Setouchi) and Kerama (site 7) Islands showed similar trend of rapid coral cover degradation from 2004 to 2006 in Kerama and from 2004 to 2007 in Amami Islands under predation by COTs. Although the outbreaks ended in 2006 in Kerama and 2007 in Amami Islands, coral cover did not show any clear recovery yet in 2012 for both islands. COTs predation re-appeared in Kerama Islands in 2011 and 2012 causing coral cover to remain depressed.

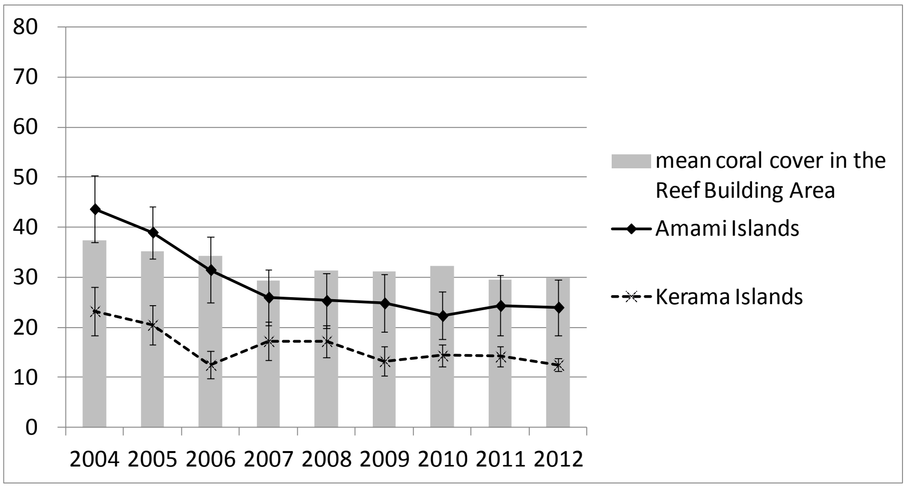

Fig. 4.3.4: Mean live coral cover (%) at Amami Islands site and Kerama Islands site from 2004 to 2012. The vertical bars of each line indicate standard error in mean coral cover.

Miyako Island and Yabiji Reefs (Fig. 4.3.5)

Miyako Island (site 9: Miyakojima) is located 300 km off south west of Okinawa Island. Yabiji reefs (site 10) are outer reefs off Miyako Island and include important fishing grounds for the local fishermen. Coral cover in Miyako Island showed gradual decrease from 2004 to 2010 because of COTs predation. It appeared in large numbers around Miyako Island since 2004. Aggregations spread among the monitoring stations around the Island. COTs also appeared in Yabiji reefs in 2004 causing rapid degradation of corals until 2009 when their numbers decreased in 2012, but aggregations still appeared around Miyako Island in 2012. Coral cover showed a rapid decline in 2011 and 2012 at both Miyako Island and Yabiji reefs resulting from typhoon damage in 2011.

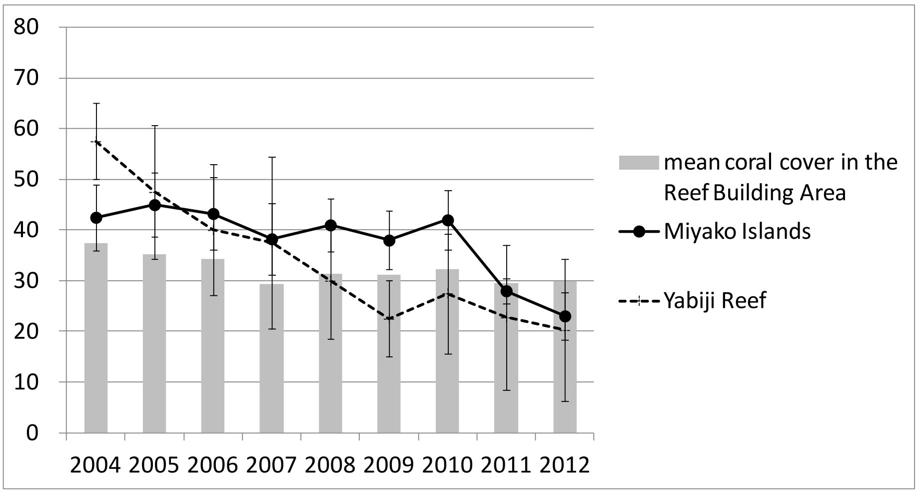

Fig. 4.3.5: Mean coral cover (%) at Miyako Islands site and Yabiji Reef site from 2004 to 2012. The vertical bars of each line indicate standard error in mean coral cover.

Ishigaki Island, Sekisei Lagoon, Iriomote Islands and Ogasawara Islands (Fig. 4.3.6)

Coral reefs around Ishigaki Island (site 11: Hirakubo-Miyara Bay and site 12: Kabira-Osaki) and Sekisei lagoon (site 13-16) showed rapid degradation in coral cover in 2007 because of bleaching by high water temperature, and typhoon damage. Corals of these areas were also under high pressure by COTs outbreak and coral cover did not recover until 2012. However, the number of COTs decreased in 2011 and 2012 both around Ishigaki Island and Sekisei Lagoon. Iriomote Island (site 17: Sakiyama Bay) had relatively high coral cover in 2004 and 2005, but showed a gradual degradation of coral cover since 2006 because of disturbances from bleaching, typhoon and COTs outbreak. The number of COTs increased in 2011 and 2012 around the northern coast of Iriomote Island indicating future reduction of coral cover in this area.

Ogasawara Islands (site 18: Chichijima) also showed relatively high coral cover than other sites in the coral reef area. However, the coral cover dropped in 2007 from typhoon damage and 2009 from bleaching by high water temperature.

The gradual degradation of coral cover since 2009 resulted from the damage by the bleaching. As the sites around Sekisei Lagoon were damaged from coral bleaching by high water temperature (2005, 2006) and typhoon (2005), the mean coral cover showed a slight trend of decrease from 2004 to 2006. In 2007 severe coral bleaching was observed in the area and mean coral cover decreased significantly. COTs outbreak also continued in many stations of these sites and coral recovery has not been observed since 2008. There was no COTs outbreak in Ogasawara Islands and coral cover was 50% from 2004 to 2007. However, mass coral bleaching was observed in the Islands in 2007 resulting in coral cover decreasing to 40% in 2011.

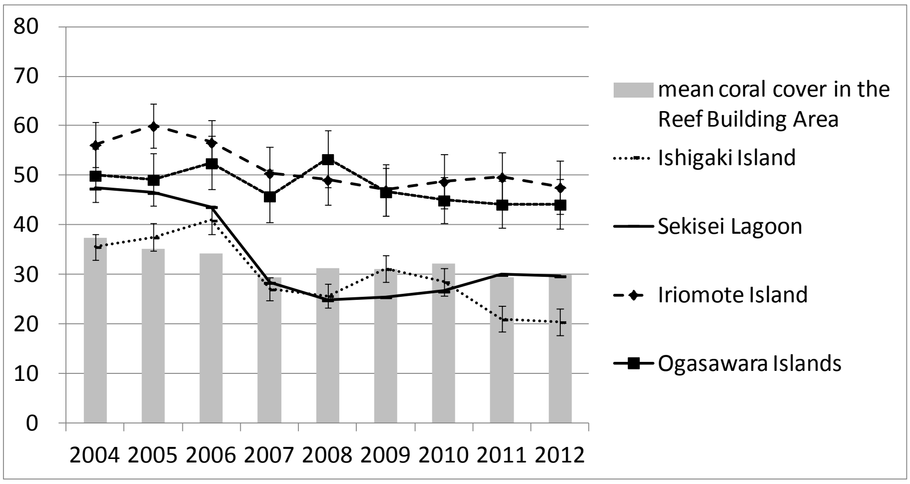

Fig. 4.3.6: Mean live coral cover (%) at Ishigaki Island site, Sekisei Lagoon site, Iriomote Island site and Ogasawara Islands site from 2004 to 2012. The vertical bars of each line indicate standard errors in mean coral cover.

Overview of Non-reef Area (high latitude coral community area)

Average coral cover of all the non-reef area sites (Fig. 4.3.7) was 30% in 2004. Small changes of between 1% increase and 3% decrease led to overall decline to 25% in 2012. These differenciation of coral cover reflected responses/effect/recovery of corals from the disturbances that occurred each year. Two events, COTs predation and typhoon damage affected coral cover, which dropped to 29% in 2007 and 2011 before the minimum coral cover of 25% was recorded in 2012.

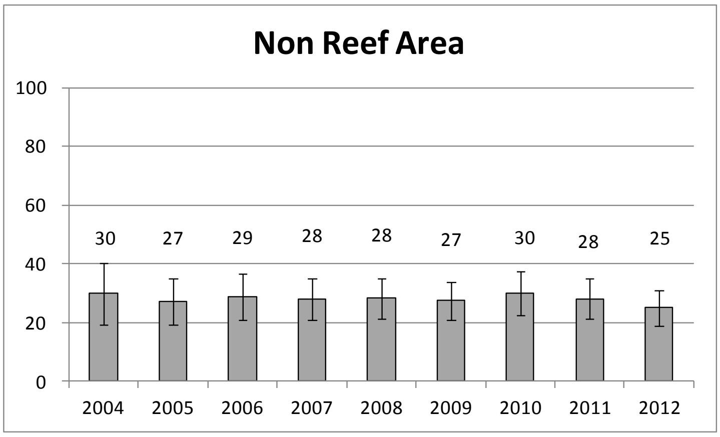

Fig. 4.3.7: Mean live coral cover (%) in non reef area from 2004 to 2012. Error bar on each column indicates standard error of mean coral cover.

Predation by COTs was also one of the major disturbances on coral communities in the non-reef area and the degradation of coral cover in 2005. Large numbers of COTs were observed around Kushimoto (site 21) in early 2000 and the first aggregation in 2004. The maximum number of individuals and degradation of coral cover was recorded in 2005. COT numbers also started increasing along the Shikoku (site 22) southern west coast in 2004. Coral cover at this site had been affected by COTs predation since 2008 and the maximum number of individuals was observed in 2010. Although the peak in the number has passed, some of the stations within the Shikoku site showed high aggregations. Along the Kagoshima (site 23) southern coast, significant numbers of COTs were recorded in 2007 and predation expanded into the site and remained until 2011. The numbers declined in 2012, but aggregations are still present. In Amakusa site (site 24), many aggregations of COTs appeared since 2002 before the monitoring program started. The number of individuals observed was low until 2007 when it increased rapidly from 2008 to reach a maximum in 2009 before decreasing.

Typhoon damage was observed in 2012 in Iki & Tsushima site (site 20: Iki) resulting in reduction of coral cover. Kushimoto (site 21) and Shikoku (site 22) are located on the major route of typhoons passing through mainland Japan from Okinawan waters, which often cause coral damage. Serious damage from typhoons was recorded in Kushimoto site in 2004, 2005 and 2009 with minor damage in 2006, 2007, 2011 and 2012. At Shikoku southern west coast site, coral cover was affected by typhoon damage in 2007 and 2011.

Kagoshima (site 23) southern coast was also affected by typhoon in 2012. In Amakusa site (site 24), typhoons hit in 2006 and 2012, but the average coral cover did not show much effect. Coral disease was one of the major disturbances together with typhoon and COTs damage coral communities in Kushimoto site (ste 21). Bleaching by lower water temperature in winter was observed around Kushimoto (site 21), Shikoku (site 22) southern west coast and Amakusa sites (site 24). It killed 20% of the coral community, especially most of the *Acropora* species in Kushimoto site (site 21) in 2012.

Site descriptions of Non-Reef Area

Tateyama, Iki and Tsusima Islands (Fig. 4.3.8)

Tateyama site (site 19) had low density coral communities with scatterd colonies of *Favites*, *Alveopora*, *Acropora* and *Psammocora*. These coral communities have been well maintained since 2004 until 2012 when a minor disturbance of *Drupella* predation occurred.

Coral communities of Iki and Tsushima Islands (site 20: Iki) showed gradual degradation of coral cover until 2009 because of disturbances from bleaching by higher/lower temperature and sedimentation. The sharp decline in 2012 was caused by typhoon damage. (The rapid decrease of average coral cover from 2004 to 2005 also resulted from low coral cover of additional monitoring stations included in 2005 and the average coral cover of original sites was unchanged between 2004 and 2005). There were coral communities with *Alveopora japonica* and Faviidae that had low coral cover of less than 5% in Tateyama site but they were maintained stably from 2004 to 2012.

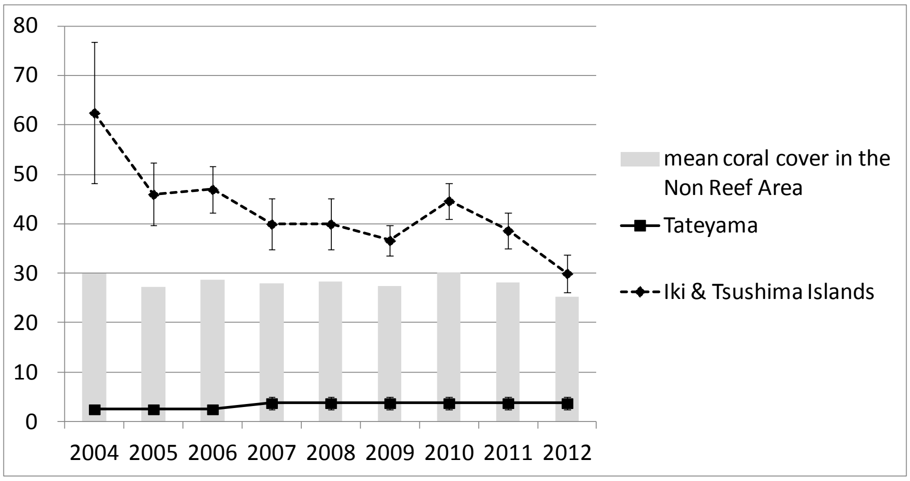

Fig. 4.3.8: Mean live coral cover (%) at Tateyama site and Iki & Tsushima Islands site from 2004 to 2012. The vertical bars of each line indicate standard error in mean coral cover.

Kushimoto and Shikoku south western coast (Fig. 4.3.9)

Coral cover of Kushimoto site (site 21) decreased from 40 to 30% in 2005 because of typhoon damage and COTs predation. Coral diseases and bleaching by lower temperature during winter were observed to affect the coral population and coral cover has not recovered up till 2012.

Coral cover showed gradual increase from 2004 to 2009 in the Shikoku (site 22) south western coast site. Mass predation by COTs was observed in this site since 2008 causing coral cover to decrease in 2011 and 2012.

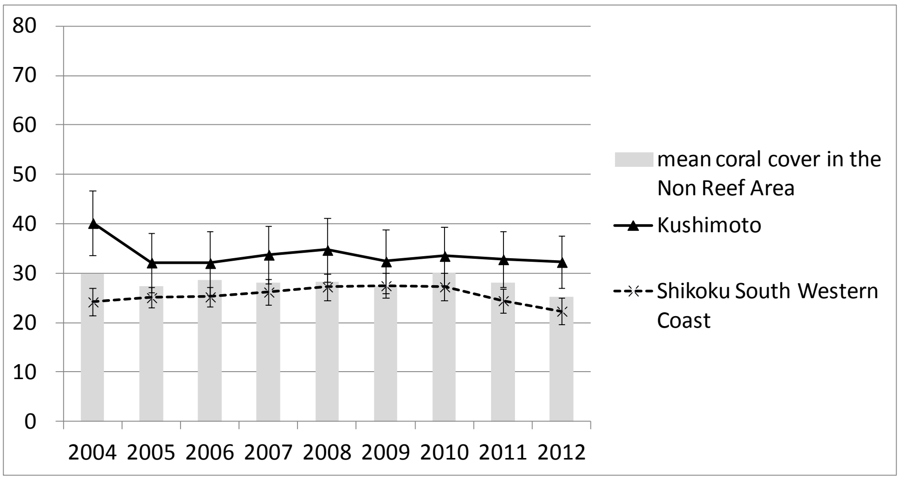

Fig. 4.3.9: Mean live coral cover (%) at Kushimoto site (Wakayama prefecture) and Shikoku South Western Coast site (Kochi and Tokushima prefecture) from 2004 to 2012. The vertical bars of each line indicate standard error in mean coral cover.

Kagoshima Southern Coast and Amakusa (Fig. 4.3.10)

Coral cover of Kagoshinma (site 23) Southern coast showed gradual degradation from

2005 to 2011 and a rapid drop in 2012. Large aggregations of COTs were observed since 2007 when it spread into this site. The rapid drop of coral cover in 2012 was caused by their predatioon. There were also typhoon damage and sedimentation of volcanic ash from the Sakura-jima eruption that affected coral populations in this site. High density aggregations of COTs were still observed in 2012.

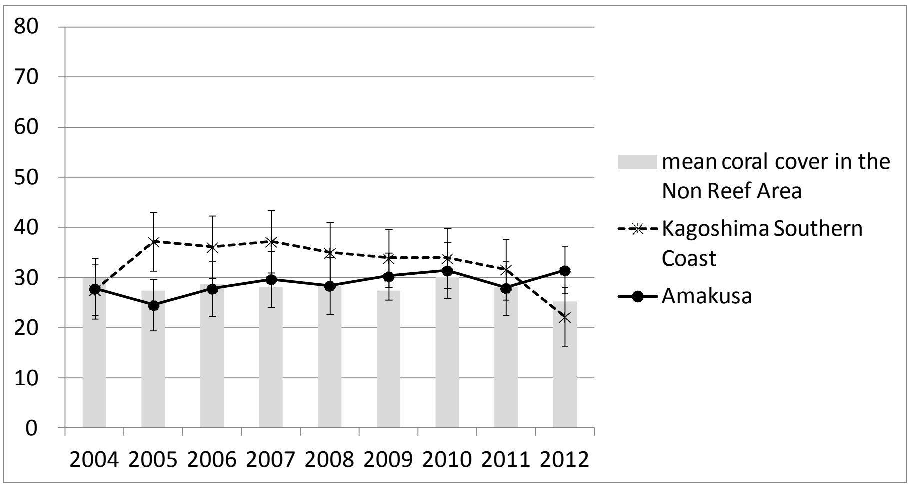

Fig. 4.3.10: Mean live coral cover (%) at Kagoshima Southern Coast site (Kagoshima prefecture) and Amakusa site (Kumamoto prefecture) from 2004 to 2012. The vertical bars of each line indicate standard error in mean coral cover.

Coral cover of the Amakusa site (site 24) did not show any significant growth under the pressures of typhoon damage, COTs predation and bleaching by lower water temperature from 2006 to 2012. The number of COTs decreased after its peak in 2009. In Kagoshima southern coast site, volcanic ash from Sakura-jima smothered coral colonies and caused mass mortality. It was one of the major disturbances to coral communities in this site together with COTs predation.

Yaku and Tanegashima Islands (Fig. 4.3.11)

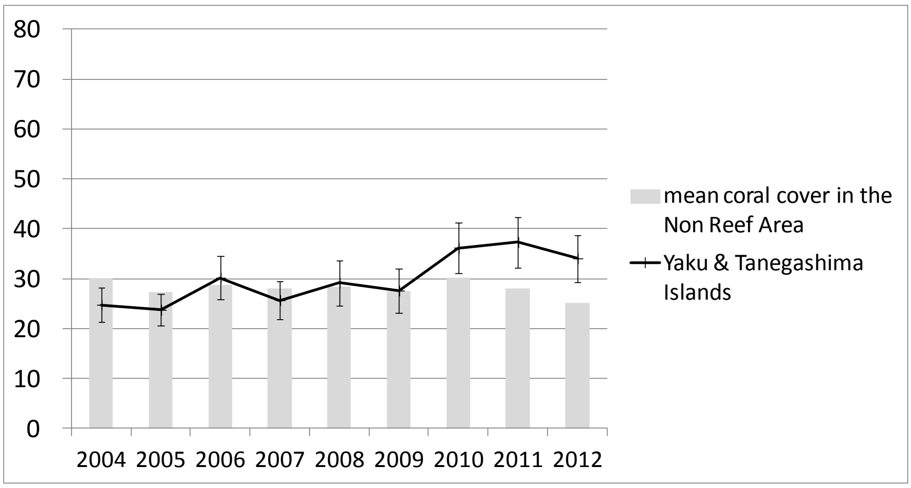

Fig. 4.3.11: Mean coral cover (%) at Yaku and Tanegashima Islands site from 2004 to 2012. The vertical bars of each line indicate standard error in mean coral cover.

Corals in Yaku and Tanegashima (site 1) Islands showed gradual increase from 2004 to 2012 without any major disturbances such as COTs outbreak, typhoon and bleaching.

MAJOR DISTURBANCES ON CORALS IN JAPAN: Acanthaster and Typhoon

Acanthaster Outbreak

Outbreak of *Acanthasterplanci* (COTs) started around 2000 in Amami islands (ste 3) and reduced average coral cover until 2007. Number have decreased since 2007 and the outbreak seemed to have ended as individuals were hardly observed from 2008 to 2012 (Table 4.3.2).

In Kerama islands (site 7), aggregations of *COTs* were observed in 2004 and coral cover was 20% because of their predation. The numbers declined since 2006 and was nomal (less than 2 individuals per 15 minute observation) from 2007. Coral cover recovered in 2010 and 2011, but COTs predation was observed again in 2011 and 2012.

Around Miyako Island (site 9) and Yabiji-reef (site 10), large aggregations were observed since 2004 and the coral cover decreased by their predataion. However, as the number of COTs declined around Miyako Island, high density populations were observed in the Yabiji-reefs in 2012. COTs aggregations were observed around Ishigaki Island since 2010 and the coral cover was 20% at the west coast and 30% along the east coast in 2012. However, the number of COTs started to decline.

Around Sekisei Lagoon (site 13-16), predation by the COTs was observed since 2003 and the numbers increased rapidly since 2007. However, a slight decline in number of individuals was observed in 2012.

In non-reef areas, COTs aggregations were observed in Kushimoto (site 21) from 2004 to 2008. Although the number of the individuals observed decreased in 2010, two different age groups were observed every year that might indicate that the reproduction and recruitment of COTs is occurring at a local level in Kushimoto site.

Table 4.3.2: Maxmum number of *Acanthaster* [Crown-of-thorns (COTs) starfish] observed at the monitoring sites from 2004 to 2012. The COTs were counted in 15 minute swim time during the annual monitoring survey at 20 to 30 stations of each monitoring site. The surveys were conducted by 2 or 3 observers and the average was calculated for each station. This table shows maximum numbers of COTs of all the stations for each monitoring site each year. Less than 2 individuals of COTs indicate normal distribution; more than 2 and less than 5 indicates a sign of outbreak; more than 5 and less than 10 indicates semi-outbreak; more than 10 indicates outbreak; and more than 50 indicates extreme aggregation.

Monitoring Site			no. of individuals of COT / 15 minutes observation								
Area	No.	Name	2004	2005	2006	2007	2008	2009	2010	2011	2012
Non Reef Area	20	Iki Island	0	0	0	0	0	0	0	0	0
	19	Tateyama	0	0	0	0	0	0	0	0	0
	21	Kushimoto	11.1	18	20	6	16	2	1	2	3
	22	Sikoku South Western Coast	1	1	3	1	12	24	56	48	28
	23	Kagoshima Southern Coast	1	1	1.3	12.8	7	1	2	50	22.5
	24	Amakusa	0	1	0	0	2	8.5	5	3.5	2
	1	Yaku & Tanegashima	1	0	0	1	1	0	0	0	0
Coral Reef Area	2	Tokara Islands		0					0		
	3	Amami Islands	2	5	10	8	0	0	0	0	0
	4	Okinawa Island (Eastern Coast)	24	6	1	1	0.5	0.5	0.5	1	0.5
	5	Okinawa Island (Western Coast)	4	2	1.5	3.5	1.5	1	2	2	4
	6	Okinawa Outer Islands	1	0	0.5	1	0.5	0	0	0.5	1
	7	Kerama Islands	12	10	3	1	1	0	1	2.5	2.5
	8	Daito Islands				10					
	9	Miyako Island	195	0.5	3	58	16.5	10	14.5	93	15.5
	10	Yabiji Reef	2	31.5	17	15.5	20.3	0	0	4	4
	11	Ishigaki Island (Eastern Coast)	0.5	0	0	0.5	1.5	4	51	13.5	1.5
	12	Ishigaki Island (Western Coast)	0.5	0	1	1.5	2.5	4	39.5	78.5	27.5
	13	Sekisei Lagoon (Northern Area)	1.5	1	2	5	10.5	4.5	10	111	118
	14	Sekisei Lagoon (Eastern Area)	6.5	3	2.5	21.5	30	36.5	13	19.5	15
	15	Sekisei Lagoon (Central Area)	1.5	1.5	2	21	7.5	1	8	6	10
	16	Sekisei Lagoon (Southern Area)	5	5.5	4.5	10.5	21	31	17.5	21.5	12
	17	Iriomote Island	3	3.5	1	23.5	52.5	48	20.5	56.5	19
	18	Ogasawara	0	0	0	0	0	0	0	1	0

< 2 (normal)

50>, ≧10 (outbreak)

5>, ≧2 (caution)

≧50 (extream aggregation)

10>, ≧5 (semi-outbreak)

In Kagoshima (site 23) southern coast site, COTs aggregations were observed from 2007 and there were still large numbers of the individuals among the monitoring stations. The outbreak seemed to be continuing at this site.

COTs was observed in large numbers since 2008 in Shikoku (site 22) southern west coast and the maximum number reached in 2010, before decreasing in 2011 and 2012.

An outbreak occurred in Amakusa (site 24) in 2002 and 2003 before the monitoring program begun. It was confined to a specific area and no aggregation was observed in any other area. However, the number of the individuals increased rapidly from 2008 and peaked in 2009 before dropping rapidly after 2010 and only one individual was observed in 2012.

Typhoon Damage

Typhoon is a regular phenomenon of the summer season in Japan and occurs when tropical low pressure increases to more than 17m/s in maximum wind speed in the area of the North West Pacific or South China Sea. The annual number of typhoons generated from 2004 to 2012 were 14 to 31 and the annual number of typhoons migrating to Japan were 7 to 19 from 2004 to 2012 (Fig.4.3.12).

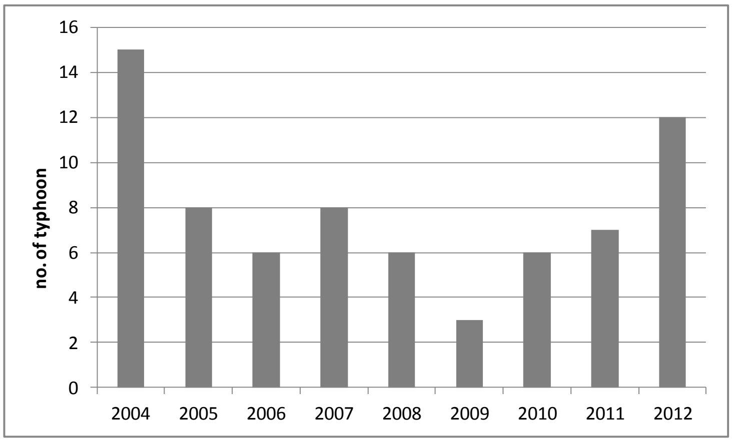

Fig. 4.3.12: Annual number of typhoons that approached Amami and Okinawa Islands from 2004 to 2012. Cited from web site of Japan Meteorological Agency (http://www.data.jma.go.jp/fcd/yoho/typhoon/statistics/accession/accession.html).

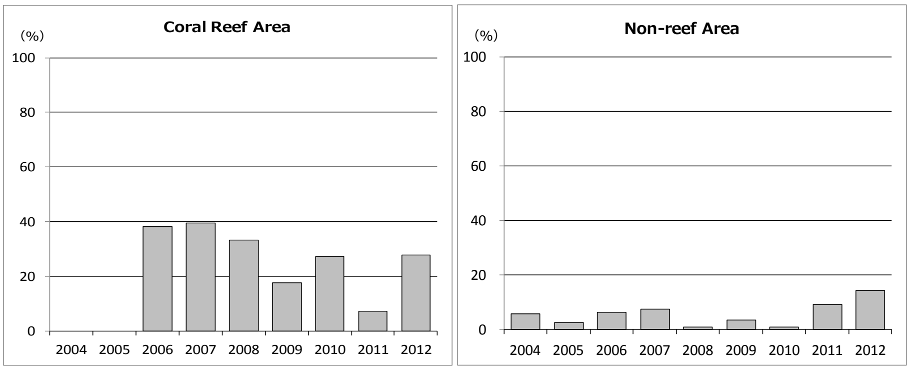

Fig. 4.3.13: Percentage of stations at coral reef area (left) and non-reef area (right) that had typhoon damage from 2004 to 2012.

Changes of population structure and distribution by global warming

Some recruitment of juvenile colonies of *Acropora solitaryensis* was found in Tateyama site. *A. solitaryensis* is usually distributed in Kushimoto southward. Warmer water temperature might have allowed this species to live in the northern area away from their original habitat.

A similar phenomenon was observed in Kushimoto site. Branching *Acropora muricata* (*A. formosa*) usually dominates subtropical waters in Okinawa while the tabulate *Acropora hyacinthus* originally dominates Kushimoto waters. However, *A. muricata* has expanded its distribution northwards and outcompeting the local species, *A. hyacinthus* resulting in a total exchange of the habitat from *A. hyacinthus* to *A. muricata* in some areas.

FISHERIES RESOURCES

Figure 4.3.14 shows the trend in the coastal fisheries catch for Okinawa. Untill 1981, catches of bottom fish such as snappers, emperors, and groupers increased in proportion to increased fishing effort (number of fishing boats, operational days). While catches of bottom fish declined sharply after 1981, partly because of over-fishing, harvests from the fish aggregating device fishery and the *Thysanoteathis rhombus* fishery increased rapidly, sustaining the coastal fishers (Kakuma 2004).

Figures 4.3.14 and 4.3.15 show the trend of the coastal fisheries catch of major bottom fish from 1973 to 2001 and from 2004 to 2012 (cited from the 34th to 41st Annual Report on Agriculture, Forestry, and Fisheries Statistics for Okinawa). Overall, the coastal fisheries resource has not recovered from the sharp decline caused by over-fishing.

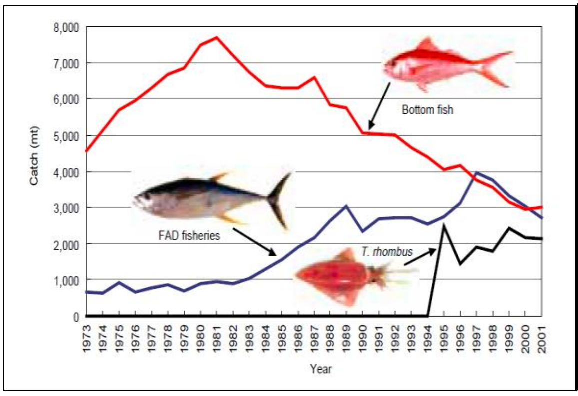

Fig. 4.3.14: The trends of the coastal fisheries catches of major bottom fish from 1973 to 1981 including snappers, emperors, groupers, rabbit fishes and parrot fishes (cited from Kakuma 2004 in the *Coral Reefs of Japan published by the Ministry of the Environment in 2004*).

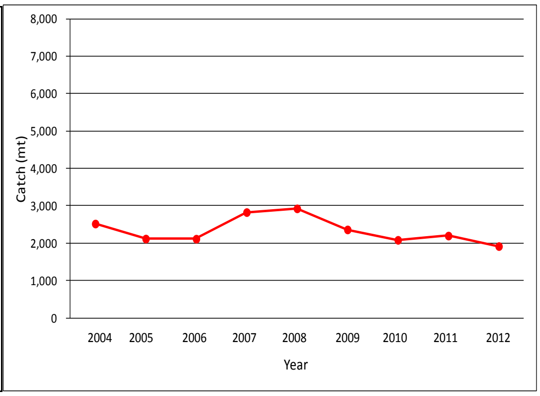

Fig. 4.3.15: The trend of the coastal fisheries catch of major bottom fish from 2004 to 2012 that calculated from the Statistics of Agriculture, Forestory and Fisheries of Okinawa Prefecture from 2004 to 2012.

CORAL REEF MANAGEMENT (2010-2014)

A new national park has been designated in Suo-Oshima in 2013 to protect the habitat of *Alveopora japonica*. Another new national park has been designated in Kerama Islands in 2014 and includes coral reefs around the islands. Revision of the National Action Plan on conservation of Coral Reef Ecosystem has been discussed in 2014 and will be developed in 2015 involving multiple central government agencies, local governments and related stakeholders. Okinawa prefectural government has conducted specific programs on coral reef conservation named Coral Reef Conservation and Recovery Project (2010-2016) and Comprehensive Crown-of-thorns starfish Countermeasure Project (2012-2017). Ministry of the Environment has also implemented their Nature Restoration Project in the Sekisei Lagoon in the Iriomote Ishigaki National Park since 2002. The Fisheries Agency conducted a program to support activities on protection of environment and ecosystem including coral rehabilitation and restoration in Okinawa. The Fisheries Agency also conducted a project on coral reef rehabilitation to develop coral mass culture in Kerama Islands and Okino-tori-shima Island.

The Marine Biodiversity Conservation Strategy in Japan has been formulated by the Ministry of the Environment to protect the biodiversity in 2011 to support the sound structure and function of marine ecosystems, and to use ecological services of the ocean, or its provisions, in a sustainable manner on the basis of the “National Biodiversity Strategy (2010)” under the “Basic Act on Biodiversity”. This is in line with the “Basic Act on Ocean Policy” and “Basic Plan on Ocean Policy”, in response to increasing public awareness on marine biodiversity. The strategy provides a basic view and direction of measures for conservation and sustainable use of marine biodiversity.

The Ministry of the Environment of Japan also discussed the identification of ecologically/biologically significant marine areas since 2011. The Ministry also has hosted the ICRI secretariat with the government of Thailand (Department of Marine and Coastal Resources) from 2014 to 2016 to organize the general meeting for leading the direction on coral reef conservation of the world.

The Ministry has also started preparation of the new National Action Plan on Conservation of Coral Reef Ecosystem since 2014 inviting other departments and agencies, local governments and academic forum that are related to coral reef conservation. The new Action Plan will be finalized at the end of Fiscal Year 2015.

The Ministry of the Environment has also continued the Nature Restoration project at the Sekisei lagoon, Okinawa, since 2006.

Okinawa prefectural government has conducted two conservation projects on coral restoration (since 2010) and counter measures for outbreak of COTs (since 2013).

Okinawa prefectural government has continued to organize a coral reef conservation council since 2008. The council organizes a small grant for coral reef conservation every year sponsored by the Aramco Japan/Saudi Aramco since 2011.

RECOMMENDATION

Corals are exposed to high pressure from typhoons, *Acanthaster* outbreak and bleaching from higher/lower water temperature that cause dynamic fluctuations of coral population from 2004 to 2012 in Japan. Typhoon and temperature changes in particular have been occurring more frequently than in the last decade potentially because of global climate change. It is strongly recommended that the resilience of the corals should be enhanced to let coral reefs survive from these increasingly frequent disturbances as well as conducting temporal counter measures such as extermination of *Acanthaster*, *Drupella*, and enhancement by coral transplanting and rehabilitation. To enhance coral resilience, effective action should be taken to reduce chronic stresses from the terrestrial area e.g. soil erosion, sewage and eutrophication for the longer term of conservation of corals. It is also emphasized that the countermeasure to global warming is another key element for conserving the coral population as it will reduce the frequency of storms and sea water temperature deviation.

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4.4. SOUTH KOREA

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SUMMARY

Corals of Korea are concentrated in the southern part of the country, particularly within the South Sea and around Jeju Island. Most species are octocorals, and scleractinian corals represent only a minor portion of the regional species composition. However, the number of scleractinian corals appears to be increasing in response to climate change. Recent studies and survey efforts revealed three additional scleractinian coral and 25 subtropical and tropical fish and invertebrate species from Jeju Island. The new records are concentrated in the southern part of Jeju Island.

COUNTRY STATISTICS AND CORAL REEF RESOURCES IN 2014

The southern part of Korea is influenced by the Tsushima Warm Current, and evinces warmer ocean temperature than other parts of the country. The sea surface temperature (SST) of this region has increased approximately 1.2 degrees Celsius over the past 100 years, at a rate significantly higher than the global and North Pacific trends (0.5 and 0.45^{0}C increase, respectively)(Takatsuki et al. 2007). Consequently, southern Korea is gradually becoming a suitable habitat for subtropical and tropical coral species, and the rapidly increasing number of new coral and other tropical species sightings upholds the trend. Coral studies in Korea have primarily focused on soft corals and azooxanthellate corals (Song 1991, Hwang and Song 2009), and information about zooxanthellate scleractinian corals remains largely unknown. To date, the most frequently reported scleractinian species include *Alveopora japonica*, *Montipora millepora* and *Psammocora albopicta* (Ministry of Maritime Affairs 2012, Kaoru et al. 2014, Fig. 4.4.1). Scleractinian coral colonies were negligible in size and over looked in past monitoring programs; however, preliminary results of recent surveys reported that scleractinian coral species including *Alveopora japonica* and *Montipora millepora* are expanding their coverage and competing with endemic kelp in southern Korea, especially at 5-10 m depth (Ministry of Maritime Affairs and Fisheries 2012, Denis et al. 2013, Fig. 4.4.2). The expansion of coral coverage and distribution, as well as the gradual decline of endemic kelp can undermine local fisheries because fishers in southern Jeju target large gastropods, such as abalone and sea snails that feed on kelp.

Fig. 4.4.1: Representative hermatypic coral species inhabiting southern Korea. A: *Alveopora japonica*, B: *Montipora millepora*, C: *Psammocora profundacella*.

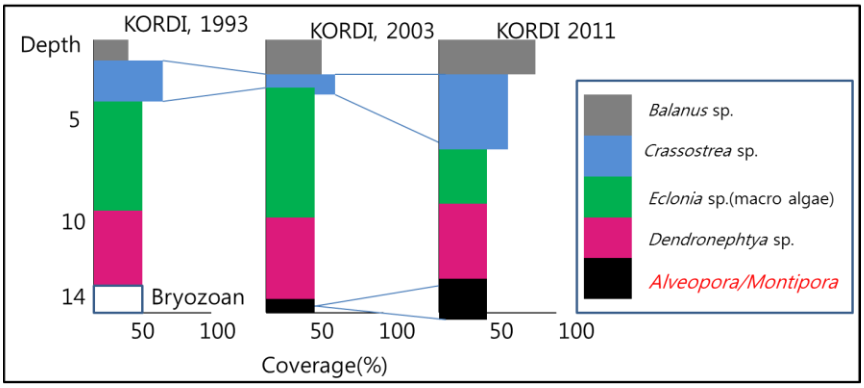

Fig. 4.4.2: Changes in species composition over 20 years in southern Korea. Note the dramatic increase of hermatypic corals.

Number of Species and Major Taxa recorded

Poleward range expansion of tropical and subtropical species into southern Korea is palpable. The number of subtropical and tropical marine species is rapidly increasing in southern Korea, particularly within the South Sea and around Jeju Island. Newly recorded species include butterflyfishes *Chaetodon wiebeli* and *Heniochus acuminatus*, a black pearl oyster *Pinctada margaritifera*, an urchin *Prionocidaris annulifera* and a seastar *Fromia monilis* (Ministry of Environment 2009). A recent study (Kaoru et al. 2014) reported three new hermatypic coral species, *Psammocora albopicta, Acanthastrea* cf. *lordhowensis* and *Favites* ?sp. from Jeju Island, and surveys led by the Ministry of Environment (2012) also recorded 25 subtropical and tropical fish and invertebrate species previously unrecorded in Korea.

Coral Reef and Non-reefal Community Monitoring Sites

Coral monitoring programs in Korea have chiefly focused on octocoral community distribution patterns and anthropogenic impacts on octocorals until 2010 (Ministry of Maritime Affairs and Fisheries 2011). Octocoral communities in southern Jeju were patchy but most abundant around 20 m in depth, and some of their habitats appeared to be disturbed by coastal development (Ministry of Maritime Affairs and Fisheries 2012). Despite adverse conditions inflicted by coastal development, abundance of most octocoral species increased in most parts of southern Jeju (Ministry of Maritime Affairs and Fisheries 2012). Scleractinian coral species except *Alveopora japonica* were rare and often neglected in monitoring programs; however since 2010, large colonies of *Alveopora japonica* and *Montipora millepora* were consistently observed in southern Jeju. Recent survey efforts led by Korea Marine Environment Management Corporation (KOEM) selected three sites within Jeju Island, where the number of scleractinian coral colonies dramatically increased, for long-term monitoring (Korea Marine Environment Management Corporation 2011).

Changes in Percent Hard Coral Cover at different Sites - comparison between 2010 and 2013

Hard coral monitoring programs in Korea are still in their incipient stage and information about hard coral coverage is virtually absent. Past surveys until 2010 mainly investigated octocoral communities and hard coral species were simply reported in the species inventory. In addition to the recent monitoring program led by KOEM, a consortium of scientists funded by Jeju Province Office started a new coral monitoring program in 2013. This program recognized the absence of hard coral species in past survey agenda despite their rapid increase in abundance and density, and thus added their growth and distribution patterns in the survey criteria.

Index Scores of Major Fish, Benthic Taxa, and Trends in Coral Reef Resource Usage

Like scleractinian corals, coral-associated fish and invertebrate species in past monitoring programs were only perfunctorily recorded in the species inventory. The aforementioned new monitoring programs incorporate subtropical and tropical fish and benthic species as important components and survey spatial and temporal heterogeneities in species composition and abundance (Korea Marine Environment Management Corporation 2011). Corals and coral-associated resources are hardly utilized by the local community and little information is available on coral reef resources usage in Korea.

Index Scores for Current Stress and Damage for Coral Reefs

It is difficult to estimate past status and magnitude of stress and damage for coral reefs in Korea. However, the most evident current threat to corals and associated organisms in southern Korea is imposed by various coastal development projects. In particular, Jeju is progressively becoming an internationally popular vacation destination and a large harbor is being constructed to meet the demand. Moreover, the naval base construction in southern Jeju is predicted to increase turbidity and sedimentation as well as change the water movement pattern of proximate areas.

Measurable Stress and Damage Summaries at Regional/National Level

The integrity of marine ecosystems in southern Korea is being compromised by climate change and coastal development. As species composition of this region originally comprised mostly temperate and few subtropical species, poleward range expansion of tropical and subtropical marine species including corals may imperil endemic species and unique biodiversity. For instance, considerable portions of endemic kelp *Ecklonia cava* around Jeju Island are being replaced by *Alveopora japonica* in response to climate change in southern Jeju (Denis et al. 2013), and tropical fish species interact actively with local fauna, which in turn could cause diversification among populations (Kim et al. in press). Changes in species composition, abundance, density and distribution may also threaten regional fisheries because they mostly target kelp-related species.

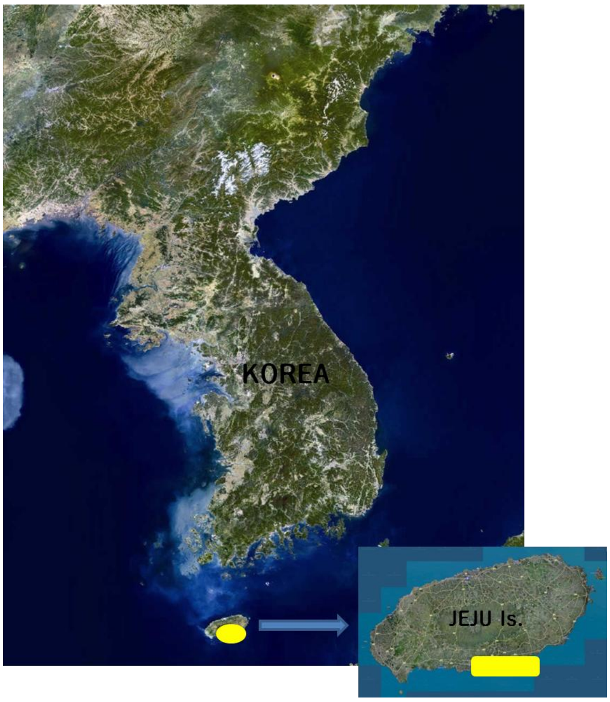

Fig. 4.4.3: Satellite image of Korea. The southernmost island, Jeju, is inhabited by several subtropical and tropical organisms. The yellow box indicates the Munseom Marine Protected Area.

MPA Attributes and Management Effectiveness Scores

Munseom and its vicinity in southern Jeju is designated and enforced as an MPA since 2002 (Fig. 4.4.3). Strong cultural influences, however, often override fisheries-related institutional restrictions in this region, and the MPA is often infiltrated by local fishers. Local fishers consider corals a threat to fisheries target species and are unhappy with the expansion of scleractinian coral species. Governmental agencies including Jeju Province Office initiated educational programs since 2008 to amend misconceptions and enhance public awareness for corals and associated organisms. Although local fishers may sporadically disturb corals, the general consensus is that extensive coastal development near the MPA increases turbidity that causes physical changes and imposes a far more serious threat to the MPA.

Recommendations and Challenges on Coral Reef Conservation and Sustainable Resource Use

Southern Korea is largely dominated by kelps and octocorals, yet scleractinian coral colonies are rapidly expanding their coverage and often replacing previous substrates. Changes in habitat composition are indicative of marine ecosystem resilience and can undermine regional fisheries and economy. New monitoring programs with an emphasis on changes in hard coral cover and distribution are therefore urgently needed, so that baseline information about the current status of kelps, octocorals and scleractinian corals becomes readily available, against which potential changes can be compared, and conservation decisions made.

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5. STATUS OF CORAL REEFS IN SOUTHEAST ASIA

5.1. CAMBODIA

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NUMBER OF SPECIES OF MAJOR TAXA RECORDED

Data were collected over four years from 2010 to 2014 throughout the Koh Rong Archipelago, with surveys carried out year-round. A total of 24 fish species were recorded in 17 families (table 5.1.1), in addition to 22 invertebrate species in 7 classes (Table 5.1.2), 27 genera of corals (Table 5.1.3) and 14 classifications of substrate (Table 5.1.3). To gain an understanding of localised stressors on reefs within the Koh Rong Archipelago, 5 physical impacts were also recorded (Table 5.1.2).

In comparison to reefs in other countries of Southeast Asia, commercial fish abundance in the Koh Rong Archipelago ranks first for parrotfish, second for grouper, and third for snapper and sweetlips, respectively (Table 5.1.4). This could be an important indicator of reef health, demonstrating that certain commercial species are not specifically targeted for food (Thorne *et al*., 2015).

Thorne *et al*., (2015) distinguished that invertebrate density and diversity are relatively uniform across the Archipelago, with the exception of one notably higher density site on the south of Koh Rong Island. It was also noted that invertebrate population abundance appears to be similar to other countries in Southeast Asia (Table 5.1.5).

Table 5.1.1: Checklist of target fish in the Koh Rong Archipelago and whether each family/species was documented during the study. *Table reference – Thorne et al., 2015.*

Fish	***Observed during study***
Lutjanidae (Snapper)	Yes
Lutjanus decussatus	Yes
Lutjanus bohar	Yes
Lutjanus fulvus	Yes
(All other Lutjanidae)	Yes
Nemipteridae (Monocle bream)	Yes
Scolopsis bilineatus	Yes
Scolopsis ciliatus	Yes
Lethrinidae spp. (Emperor)	Yes
Carangidae spp. (Jack)	Yes
Sphyraenidae (Barracuda)	No
Sphyraena obtusata	Yes
Sphyraena barracuda	Yes
(All other Sphyraenidae)	No
Serranidae (Grouper)	Yes
Cromileptes altivelis	Yes
Cephalopholis boenak	Yes
Cephalopholis argus	Yes
Cephalopholis formosa	Yes
Plectopomus areolatus	Yes
Epinephelus merra	Yes
(All other Serranidae)	No
Sygnathidae spp. (Seahorse/Pipefish)	No
Muraenidae spp. (Moray eel)	No
Chaetodontidae (Butterflyfish)	Yes
Chelmon rostratus	Yes
Heniochus acuminatus	Yes
Chaetodon octofaciatus	Yes
Siganidae (Rabbitfish)	Yes
Siganus corallinus	Yes
Siganus virgatus	Yes
Siganus javus	Yes
Siganus guttatus	Yes
Pomacentridae (Damselfish)	Yes
Amphiprioninae	Yes
Haemulidae (Sweetlips)	Yes
Hemiscyliidae spp. (Bamboo shark)	No
Dasytidae spp. (Blue-spotted ribbontail ray)	No
Holocentridae spp. (Soldierfish/Squirrelfish)	Yes
Mullidae (Goatfish)	Yes
Scaridae spp. (Parrotfish)	Yes

Table 5.1.2: Checklist of target invertebrates and impacts documented in the Koh Rong Archipelago, and whether each species was documented during the study. Presence and absence of recorded impacts is also noted. *Table reference – Thorne et al., 2015.*

Invertebrates	***Observed during study***
Annelida (Segmented worms)	
Spirobranchius spp.	Yes
Sabellastarte spp.	Yes
Platyhelminthes (Flatworms)	Yes
Cephlapoda (Cephlapods)	
Teuthida (Order)	No
Octopoda (Order)	No
Sepia spp.	No
Gastropoda (Gastropods)	
Calliosoma spp.	No
Drupella spp.	Yes
Nudibranchia spp.	Yes
Cypraeidae spp.	Yes
(All other gastropoda)	Yes
Bivalvia (Bivalves)	
Tridacna spp.	Yes
Crustacea (Crustaceans)	
Stenopus hispidus	No
Nephropidae spp.	Yes
Echinodermata (Echinoderms)	
Acanthaster planci	Yes
Culcita novaguinea	Yes
Protoreaster nodosus	No
Diadema spp.	Yes
Echinotrix spp.	Yes
Crinoidea spp.	Yes
Thelenota ananas	No
Stichopus chloronotus	No
Holothuria edulis	No

Impacts	***Observed during study***
Anchor damage	Yes
Dynamite damage	Yes
General trash	Yes
Fishing trash (nets, rope, traps etc.)	Yes
Coral disease (White band and black band)	No

Table 5.1.3: Checklist of target corals and substrates in the Koh Rong Archipelago and whether each species was documented during the study. Presence and absence of recorded substrates is also noted. *Table reference – Thorne et al., 2015.*

Corals	***Observed during study***
Acropora spp.	Yes
Astreopora spp.	Yes
Porites spp.	Yes
Goniopora/Alveopora spp.	Yes
Pavona decussata	Yes
Ctenactis echinata	Yes
Herpolitha limax	No
Polyphyllia talpina	No
Podabacia spp.	Yes
Galaxea spp.	Yes
Pectinia spp.	No
Lobophyllia spp.	Yes
Diploastrea heliopora	Yes
Echinopora spp.	Yes
Euphyllia spp.	No
Plerogyra spp.	No
Tubastrea micrantha	No
Turbinaria spp.	Yes
Pseudosiderastrea spp.	Yes
Brain coral (small, medium, large)	Yes (all three)
Tubipora spp.	No
Millepora spp.	No
Heliopora sp.	No
Favia spp.	Yes
Favites spp.	Yes

Substrates	***Observed during study***
Rock (geo-bedrock and dead coral)	Yes
Rubble	Yes
Sand	Yes
Silt	Yes
Nutrient Indicator Algae (NIA)	Yes
Hard coral (detailed above)	Yes
Soft coral	Yes
Sponge	Yes
Recently Killed Coral (RKC)	Yes
Anemone	Yes
Zoanthids	Yes
Corallimorphs	Yes
Halimeda spp.	No
Tunicates	Yes

Table 5.1.4: Comparison of key commercial fish family abundance (individuals/500 m^{-3}) between four Southeast Asian countries and the Koh Rong Archipelago. 'Rank' indicates the Archipelago's position in relation to the other countries (on a scale of 1-5) for each taxon. Comparison data were collated from Chelliah *et al*., 2012. Table reference – Thorne et al., 2015.

Fish	*Koh Rong Archipelago*	*Brunei*	*Philippines*	*Thailand*	*Malaysia*	*Rank*
Lutjanidae (Snapper)	7	1.45	2.14	20.63	11.13	**3**
Serranidae (Grouper)	2	0.19	0.18	7.68	0.71	**2**
Chaetodontidae (Butterflyfish)	3	1.73	12.57	6.2	4.47	**4**
Haemulidae (Sweetlips)	0.13	0.26	0.06	0.02	0.25	**3**
Scaridae spp. (Parrotfish)	12	1.63	2.19	6.34	2.53	**1**

Table 5.1.5: Comparison of invertebrate taxa abundance (individuals/100 m^{-2}) between four Southeast Asian countries and the Koh Rong Archipelago. 'Rank' indicates the Archipelago's position in relation to the other countries (on a scale of 1-5) for each taxon. Comparison data were collated from Chelliah et al., 2012. Table reference – Thorne et al., 2015.

Invertebrates	*Koh Rong Archipelago*	*Brunei*	*Philippines*	*Thailand*	*Malaysia*	*Rank*
***Diadema* spp.**	94	0.02	19.45	94.74	35.36	**2**
***Echinotrix* spp.**	0.02	0	0.01	0	0	**1**
Holothuria spp.	0	0.5	0.02	1.61	1.56	**5**
Acanthaster planci	0.04	0.03	0.39	0.15	0.21	**3**
Nephropidae spp.	0.03	0.04	0.03	0.2	0.01	**3**
Tridacna gigas	2	0.17	2.5	14.96	1.72	**3**

CORAL REEF MONITORING SITES

Over the monitoring period, from 2010 to 2014, a total of 156 sites were surveyed with two replicate surveys at each site (Fig. 5.1.1). Each survey consisted of four replicate transects, based on an adaptation of the Reef Check methodology (Hodgson *et al*., 2006). The issue of pseudo-replication in this study was discussed by Thorne *et al.* (2015) and, due to the low taxonomic specificity in the methods (typically to family level -Hodgson & Stepath, 1998), it was deemed not to be of relevance.

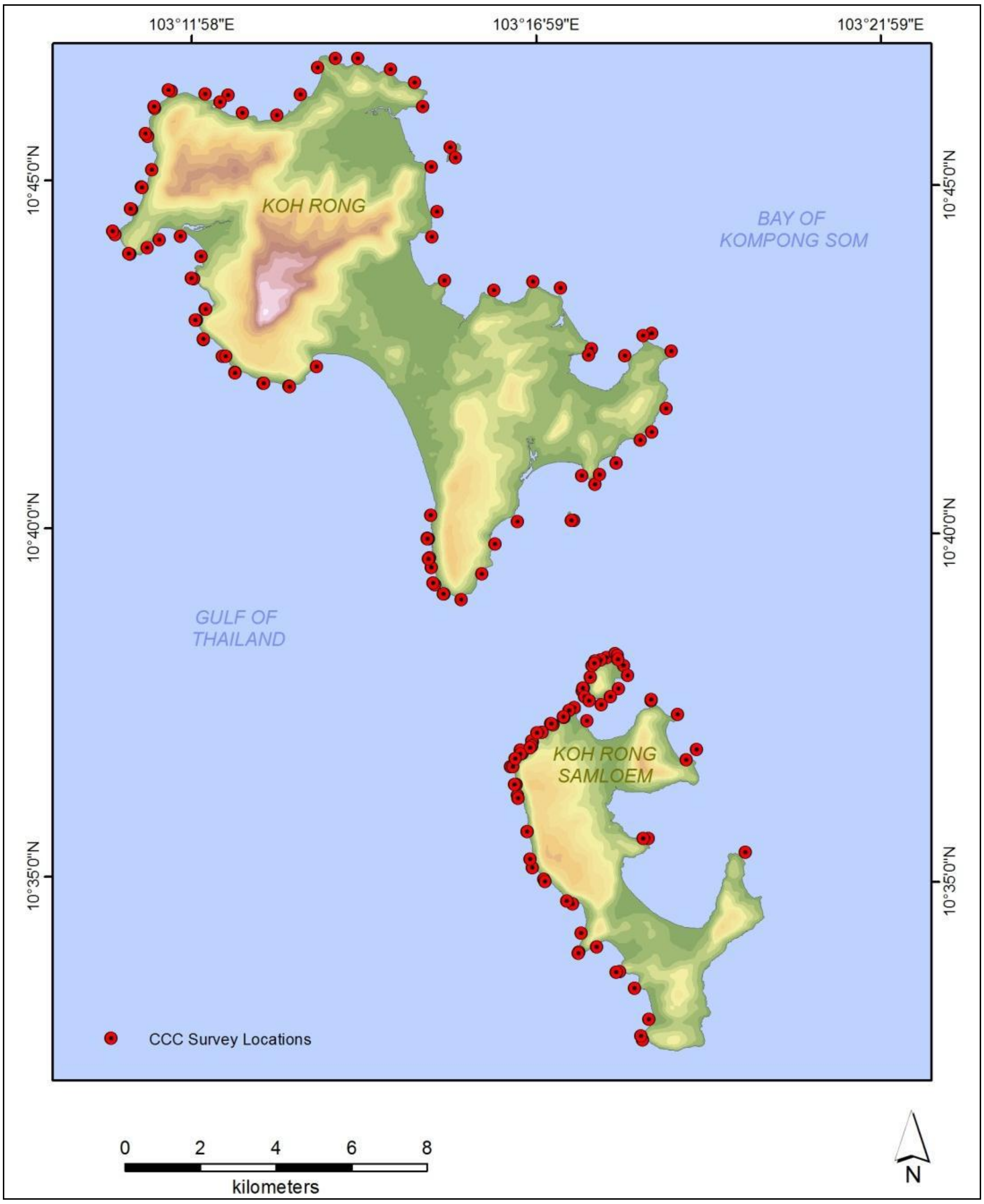

Fig. 5.1.1: Map of the coral monitoring sites of Cambodia. The monitoring survey were conducted by Coral Cay Conservation (CCC) around Koh Rong and Koh Rong Samloem.

RECOMMENDATIONS AND CHALLENGES ON CORAL REEF CONSERVATION AND SUSTAINABLE RESOURCE USE

a. **Implement an effective zonation plan following consultation with all island stakeholders**, including the island concession holders, tourism industry, local and national authorities, enforcement agencies and island communities. Several consultation rounds need to be conducted, drawing on local knowledge and experience, in order to reach a general consensus for the implementation of a zonation plan that balances different needs and goals. The zone map should be included in the Marine Fisheries Management Area (MFMA) –a national term for a specific type of multiple-use MPA- proclamation [Prakas], to maximise support for it's implementation. See further comments on zoning in section 5.1.d. below.

b. **Establish and implement an adaptive MFMA management plan**, which is designed to contribute to long-term biophysical, socio-economic and governance goals and objectives of the MFMA and can be monitored using verifiable indicators. This plan should complement and support already established individual management plans of the three Community Fisheries (CFis) and align with targets and timing of the Strategic Planning Framework for Fisheries 2010-2019 (Fisheries Administration, 2011). Planning should be carried out with the participation of multiple sectors. The Technical Working Group (TWG) – MFMA is already mandated to develop and update management plans and should coordinate this process.

c. **Use existing CFis as the building blocks of an effective MFMA**. The MFMA should strengthen not replace the CFis, embedding them in the broader management of the seascape. The presence of CFis provides an opportunity to enhance the rights of local resource users at village level, which in turn will improve MFMA effectiveness. The mandate of CFis to manage their own areas should be fully acknowledged and they should be encouraged to develop and implement their own internal by-laws within the scope of the existing Law on Fisheries and national CFi legislation.

d. **Use existing structures to support MFMA management**, particularly the Provincial Management Committee (PMC) and TWG - MFMA. Ensure clear guidelines on the roles, responsibility, contributions of each stakeholder group, and clarity on decision making processes so as to expedite management responses.

e. **Prohibit trawling and other destructive fishing methods within the MFMA**. Law enforcement and increased capacity through materials and manpower are needed to ensure illegal activities and encroachment by foreign vessels are not threatening fisheries resources, local livelihoods and marine biodiversity. Approaches should also seek to incentivise compliance by local stakeholders to MFMA rules and the zoning plan.

f. **Safeguard against negative livelihoods impacts and ensure food security and diversified livelihoods strategies**. Poor users of marine resources must have viable options for diversifying away from the use of protected fisheries resources. Recognise that biological benefits of no-take zones will take time to accrue, and that the MFMA should create an opportunity to enhance livelihoods and build capacity to take advantage of new opportunities that the MFMA might create, for example, involvement in the tourism sector. The time for this process should not be underestimated.

g. **Secure domestic budget allocations and implement sustainable financing mechanisms for MFMA management costs.** While government allocations may remain initially quite small, tangible and early contributions will demonstrate willingness and commitment to island stakeholders, engendering further support and collaboration for MFMA implementation. As a minimum, funds are required for education and outreach, demarcation, surveillance and monitoring, enforcement, and performance monitoring and evaluation. A diversified financing portfolio should be developed to support such costs, incorporating market-based funding sources and a benefit sharing mechanism with island communities.

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5.2. INDONESIA

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OVERVIEW OF THE CORAL REEFS IN INDONESIA

Basic information of Indonesian reefs is shown in table 5.2.1.

Table 5.2.1: Basic information of Indonesian reefs

Total area	5.0 million km^2	Continental shelf	1.5 million km^2
Total sea	3.1 million km^2	Exclusive Economic Zone	2.7 million km^2
Total reef area*	39,538 km^2 (16% of coral reefs of the world)	Total islands	17,508
Total reef area in MPA*	25%	Total coastline	81,000 km
Total number of MPAs*	131	Length: east-west	5,100 km
Archipelagic / inland waters	2.8 million km^2	north-south	1,888 km
Territorial sea (12 miles)	0.3 million km^2	Population	218 million (2005)

*Notes: All the data were provided by Indonesian Science Institute (LIPI), except data marked with * which is cited from "Reefs at Risk Revisited".*

Dirhamsyah (2005) noted that 26.5 percent of the Indonesian Gross National Product was derived from the utilization of coastal and marine resources in 2002. Fish and other marine resources make a significant contribution to the supply of food, employment, and foreign exchange. More than 60% of animal protein consumed by the population is derived from the fisheries sector, and per capita consumption was estimated to be 21.7 kg per year in 2002. Employment in the primary fishing sector was roughly 1,805,470 people and exports exceeded imports by just over US$ 1.6 million in 2000.

BIODIVERSITY

Indonesia is noted as a country with the most marine biodiversity in the world. Veron et al (2009) noted that the highest zooxanthellate coral species richness resides in the Raja Ampat archipelago at the Bird's Head Peninsula, with 553 species (equivalent to 69% of the world's total species complement) and individual reefs supporting up to 280 species/ha.

Indonesia also has more coral reef fish diversity than anywhere else in the world: 34% (2,228) of the world's coral reef fish species (6,000), and 52% of the coral reef fishes in the Indo-Pacific region (4,050) (Allen, 2003, 2007).

Table 5.2.2: Biodiversity of Indonesian reefs

Taxa	Species number in Indonesia	Total species number in the world
Coral (rank 1)	590	798** (Veron et all, 2009)
Seagrass	15*** (CT atlas, 2005)	72*** (CT atlas, 2005)
Mangrove	45*** (CT Atlas)	73*** (CT Atlas)
Sponge	850	
Coral Reef Fish (rank 1)	2057**** (Allen, 2003)	6000**** (Allen, 2007)
Crustaceans	1512	
Echinoderms	1412	
Algae	782	
Mollusks	2500	
Mammals	24	
Reptiles	37	
Turtles	6	7
Sea Birds	151	

*Notes: All the data were provided from Indonesian Science Institute (LIPI), except the data with **, *** and ****. The data with ** was cited from "Veron et al 2009", the data with *** was cited from "CT Atlas 2005" and the data with **** was cited from "Allen 2003".*

CORAL REEF MONITORING SITES

Coral reef monitoring sites in Indonesia in general is divided into three: Sites at MPAs managed under Forestry Ministry, MPAs managed by Ministry of Marine and Fisheries Affairs (MMAF), and data taken by Indonesian Science Institute (ISI). Most of the data is collected under a collaboration with local stakeholders (local government or universities), partners (NGOs), or within the three institutions.

Forestry Ministry collected data from 7 marine national parks: Bunaken National Park

(NP), Karimun Jawa NP, Taka Bonerate NP, Cendrawasih Bay NP, Wakatobi NP, Togean NP, and Thousands Islands NP.

MMAF and ISI conducted collaboration for Coral Reef Rehabilitation and Management Program (COREMAP) II between 2004 and 2011. In between this period, coral reef monitoring was conducted in West of Indonesia that includes: East Coast of Sumatera: Natuna Regency (24 stations), Bintan Regency (24 stations), Lingga Regency (8 station) and Batam Municipality (20 station); and West Coast of Sumatra: Nias Regency (11 station), South of Nias (12 stations), Central Tapanuli Regency (17 stations) and Mentawat Regency (18 Stations). While in East of Indonesia, coral monitoring sites include Pangkajene and islands (Pangkep) Regency (11 stations), Selayar Islands Regency (10 stations), Buton Regency (7 stations), Wakatobi Regency (15 stations located in some of the COREMAP Locally Marine Manage area), Sikka Regency (15 stations), Biak Regency (13 stations), and Raja Ampat Regency (7 stations located in some of the COREMAP Locally Marine Manage areas).

MMAF also collaborated with NGO partners to measure coral reef condition in other MPAs, both established and those under development, such as in Kofiau (26 to 32 stations), Berau, (18 to 36 stations), Bali (48 stations), Alor (33 to 46 stations), and East Flores (15 to 37 stations).

SITE CHANGES IN PERCENT HARD CORAL COVER

Spatial and temporal comparison in national parks in Indonesia is statistically challenging. Except in several areas, limited resources caused an inconsistency of the methodology used (ranging from LIT, PIT, and RC), as well as the monitoring sites. Nevertheless, from the data collected from 2006-2011, Cendrawasih NP had the highest coral cover and Wakatobi NP had the lowest (Table 5.2.3). Bunaken NP showed a relatively stable coral cover between 2006 and 2009. There was decrease of coral cover percentage in 3 national parks in 2011, probably related to the mass bleaching event in 2010.

Table 5.2.3: Summary of coral monitoring data in National Parks in Indonesia.

no	Location (Marine National Park)	Total area of coral reefs (ha)	Coral cover (%)					
			2006	2007	2008	2009	2010	2011
1	Bunaken	11,709	48.48	48.35	-	48.05	-	-
2	Karimun Jawa	7,947	47.70	-	46.78	58.32	51.76	-
3	Taka Bonerate	66,304	-		51.80	54.60	-	46.30
4	Teluk Cenderwasih	25,909	54.24	-	49.88	55.175	46.61	48.20
5	Kep. Wakatobi	78,874	-	-	-	29.4	35.6	25.10
6	Kep. Togean	10,277			34.70		46.35	41,74
7	Kep. Seribu	1,750		30.40		35.06		

(Data Source: Ministry of Forestry, Indonesia)

In West of Indonesia, COREMAP collected reef monitoring data by using a modified LIT on permanent transects. In general, COREMAP data in the West of Indonesia shows an increasing trend of percentage coral cover except for Lingga Regency (Fig

5.2.1). This is especially for islands at Tambelan sub-district, Bintan Regency. The percentage of hard coral cover kept increasing from 61.43 % in 2004 to 67.11 % in 2009, and 72.63 % in 2010. Meanwhile, the percentage of dead coral with algae decreased from 25.78% and in 2004 to 22.51% in 2009 and 17.28 % in 2010 (Giyanto et al, 2014).

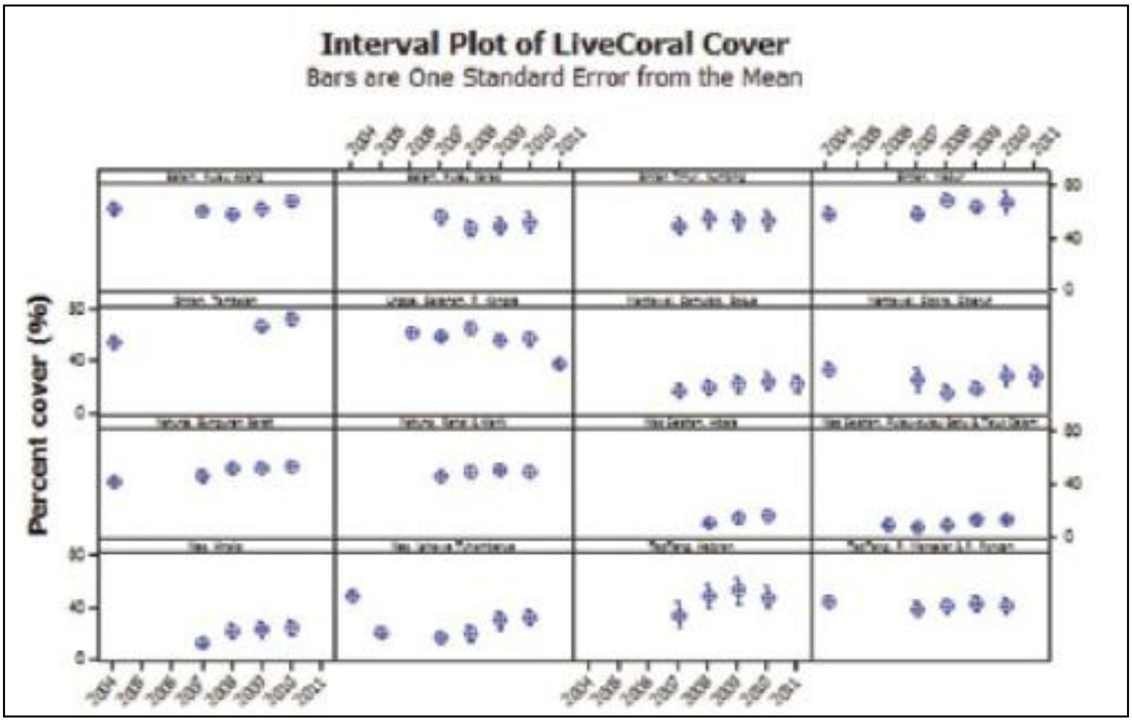

Fig. 5.2.1: Average of coral cover (%) in the West of Indonesia. The error bar indicates standard deviation.

In East of Indonesia COREMAP used PIT on permanent transect. Giyanto et al (2014) noted several patterns of percentage coral cover. Percentage coral cover in Biak and Padaido Islands declined, contrary to Selayar that showed an increasing trend, while LMMA Wakatobi tended to be stable (Fig.5.2.2). The combination of a strong storm (2009), blast fishing, and coral bleaching (2010) are the major causes of the decline in Biak. In 2006, average percentage coral cover in East of Biak and Padaido Islands was 22.97%. In 2009, the percentage slightly increased to 26.14%. In the 2010 monitoring, it plummeted to 20.08%. The trend continued to drop in 2011 to 17.60%.

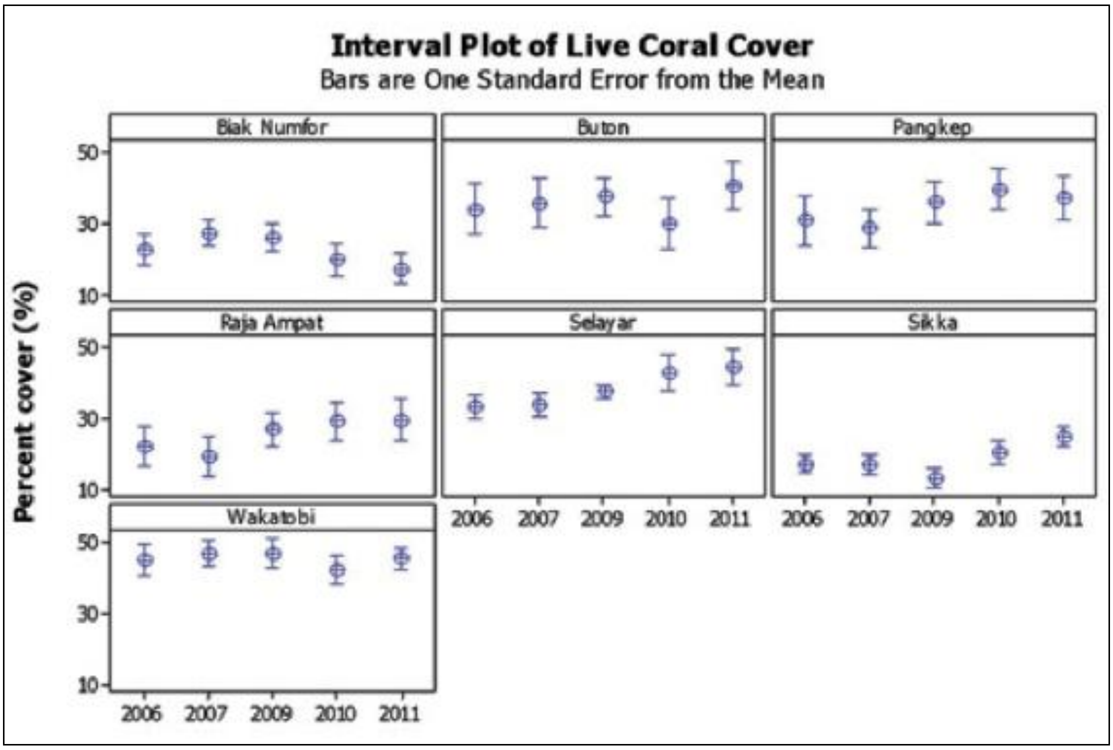

Fig. 5.2.2: Average live coral cover (%) with standard deviation in the East of Indonesia.

MMAF in collaboration with TNC found that hard coral cover in Kofiau was stable at around 30% (2000 vs. 2012 data), while that in Berau dropped significantly from 58% in 2007 to 2011 in 2012 (table 5.2.4).

Table 5.2.4: Hard coral cover in Kofiau and Berau

no	sites	Coral cover (%)				
		2003	2007	2009	2010	2011
1	Kofiau	-	-	33	26	30
2	Berau	58	52	26	-	25

Alor, East Flores, and Bali are among some of MMAF MPAs that are still under development. However, coral reef monitoring data had already been started. In Alor, in collaboration with NGO partner WWF, coral reef monitoring showed that hard coral percentage remained at around 34% in 2011 and 2013, while in East Flores it declined from 22% in 2012 to 16% in 2013. In Bali, a baseline for coral reef was set in 2013 in collaboration with CII and CTC. The percentage hard coral cover on average was 38.2% with a range of 21.5% to 68% (Mustika, 2012).

INDEX SCORES OF MAJOR BENTHIC TAXA AND FISH

Latest data from Ministry of Forestry showed that in general Taka Bone Rate and

Waka Tobi NP had the highest average score for benthic taxa (only a difference of 1 score), with Bunaken NP the lowest score (Table 5.2.5).

Table 5.2.5: Index scores of major benthic taxa and fish at the National Parks.

Region / Area / Site	Coral		Mollusc		Crustacean (Lobster)	Echinoderm			Algae	
	Hard coral	Soft coral	Tridacna	Triton		Diadema	Sea cucumber	COT	NIA	Coralline Algae
Bunaken NP	3	1	1	2	1	1	2	1	1	5
Karimun Jawa NP	4	3	1 (186/ha)	-	-	-	1 (3/ha)	1 (22/ha)	2	1
Takabonerate NP	5	1	5	5	4	4	3	4	1	3
Teluk Cenderawasih NP	3	5	1	No data	No data	No data	5	No data	No data	1
Wakatobi NP	3	3	5	2	5	5	5	5	No data	1
Togean NP	3	3	3	2	2	3	2	4	4	3
Kepulauan Seribu NP	3	1	2	1	1	5	3	4	No data	5

Data for fish were not as complete as for the major benthic groups. The database of the Ministry of Forestry had complete data only from 3 national parks, with Taka Bone Rate having the highest cumulative score (Table 5.2.6).

Table 5.2.6(1): Index scores of major fish at the National Parks.

Region / Area / Site	Grouper		Snapper		Sweetlips		Butterfly fish		Fusilier fish		Surgeon fish	
	2006	2012	2006	2012	2006	2012	2006	2012	2006	2012	2006	2012
Bunaken NP	No data	1	No data	2	No data	2	No data	2	No data	2	No data	1
Karimun Jawa NP	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Takabonerate NP	5	3	5	3	5	4	5	4	5	3	5	3
Teluk Cenderawasih NP	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Wakatobi NP	5	5	5	4	5	5	5	5	1	1	5	5
Togean NP	No data	2	No data	2	No data	3	No data	3	No data	5	No data	2
Kepulauan Seribu NP	4	3	5	5	2	1	5	5	5	4	3	2

Table 5.2.6(2): Index scores of major fish at the National Parks (continue).

Region / Area / Site	Rabbit fish		Parrot fish		Damsel fish		Angel fish		Trigger fish		All fish species	
	2006	2012	2006	2012	2006	2012	2006	2012	2006	2012	2006	2012
Bunaken NP	No data	1	No data	1	No data	2	No data	2	No data	2	No data	2
Karimun Jawa NP	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Takabonerate NP	5	3	5	4	5	4	5	3	5	3	5	3
Teluk Cenderawasih NP	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Wakatobi NP	4	4	3	3	1	1	5	5	5	5	1	1
Togean NP	No data	2	No data	3	No data	4	No data	2	No data	4	No data	3
Kepulauan Seribu NP	5	4	5	5	5	5	5	4	1	1	4	3

INDEX SCORES FOR CURRENT LEVELS AND TRENDS IN CORAL REEF RESOURCE USAGE

Bunaken NP and Kepulauan Seribu NP has the highest scores for level and trends in Coral Reef Resource usage (Table 5.2.7). This is expected, as both are located very close to big cities: Manado and Jakarta respectively.

Table 5.2.7: Index scores for current levels and trends in coral reef resource usage at the National Parks.

Region / Area / Site	Extractive				Semi-extractive / Non-extractive			
	Fisheries (Reef fish and other reef organisms)			Coral Mining	Tourism			Research
	Small-Scale	Med to Large Scale	Aqua-culture		Resorts / Hotels	Dive Operators	Live-Aboard	
Bunaken NP	3	4	2	3	2	3	3	3
Karimun Jawa NP	3	2	2	1	2	2	1	3
Takabonerate NP	3	3	2	2	2	2	2	2
Teluk Cenderawasih NP	2	2	2	No data	2	2	3	3
Wakatobi NP	3	3	2	2	2	2	2	2
Togean NP	3	2	1	2	2	2	3	2
Kepulauan Seribu NP	3	2	3	4	3	4	2	2

INDEX SCORES FOR CURRENT STRESS AND DAMAGE FOR CORAL REEFS

As predicted, the data from Ministry of Forestry showed that the two parks with high index score for the level and trend of usage also showed a high index score for stress and damage to coral reefs (Table 5.2.8). However, it is interesting to see that Taka Bone Rate had the highest index scores for current stress and damage for coral reefs, despite its low index score for the current level and trends of coral reef usage.

Table 5.2.8: Index scores for current stress and damage for coral reefs at the National Parks.

Region / Area / Site	Sediments & nutrients (land-based)	Destructive fishing methods	Anchor, trawler & other kind of damages (divers, trampling, etc)	Coastal development (ports, airports, dredging, etc.)	Coral breaching	Coral diseases	Outbreaking or invasive organisms (COTs, Drupella, Diadema, etc)	Coral damage from natural events (storms, etc)
Bunaken NP	3	3	2	2	3	3	4	3
Karimun Jawa NP	1	3	3	2	3	2	1	2
Takabonerate NP	2	4	3	3	4	3	3	2
Teluk Cenderawasih NP	2	2	2	2	1	1	1	1
Wakatobi NP	2	4	2	3	2	2	2	2
Togean NP	2	3	3	3	2	3	3	2
Kepulauan Seribu NP	3	3	4	3	3	3	2	2

MEASURABLE STRESS AND DAMAGE SUMMARIES AT REGIONAL/NATIONAL LEVEL

Reef at Risk Revisited (2012) put about half of the reefs of Indonesia under the medium risk of threats, with only 9% under the low threat category located mostly in the more sparsely populated eastern areas. Overfishing, destructive fishing (blast and poison fishing), and sedimentation and pollution are the significant threats with coastal development a growing threat. This region has also suffered from mass bleaching events, with the last one in 2009-2010 arguably the most serious, killing up to 100% of coral in several areas (Setiasih et al, 2010).

MPA ATTRIBUTES, THREAT LEVEL, AND MANAGEMENT EFFECTIVENESS SCORES

Forestry Ministry conducted several management effectiveness measurements in some of their MPAs using a modified version of the World Bank's Score Card to Assess Progress in Achieving Management Effectiveness Goals for Marine Protected Areas (2004). The measurement was conducted in 2009/2007 and 2010 in Takabone Rate NP, Wakatobi NP, and Teluk Maumere Tourism Recreational Park (TRP) (table 5.2.9). TRP in general has less resources compared to national parks and thus had a lower score compared to the other 2 NPs. However, Teluk Maumere showed an increasing trend in management score between 2007 and 2010, while the overall management scores for the two NPs decreased.

Table 5.2.9: World Bank Score Card for 3 of Marine National Park in Indonesia.

Process Element	Takabone Rate NP			Wakatobi NP			Teluk Maumere TRP		
	2009	2010	Change (+/- %)	2009	2010	Change (+/- %)	2007	2010	Change (+/- %)
Context	19	20	5.26	20	22	10	13	15	15.38
Planning	14	12	-14.29	12	11	- 8.33	6	10	66.67
Inputs	13	10	- 23.08	8	10	25	7	7	0
Process	22	17	- 22.73	18	18	0	10	11	10
Outputs	26	20	- 23.08	20	22	10	11	11	0
Outcomes	24	20	- 16.67	21	12	- 42.86	7	7	0
TOTAL	118	99	- 16.1	99	95	- 4.04	41	61	48.73

Note: Based on World Bank 2004 (Score Card to Assess Progress in Achieving Management Effectiveness Goals for Marine Protected Areas, adapted by F Staub and M E Hatziolos, World Bank, Washington DC), and Modified by Peter Mous (MPA Consultant), and applied to 3 Marine Conservation Areas (Taka Bonerate NP, Wakatobi NP, Teluk Maumere TRP) that implemented Marine Parks supported by COREMAP II.

Moreover, in 2010, Forestry Ministry, partnering with WWF, implemented the Management Effectiveness Tracking Tools (METT), developed by WWF and the World Bank to help track and monitor progress in the achievement of worldwide protected area management effectiveness target in the 7 marine NPs. Management of Bunaken NP stood out as the most effective. The highest level of threats was identified at Togean NP, which is the youngest of all NPs (Table 5.2.10).

Table 5.2.10: METT (Management Effectiveness Tracking Tools) score in 4 national parks in Indonesia

Location	Management Issue	Threats
Karimun Jawa NP	48	41
Kepulauan Seribu NP	80	72
Togean NP	56	**98**
Taka Bonerate NP	55	83
Bunaken NP	**86**	79
Wakatobi NP	72	76
Teluk Cendrawasih NP	67	24

SUMMARY OF MPA ATTRIBUTES IN INDONESIA

Table 5.2.11: MPA Attributes

Total number of MPAs - Declared	131	
Total number of MPAs – Proposed	n..a.	
% of Declared MPAs with Coral Reefs Represented	131	
Total % of Reefs Within Declared MPAs	25%	
% of Declared MPAs that have management effectiveness rating of: *(please indicate management effectiveness protocol used for rating)*	Unknown	See narrative
	Poor	See narrative
	Moderate	See narrative
	Good	See narrative
	Very Good	See narrative
% of Declared MPAs with Areas that are:	Unknown	9
	<10, 000 ha	51
	Between 10,000 & 30,000 ha	20
	Between 30,000 & 50,000 ha	12
	Between 50,000 & 100,000 ha	12
	> 100,000 ha	27
% of Declared MPAs established:	Before 1994	13
	Between 1994 & 2006	33
	After 2006	86

PRINCIPLE ACTS AND REGULATIONS AFFECTING CORAL REEFS

The Constitution of Republic Indonesia 1945 chapter 33 (3) stated that the land and the waters as well as the natural riches (thus, coral reef) therein are to be controlled by the state to be exploited to the greatest benefit of the people. Coral reef conservation was originally managed under Forestry, while the marine fisheries were under Agriculture Ministry. Both Ministries had declared several MPAs in Indonesia. With the development of a Ministry specifically designated to manage Indonesia's marine area in 1999, and the development of the regional autonomy policy, local governments (based on act UU 27/2007) and Ministry of Marine Affairs (MMAF) also manage MPAs under government regulation 60/2007 and act 45/2009. Directorate of Conservation for Areas and Fish Species of Directorate-General of marine, coastal and small islands of MMAF is the institution responsible to regulate and manage these policies.

In December 2013, MMAF and local governments had initiated the development and management of about 11 million ha of MPAs while 4.6 million ha of MPAs are managed by the Forestry Ministry, including 7 national parks, (dit KKJI, 2013). In January 2014, Government released act no. 1/2014, a revision of UU 27/2007, to hand over the management of the 7 national parks from Forestry to MMAF. Indonesia has now in total established 15,764,210.00 ha in 131 MPAs. The Government is aiming to establish 20 million ha of MPAs in 2020 (dit KKJI, 2013). In the face of the changing climate, MMAF has just set up guidelines of MPA network development that takes resilience as one of the main consideration factors (MMAF regulation 13/2014).

In total there are at least 13 government agencies at national level that are involved in marine/coral reef management in Indonesia (see Table 5.2.12). The national level agencies will set programs at national level that provides guidelines or standard operational framework and policy to manage coral reefs at provincial level. In general, operational aspects of local coral reef management are set by agencies at provincial and regency government, except for areas that are considered of national strategic importance. Act 32/2004 delineates provincial marine territory as 12 nautical miles from coastline to open sea, while the regency marine territory is a third from provincial marine territory.

Table 5.2.12: National Government Agencies involved in coastal and marine management (Adjusted from Dirhamsyah, 2005)

No	Agency	Responsibility	Legislation
1	National Coordinating Body for Ocean Safety	• To coordinate maritime law enforcement activities in Indonesia	• Cooperation Decree of 1972
2	National Planning Agency	• To coordinate coastal and marine development plan • To develop coastal and marine spatial planning	• Act 80/1958 • Act 24/1992 • Act 25/2000 • Act 17/2003 • Act 26/2007
3	Ministry of Marine Affairs and Fisheries	• To undertake fisheries management and ensure compliance by both Indonesian fishermen and foreign fishing vessels; • To control illegal fishing; • To prevent the exotic diseases through importation of infected marine species. • To conserve, preserve and utilize marine biodiversity and its ecosystems; • Management authority for CITES.	• Act No. 9 of 1985 • Act No. 5 of 1990 • Act No. 16/1992 • Act No. 5 of 1994 • Act no 31/2004 • Act no 27/2007 • Act no 45/2009 • Act no 1/2014
4	Ministry of Forestry	• To conserve, preserve and utilize marine biodiversity and its ecosystems in the designated marine national parks (7)	• Act No. 5 of 1990 • Act No. 41 of 1999 • Govt Act No. 7 of 1999 • Govt Act No. 8 of 1999 • Govt Act No. 28 of 2011
5	Ministry of Energy and Mineral Resources	• To prevent negative impact of mining activities on Indonesian marine and coastal areas	• Act No. 22 of 2001 • Act No. 11 of 1967
6	Ministry of National Education	• To preserve cultural material on marine and coastal areas.	• Act No. 5 of 1992
7	Ministry of Transportation and Communication	• To manage shipping activities in Indonesia; • To establish sea-lanes for foreign and domestic ships; • To conduct search and rescue operations; • To prevent marine pollution generated from oil spills.	• Act No. 21 of 1992

8	State Ministry for Environment	• To monitor marine pollution; • To preserve and conserve the marine environment and ecosystems in all Indonesian territorial waters and the zones beyond its territory, the EEZ and Continental Shelf.	• Act No. 23 of 1997
9	Indonesian Navy	• To enforce maritime laws only on the areas beyond the territorial sea, including the EEZ, and Continental Shelf.	• Act No. 5 of 1983 • Act No. 9 of 1985 • Act No. 5 of 1990 • Act No. 21 of 1992 • Act No. 23 of 1997 • Act No. 2 of 2002
10	Indonesian Air Force	• To conduct air surveillance in all Indonesia territorial waters and the zones beyond its territory, including the EEZ and Continental Shelf	• Act No. 20 of 1982
11	Marine Police	• To enforce maritime laws in internal and inshore waters.	• Act No. 2 of 2002 • Act No. 8 of 1991 • Act No. 8 of 1981 • Act No. 12 of 1951
12	Directorate General of Immigration	• To control the entry of individuals into Indonesia.	• Act No. 9 of 1992
13	Directorate General of Customs	• To control the importation of illicit drugs and illegal goods.	• Act No. 10 of 1995

Note: Additional Acts of relevance are: Act No. 8/1981 concerning the Criminal Code; Act No. 2/2002 concerning the Indonesian Police, and Act No. 4/2004 concerning Judicial Power.

RECOMMENDATIONS AND CHALLENGES ON CORAL REEF CONSERVATION AND SUSTAINABLE RESOURCE USE

As mentioned, Reef at Risk Revisited report (2011) noted overfishing, destructive fishing (blast and poison fishing), sedimentation and pollution, coastal development, and global climate change as threats to coral reefs in Indonesia. Coral reef managers have to face these threats while facing challenges from Indonesia's geographic condition.

Indonesia has more than 17 thousands islands, scattered in about 5000 km length of the equator with only about 6000 being inhabited (Wikipedia). About 57% of the population is centered on Java Islands, another 30% around Sumatra and Bali Islands and similarly with the infrastructure and human resources.

Many of reef areas in Indonesia are located in remote areas, especially in the East, where the reefs in general are in better condition. However, these areas are among the highest challenge for reef managers in dealing with logistic and resources. On the other hand, reefs in densely populated areas in Indonesia face another challenge, as it has to deal with high level of stress. The condition resulted in a remarkable amount of MPA financing required for the management.

With less than 10 percent of reefs in Indonesia under a low threat risk (Burke et al, 2011) we are in urgent need to identify the management gap to overcome the geographic condition and the resources. Dirhamsyah (2005) identified these following aspects:

1. Lack of community participation;
2. Weakness in national and local legislative framework;
3. Lack of national policy and planning;
4. Lack of law enforcement and compliance systems;
5. Weakness in institutional arrangements for coastal and coral reef resources management;
6. The general lack of political and bureaucratic commitment and lack of interagency cooperation at the national and regional government levels.

Moreover, Setiasih et al (2012) also noted the weakness of monitoring and evaluation of coral reef management, which hinders improvement. Many management plans focus more on ambient monitoring, mostly ecological; there are very few coral reef management plans that also assess the management, performance indicator, impact evaluation, and systematic evaluation. The role of science in management has to be improved. There is an urgent need to build a more conducive integration mechanism between science and management in advising policy and building adaptive management.

With the current threats, and the management challenges in Indonesia, partnership is a key. In general, a location with strong partnerships has better data availability and management tools (Setiasih et al, 2012). However they have challenges in terms of program sustainability. Setiasih et al (2012) suggested a partnership model in improving coral reef management in Indonesia (Fig. 5.1.3).

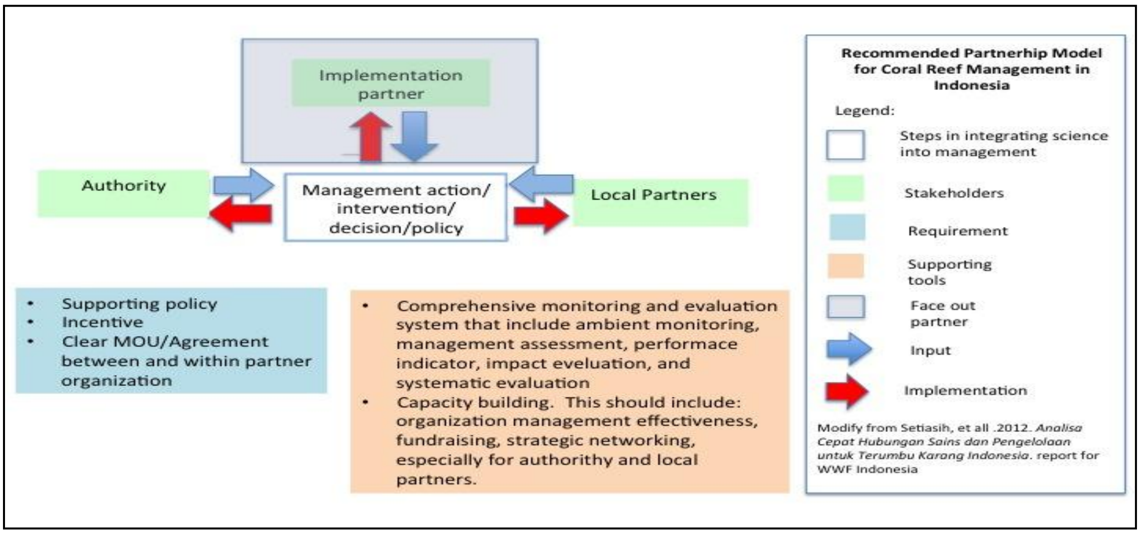

Fig. 5.2.3: Recommended partnership model for Coral Reef Management in Indonesia.

In developing and implementing coral reef management, three stakeholders have to work together closely. They are:

- The authority: the official reef manager for the area. The staff includes park managers, head of management unit, etc.
- Implementation partners: main facilitators that have dedicated resources to support the site authority over a certain period of time, for example: NGOs or government program/project
- Strategic partners: those who have a special interest in the area because of their expertise or because of the location. They are likely to be based in or close to the area, this may include: local NGOs, local universities, community groups, etc.

The management plan has to include a clear phasing out process of the implementation partners, as their resources are unlikely to be sustainable for the designated area, and they usually are not local organization based on site. The phasing out process has to include a plan to develop sustainable resources to run the coral reef management after the project/program is closed. Therefore, it is important that capacity building for local partners is not only including the technical aspect, but also organization and financial skills.

To assure that management is properly measured, we need to develop more monitoring and evaluation system on top of ecological monitoring. Mascia et al (in review), mentioned the importance of having a performance indicator, management assessment, impact evaluation, and systemic evaluation.

Moreover, it is important to set legal support for the process (such as supporting policy and incentive system as well as MOU and agreement between and within implementing partners). Dirhansyah (2005) suggested that to improve coral reef management we need to:

1. Establish a national ocean policy; amendment of several natural resource laws and the enactment of a new integrated natural resources law;
2. Establish horizontal and vertical interagency cooperative mechanisms for policy and management planning and implementation;
3. Establish national and regional law enforcement units;
4. Create a new Coordinating Ministry for Ocean Activities.

With a vast and scattered reef area, more and more organizations focus and recommend a community based management or co-management concept to manage coral resources (Dirhansyah, 2005; Suharsono, 2008). This approach has been implemented in many of COREMAP sites and MMAF new MPAs, including in Raja Ampat. However, it is important to always build a strong alignment of this approach to a bigger management platform. In Bali, for example, MMAF with local government and partners are in a process to develop an MPA network of a series of Locally Marine Managed Areas across the islands.

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5.3. MALAYSIA

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SUMMARY

The status of Malaysian coral reefs in 2013 was primarily based on the results of Reef Check Malaysia surveys at 196 reef sites. The mean live coral cover for Malaysia was 'Fair' at 48.3% with a range from 17.4% to 75.7%. The surveys divided Malaysian reefs into their three marine eco-regions and found that the reefs in Sunda Shelf eco-region was at 57.6% (Good), Straits of Malacca 44.6% (Fair) and North Borneo 39.5% (Fair). The results suggested that all reefs in Malaysia are under high anthropogenic threats. It is encouraging that support is given by relevant authorities to the reef monitoring efforts by an NGO such as Reef Check Malaysia. Nevertheless the number of monitoring sites is still inadequate and must be increased inclusive of permanent transects or quadrats at crucial reef sites to be able to monitor accurate changes. After the mass coral bleaching event in 2010, a coral bleaching response plan for Malaysia has been developed and is hoped to be used effectively in the next mass coral bleaching event. In addition, new management plans for three marine park areas in Peninsular Malaysia have just been finalised and should enhance their management and effectiveness in conserving the marine resources and will be useful for other marine protected areas to emulate.

INTRODUCTION

Country statistics and coral reef resources 2014

Malaysia is located slightly north of the equator and comprises Peninsular Malaysia, Sarawak and Sabah. The latter two are on the island of Borneo and Peninsular Malaysia is a part of continental Southeast Asia. Malaysia is bordered by the Andaman Sea and Straits of Malacca on the west, South China Sea in the middle and Sulu Sea and Celebes Sea on the east. The main climatic drivers of its marine environment are the northeast monsoon (Nov-Mar) and the southwest monsoon winds (May-Sept).

Coral reefs are found mainly as fringing reefs off Peninsular Malaysia's west and east coast, submerged reefs off Sarawak and fringing reefs around Sabah. There are a few

Malaysian atoll reefs in the Spratlys which include Pulau Layang-Layang. More than 70% of Malaysian coral reefs are in Sabah waters and waters off the eastern part of Sabah are within the Coral Triangle (Veron et al. 2009).

Number of species of major taxa recorded

Peninsular Malaysia waters have been reported to harbour approximately 480 species of scleractinian corals (Affendi and Rosman 2011) which includes 398 species from its east coast (Huang et al. 2014). Whereas for Sabah, Zarinah et al. (2012) reported 471 species of scleractinian corals and Ditlev (2003) discovered 8 new species from Darvel Bay on its east coast. Nevertheless the studies by Affendi and Rosman (2011) and Zarinah, Ridzwan, and Affendi Johari (2011) have stated that their species lists need reconfirmation.

Biodiversity studies of marine organisms in Malaysia have been sparse due to the lack of local expertise in taxonomy and research funding. Nevertheless species diversity studies is still ongoing and results have been encouraging but the present species list is still regarded as an underestimate. The list has approximately 140 species of chondrichthyan fish which includes 7 orders of sharks with 2 new species of swell sharks (Ali, Gambang, and Annie Lim 2011), up to 30 species of marine mammals including dugongs and orcas (Jaaman and Bali 2011; Ponnampalam 2012), 12 species of seagrasses (Bujang and Zakaria 2011), 375 species of seaweeds (Phang 2006) with 91 species in Sarawak (Nurridan 2011), 525 species of decapod crustaceans (Cob et al. 2011), 581 species of marine shelled molluscs (Nur Leena and Arshad 2011), up to 44 species of sea cucumbers (Sim and Kee Alfian 2011; Ilias 2011) and lastly 13 genera with 19 species of sea stars (Sim and Kee Alfian 2011).

In late 2010, an expedition to reef areas in Semporna, Sabah (Kassem, Hoeksema, and Affendi 2012) which is a part of the Coral Triangle, documented 44 species of mushroom corals (Fungiidae), 104 species of shrimps, 130 species of seaweeds, 690 species of reef fish in 265 genera and 72 families. The reef fish species count could reach 966 species with more extensive surveys.

STATUS OF CORAL REEFS

The National Reef Check Survey Programme has been implemented since 2007 with the latest coral reef monitoring report for Malaysia for the year 2013 (Reef Check Malaysia 2014). Reef Check Malaysia is a local non-profit NGO which is advised by local marine scientists. The surveyed areas were divided into three according to their marine eco-regions (Spalding et al. 2007) which are Malacca Straits (Eco-region 118), Sunda Shelf (Eco-region 117) and North Borneo (Eco-region 126). There are 93 survey sites in Peninsular Malaysia and 103 sites in Sabah and Sarawak at present (Table 5.3.1).

Using live coral cover (LCC) percentage to categorise a health rating (Chou et al. 1994), with 0-25% categorised as 'Poor', 26-50% as 'Fair', 51-75% as 'Good' and 76-100% as 'Excellent', Malaysian coral reefs stand at 'Fair'. The mean percentage LCC for Malaysia is 48.3%. Nevertheless targeted fish species abundance is low such as groupers (0.62 individuals per 500m^3) and invertebrates such as lobsters (0.02 individuals per 100m^2).

In the Sunda Shelf eco-region, the mean percentage LCC is 'Good' at 57.6% with only Kuching having the 'Excellent' rating at 75.7%, which was the highest for Malaysian coral reefs (Table 5.3.2).

Table 5.3.1: Reef Check Malaysia survey locations and sites surveyed in 2013 with reference to their eco-region and protection status. *SIMCA = Sugud Islands Marine Conservation Area.*

Number and Eco-Region	**Location**	**Sites surveyed**	**Protection status**
117 - Sunda Shelf	<u>Peninsular Malaysia (east coast)</u>		
	Pulau Perhentian	11	Federal Marine Park
	Pulau Redang	12	Federal Marine Park
	Pulau Tioman	27	Federal Marine Park
	Pulau Kapas	5	Federal Marine Park
	Pulau Bidong/Yu	6	Federal Marine Park
	Pulau Tenggol	6	Federal Marine Park
	Pulau Pemanggil	6	Federal & State Marine Park
	Pulau Sibu/Tinggi	10	Federal & State Marine Park
	Pulau Babi Tengah	1	Federal & State Marine park
	<u>Sarawak</u>		
	Miri	5	None
	Kuching	6	None
118 – Malacca Straits	<u>Peninsular Malaysia (west coast)</u>		
	Kepulauan Sembilan & Pulau Pangkor Laut	9	None
126 – North Borneo	<u>Sabah</u>		
	Pulau Lankayan	15	Protected area by SIMCA
	Pulau Mataking	6	None
	Semporna	14	None
	Pulau Mantanani	13	None
	Kota Belud	2	None
	Tunku Abdul Rahman Park	18	State Park
	Labuan	3	Federal Marine Park
	Tun Sakaran Marine Park	12	State Park
	Lahad Datu	9	None
	TOTAL	**196**	

In the Malacca Straits eco-region, only one location was surveyed and it had a 'Fair' rating with 44.6% LCC (Table 5.3.2). Coral reefs in this region are sparse and difficult to survey due to high turbidity and very low visibility. Horizontal visibility at best times is around 1 metre.

In the North Borneo eco-region, the mean percentage LCC is 'Fair' at 39.5%. The highest percentage LCC was in Labuan Marine Park with 56.2% and Pulau Lankayan privately managed protected area at 54.0%. The other two marine parks surveyed had only 'Fair' rating with 40.7% LCC for Tunku Abdul Rahman Park and 43.2% for Tun Sakaran Marine Park (Table 5.3.2). This eco-region had the lowest LCC in Malaysia, which was at Kota Belud with a 'Poor' rating at 17.4%.

Table 5.3.2: Percentage live coral cover of surveyed locations by Reef Check Malaysia in 2013 and coral reef health rating (Chou et al. 1994). *Percentage live coral cover = % Hard coral cover + % Soft coral cover.*

Number and Eco-Region	**Location**	Live coral cover (%)	Coral reef health rating
117 - Sunda Shelf	Peninsular Malaysia (east coast)		
	Pulau Perhentian	56.6	Good
	Pulau Redang	54.8	Good
	Pulau Tioman	55.8	Good
	Pulau Kapas	58.4	Good
	Pulau Bidong/Yu	54.5	Good
	Pulau Tenggol	56.2	Good
	Pulau Pemanggil	48.8	Fair
	Pulau Sibu/Tinggi	55.8	Good
	Pulau Babi Tengah	63.7	Good
	Sarawak		
	Miri	53.1	Good
	Kuching	75.7	Excellent
	Mean	*57.6*	*Good*
118 – Malacca Straits	Peninsular Malaysia (west coast)		
	Kepulauan Sembilan & Pulau Pangkor Laut	44.6	Fair
126 – North Borneo	Sabah		
	Pulau Lankayan	54.0	Good
	Pulau Mataking	36.3	Fair
	Semporna	26.5	Fair
	Pulau Mantanani	40.6	Fair
	Kota Belud	17.4	Poor
	Tunku Abdul Rahman Park	40.7	Fair
	Labuan	56.2	Good
	Tun Sakaran Marine Park	43.2	Fair
	Lahad Datu	40.9	Fair
	Mean	*39.5*	*Fair*

In addition to the above, in late 2010, an expedition to Semporna coral reefs which surveyed 60 sites found that 5% of the sites were 'Excellent', 23% 'Good', 38% 'Fair' and 35% 'Poor'. Most of the sites had signs of damage from the destructive fishing practice of fish bombing.

THREATS TO CORAL REEFS

Threats to the coral reef sites surveyed in 2013 include sedimentation, fish bombing, trawling, mass coral bleaching, crown-of-thorns seastar infestations and eutrophication (Table 5.3.3). Overfishing is assumed to be rampant but there is insufficient data to prove this.

Table 5.3.3: Threats to coral reefs survey sites in 2013.

Number and Eco-Region	Location	Sedimen-tation	Fish Bombing	Trawling	Mass Coral Bleaching	Crown of Thorns Starfish	Eutrophi-cation
117 - Sunda Shelf	Peninsular Malaysia (east coast)						
	Pulau Perhentian			X	X	X	X
	Pulau Redang			X	X	X	X
	Pulau Tioman			X	X	X	X
	Pulau Kapas	X		X	X	X	
	Pulau Bidong/Yu			X	X	X	
	Pulau Tenggol			X	X	X	
	Pulau Pemanggil			X	X	X	
	Pulau Sibu/Tinggi	X		X	X	X	X
	Pulau Babi Tengah	X		X	X	X	
	Sarawak						
	Miri	X		X	X		
	Kuching	X		X	X		X
118 – Malacca Straits	Peninsular Malaysia (west coast)						
	Kepulauan Sembilan & Pulau Pangkor Laut	X		X			
126 – North Borneo	Sabah						
	Pulau Lankayan		X		X		
	Pulau Mataking		X				
	Semporna	X	X	X			X
	Pulau Mantanani		X	X			X
	Kota Belud	X	X	X			
	Tunku Abdul Rahman Park	X			X		X
	Labuan			X	X		X
	Tun Sakaran Marine Park	X	X				
	Lahad Datu	X	X	X			

RECOMMENDATIONS

The only long term monitoring coral reef program in Malaysia is the one currently done by Reef Check Malaysia with 196 sites. They are supported by relevant authorities such as the Department of Marine Parks Malaysia, Johor National Park

Corporation and Sabah Parks. However it is recommended that the number of sites be increased especially for sites in the Malacca Straits and sites outside of Marine Protected Areas. Permanent transects or quadrats must be established at crucial reef sites to monitor accurate changes due to the changing marine environment. This can only be done if more support is given by funding agencies and corporate sponsors.

During the 2010 mass coral bleaching event, insufficient information was disseminated to the stakeholders. This resulted in a lack of effective action. A coral bleaching response plan has been published in 2013 by the Department of Marine Parks Malaysia and Reef Check Malaysia and it is hoped that this will be used effectively in the next mass coral bleaching event.

The Department of Marine Parks Malaysia with the United Nations Development Programme (UNDP) with funding from the Global Environment Facility (GEF) and the Government of Malaysia recently completed a crucial project that took 5 years to complete. The project 'Conserving Marine Biodiversity through Enhanced Marine Park Management and Inclusive Sustainable Island Development' was done at three marine park areas on the east coast of Peninsular Malaysia, which were Pulau Redang, Pulau Tioman and Pulau Sibu/Tinggi. With this new management plan it is hoped that the marine resources in these areas will flourish and be an example for emulation by other Marine Protected Areas in Malaysia.

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5.4. MYANMAR

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SUMMARY

Myanmar, situated in the eastern part of the Bay of Bengal and bordering Thailand in the south and Bangladesh in the west, has a favorable environment for corals in the coastal waters especially in the Myeik (Mergui) archipelago. More than 800 islands are in the Myeik Archipelago and this island ecosystem is very important in the Bay of Bengal region.

Corals can be found mainly in the Myeik archipelago as coral communities and fringing reefs developing on sandy bottom, limestone rock and granite rock. Some islands situated in the southern part of Rakhine coastal region and Cocos Islands situated in Deltaic coastal region have corals. Different kinds of corals can be found from the shallow water to about 30 meters depth based on surveys by Fauna and Flora International-Myanmar Programme team. Most of coral varieties can be found in the outer islands and branching corals are most dominant type in the turbid waters of the inner islands. Corals can be found in the sheltered parts of the islands and this is common in the Myeik archipelago.

Fauna and Flora International-Myanmar Programme signed an MoU with Ministry of Environmental Conservation and Forestry for marine conservation programme in Myanmar and regular monitoring programme on coral reefs started in 2012. Coral monitoring areas cover the entire Myeik archipelago starting from the islands situated in the northern part. Random surveys have been done at all of the main island groups in the Myeik archipelago. Reef Check survey training sessions were also conducted in 2013 and 2014 in collaboration with Ministry of Environmental Conservation and Forestry for Myanmar scientists including concerned government departments from Forest Department, Environmental Conservation Department, Department of Fisheries and Mawlamyine University and civil societies from Biodiversity and Nature Conservation Association and FFI-Myanmar Programme staffs (Figs. 5.4.1 & 2).

Trained Myanmar scientists are surveying coral condition of the islands using Reef Check survey method. Their surveys showed that corals can be found around most of the islands even in very turbid waters at the river mouth region to very clear water in the outer islands.

Fig. 5.4.1 Reef Check training in 2013

Fig. 5.4.2 Reef Check training in 2014

Many traces of dynamite fishing that happened in former years were seen but some areas have recovered with many coral recruits. Different coral types such as branching corals, table plate corals, massive corals, encrust corals, solitary corals and varieties of soft corals were found in different places of the surveyed islands.

COUNTRY STATISTICS AND CORAL REEF RESOURCES IN 2014

Total land area of Myanmar is 677,000 km^2 and bordering Bangladesh, India, China, Laos and Thailand, and is one of the largest countries in South-east Asia. Total length of coast line is about 2280 km starting from Naff river in the north bordering Bangladesh to Pakcham river in the south bordering Thailand. The Continental shelf covers approximately 230,000 km^2. The approximate area of Exclusive Economic Zone (EEZ) is about 486,000 km^2.

The coastal zones of Myanmar can be divided into three main areas, namely Rakhine coastal zone, Deltaic coastal zone and Tanintharyi coastal zone. Many rivers flow into the coastal zones such as the Mayu and Kaladan rivers in the Rakhine coastal zone; the Ayeyarwady, Sittaung and Thanlwin rivers in Deltaic coastal zone and the Ye, Dawei, Tanintharyi and Lenya rivers in the Tanintharyi coastal zone (Fig. 5.4.3). Among the coastal zones, Myeik archipelago situated in the Tanintharyi coastal zone is the most important zone for coral ecosystem in Myanmar.

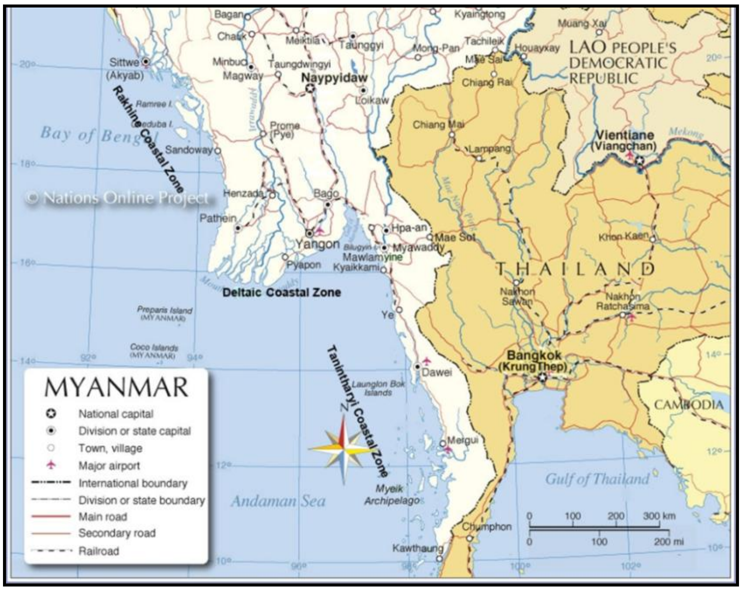

Fig. 5.4.3: Coastal zones in Myanmar

From the report of Myanmar to BOBLME (Bay of Bangal Large Marine Ecosystem) in 2011, , 51 species of anthozoan corals belonging to 20 families and 30 genera were present along Rakhine coast, 3 species belonging to 2 families and 2 genera from Delta areas (Maw-tin, Heingyi-Kyun, Pyin-kha-yaing) and 93 species belonging to 21 families and 47 genera from Tanintharyi coast based on records by San San Win (1993) and Mya Than Tun and Tint Tun (2002). About 518 species of hard corals were identified from the entire coastal regions in Myanmar by Marine Science Department, Mawlamyine University (Cherry Aung, 2009).

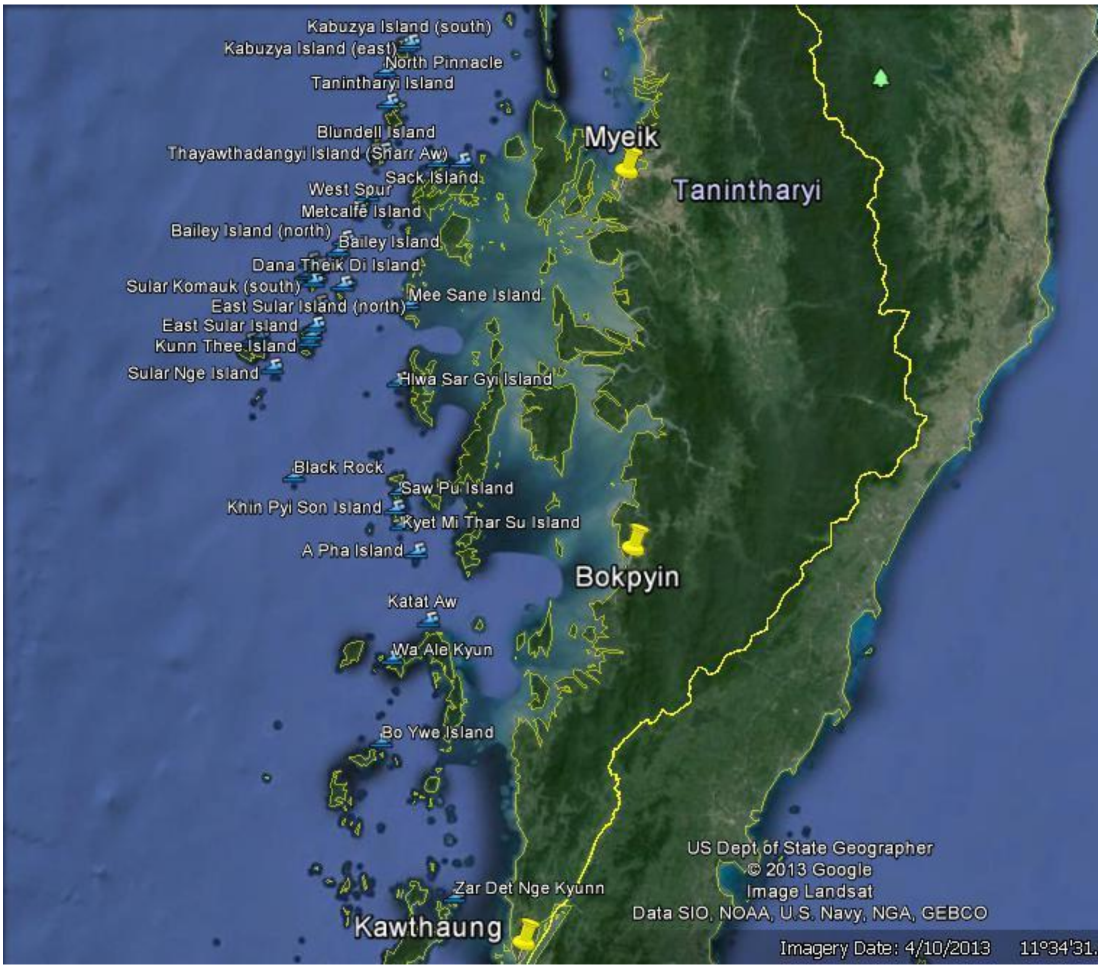

Fig. 5.4.4: Coral reef monitoring sites in March 2014 liveaboard trip by FFI-Myanmar Programme

Fauna and Flora International-Myanmar Programme has been conducting regular surveys in the Myeik archipelago using Reef Check technique starting from January 2013 using liveaboard trips. Traces of the impacts of 2010 bleaching problem that occurred in the entire region were seen in many surveyed sites. Many new coral recruits were recorded in the entire survey. More than 80% hard coral cover were recorded in some surveyed sites. During the liveaboard trip conducted in March 2014 in collaboration with international scientists, 288 hard coral species were identified in the Myeik archipelago (Table 5.4.1). Survey sites in March 2014 liveaboard trip are shown in Figure 5.4.4. This identified species list is only covered in some parts of the Myeik archipelago. More species can be identified in the future.

NUMBER OF SPECIES OF MAJOR TAXA RECORDED

288 coral species were identified by David Obura in March 2014 liveaboard trip conducted by Fauna and Flora International in collaboration with international scientists (Table 5.4.1). Survey points in the liveaboard trip are shown in Figure 5.4.4. Among 288 species, 6 species could be identified only into genus level. Some corals

found along survey are shown in Figure 5.4.5.

Table 5.4.1 Identified coral species until March 2014. (data provided from David Obura)

No.	Family	Genus	Species
1	Acroporidae	*Acropora*	*acuminata*
2	Acroporidae	*Acropora*	*appressa*
3	Acroporidae	*Acropora*	*aspera*
4	Acroporidae	*Acropora*	*austera*
5	Acroporidae	*Acropora*	*bifurcata*
6	Acroporidae	*Acropora*	*cerealis*
7	Acroporidae	*Acropora*	*clathrata*
8	Acroporidae	*Acropora*	*cytherea*
9	Acroporidae	*Acropora*	*digitifera*
10	Acroporidae	*Acropora*	*divaricata*
11	Acroporidae	*Acropora*	*echinata*
12	Acroporidae	*Acropora*	*gemmifera*
13	Acroporidae	*Acropora*	*granulosa*
14	Acroporidae	*Acropora*	*horrida*
15	Acroporidae	*Acropora*	*humilis*
16	Acroporidae	*Acropora*	*hyacinthus*
17	Acroporidae	*Acropora*	*inermis*
18	Acroporidae	*Acropora*	*intermedia*
19	Acroporidae	*Acropora*	*kosurini*
20	Acroporidae	*Acropora*	*latistella*
21	Acroporidae	*Acropora*	*loripes*
22	Acroporidae	*Acropora*	*lutkeni*
23	Acroporidae	*Acropora*	*macrostoma*
24	Acroporidae	*Acropora*	*microphthalma*
25	Acroporidae	*Acropora*	*muricata*
26	Acroporidae	*Acropora*	*nana*
27	Acroporidae	*Acropora*	*nasuta*
28	Acroporidae	*Acropora*	*retusa*
29	Acroporidae	*Acropora*	*robusta*
30	Acroporidae	*Acropora*	*roseni*
31	Acroporidae	*Acropora*	*rudis*
32	Acroporidae	*Acropora*	*samoensis*
33	Acroporidae	*Acropora*	*secale*
34	Acroporidae	*Acropora*	*selago*
35	Acroporidae	*Acropora*	*spicifera*
36	Acroporidae	*Acropora*	*subulata*
37	Acroporidae	*Acropora*	*tenuis*
38	Acroporidae	*Acropora*	*valida*
39	Acroporidae	*Acropora*	sp1
40	Acroporidae	*Alveopora*	*tizardi*
41	Acroporidae	*Astreopora*	*expansa*
42	Acroporidae	*Astreopora*	*gracilis*

43	Acroporidae	*Astreopora*	*incrustans*
44	Acroporidae	*Astreopora*	*listeri*
45	Acroporidae	*Astreopora*	*myriophthalma*
46	Acroporidae	*Astreopora*	*ocellata*
47	Acroporidae	*Isopora*	*palifera*
48	Acroporidae	*Montipora*	*aequituberculata*
49	Acroporidae	*Montipora*	*calcarea*
50	Acroporidae	*Montipora*	*confusa*
51	Acroporidae	*Montipora*	*cryptus*
52	Acroporidae	*Montipora*	*digitata*
53	Acroporidae	*Montipora*	*efflorescens*
54	Acroporidae	*Montipora*	*effusa*
55	Acroporidae	*Montipora*	*floweri*
56	Acroporidae	*Montipora*	*foveolata*
57	Acroporidae	*Montipora*	*hispida*
58	Acroporidae	*Montipora*	*informis*
59	Acroporidae	*Montipora*	*monasteriata*
60	Acroporidae	*Montipora*	*nodosa*
61	Acroporidae	*Montipora*	*spongodes*
62	Acroporidae	*Montipora*	*stilosa*
63	Acroporidae	*Montipora*	*tuberculosa*
64	Acroporidae	*Montipora*	*undata*
65	Acroporidae	*Montipora*	*verrucosa*
66	Agariciidae	*Coeloseris*	*mayeri*
67	Agariciidae	*Gardineroseris*	*planulata*
68	Agariciidae	*Leptoseris*	*amitoriensis*
69	Agariciidae	*Leptoseris*	*foliosa*
70	Agariciidae	*Leptoseris*	*glabra*
71	Agariciidae	*Leptoseris*	*incrustans*
72	Agariciidae	*Leptoseris*	*mycetoseroides*
73	Agariciidae	*Leptoseris*	*scabra*
74	Agariciidae	*Leptoseris*	*solida*
75	Agariciidae	*Pachyseris*	*rugosa*
76	Agariciidae	*Pachyseris*	*speciosa*
77	Agariciidae	*Pavona*	*cactus*
78	Agariciidae	*Pavona*	*clavus*
79	Agariciidae	*Pavona*	*decussata*
80	Agariciidae	*Pavona*	*duerdeni*
81	Agariciidae	*Pavona*	*explanulata*
82	Agariciidae	*Pavona*	*maldivensis*
83	Agariciidae	*Pavona*	*varians*
84	Agariciidae	*Pavona*	*venosa*
85	Astrocoeniidae	*Stylocoeniella*	*armata*
86	Astrocoeniidae	*Stylocoeniella*	*guentheri*
87	Coscinaraeidae	*Anomastrea*	*irregularis*
88	Coscinaraeidae	*Coscinaraea*	*columna*
89	Coscinaraeidae	*Coscinaraea*	*crassa*

90	Coscinaraeidae	*Coscinaraea*	*exesa*
91	Coscinaraeidae	*Coscinaraea*	*monile*
92	Coscinaraeidae	*Coscinaraea*	*wellsi*
93	Coscinaraeidae	*Coscinaraea*	sp1
94	Dendrophylliidae	*Tubastrea*	*micrantha*
95	Dendrophylliidae	*Tubastrea*	sp1
96	Dendrophylliidae	*Turbinaria*	*frondens*
97	Dendrophylliidae	*Turbinaria*	*irregularis*
98	Dendrophylliidae	*Turbinaria*	*mesenterina*
99	Dendrophylliidae	*Turbinaria*	*peltata*
100	Dendrophylliidae	*Turbinaria*	*stellulata*
101	Euphyllidae	*Euphyllia*	*ancora*
102	Euphyllidae	*Euphyllia*	*glabrescens*
103	Euphyllidae	*Physogyra*	*lichtensteini*
104	Euphyllidae	*Plerogyra*	*sinuosa*
105	Faviidae	*Barabattoia*	*amicorum*
106	Faviidae	*Caulastrea*	*connata*
107	Faviidae	*Cyphastrea*	*chalcidicum*
108	Faviidae	*Cyphastrea*	*microphthalma*
109	Faviidae	*Cyphastrea*	*serailia*
110	Faviidae	*Diploastrea*	*heliopora*
111	Faviidae	*Echinopora*	*gemmacea*
112	Faviidae	*Echinopora*	*lamellosa*
113	Faviidae	*Echinopora*	*pacificus*
114	Faviidae	*Favia*	*danae*
115	Faviidae	*Favia*	*favus*
116	Faviidae	*Favia*	*helianthoides*
117	Faviidae	*Favia*	*lizardensis*
118	Faviidae	*Favia*	*maritima*
119	Faviidae	*Favia*	*matthai*
120	Faviidae	*Favia*	*maxima*
121	Faviidae	*Favia*	*pallida*
122	Faviidae	*Favia*	*rosaria*
123	Faviidae	*Favia*	*rotumana*
124	Faviidae	*Favia*	*speciosa*
125	Faviidae	*Favia*	*stelligera*
126	Faviidae	*Favia*	*truncatus*
127	Faviidae	*Favia*	*veroni*
128	Faviidae	*Favia*	*vietnamensis*
129	Faviidae	*Favites*	*abdita*
130	Faviidae	*Favites*	*acuticolis*
131	Faviidae	*Favites*	*bestae*
132	Faviidae	*Favites*	*chinensis*
133	Faviidae	*Favites*	*complanata*
134	Faviidae	*Favites*	*halicora*
135	Faviidae	*Favites*	*pentagona*
136	Faviidae	*Favites*	*russelli*

137	Faviidae	*Favites*	*spinosa*
138	Faviidae	*Favites*	*vasta*
139	Faviidae	*Goniastrea*	*aspera*
140	Faviidae	*Goniastrea*	*australensis*
141	Faviidae	*Goniastrea*	*edwardsi*
142	Faviidae	*Goniastrea*	*minuta*
143	Faviidae	*Goniastrea*	*palauensis*
144	Faviidae	*Goniastrea*	*pectinata*
145	Faviidae	*Goniastrea*	*retiformis*
146	Faviidae	*Leptastrea*	*aequalis*
147	Faviidae	*Leptastrea*	*pruinosa*
148	Faviidae	*Leptastrea*	*purpurea*
149	Faviidae	*Leptastrea*	*transversa*
150	Faviidae	*Leptoria*	*irregularis*
151	Faviidae	*Leptoria*	*phrygia*
152	Faviidae	*Montastrea*	*annuligera*
153	Faviidae	*Montastrea*	*curta*
154	Faviidae	*Montastrea*	*magnistellata*
155	Faviidae	*Montastrea*	*salebrosa*
156	Faviidae	*Montastrea*	*valenciennesi*
157	Faviidae	*Oulophyllia*	*crispa*
158	Faviidae	*Oulophyllia*	*levis*
159	Faviidae	*Parasimplastrea*	*sheppardi*
160	Faviidae	*Platygyra*	*acuta*
161	Faviidae	*Platygyra*	*carnosus*
162	Faviidae	*Platygyra*	*daedalea*
163	Faviidae	*Platygyra*	*lamellina*
164	Faviidae	*Platygyra*	*pini*
165	Faviidae	*Platygyra*	*ryukyuensis*
166	Faviidae	*Platygyra*	*sinensis*
167	Faviidae	*Platygyra*	*verweyi*
168	Faviidae	*Platygyra*	*yaeyamaensis*
169	Faviidae	*Plesiastrea*	*versipora*
170	Faviidae	*Plesiastrea*	sp1
171	Fungiidae	*Ctenactis*	*echinata*
172	Fungiidae	*Cycloseris*	*costulata*
173	Fungiidae	*Cycloseris*	*erosa*
174	Fungiidae	*Cycloseris*	*patelliformis*
175	Fungiidae	*Cycloseris*	*somervillei*
176	Fungiidae	*Fungia*	*concina*
177	Fungiidae	*Fungia*	*corona*
178	Fungiidae	*Fungia*	*danai*
179	Fungiidae	*Fungia*	*fungites*
180	Fungiidae	*Fungia*	*granulosa*
181	Fungiidae	*Fungia*	*moluccensis*
182	Fungiidae	*Fungia*	*paumotensis*
183	Fungiidae	*Fungia*	*repanda*

184	Fungiidae	*Fungia*	*scabra*
185	Fungiidae	*Fungia*	*scruposa*
186	Fungiidae	*Fungia*	*scutaria*
187	Fungiidae	*Fungia*	*seychellensis*
188	Fungiidae	*Herpolitha*	*limax*
189	Fungiidae	*Herpolitha*	*weberi*
190	Fungiidae	*Lithophyllon*	*undulatum*
191	Fungiidae	*Podabacia*	*crustacea*
192	Fungiidae	*Podabacia*	*lankaensis*
193	Fungiidae	*Polyphillia*	*onovaehiberniae*
194	Fungiidae	*Polyphillia*	*talpina*
195	Fungiidae	*Sandalolitha*	*dentata*
196	Fungiidae	*Sandalolitha*	*robusta*
197	Hydrozoa	*Heliopora*	*coerulea*
198	Hydrozoa	*Millepora*	*exesa*
199	Hydrozoa	*Millepora*	*platyphylla*
200	Hydrozoa	*Millepora*	*tenaera*
201	Merulinidae	*Hydnophora*	*exesa*
202	Merulinidae	*Hydnophora*	*microconos*
203	Merulinidae	*Hydnophora*	*rigida*
204	Merulinidae	*Merulina*	*ampliata*
205	Merulinidae	*Scapophyllia*	*cylindrica*
206	Mussidae	*Acanthastrea*	*brevis*
207	Mussidae	*Acanthastrea*	*echinata*
208	Mussidae	*Acanthastrea*	*hemprichii*
209	Mussidae	*Acanthastrea*	*regularis*
210	Mussidae	*Acanthastrea*	*rotundoflora*
211	Mussidae	*Acanthastrea*	*subechinata*
212	Mussidae	*Australomussa*	*rowleyensis*
213	Mussidae	*Blastomussa*	*merletti*
214	Mussidae	*Cynarina*	*lachrymalis*
215	Mussidae	*Lobophyllia*	*corymbosa*
216	Mussidae	*Lobophyllia*	*flabelliformis*
217	Mussidae	*Lobophyllia*	*hataii*
218	Mussidae	*Lobophyllia*	*hemprichii*
219	Mussidae	*Lobophyllia*	*pachysepta*
220	Mussidae	*Lobophyllia*	*robusta*
221	Mussidae	*Micromussa*	*amakusensis*
222	Mussidae	*Scolymia*	*australis*
223	Mussidae	*Symphyllia*	*agaricia*
224	Mussidae	*Symphyllia*	*radians*
225	Mussidae	*Symphyllia*	*recta*
226	Mussidae	*Symphyllia*	*valenciennesi*
227	Oculinidae	*Galaxea*	*fasicularis*
228	Oculinidae	*Galaxea*	*paucisepta*
229	Pectiniidae	*Echinomorpha*	*nishihira*
230	Pectiniidae	*Echinophyllia*	*aspera*

231	Pectiniidae	*Echinophyllia*	*echinata*
232	Pectiniidae	*Echinophyllia*	*echinoporoides*
233	Pectiniidae	*Echinophyllia*	*Patula*
234	Pectiniidae	*Echinophyllia*	*taylorae*
235	Pectiniidae	*Mycedium*	*elephantotus*
236	Pectiniidae	*Mycedium*	*robokaki*
237	Pectiniidae	*Oxypora*	*crassispinosa*
238	Pectiniidae	*Oxypora*	*Lacera*
239	Pectiniidae	*Pectinia*	*africana*
240	Pectiniidae	*Pectinia*	*alcicornis*
241	Pectiniidae	*Pectinia*	*lactuca*
242	Pectiniidae	*Pectinia*	*paeonia*
243	Pocilloporidae	*Madracis*	*Kirbyi*
244	Pocilloporidae	*Pocillopora*	*damicornis*
245	Pocilloporidae	*Pocillopora*	*danai*
246	Pocilloporidae	*Pocillopora*	*eydouxi*
247	Pocilloporidae	*Pocillopora*	*Indiania*
248	Pocilloporidae	*Pocillopora*	*ligulata*
249	Pocilloporidae	*Pocillopora*	*verrucosa*
250	Pocilloporidae	*Pocillopora*	*woodjonesii*
251	Pocilloporidae	*Pocillopora*	*zelli*
252	Poritidae	*Goniopora*	*albiconus*
253	Poritidae	*Goniopora*	*columna*
254	Poritidae	*Goniopora*	*djiboutiensis*
255	Poritidae	*Goniopora*	*lobata*
256	Poritidae	*Goniopora*	*minor*
257	Poritidae	*Goniopora*	*pendulus*
258	Poritidae	*Goniopora*	*planulata*
259	Poritidae	*Goniopora*	*somaliensis*
260	Poritidae	*Goniopora*	*stokesi*
261	Poritidae	*Goniopora*	*stutchburyi*
262	Poritidae	*Goniopora*	sp1
263	Poritidae	*Porites*	*annae*
264	Poritidae	*Porites*	*aranetai*
265	Poritidae	*Porites*	*australensis*
266	Poritidae	*Porites*	*cylindrica*
267	Poritidae	*Porites*	*deformis*
268	Poritidae	*Porites*	*horizontalata*
269	Poritidae	*Porites*	*lichen*
270	Poritidae	*Porites*	*lobata*
271	Poritidae	*Porites*	*lutea*
272	Poritidae	*Porites*	*monticulosa*
273	Poritidae	*Porites*	*nigrescens*
274	Poritidae	*Porites*	*profundus*
275	Poritidae	*Porites*	*rus*
276	Poritidae	*Porites*	*silimaniana*
277	Poritidae	*Porites*	*solida*

278	Poritidae	*Porites*	*stephensoni*
279	Siderastreidae	*Psammocora*	*albopicta*
280	Siderastreidae	*Psammocora*	*digitata*
281	Siderastreidae	*Psammocora*	*explanulata*
282	Siderastreidae	*Psammocora*	*niestraazi*
283	Siderastreidae	*Psammocora*	*obtusangula*
284	Siderastreidae	*Psammocora*	*profundacella*
285	Siderastreidae	*Pseudosiderastrea*	*tayami*
286	Siderastreidae	*Pseudosiderastrea*	sp1
287	Siderastreidae	*Siderastrea*	*savignyana*
288	Trachyphylliidae	*Trachyphyllia*	*geoffroyi*

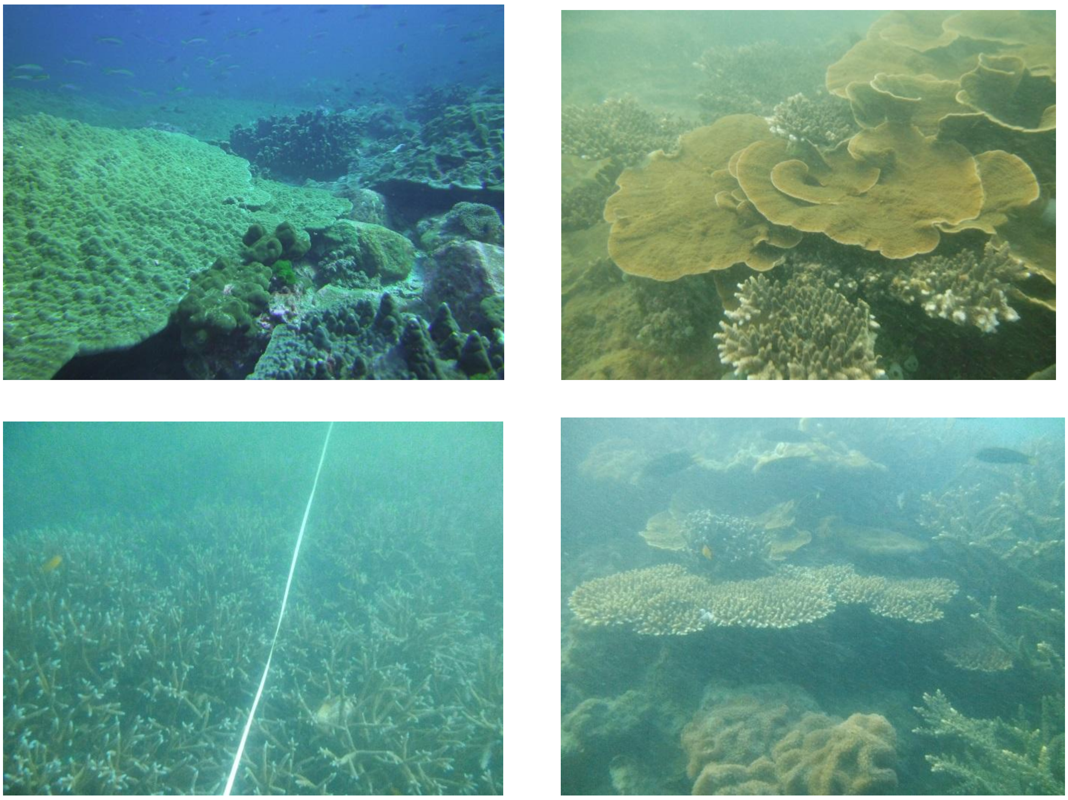

Fig. 5.4.5: Corals at survey sites

CORAL REEF MONITORING SITES

FFI-Myanmar Programme is monitoring the entire Myeik archipelago in collaboration with Ministry of Environmental Conservation and Forestry, which started from 2013. Surveyed stations done until March 2014 are shown in Figure 5.4.5. Most of surveys were done at the Thayawthadan island group, La ngann island group, Lampi Marine Protected Area, Kyun philar island group and Zardetgyi island group. Some of the inner islands were also surveyed through spot checks, which revealed good coral cover.

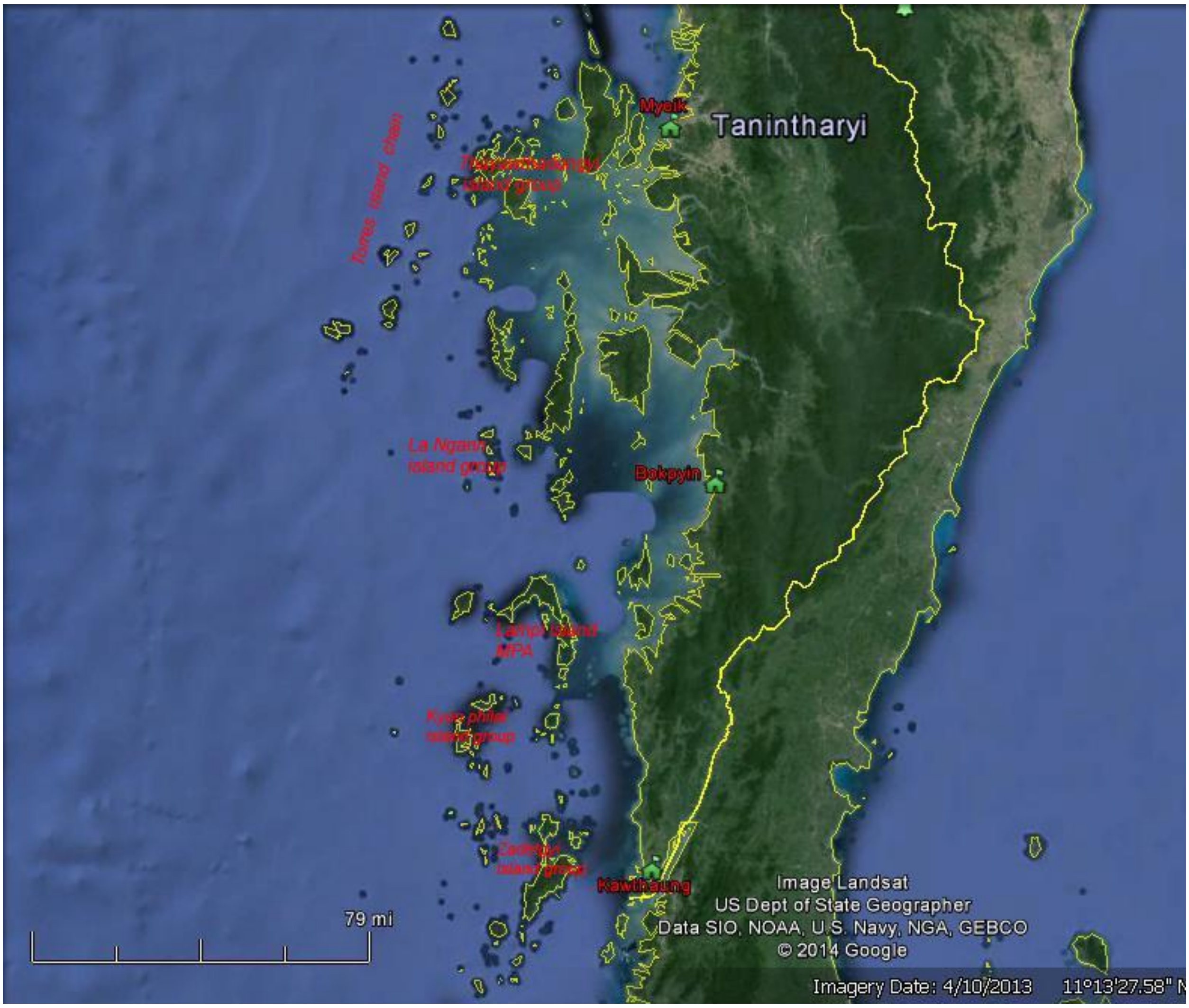

Fig. 5.4.6: Surveyed island groups covered by FFI-Myanmar programme team in 2013 & 2014

INDEX SCORES OF MAJOR BENTHIC TAXA

Corals in Myeik archipelago can be found mostly on sandy bottom and limestone but many corals growing on granite rock were also recorded. Major benthic condition of most corals in the inner islands of Myeik archipelago is dominated by limestone and sandy bottom. Corals growing on granite bottom are seen in the outer islands especially solitary islands in the ocean.

INDEX SCORES FOR CURRENT LEVELS AND TREND IN CORAL REEF RESOURCE USAGE

All of the local communities living on the islands depend on the collection of invertebrates such as sea cucumber, chitons and giant clam. This livelihood is not sustainable for the local communities because of their uncontrolled collection and there is no proper regulation or effective law enforcement. If there is no regular management plan in place, the invertebrate resources will be depleted in the near future. There is no regular trading business on ornamental fish but some people are doing ornamental fish trading with nearby countries.

MEASURABLE STRESS AND DAMAGE SUMMARIES AT REGIONAL/NATIONAL LEVEL

The most severe impact to the reef is dynamite fishing and this was happened everywhere in the Myeik archipelago especially in the outer islands. Traces of dynamite fishing were seen during the surveys. The other noticeable impact was anchorage problem found at islands especially near human settlements. The other common problem was fishing using baby trawls near the islands. This fishing technique destroys the entire bottom including coral beds. Coral sand mining is also one of the important impacts to the island ecosystems especially where corals exist. The most important problem in the near future is unsustainable development of the coastal zone and especially on the islands for the tourism industry. Sedimentation caused by erosion from the mainland and from the islands also smothers corals and associated animals by burying them. Uncontrolled logging in the watershed areas on the mainland and logging on the islands are primary causes for erosion problem.

PRINCIPLE ACTS AND REGULATIONS AFFECTING CORAL REEFS

The law relating to fishing rights of foreign vessels (1984) and Myanmar Fisheries Law (1990) clearly prohibit the use of explosives, poison and toxic chemicals, harmful agents and damaging gears. However, the difficulty in having access to remote areas, lack of adequate infrastructure, insufficient manpower and lack of trained personnel are some of the major constraints in effective management of the resources.

RECOMMENDATIONS AND CHALLENGES ON CORAL REEF CONSERVATION AND SUSTAINABLE RESOURCE USE

1. Collaboration with responsible government departments of Myanmar and local governments for coral reef conservation.
2. Capacity building activities on coral reef conservation is essential for concerned government departments, local government and local stakeholders.
3. Awareness raising activities on the relationship of sustainable livelihood and conservation on coral is urgent requirement to local stakeholders.
4. Find out alternative sustainable livelihood for local communities.
5. Find out potential opportunities for effective law enforcement.
6. Suitable laws and regulations relevant to coral conservation and sustainable resource use have to be adopted in collaboration with concerned government departments and local government.
7. Locally managed marine areas and new Marine Protected Areas should be designated in collaboration with concerned government departments and local government.

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5.5. PHILIPPINES

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SUMMARY

A brief background on the nationwide surveys initiated at the end of the 1970's to the mid-1980 highlighted the urgency to respond to the declining state of coral reefs in the Philippines. Using quadrats laid perpendicular to shore, estimates of the percent live coral cover of hard and soft corals in reef surveys categorized quartile categories reported by Gomez and Alcala (1979), Gomez et al. (1981).They reported that a considerable proportion (around >30% of the sites) were in poor condition (i.e. having less than 25% live coral) while only around 30% were in good (50-75% live coral cover) and excellent condition (75-100% cover). Despite a change in methodology to line intercept transects and point intercepts transects laid parallel to shore, these % categories were carried over the next decades (1985-2005). Alarm was seen in having a considerably lower proportion, i.e. around 20% were in good to excellent category and around 50% were in a poor state. The prevalent threats to reefs from overexploitation, siltation and poor land uses were re-echoed to increase protection measures. These multiple concerns provided the impetus for the increase in efforts for establishing more functional and effective Marine Protected Areas (MPA), learning from the good practices of Alcala and colleagues. In addition, the focus in MPA monitoring of reef benthos and their associated fish benthos inside and outside the no-take marine reserves/sanctuaries showed improvements in most of the sites surveyed. While protection through MPA served as sentinels that showed promising positive impacts, more concerted and accelerated actions are necessary to meet the future. The other drivers such as unregulated coastal development, rapid population growth and climate change including extreme events like super typhoons

produce rapidly changing social and ecological states manifested at various spatial and temporal scales. These challenges would require enhanced understanding through advance science and technology to cope and be resilient. It is imperative to ACT NOW (**A**ccelerate, **C**oordinate, **T**hreat reduction, **N**etworking, **O**rganizational development and **W**orking together synergies) on these recommended strategies within an Integrated Coastal Management (ICM) approach.

INTRODUCTION

The country's report on the status of coral reefs was initiated by Gomez and Alcala (1979) and Gomez et al. (1981) as the product of a national program (Licuanan and Aliño 2014) under the project entitled "Investigation of the Coral Resources of the Philippines" [Gomez et al. 1994]. This project provided the first nationwide status reports of the conditions of the reef using a quartile percentage cover, namely: poor (0-24%), fair (25-49.9%), good (50-74.9%) and excellent (75-100%). This was followed by updates in 1994 (Gomez et al. 1994) and 2002 (Licuanan and Gomez 2002). Moreover, in 2002 through the Philippine Coral Reef Information Network, a compilation of the status of the reefs was presented in the Philippine Coral Reef Atlas (Aliño et al. 2002). The succeeding updates in 2004 (Nañola et al. 2006) included the status of reef fishes as well as the reef benthos attributes utilizing the ASEAN-Australia Cooperative project on Living Coastal Resources (LCR). An enhanced modified method using underwater fish visual census (UWFVC, Nañola et al. 2006) incorporating the condition of the reef benthos provided an added insight on fish and benthos relationships (Sale 1991, Hilomen et al. 1988, Uychiaoco et al. 1994). Subsequently modifications on the FVC allowed for fish biomass estimates and provided some classification of categories based on biomass abundance levels of exploitation such that: total fish biomass of <10mt/km^2 were classified as low biomass implicating overfished conditions, 11 to 20mt/km^2 as being moderately fished, 21 to 40 mt/km^2 as reefs with minimal fishing and >41 mt/km^{2}with very low fishing pressure and usually concordant with fully protected reefs (Nanola et al. 2006). In the same year, through the Coral Reef Information Network of the Philippines (PhilReefs) series, emphasis on the need for monitoring activities on reefs was undertaken by looking at repeated assessments through time to show the trends of coral cover including the fish biomass (Philreefs 2004). Hence, the succeeding reports broadened its scope towards a State of the Coasts report (Philreefs 2008, 2010) incorporating management considerations of the prevailing pressures and threats in the area. These were precursors of a contextual framework using the DPSIR (Drivers, Pressure, State, Impact and Responses, OECD 2003) which is akin to the general approach used in the State of the Coral Triangle Reports (Philippines 2013 and ADB 2014) with latest state of the coast report already in press (Philreefs 2013; PEMSEA 2013). Subsequently, most of the sites covered from 2004 are marine protected areas (MPA) or fish sanctuaries/reserves. Oftentimes, these are the only sites that have regular monitoring activities as part of the monitoring and evaluation component of their MPA management or Coastal Resources Management programs (Arceo et al. 2008).

While the concept of MPA in the country is not new, accelerating its management effectiveness has been an important advocacy in the country through the MSN (Marine Protected Areas [MPA] Support Network) The oldest marine reserve was established in early and mid 1970s (Alcala 1988). Full protection has already shown positive results in many sites in the Visayas (Russ and Alcala 2004, Alcala and Russ 2006, Abesamis et al. 2005). To date, there are more than 1,600 MPAs around the country as reported in the MSN database (see Cabral et al. 2014). However, despite few numbers attaining effective full protection, only around 15-25% are estimated to be fully protected from a total of around 500 (ca mid-1990's) to more than 1,000 MPAs (Arceo et al. 2008). While this low effectiveness of protection and widespread overexploitation still persist, considerable advances have occurred through inter-Local Government Unit collaboration (Philippines 2013; Ecogov 2011). Nevertheless, latest records suggest leapfrogging scaling-up accelerated measures are needed to overcome the gap in the poor management of reefs to mitigate for negative results that lead to localized extinction or extirpation (Lavides et al. 2010; Nanola et al. 2011) and mitigate its ramifications to food security and poverty.

Meta-analysis of some reefs around the country showed increase in fish abundance (Maliao et al. 2009) and a positive increase in coral cover through time (Magdaong et al. 2013). As mentioned earlier, while the reporting is constrained by its coverage of different reef sites albeit in the general area, extra caution should be taken for a nuanced insight in implicating an overall national condition of the reefs from an agglomeration of site specific situations.

The marine scientists in the Philippines have recognized the limitations of the reporting process. Thus, in 2014, two national agencies (i.e. Department of Environment and Natural Resources; Department of Science and Technology) with a stake on coral reefs funded a national program to provide the status of reefs including proposed standard methods. Licuanan and Aliño (2014) also proposed a framework for a coral reef assessment program at the national level, to include the following: a) matrices of habitat health (e.g. benthic cover not limited to hard corals); b) mapping of reef assessment units (e.g. to consider the geological structure of the reef including accuracy and precision); c) objective and the sampling design (e.g. matching of sampling design with the objectives including representativeness to cover biogeographic regions); and d) reef assessment (e.g. reef typology and its corresponding classes). These are crucial requisites for a more systematic national coral reef monitoring program.

Despite these limitations, this update on the status of the Philippine coral reefs is provided covering the period from 2008 to 2014. This report, while primarily being influenced by the location of project based sites with varying objectives, should be taken in the context of looking at trends inside and outside MPA sites, in eliciting insights of present and future challenges and opportunities and ways to move forward

REVISITING CONDITION STATES AND IMPLICATIONS TO MONITORING

Status of reef benthos

Data from different sites in the Philippines surveyed from 2008 to 2014 show that around 46% of the reefs are in fair condition, 18% in poor condition, 31 % in good condition and 4% in excellent condition (Figure 5.5.1).

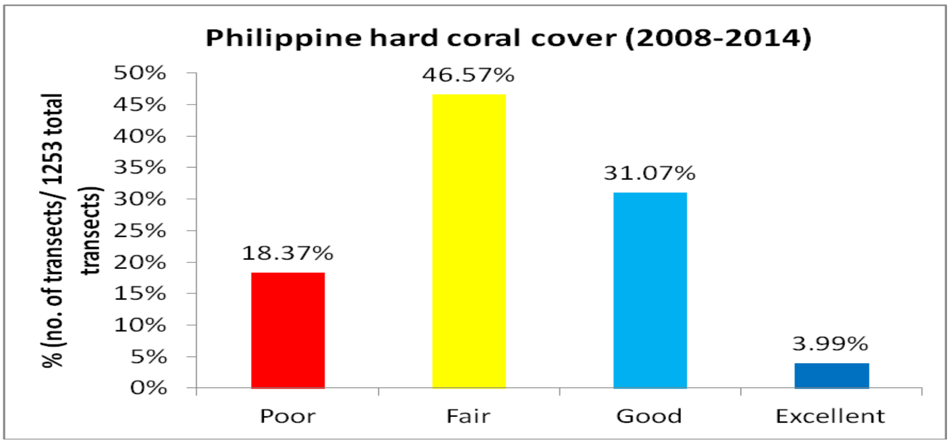

Fig. 5.5.1: Percentage of transects surveyed in 2008-2014 falling into the different categories of reef status based from quartile percentage hard coral cover (see Gomez and Alcala 1978; Gomez et al. 1981) from 74 municipalities in the Philippines.

A slight decline from the previously reported 5% in excellent condition by Gomez et al. (1981) in a span of more than three decades may be due to closure problems in the mismatch of proportions in disparate ways of project sampling design, and focus made i.e. in MPA areas. For example, the increase in reefs with good and fair cover and a decline of proportion under the poor category level (Figure 5.5.2) further reinforces this shift due to MPA samples (Aliño 2012, unpublished report).

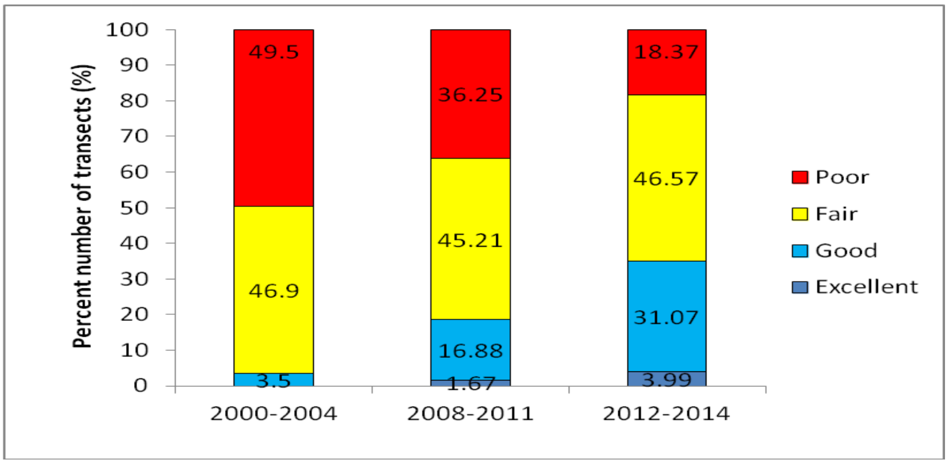

Fig. 5.5.2: Trends in benthos cover from 2000 to 2014. Sources: 2000- 2004 (Nanola et al. 2006); 2008-2011 (Philreefs in press); 2012-2014 (this study).

Most of the reefs with good cover are found on the eastern side of the Philippines (Figure 5.5.3). Reefs located in the Visayas Region and in the West Philippine Sea show from poor to fair cover.

Despite the decline in reefs with excellent condition, 57% of the sites (n =28) monitored showed improvement in terms of cover through time as a result of protection while 44% of the sites showed an increase outside the MPAs. Overall, 36% of the sites showed improvement in coral cover.

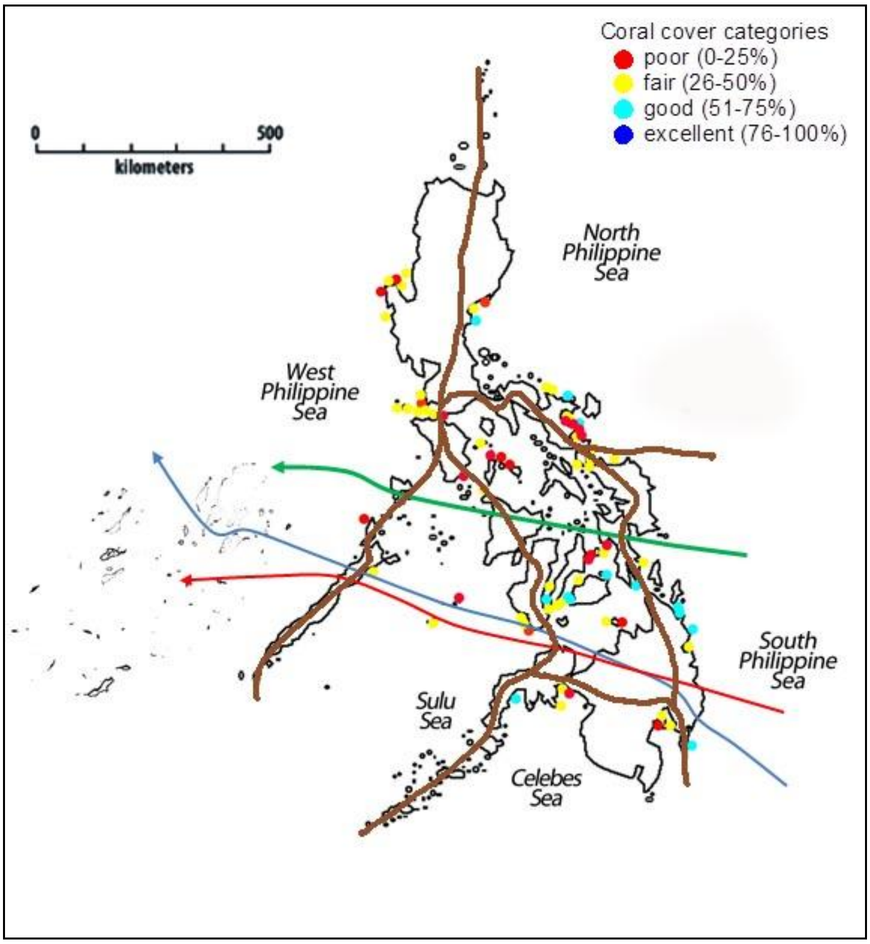

Fig. 5.5.3: Philippine map and its biogeographic regions (brown lines; Aliño and Gomez 1994) showing the color coded hard coral cover data that were surveyed from 2008 to 2014 in 73 municipalities. Typhoon paths: Blue arrow for Typhoon Washi (*Sendong*), Red arrow for Typhoon Bopha (*Pablo*) and Green arrow for Typhoon Haiyan (*Yolanda*).

Status of reef fishes

The survey conducted from 2008 to 2014 show that majority of the sites covered fell under medium biomass category (28%), also regarded as areas moderately fished. On the other hand, sites with very low to low biomass category (i.e. < 10 mt/km^2) and considered as overfished comprise 25% of the total sites surveyed (Figure 5.5.4).

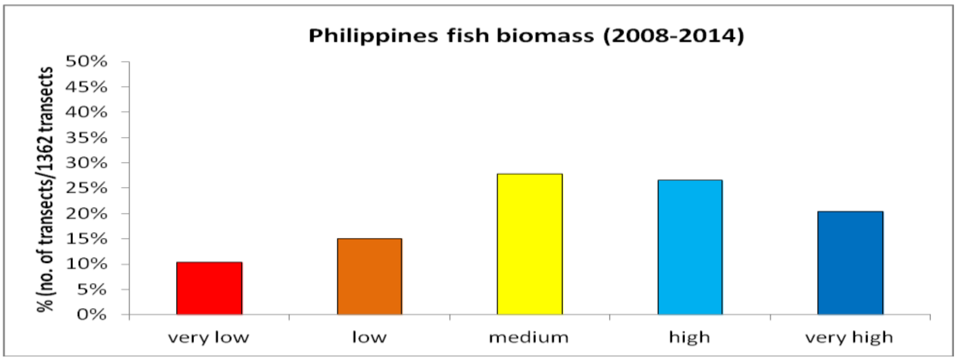

Fig. 5.5.4: Percentage of transects in 49 municipalities surveyed in 2008-2014 falling into the different categories of fish biomass (mt/km^2) (see Nanola et al. 2006).

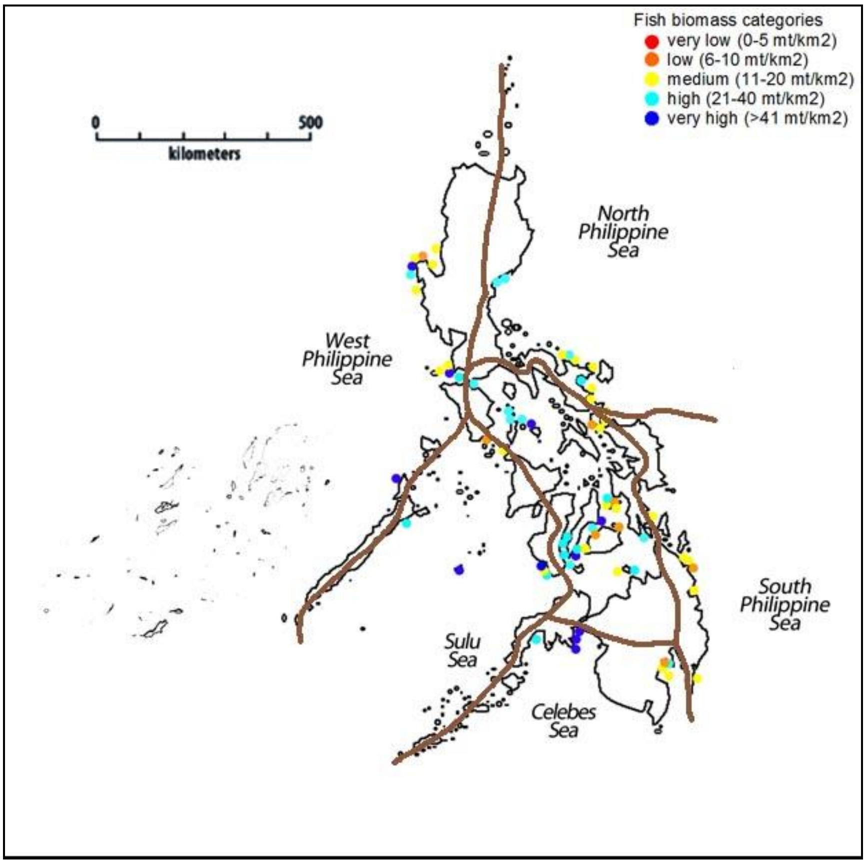

Fig. 5.5.5: Philippine map and its biogeographic regions (brown lines; Aliño and Gomez 1994) showing the color coded fish biomass classification that were surveyed from 2008 to 2014 in 49 municipalities.

Low (6 to 10 mt/km^2) to medium (11-20 mt/km^2) biomass categories were prominent on the eastern portion of the Philippines while high to very high biomass was more common in Visayas Region and in the western side of the country (Figure 5.5.5).

This trend may be attributed to the higher number of MPAs in these areas as compared to the Pacific side of the country (see Cabral et al. 2014).

Fish biomass inside MPAs improved in 71% of the sites monitored. Sites outside protected areas also showed increase in biomass, comprising 67% of the total sites surveyed (n=28).

REPRESENTATIVENESS, AREAL EXTENT OF HABITATS AND COVER: CONSIDERATIONS ON REEF STATES

For over more than three decades, the proportion of reefs in excellent condition (4%, this study) did not show a dramatic decline between the first status report that showed 5% of excellent reef cover (Gomez and Alcala 1979; Gomez et al. 1981) and the status reports of 2004 (Nañola et al. 2006) that indicated a decline by 1.5%. The decline was mainly attributed to the bleaching event of 1998 caused by El Niño event that was recorded in the country (Arceo et al. 2001). After more than a decade, coral cover may show recovery mainly attributed to the establishment of MPAs that showed an average of 70 MPAs established yearly from 1998 to 2006 (Arceo et al. 2008, Cabral et al. 2014). This pattern has been suggested in the meta-analysis conducted by Magdaong et al. (2013). More importantly, since after the 2004 assessment efforts were focused on the monitoring activities on MPAs, leaving a considerable gap in the unmanaged areas such as the large disputed areas in the Kalayaan Islands Group in the West Philippine Sea and the less assessed areas in the North Philippine Sea (e.g. the Benham rise seamount, see also below).

Another gap aside from assessment of reef status is the evaluation of the degree of threats as influenced by natural and human induced hazards. The Philippines is one of the most vulnerable areas to typhoons where major disturbances result in heavy damage to reefs. In 2011, Typhoon Washi (*Sendong*) hit the northern part of Mindanao and the adjacent regions. Typhoon Bopha (*Pablo*) struck the country in 2012 again hitting northern Mindanao. Then in 2013 the Super Typhoon Haiyan (*Yolanda*) struck the Visayas and the northern Palawan areas (Deocadez et al. unpublished in the 2014 APCRS Presentation). Anecdotal reports and personal communication (Dr. Willy Campos and Dr. Rene Abesamis) of these typhoons particularly Bopha and Haiyan, caused close to 100% damaged in some specific reef areas along their paths. However, at the national level, the damaged area may be overwhelmed by the overall trends shown in a slight increase in coral cover based from the MPA sites that were surveyed (Figures 5.5.2 and 5.5.3). The presence of information in one of the country's largely less accessible reef areas, like the Kalayaan Group of Islands at the West Philippine Sea might show a different trend. This aspect has been mentioned by Licuanan and Aliño (2014) as an issue of representativeness of reef types and accessibility.

On the other hand, the deep reefs on the eastern seaboard of the Philippines, the Benham Bank as part the North Philippine Sea had almost 100% coral cover (Figure 5.5.6) in nearly all of the sites surveyed. These reefs are found at depths between 55 to 65m with the surveyed reef area approximately 25km^2 may have remained unaffected for several hundred years. If taken out of context this could bias the nationwide results suggesting a potentially higher cover for the country, if other deep coral reefs are explored. Again, this is an issue related to the use of typologies in systematically designing future assessments and monitoring efforts (Licuanan and Aliño 2014).

The trend for reef fishes further highlight the importance of a more nuanced cautionary context of the state of reefs and the imperative for its wise use and understanding. In the 2004 report, only 23% of the sites surveyed showed biomass levels >20 mt/km^2 (see Nañola et al. 2006). In this report, around 45% of the sites monitored showed fish biomass >20mt/km^2. This may suggest that close to 50% of the reefs examined were predominantly located in MPAs and are getting better and if sustained may move towards resiliency if the prevailing threats are addressed. Resilient reefs can also be considered as those that have herbivore biomass >10 mt/km^2 (Adam et al. 2011).

Fig. 5.5.6: Foliose corals dominated the Benham Bank seamount located at the North Philippine Sea marine biogeographic region (Benham Bank Report; Dizon 2014).

Based on the data presented by Nañola (2012) for fringing reefs, at least half of the total fish biomass is composed of herbivorous reef fishes. So with a total fish biomass of 20mt/km^2, around 10mt/km^2 are herbivorous reef fishes suggesting indication of proxies for resiliency. Note though that for protected offshore atolls, carnivores are the dominant tropic groups like in Tubbataha (Nañola 2012). Thus further understanding of the interaction of deep and shallow reefs, like those of the offshore reefs in the Benham bank and the Kalayaan Island Group would need to be pursued. The complexity of reef types, their interactions and connectedness as associated to their prevalent threats and the trophic interactions are relevant in assessing the status of reefs and their potential for recovery. Improving integrated coastal governance of the Philippine archipelago needs to be undertaken through adaptive management approaches.

RECOMMENDATIONS AND MOVING FORWARD

The prevalent threat of overfishing, illegal and destructive fishing have profound influence on whether reefs in the Philippines can sustain their provisioning of food and livelihood. Other drivers such as runaway overpopulation and unregulated coastal development may be more challenging to deal with including the associated siltation, pollution and poor land use practices that would need more integrated coastal management (ICM) approaches that are encompassed in an overall archipelagic policy. MPAs have been shown to have good results and the regular monitoring, evaluation, response and feedback systems are starting to be in place. Reefs and their associated ecosystems can be used as sentinel ecosystems to gauge the effectiveness of management interventions. The suggestions of Licuanan and Aliño (2014) should be incorporated in reef assessments and monitoring efforts.

Progress in the development and evolution of the national coral reef status reports will need to move towards addressing integrated coastal management concerns. These efforts may allow opportunities to link sectoral (e.g. MPA to help sustain fisheries and tourism objectives) issues to an overall context of a sustainable Philippine archipelagic development agenda. Responses and feedback adjustment through the State of the Coasts Report as proposed in the Executive Order 533 would be one model to consider, or adopting the CTI format utilized in the State of the Coral Triangle Report (SCTR) would be another mode (ADB 2014a &b). To enhance the integration of reef fisheries information, efforts should be made to include and complement the State of Marine Resources Report (SMRR). The appropriate monitoring and evaluation processes and systems that would be put in place would help complete the CRM (Coastal Resources Management) cycle.

Long term monitoring of reefs can be improved with the use of scientific innovations and more automated technologies (e.g. ARRAS [A Rapid Reef Assessment System]), better visualization, photo-video documentation and the inclusion or linkages to other databases (e.g. Reef Check) with Geographic Information Systems (e.g. the CTI Atlas), through integrated information, communication systems. Operational responses that can aid decisions such as helping effective ICM require a strategic program to address the imperatives now and into the future. So ACT NOW by:

Accelerating scaling up actions (e.g. ICM and Ridge to Reef).

Continuing coordination of communities (e.g. ICT and Communities of Practice).

Threat reduction and thresholds capacities maintained (e.g. Joint enforcement).

Networking should be continued (e.g. Social-Ecological Governance networks).

Organizational development and programmatic strategies (e.g. Capacity building).

Working together and synergizing (e.g. Incentives systems for cooperation).

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5.6. THAILAND

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SUMMARY

Thailand is one of the most biodiversity-rich countries as it is located within two major biogeographical regions. Coral reefs in Thailand can be divided into four distinct groups with different oceanographic conditions, i.e., the Inner Gulf of Thailand, the Eastern Gulf of Thailand, the Western Gulf of Thailand and along the coastline of the Andaman Sea. A total of 389 coral species were recorded. Manta tow survey and observation on permanent transects and quadrats were carried out in 133 study sites. Average live cover in Thai waters decreased after the 2012 coral bleaching event until the present day. Many coral reef sites in Thai waters are good for tourism use. High percentage of monitoring reef sites in several provinces has been intensively visited by local and foreign tourists. Most anthropogenic stress and damage for coral reefs in Thai waters were caused by sediment from coastal development activities, tourism and fishery impacts, marine debris and land-based wastewater. Anomalous seawater temperatures were recorded in Thai waters during the summer months of 2014. Coral bleaching was obvious at Mu Ko Angthong (Western Gulf of Thailand) and Mu Ko Surin (Andaman Sea). It was also reported from Mu Ko Lan (Inner Gulf of Thailand), Mu Ko Samed and Mu Ko Chang (Eastern Gulf of Thailand), Ko Tao and Ko Losin (Western Gulf of Thailand) and Mu Ko Phi Phi (Andaman Sea). The coral species susceptible to bleaching varied among study sites.

Recommendations on coral reef management for the coral bleaching crisis, coping with anthropogenic disturbances and managing marine national parks in Thailand are proposed.

COUNTRY STATISTICS AND CORAL REEF RESOURCES IN 2014

Thailand is located in the Southeast Asian peninsula with a latitudinal and longitudinal extent of 15 °N and 100 °E and the country statistics are in Table 5.6.1.

Table 5.6.1 Important country statistics.

		Sources
Population	66.79 million baht (2012)	http://www.worldbank.org
GDP	366.0 billion baht (2012)	http://www.worldbank.org
Land areas	514,000 km^2	http://www.seafdec.or.th
Maritime zones	320,000 km^2	http://marinepolicy.trf.or.th
Total coastline	3,219 km	http://marinepolicy.trf.or.th
International Tourist Arrivals to Thailand	26, 546,725 (2013)	http://tourism.go.th
Fisheries production (marine capture)	1,610,400 tons (2011)	http://www.fishery.go.th
Fisheries production (coastal aquaculture)	817,000 tons (2011)	http://www.fishery.go.th
Value of fisheries production (marine capture)	49,630.6 million baht (2011)	http://www.fishery.go.th
Value of fisheries production (coastal aquaculture)	81,422.7 million baht (2011)	http://www.fishery.go.th
Fisheries control area	52,241 km^2 (9 sites)	http://www.fishery.go.th
National marine park area	5,685 km^2 (21 sites)	http://www.dnp.go.th
Environmental protected area	12,190 km^2 (6 sites)	http://www.onep.go.th
RAMSAR site area	4,226 km^2 (9 sites)	http://www.onep.go.th
Marine archeological protected area	27 km^2 (1 site)	http://www.finearts.go.th
Mangrove area	2,527 km^2	http://www.dmcr.go.th
Seagrass area	200 km^2	http://www.dmcr.go.th
Coral reef area	205.21 km^2	http://www.dmcr.go.th

The bordering countries include Cambodia, Lao PDR, Malaysia and Myanmar. It is one of the most biodiversity-rich countries as it is located within two major biogeographical regions, i.e. the Indochinese region in the north and the Sundaic region in the south. The watersheds and main river basins are connected to the Mekong River, the Gulf of Thailand and the Andaman Sea. The Gulf of Thailand is a relatively shallow area of 320,000 km^2 of the South China Sea, with an average 45 meter depth and maximum depth of only 80 meters. Its boundary is defined by the line from Cape Bai Bung in southern Vietnam to the city of Kota Baru on the Malaysian coast and it has a coastline of about 1,840 kilometers. Water exchange in the gulf is slow, and the strong water inflow from the rivers makes the gulf low in salinity (3.05-3.25%) and rich in sediments. The main rivers which empty into the gulf are the Chao Phraya, Tha Chin, Mae Klong and Bang Pakong Rivers at the upper gulf, and the Tapi River into Bandon Bay in the western gulf. The Andaman Sea is a body of water to the southeast of the Bay of Bengal. It is part of the Indian Ocean. The Andaman Sea is approximately 1,200 km (north-south) and 650 km wide (east-west), with an area of 797,700 km^2. Its average depth is 870 m, and the maximum depth is 3,777 m. Salinity is 31.5–32.5 psu in summer and 30.0–33.0 in winter in the southern part. In the northern part, it decreases to 20–25 psu due to the inflow of fresh water from the Irrawaddy River.

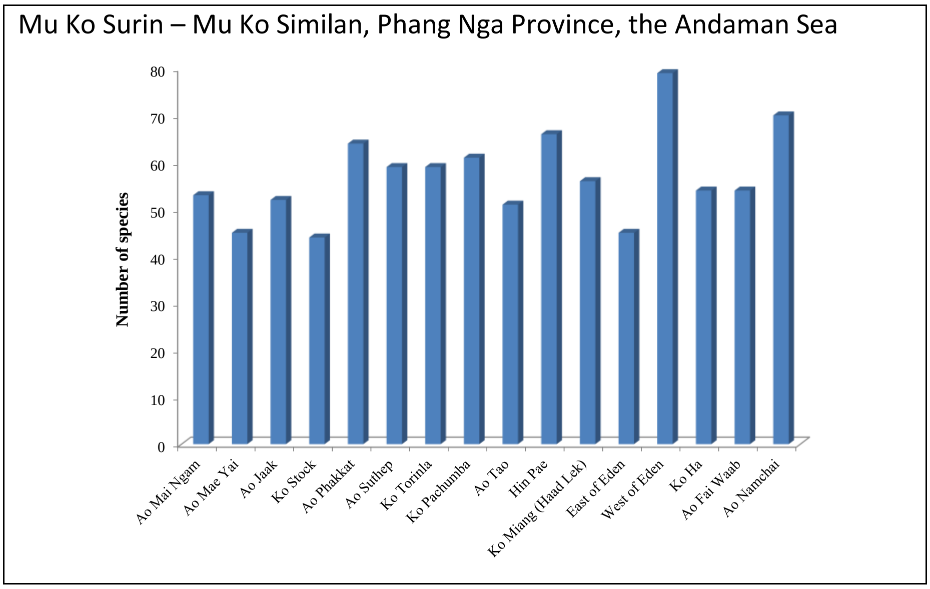
Coral reefs in Thailand can be divided into four distinct groups with different oceanographic conditions, i.e., the Inner Gulf of Thailand (Chonburi Province); the Eastern Gulf of Thailand (Rayong, Chanthaburi and Trat Provinces); the Western Gulf of Thailand (Prachuab Kirikhan, Chumporn, Surat Thani, Nakhon Si Thammarat, Songkhla, Pattani and Narathiwat Provinces); and along the coastline of the Andaman Sea (Ranong, Phuket, Phang Nga, Krabi, Trang and Satun Provinces). There are three reef types in Thai waters, i.e. coral communities with no true reef structure; developing fringing reefs; and early formation of fringing reefs.

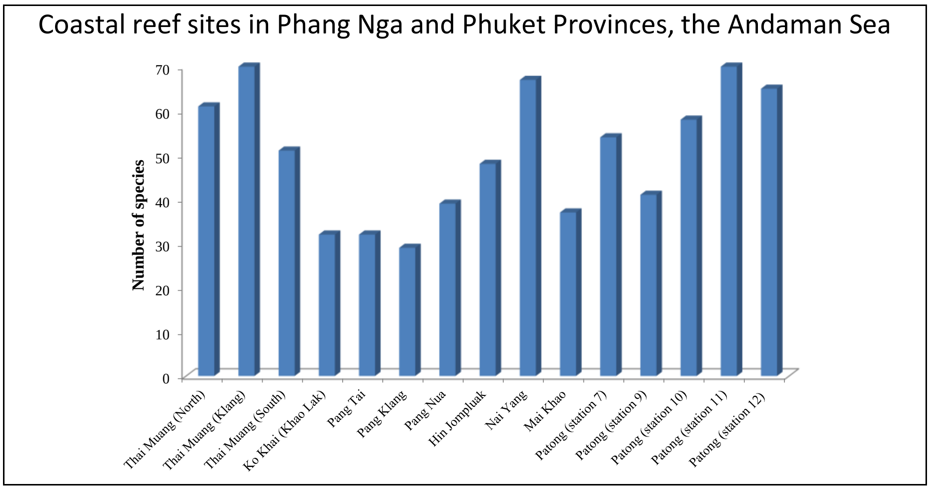
NUMBER OF SPECIES OF MAJOR TAXA RECORDED

The diversity of organisms found in coral reefs in Thai waters is summarized in Table 5.6.2. The data were compiled from various scientific reports and published literature.

Table 5.6.2 Diversity of marine organisms in Thai waters.

Taxonomic group	Number of species	Sources
Seaweeds	77 (Western Gulf of Thailand)	Coppejans et al., 2010
Marine sponge	74 (Eastern Gulf of Thailand)	Putchakarn, 2011
	89 (Western Gulf of Thailand)	Putchakarn and Hongpadtharakiree, 2013
Scleractinian corals	389	www.dmcr.go.th
Marine gastropods	454	Sanpanich and Duangdee, 2013
Nudibranchs	96	Chavanich et al., 2013
Marine bivalves	594 (Gulf of Thailand)	Jensen, 2004
	321 (Eastern Gulf of Thailand)	Sanpanich, 2011
Cephalopods	77	ONEP, 2008
Shrimps, prawns and lobsters	68	ONEP, 2008
Crabs	108	ONEP, 2008
Marine calanoid copepods	41 (Mu Ko Surin, Andaman Sea)	Teeramathee et al., 2013
Sea feathers	39	ONEP, 2008
Sea stars	69	ONEP, 2008
Brittle stars	112	ONEP, 2008
Sea urchins	67	ONEP, 2008
Sea cucumbers	94	ONEP, 2008
Tunicates	12 (Eastern Gulf of Thailand)	Munkongsomboon 2007
Fishes	400 (Gulf of Thailand)	Satapoomin, 2007
	880 (Andaman Sea)	





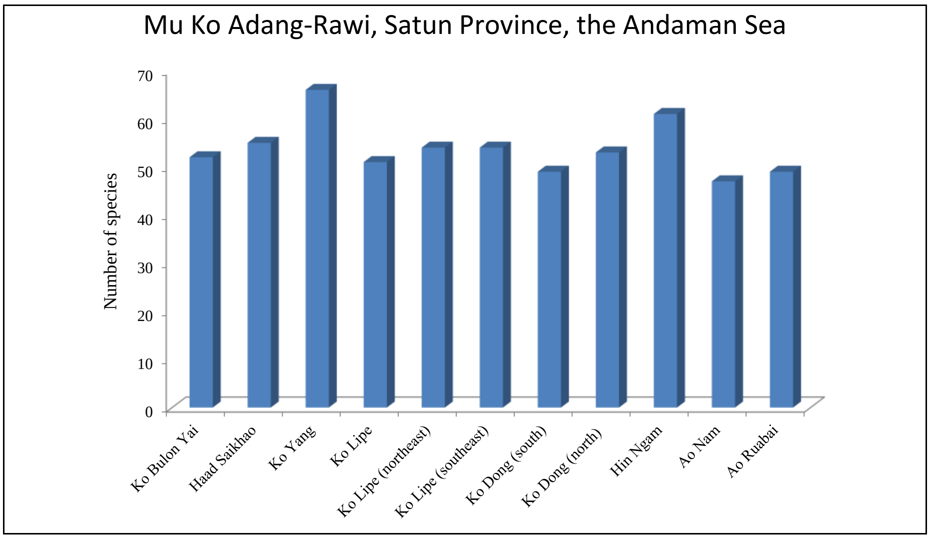


Fig.5.6.1: Diversity of reef fishes in the Andaman Sea.

The extensive surveys on reef fish diversity in the Andaman Sea revealed that there was much spatial variation. The results are summarized in Figure 5.6.1.

CORAL REEF MONITORING SITES

Manta tow survey and observation of permanent transects and quadrats were carried out in 133 study sites based on Department of Marine and Coastal Resources (2013), Chanmethakul (2013) and a database from Marine Biodiversity Research Group, Ramkhamhaeng University. A list of coral reef monitoring sites is shown in Table 5.6.3 and Figure 5.6.2.

Table 5.6.3: Coral reef monitoring sites in the Gulf of Thailand and the Andaman Sea.

Andaman Sea	Ko Surin Tai - Ao Pak Kaad,	- Northeast
Ranong Province	Ko Torinla (North)	- South
Ko Chang	**Phuket Province**	- Northwest
- Ao Ban Bangkalow	Ko Wa Yai	Ko Aeo
- Ao Yai (south)	Ko Wa Noi	- West
Ko Phayam	Ko Phae	- East
- North	Ko Phi	Ko He
- West	Ko Wa Noi	- West
- East	Ko Phae	- South
- South	Ko Phi	- North
Ko Khangkhao	Ko Payu	Ko Mai Thon
Ko Kam Nui	Ko Ngam	- East
Ko Luk Kam Ok	Ko Hea	- west
Ko Luk Kam Klang	Ban Laem Khad	Ao Chalong
Phangnga Province	Ko Thanan	Ko Bon
Ko Lipi	Ko Raet	- East
Ko Khai Nai	Ko Nakha Yai	- west
Ko Khai Nok	- West	**Krabi Province**
- North	- East	Ko Pu
- Klang	- North	- North
- South	Ko Nakha Noi	- west
Ko Dokmai	Laem Yamu	Ko Lola
Ko Roi	Ko Rang Noi	Ko Ka
Ko Boi Yai	Ko Rang Yai	Ko Siboya
- West	Ko Maphrae	Laem Hin
- East	Ko Mali	Laem Pho
Ko boi Noi	Ko Sire	Laem Nang to Ao Nam Mao
Ko Ba Tang	Ko Taphao Noi	Khao Laem Nang
Ko Thong	Ko Taphao Yai	Ko Laolaling
Ko Dang	Ao Man-Ao Kham	Ko Pakka
Ko Kudu Yai	Ao Tang Ken	Ko Yalahutung
Ko Ku Du Noi	- North	Ko Saya
Ko Yao Yai	- South	**Trang Province**

- Laem Hua Lan	Leam Phan Wa	Ko Kradan (East)
- Laem Pak Khlong	- East	Ko Chuak (East)
- southwest	- West	Ko Maa (East)
-Ao Son to Ao Lo Po Noi	Ban Khao Khad	
- Northwest	Ko Thanan	
Ko Surin North- Ao Jaak	Ko Lon	
Gulf of Thailand	**Trat Province**	**Surat Thani Province**
Chonburi Province	Ko Chang (West)	Ko Pha-ngan - Ko Ma
Ko Raet	Ko Kradat	Ko Kong Than Sadet
Ko Samae San	Ko Mak	Ko Samui (North)
Ko Pla Muk	Ko Kham	Ao Thong Tanote, Ko Samui
Ko Kham	Ko Lom	Laem Sed, Ko Samui
Ko Chuang	Ko Rayang Nok	Ko Tan (Northeast)
Hin Chalam	Ko Rayang Nai	**Nakhon Si Thammarat Province**
Ko Rong Nang-Ko Rong Khon	Hin Gurk Maa	Ko Kra Yai
Ko Chan	Ao Phak Weang, Ko Kut	Ko Kra Klnag
Ko Chanh Klua	Ao Phrao, Ko Kut	Ko Kra Lek
Laem Samae San	Ao Kalang, Ko Kut	
Ko Lan	**Prachuap Khiri Khan Province**	
Ko Sak	Ko Sadao	
Ko Khrok	Ko Raet	
Hin Ta Sin	Ko I-Aen	
Ko Khang Khao (North)	Ko Lueam	
Ko Khang Khao (West)	**Chumphon Province**	
Ko Khang Khao (Southeast)	Ko Yung	
Chanthaburi Province	Ko Kula	
Ko Saba	Ko Mat Wai Noi	
Ko Nom Sao	Ko Mat Wai Yai	
Hin Ai Lao		

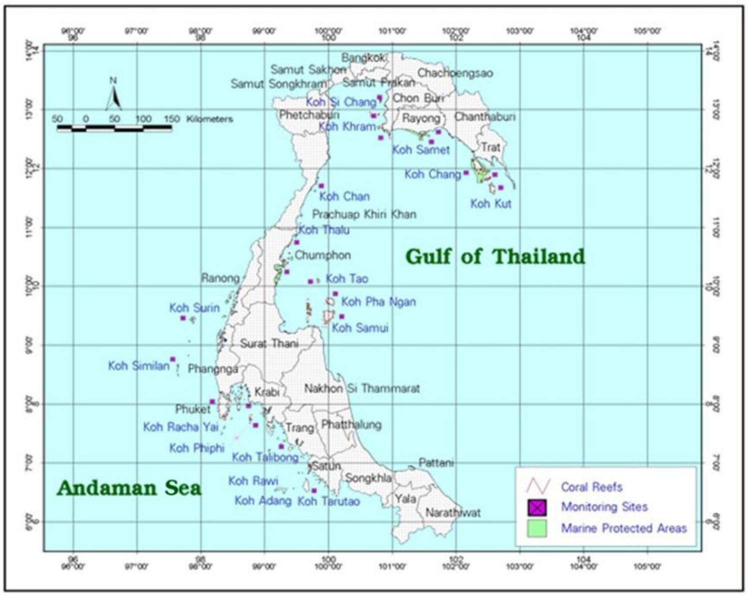
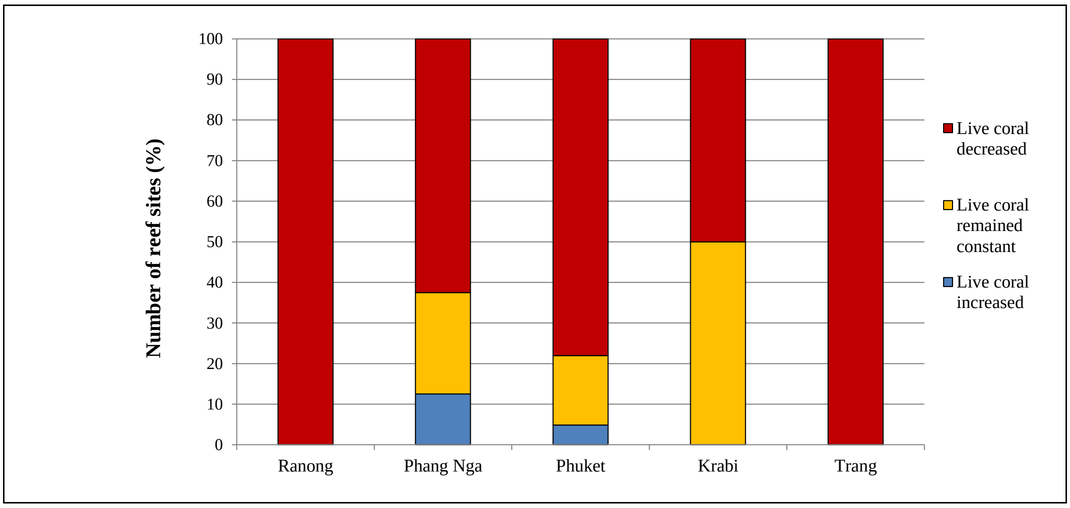


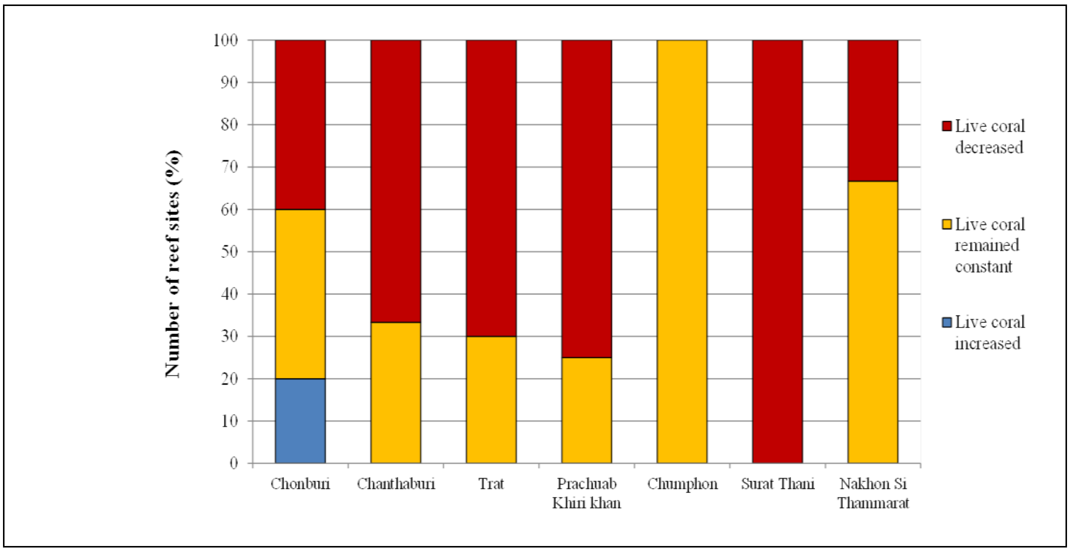
Fig. 5.6.2: Location of coral reef monitoring sites in Thai waters.

SITE CHANGES IN PERCENT HARD CORAL COVER

In general, average live cover in Thai waters decreased after the 2012 coral bleaching event until the present day (Klinthong and Yeemin, 2012, Klinthong et al., 2013a, b; Pengsakun et al, 2012a, b; Suantha and Yeemin, 2011; Sangmanee et al., 2012b; Sutthacheep et al., 2011b; 2012a, 2013a, b; Yeemin et al., 2012a; 2013a, b, c; Yucharoen and Yeemin, 2012). In the Andaman Sea, average live coral cover at most monitoring sites (>70%) decreased. The coral cover at most monitoring sites (>60%) also decreased. The coral reefs in Chumphon and Nakhon Si Thammarat Provinces were in relatively good condition (Fig. 5.6.3).



Andaman Sea



Gulf of Thailand

Fig. 5.6.3: Changes in percentage of live coral cover between before the 2010 coral bleaching event and the surveys in 2012-2013.

INDEX SCORES OF MAJOR BENTHIC TAXA

Populations of two major reef associated benthic macroinvertebrates, i.e. a giant clam *Tridacna squamosa* and a sea urchin *Diadema setosum* in the Gulf of Thailand were examined. In the past, giant clams represented an important component of coral communities in the Gulf of Thailand. The status of population density of the giant clam *Tridacna squamosa* on coral communities in the Gulf of Thailand were investigated following the 2010 mass coral bleaching event. The surveys were completed during several field trips at 39 study sites in eight Island groups, i.e. Ko Sichang, Ko Lan and Ko Phai, Chonburi Province (Inner Gulf of Thailand), Ko Chang and Ko Kut, Trat Province (Eastern Gulf of Thailand) and Ko Thalu, Prachuap Khiri Khan Province and Ko Tao and Ko Samui, Surat Thani Province (Western Gulf of Thailand). Higher population densities of the giant clams (up to 0.8 ind.m^{-2}) were obvious at the study sites in Ko Kut, Ko Thalu and Ko Tao while very low population densities were observed at other study sites (Fig. 5.6.4) (Sangmanee and Yeemin, 2013).

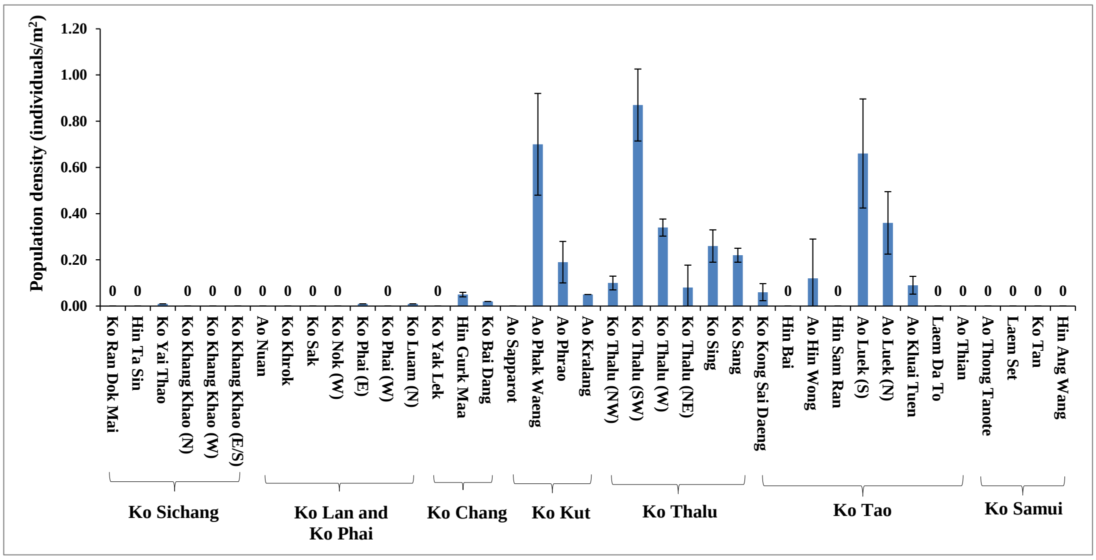


Fig. 5.6.4: Abundance of *Tridacna squamosa* at the study sites in the Gulf of Thailand.

The sea urchin *Diadema setosum* is the most dominant invertebrate of coral communities in the Gulf of Thailand. The population densities of *D. setosum* were investigated at 26 study sites in the Gulf of Thailand with contrasting habitat structures and anthropogenic disturbances. The highest population density of *D. setosum* was observed in Hin Rab of Ko Chang group (mean 11.2 individuals.m^{-2}) while the lowest was in Ko Taen of Ko Samui group (mean 0.1 individuals.m^{-2}). No sea urchins were observed in some coral communities of Ko Samui group (Fig. 5.6.5). This finding implies the impact of collecting sea urchins for local restaurants (Sangmanee et al., 2012a).

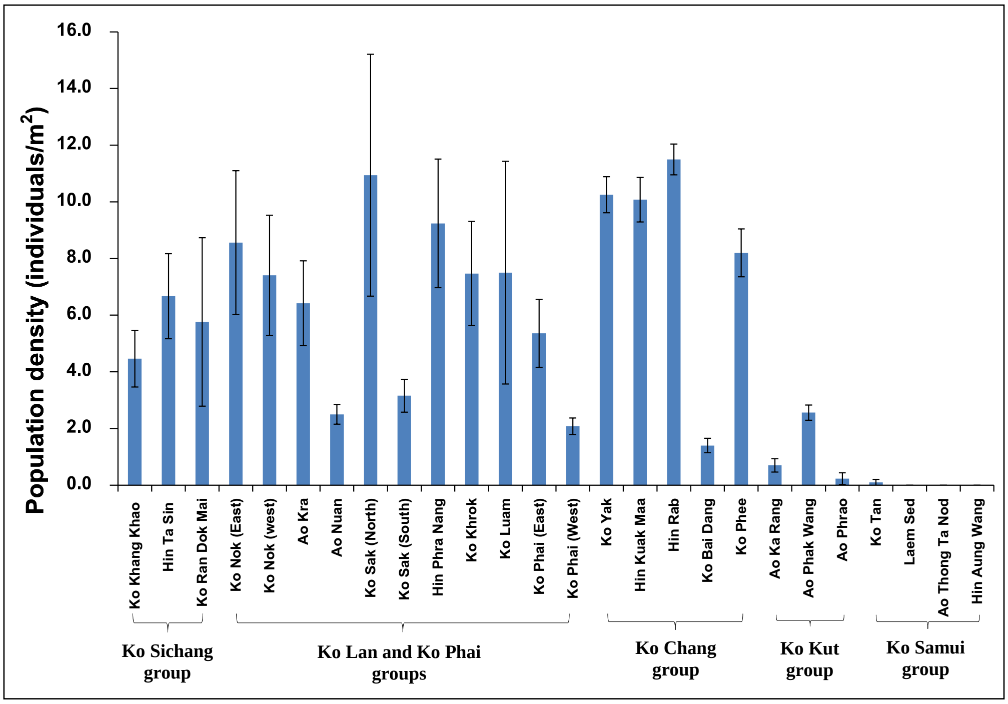


Fig. ! land.

INDEX SCORES FOR CURRENT LEVELS AND TRENDS IN CORAL REEF RESOURCE USAGE

Many coral reef sites in Thai waters are good for tourism use. A high percentage of monitoring reef sites in Phang Nga, Phuket, Krabi, Trang and Satun Provinces in the Andaman Sea and Rayong, Chanthaburi, Trat, Chumphon and Surat Thani Provinces in the Gulf of Thailand has been intensively visited by local and foreign tourists (Fig. 5.6.6).

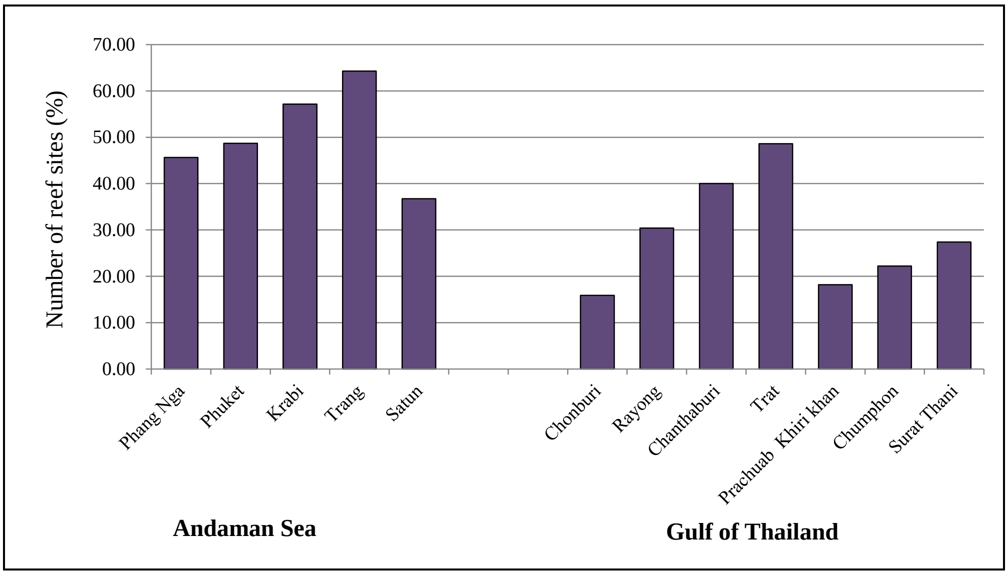


Fig. 5.6.6: Percentage of coral reef monitoring sites for tourism use.

INDEX SCORES FOR CURRENT STRESS AND DAMAGE FOR CORAL REEFS

Most stress and damage on coral reefs in Thai waters were caused by sediment from coastal development activities, tourism and fishery impacts, marine debris and land-based wastewater (Fig. 5.6.7). Most coral reef monitoring sites in the Gulf of Thailand and the Andaman Sea were obviously affected by heavy sedimentation (Yeemin et al., 2013d). Impacts from divers and boat anchoring were frequently observed at many reef sites (Yeemin et al., 2011). The impacts of wastewater on coral reefs were recorded from reef monitoring sites in Surat Thani Province, the Gulf of Thailand and Phuket Province, the Andaman Sea. Activities of local fishers also caused direct physical damage to coral reefs at several monitoring sites in the Andaman Sea.

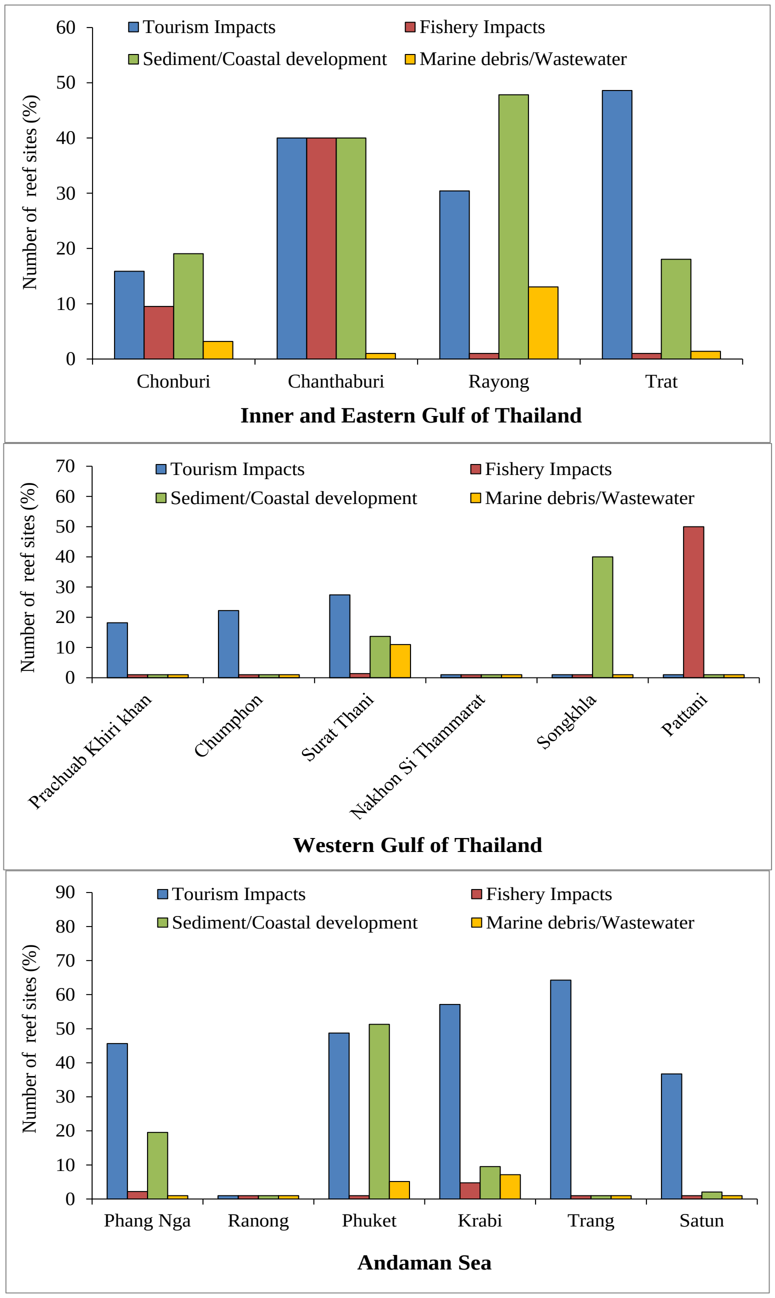


Fig. 5.6.7: Stress and damage to coral reefs in Thai waters.

MEASURABLE STRESS AND DAMAGE SUMMARY AT NATIONAL LEVEL

A summary of stress and damage for coral reefs in Thailand is shown in Fig. 5.6.8. Tourism and sediment from coastal development were the major threats on coral reef monitoring sites in Thailand. Impacts of fishing activities, marine debris and wastewater on coral reefs were also recorded at several monitoring sites in the Gulf of Thailand and the Andaman Sea.

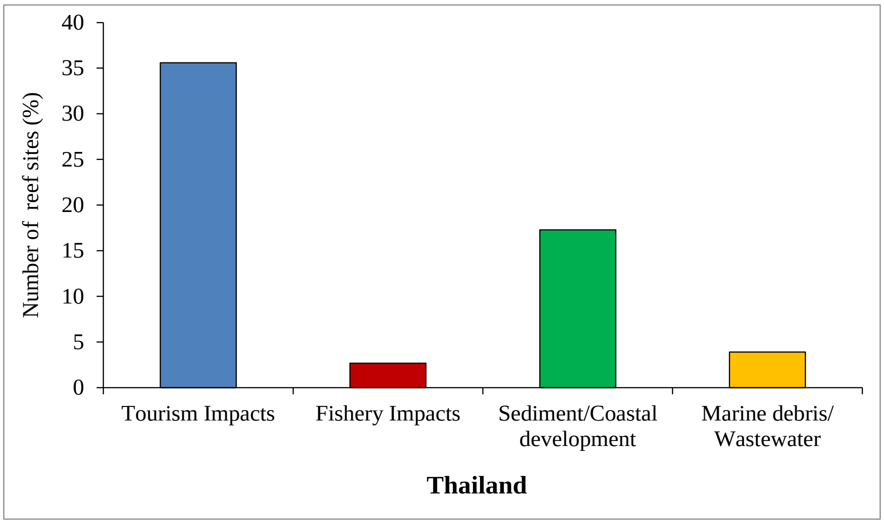


Fig. 5.6.8: Summary of stress and damage for coral reefs in Thailand.

IMPACTS OF THE 2014 CORAL BLEACHING EVENT

Average seawater temperature recorded at Mu Ko Surin, the Andaman Sea by data loggers was up to 32 °C in May 2014 (Fig. 5.6.9).

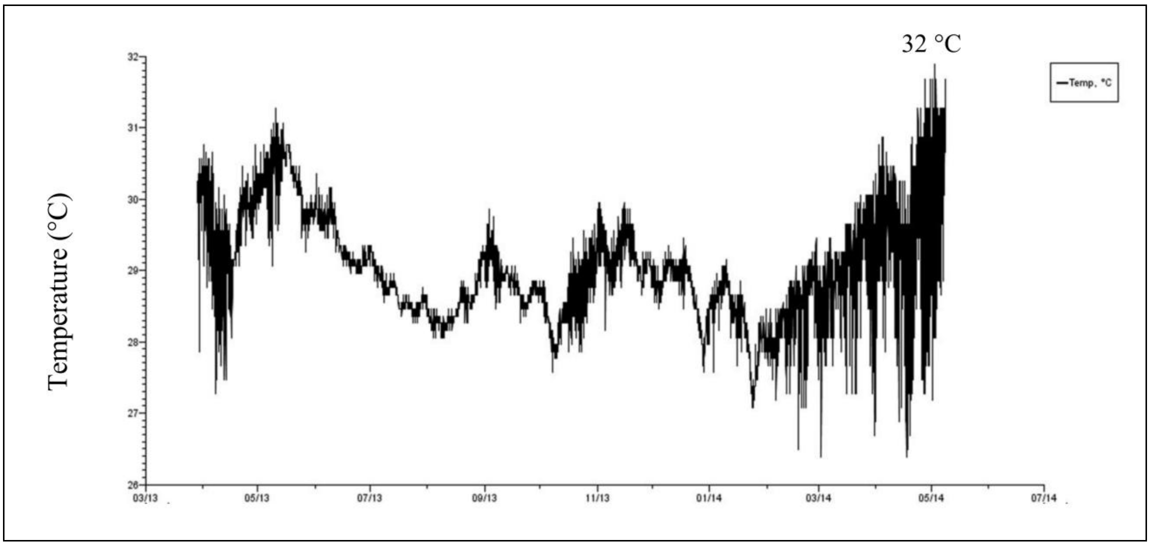


Fig. 5.6.9: Seawater temperature recorded by a data logger at Mu Ko Surin, the Andaman Sea.

The surveys during the 2014 coral bleaching event revealed that coral bleaching at Mu Ko Angthong (Western Gulf of Thailand) and Mu Ko Surin (Andaman Sea) was more severe compared to Mu Ko Phi Phi (Andaman Sea) (Fig. 5.6.10).

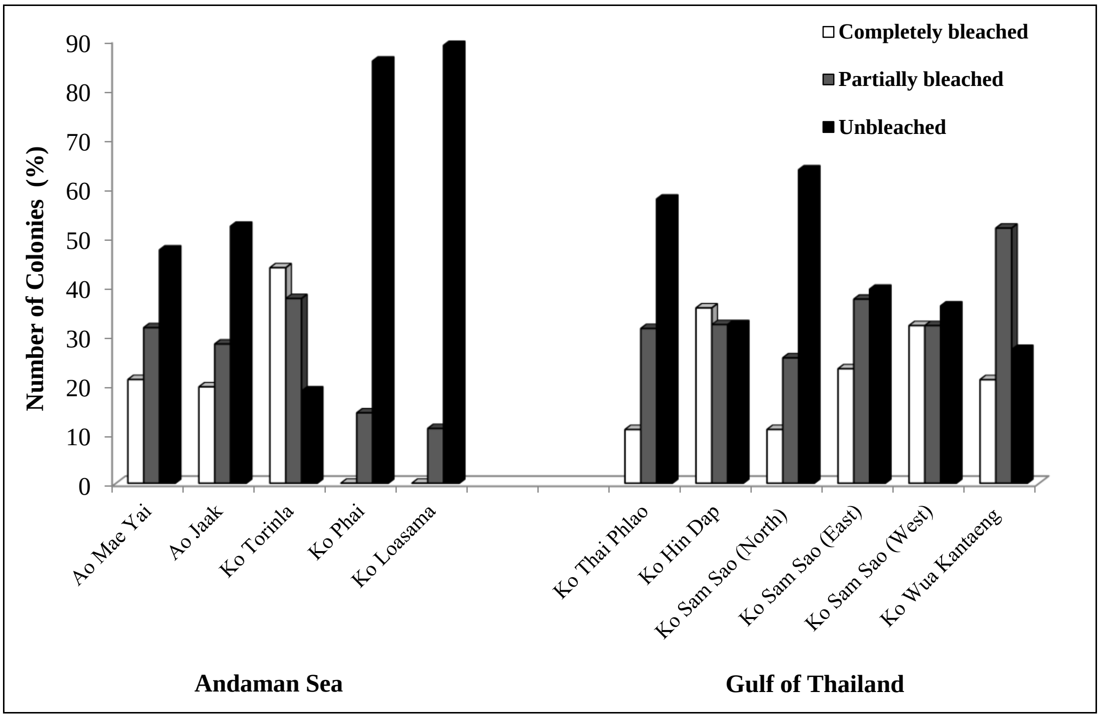
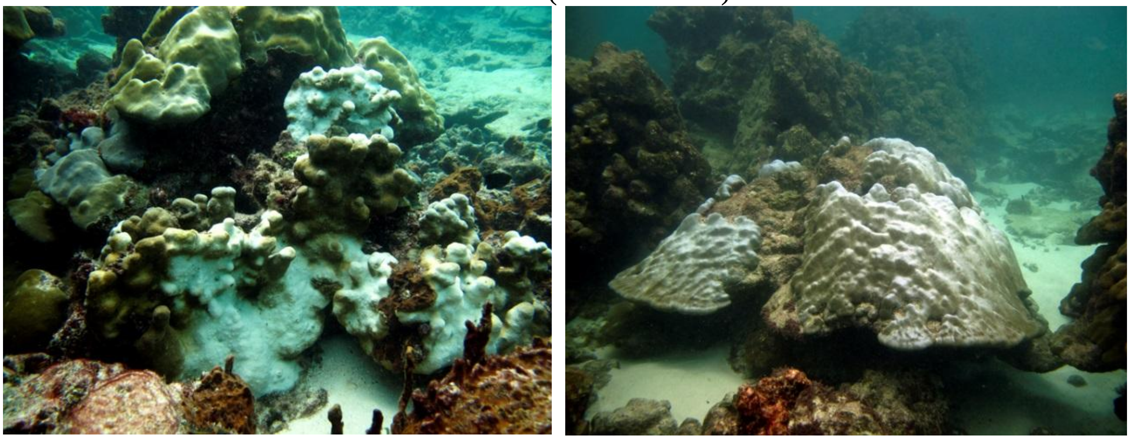


Fig. 5.6.10: Coral bleaching in the Andaman Sea and the Gulf of Thailand

Coral bleaching was also reported from Mu Ko Lan (Inner Gulf of Thailand), Mu Ko Samed and Mu Ko Chang (Eastern Gulf of Thailand), Ko Tao and Ko Losin (Western Gulf of Thailand). The most susceptible coral species to bleaching at Mu Ko Surin were *Acropora* spp. and *Pocillopora* spp. while *Porites* spp. were more resistant. However the highly susceptible coral species at Mu Ko Phi Phi were *Porites* spp., *Acropora* spp. and *Pocillopora* spp. but *Symphyllia* spp. and *Lobophyllia* spp. were unaffected. The susceptible corals at Mu Ko Angthong were *Porites* spp., *Fungia* spp., *Pavona* spp., *Galaxea* spp. and *Favia* spp. while *Goniastrea* spp. were unaffected (Fig. 5.6.11).

Mu Ko Surin (Andaman Sea)



Mu Ko Phi Phi (Andaman Sea)

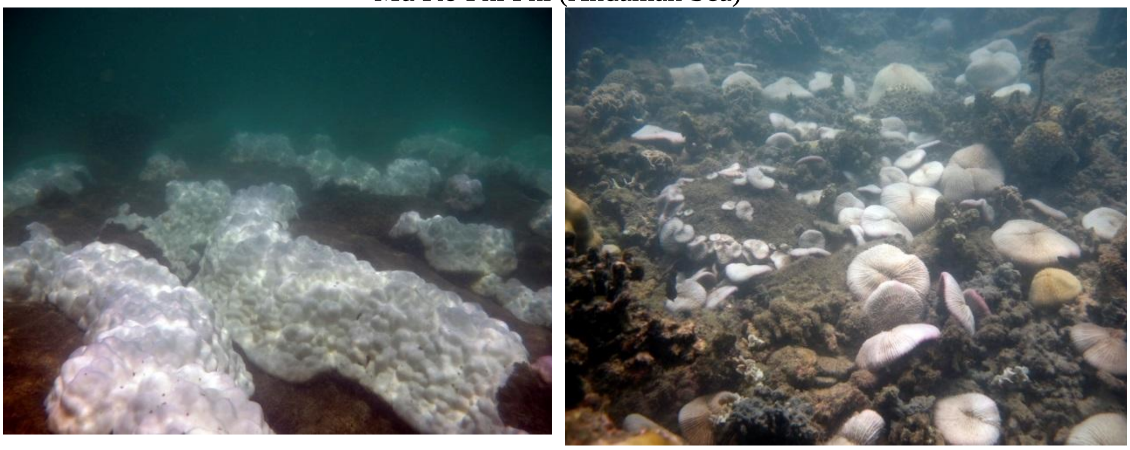


Fig. 5.6.11: Coral communities during the 2014 coral bleaching event at Mu Ko Angthong (Western Gulf of Thailand)

MPA ATTRIBUTES AND MANAGEMENT EFFECTIVENESS SCORES

The national parks that submitted completed assessments are: Ao Phang-nga, Than Bok Khorani, Hat Wanakon, Khao Lampi - Hat Thai Mueang, Laem Son, Mu Ko Similan, Lam Nam Kra Buri, Mu Ko Lanta, Mu Ko Phetra, Khao Laem Ya - Mu KoSamet, Khao Lak – Lam Ru, Mu Ko Surin, Sirinat, Hat Noppharat - Mu Ko Phi Phi, Than Sadet - Ko Pha-ngan, Ao Manao - Khao Tanyong (Hockings et al., 2012). The 16 surveyed parks all contain components of both marine and terrestrial areas. Most are designated as National Parks, although two parks are awaiting final gazettal. There are five Ramsar sites, three ASEAN Heritage Parks, and a World Heritage proposal is being considered for the marine parks in the Andaman Sea. Most national parks are conserved for a mixture of biological, cultural and recreational values. The most common threats to these values include poaching, encroachment by neighbors for both agriculture and urban development, visitor impacts from inappropriate levels of use, incompatible land use, climate change, especially coral bleaching, littering and pollution, illegal fishing and storm impacts.

Efforts to foster joint management are commendable but not widely implemented in all marine national parks. More work will be needed to engage local communities and other stakeholders in empowered site level management. Department of National Parks, Wildlife and Plant Conservation (DNP) is a relatively well-staffed agency but its effectiveness is reduced because of a rigid hierarchical structure with long accountability chains and poor delegation of authority to field-based managers. The appointment and staff rotation policy of the agency further reduces efficiency and effectiveness. Park rangers often have a good understanding of local conditions and a positive relationship with stakeholders but when staff are rotated frequently the acquired knowledge and relationships are often lost.

Fish stocks outside of the marine national parks decline therefore pressure from illegal fishing is likely to increase. Visitor pressure in most national parks is causing damage despite DNP efforts to establish carrying capacities and monitor use. DNP has established systems for community involvement at the site level but this activity receives relatively little staff time and budget and hence many issues with stakeholders and communities remain unresolved. Improvement in staff skills and training will be needed before internal capacity for marine based research and monitoring can be improved. A more structured process to consult with and involve universities and external researchers should be pursued to better manage and direct research and monitoring activities. The Marine National Park Research Centres in Phuket (Northern Andaman), Trang (Southern Andaman) and Chumphon (Gulf of Thailand) have already made progress in building these relationships and providing a better research and monitoring service in support of DNP (Hockings et al., 2012).

RECOMMENDATIONS AND CHALLENGES ON CORAL REEF CONSERVATION AND SUSTAINABLE RESOURCE USE

Coral reef management actions under the coral bleaching crisis are proposed (Samsuvan and Yeemin, 2012; Sutthacheep et al., 2011a, 2012b; Yeemin et al., 2012b). The management actions are categorized into three groups i.e. protect resistance, build tolerance and promote recovery (Table 5.6.11).

Table 5.6. 11: A list of coral reef management actions under the coral bleaching crisis

Protect resistance	- reduce stresses on coral reefs, such as light, temperature, freshwater, etc. - protect resistant coral reefs to bleaching - select appropriate coral species and genetic trait for coral rehabilitation projects
Build tolerance	- reduce stresses on coral reefs, such as light, temperature, freshwater, etc. - rotation or temporary closure of particular reef sites for tourism purposes - coral reef zoning for utilization - environmental-friendly coral reef utilization - reduce sedimentation loads into coral reefs - reduce nutrients and wastewater flowing into coral reefs
Promote recovery	- control outbreaks of coral predators and space competitors - regulate appropriate fishing practices on coral reefs - control water quality from land-based, islands and tour vessels - reduce sedimentation loads into coral reefs - protect corals from direct and indirect damaged - implementation of the activities under the national coral reefs management strategic and action plans - protect the resistant areas to coral bleaching - protect the areas with available substrates for coral recruitment - establish hard substrates for coral recruitment - protect coral settlers - coral transplantation by selecting appropriate species/genetics and areas - culture of sexually and asexually derived juvenile corals - reef rehabilitation using naturally broken coral fragments - establish artificial reefs for diving/fisheries/ nursery ground

Department of Marine and Coastal Resources (2013) recommended coral reef management actions to address anthropogenic disturbances:

- control all coastal development activities in order to prevent land-based sediment.
- strictly control and monitor the environmental impact assessment process.
- restore mangroves and seagrass beds.
- enhance knowledge of local tourist guides for environmentally friendly tourism.
- build adequate wastewater treatment systems.
- campaign for fishermen to not dispose debris nets into the sea.
- strictly control illegal dredging.
- enhance knowledge of fishermen on good practices for fishing in coral reefs in order to mitigate the impacts.

Hockings et al. (2012) provided key recommendations for marine national parks in Thailand:

- review and reform the National Parks Act (1961)
- adopt the Thai Protected Area Master Plan and complete the Thai protected area system
- initiate an integrated programme to improve fisheries management within marine national parks
- reform DNP and interagency relationships within the Thai Ministry of Natural Resources and Environment and other relevant Ministries
- establish a sustainable financing base for marine protected area management
- reform staff placement and training policies to provide continuity in delivery of services and programs
- develop an integrated programming, planning, research, monitoring and reporting system
- include local communities in marine national park decision-making by assessing and adopting different governance mechanisms
- develop partnerships with the tourism industry and Ministry of Tourism to protect and restore marine national park natural values
- address the key threats to the condition of biodiversity within marine national parks by undertaking a risk-based vulnerability assessment of climate change, extreme weather events, tsunamis and earthquakes

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5.7. VIETNAM

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SUMMARY OF CORAL REEFS IN VIETNAM

Coral reefs are important habitats in coastal waters of Vietnam, playing important roles such as serving as biodiversity reservoirs, and for fisheries and tourist development in the coastal zone. Monitoring activities of coral reefs have been established since 1998 at three locations along the coast of Vietnam including Nha Trang Bay, Hon Cau and Con Dao islands. These have been expanded with an additional 4 sites at Ha Long Bay, Van Phong Bay, Ninh Hai and Phu Quoc in 2000 to 2002. However, no ongoing coral reef monitoring programmes have officially been conducted since 1998. Main sources of funding for ongoing monitoring activities were supported by provincial, national and international agencies under the framework of various projects. Main agencies or institutions coordinating monitoring programmes included Institute of Oceanography, Research Institute of Marine Fisheries and MPA authorities. The number of monitoring sites conducted in the period of 2010-2012 was 33 at Nha Trang Bay, Ninh Hai coast, Hon Cau Island and Phu Quoc islands.

Overall status of coral reef benthos surveyed at 89 sites from 10 key areas during 2010-2011 showed a low overall average value of live coral cover. There were no reefs in excellent condition (> 75% cover), only 2.2% of reefs in good condition (range 51-75 % cover), 34.4% reefs in fair condition (26-50% cover) and 63.5% of reefs in poor condition (< 25% cover). Comparison with monitoring data between time periods from 1994 to 2012 indicate that overall mean cover of hard corals declined notably from 34.6% in 1994 to 25.6% in 2006 and 21.1% in 2012. Among them, reefs that are improving between 1994 and 2012 averaged 10.8% whereas reefs that are declining or remained unchanged were 55.4% and 30.0% respectively.

There are 16 MPAs approved by the Prime Minister in May 2010 with a total planned area of the whole system of 270,271 ha and 169,617 ha of marine area. All of the MPAs planned support coral reefs and more than 57% of the area of known coral reefs in the coastal waters are represented inside the declared MPAs. Up to middle of 2014, only 6 MPAs have been declared including Nha Trang Bay (established in 2001), Cu Lao Cham (2004), Phu Quoc (2007), Nui Chua (2008), Con Co (2010) and Hon Cau (2011). Of these, 16.7% of MPAs had good management (Cu Lao Cham), 50.0% moderate (Nha Trang, Nui Chua/Ninh Hai and Phu Quoc) and 33.3% poor (Con Co

and Hon Cau).

For governance structure, Ministry of Agriculture and Rural Development (MARD) has been identified as the overall environmental authority, and the Agency for Fisheries Exploitation and Protection is responsible for protection of marine resources.

Up to present, there are no current legislations directly related to coral reef conservation and management. Most of management activities have been mainly based on some major laws (Law on Environmental Protection approved in 2005 and Law of Fisheries adopted in 2003), decrees (Decree No. 43/2003/ND-CP issued in 2003 to declare list of species needed to be protected, restored and giving solutions for protection aquatic ecosystems, genetic diversity, aquatic biodiversity; Decree No. 27/2005/ND-CP adopted in 2005 on detailed guidance of Fisheries Law on marine protected areas in Vietnam), ordinances (Ordinance on the Protection and Development of Fisheries Resource approved in 1989, Ordinance on Tourism approved in 2000) and resolutions (Resolution 45/CP issued in 1993 on management reform and development of the tourist sector), Biodiversity Action Plan for Vietnam (BAP) approved in 2007, National Strategy on Management of Protected Area System approved in 2003.

Currently, there are some ongoing coral reef initiatives and projects supported by local agencies including annual monitoring programmes by Quang Nam, Khanh Hoa, Ninh Thuan and Kien Giang Provincial People's Committees. Major local agency-funded research activities are Ministry of Science and Technology (MOST), MARD, Ministry of Natural Resources and Environment (MONRE) and Vietnam Academy of Science and Technology (VAST) and some small funding is provided by provincial governments. There are no local volunteer and NGO-funded activities/programmes for coral reefs at present. At international level, there is an ongoing project entitled "Demonstration of Sustainable Management of Coral Reef Resources in the Coastal Waters of Ninh Hai District, Ninh Thuan Province, Viet Nam" currently support by UNEP/GEF related to research and monitoring activities. In addition, another small scale project to apply the Green Fins approach in Vietnam is supported by Mangroves for Future through UNEP with Nha Trang bay as a demonstration site.

With current projects approved and proposed in 2014, Cu Lao Cham, Nha Trang Bay and Phu Quoc have high potential to keep monitoring activities going from this year to the next few years. Some sites established at Con Dao, Van Phong Bay and Hon Cau may be discontinued due to lack of funding and human resources. In 2012-2013, four new monitoring sites were established in the waters surrounding the Ninh Thuan I & II Nuclear Power Plant (Ninh Thuan Province) for long-term monitoring of changes of coral reefs under future impacts from these Nuclear Power Plants.

Problems and limitations of monitoring activities/programmes in Vietnam were due to lack of personnel, logistics and funding. Although, monitoring activities have been conducted since 1998, however most of these activities had been combined with other activities within the framework of different projects. No permanent funding has been allocated for monitoring programmes in Vietnam.

Results from monitoring activities have positively contributed to the enhancement of management of coral reefs. Keeping these activities ongoing should be a major need and requirement at present and in the future. A total of 80 sites are proposed for monitoring at 10 key areas for the future including 8 sites at Ha Long-Cat Ba, Con Co (8), Cu Lao Cham (8), Van Phong Bay (8), Nha Trang Bay (8), Nui Chua/Ninh Hai coast (8), Hon Cau (8), Phu Quy (8), Con Dao (8) and Phu Quoc (8). Reefcheck indicators combined with additional local indicators should be used for monitoring at all proposed areas. Development of a monitoring network through training on monitoring methods for staff of MPAs together with appropriate support for infrastructure and funding should be considered as important for successful monitoring programmes in Vietnam in the future.

Table 5.7.1: List of marine protected areas in Vietnam planned until 2020.

No.	Name of MPAs/Province	Category (IUCN, Fisheries Law)	Total area (ha)	Marine area (ha)
1	Dao Tran /Quang Ninh	III	4,200	3,900
2	Co To/Quang Ninh	II	7,850	4,000
3	Cat Ba/Hai Phong	I	20,700	10,900
4	Bach Long Vi/Hai Phong	III	20,700	10,900
5	Hon Me/Thanh Hoa	III	6,700	6,200
6	Con Co/Quang Tri	II	2,490	2,140
7	Hai Van-Son Cha/Thua Thien Hue	II	17,039	7,626
8	Cu Lao Cham/Quang Nam	I	8,265	6,716
9	Ly Son/Quang Ngai	III	7,925	7,113
10	Nha Trang/Khanh Hoa	I	15,000	12,000
11	Nam Yet/Khanh Hoa	II	35,000	20,000
12	Nui Chua/Ninh Thuan	I	29,865	7,352
13	Hon Cau/Binh Thuan	II	12,500	12,390
14	Phu Quy/Binh Thuan	III	18,980	16,680
15	Con Dao/Ba Ria-Vung Tau	I	29,400	23,000
16	Phu Quoc/Kien Giang	II	33,657	18,700
Total			**272,71**	**169,617**

COUNTRY STATISTICS AND CORAL REEF RESOURCES

The coastline of Vietnam extends for some 3,260 km with more than 3,000 inshore and offshore islands and islets which extend to claims covering the Spratly and Paracel archipelagos. The population in 2013 was 90 million with a population density of 271 pers./km^2. Total land area is about 331,689 km^2. Marine area includes the continental shelf (up to 200m depth) of 352.420 km^2, territorial sea (up to 12 nm) of 158,569 km^2 and claimed Exclusive Economic Zone (EEZ) of 1,000,000 km^2.

Total area of coral reefs of Vietnam is estimated at about 1,122 km^2. In 2010, there were 16 MPAs approved by the central government under Decision 742/TTg-, dated 26 May 2010. A total planned area of the whole MPA system is 270,271 ha, of which 169,617 ha is marine area (Table 5.7.1). Among the 16 approved MPAs, the six existing MPAs that have been developed and are operating are Nha Trang Bay (established in 2001), Cu Lao Cham (2004), Nui Chua (2005), Phu Quoc (2007), Con Co (2010) and Hon Cau (2011). Some MPAs are in the process of establishment in the near future.

NUMBER OF SPECIES OF MAJOR TAXA RECORDED

Synthesized data from previous and recent additional studies show that there are over 403 species and 75 genera of scleractinian reef-building corals in the coastal waters of Vietnam (Table 5.7.2). The waters in the south supported a higher number of species (398 species belonging to 72 genera) compared with the less diverse areas in the west of the Gulf of Tonkin (176 species in 52 genera), the central area (from Con Co to Phu Yen: 252 species in 61 genera) and the south-west of the Gulf of Thailand (251 species in 52 genera). Most of the locations supporting a higher diversity of reef corals (>300 species) were mainly in the south including Nha Trang Bay (350 species; Vo Si Tuan *et al*., 2004), Ninh Hai coast (310 species; Vo Si Tuan *et al*., 2014) and Con Dao (307 species; Vo Si Tuan *et al.*, 2005). Meanwhile, the number of species recorded at locality level is lower in the north (Nguyen Huy Yet et al., 2011). It is noted that the genus *Scapophyllia* recorded in Ninh Hai waters (Ninh Thuan Province) was newly recorded for the western coastal waters of the South China Sea. Comparison with some adjacent areas of the countries bordering the South China Sea indicate that the scleractinian reef-building corals in the south of Vietnam are diverse and more or less similar to those found in the west of Luzon (433 species) and the south of Palawan (398 species) of the Philippines, and the east of Malay Peninsula (398 species) (Huang *et al*., 2014).

Overall diversity for the five major taxonomic groups of reef-associated communities (fish, molluscs, crustaceans, echinoderms and algae) amounted to over 2,128 species (Table 5.7.2). Reef fish was the most diverse group with more than 763 species. Richest areas with more than 200 species were in the south including Van Phong Bay (267 species), Nha Trang Bay (528 species), Ninh Hai coast (244 species), Hon Cau (306 species; Nguyen Van Long, 2009a) and Con Dao (202 species; Vo Si Tuan *et al.*, 2005) compared to the less diverse in the north including Dao Tran (157 species), Cat Ba (230 species), Ha Long (111 species), Hon Me (53 species), Con Co (217 species; Nguyen Van Quan, 2005b), Co To (132 species; Do Van Khuong et al., 2005), and in the southwest such as Phu Quoc (152; Nguyen Van Long et al., 2008a). Of these, the families Pomacentridae (66 species) and Labridae (61 species) were both well represented, as well as the Chaetodontidae (32 species). Cluster analysis based on the presence/absence of the ten most common families of fishes from different areas along the coast indicated that there are 7 distinct assemblages of reef fish communities distributed in the waters of Vietnam including the north of Tonkin Gulf, the south of Tonkin Gulf, the north-central waters, the south-central waters, southeastern waters, southwestern waters and Spratly Islands (Nguyen Van Long,

Table 5.7.2: Number of species of major taxa recorded in Vietnam. NA: No available data; *: MPAs planning.

Area	Estimated coral reef area (ha)	Within existing MPA's (ha)	Hard coral	Fish	Molluscs	Crustacean	Echinoderm	Reptile	Marine mammal	Seagrass	Algae
Dao Tran*	NA	NA	48	157	NA	NA	NA	NA	NA	NA	NA
Co To*	370	370	121	133	148	NA	NA	NA	NA	NA	34
Ha Long-Cat Ba*	500	500	171	230	241	25	7	4	2	NA	91
Bai Tu Long	NA	NA	115	119	54	NA	NA	NA	NA	NA	45
Bach Long Vi*	1,578	1,578	93	46	91	NA	NA	2	NA	NA	112
Hon Me*	NA	NA	72	53	NA	NA	NA	NA	NA	NA	8
Con Co*	274	274	166	217	92	NA	NA	NA	NA	NA	49
Hai Van-Son Cha*	NA	NA	102	132	53	60	12	4	NA	NA	103
Da Nang	105	NA	226	162	32	4	12	NA	NA	3	72
Cu Lao Cham*	311	311	227	187	129	10	21	2	NA	5	122
Ly Son*	1,704	1,704	79	88	NA	NA	NA	NA	NA	NA	NA
Phu Yen	303	NA	139	211	73	2	1	NA	NA	7	49
Van Phong	1,618	NA	292	267	52	NA	15	3	NA	9	31
Nha Trang*	731	183	350	528	236	3	30	3	3	10	116
Ninh Hai (Nui Chua*)	2,330	1,070	310	244	110	22	18	3	NA	3	188
Hon Cau*	506	506	184	306	52	2	26	3	NA	4	163
Phu Quy*	1,488	1,488	239	89	NA	NA	NA	NA	NA	8	NA
Con Dao*	903	903	307	202	137	109	72	2	5	11	84
Nam Du	80	NA	126	108	NA	NA	NA	NA	NA	NA	NA
Phu Quoc*	474	292	251	152	106	NA	17	4	2	9	53
Tho Chu	80	NA	198	99	NA	NA	NA	3	NA	NA	NA
Total	**13,355**	**9,179**	**403**	**763**	**675**	**140**	**104**	**4**	**5**	**15**	**356**

2009b). South-central Vietnam supported the highest diversity and abundance of reef fish communities, especially for damselfishes (Pomacentridae), wrasses (Labridae), butterflyfishes (Chaetodontidae), parrotfishes (Scaridae) and surgeonfishes (Acanthuridae). This was more or less similar to those recorded in Spratly Islands, north-central Vietnam and southeast Vietnam but distinguishable from the Tonkin Gulf and southwest Vietnam because these latter areas supported very low diversity of butterflyfishes and were lacking in surgeonfishes.

Molluscs was the second most diverse with over 675 species followed by Crustaceans (> 251 species) and Echinoderms (105 species) (Table 5.7.2). Seaweeds in coral reefs are composed of some 356 species. Similar to that noted above, the areas that supported a higher diversity of macro-invertebrates and seaweeds were mainly in the south (Nha Trang Bay, Ninh Hai, Hon Cau and Con Dao).

Four species of marine reptiles, *Chelonia mydas, Eretmochelys imbricata*, *Caretta caretta* and *Dermochelys coriacea* are found in the waters around coral reefs. The marine waters of Nui Chua National Park (Ninh Hai district, Ninh Thuan province) comprise a diverse array of habitats such as coral reefs and seagrass beds and the beaches are one of the most important mainland nesting sites of the first three reptile species. Con Dao and Phu Quoc are important nesting areas for marine turtles in the offshore islands. Data and information collected from local consultations and surveys in Nha Trang, Con Dao and Phu Quoc indicate that there are 5 species of marine mammals including *Dugong dugon, Steno bredanensis, Sousa chinensis, Delphinus sp.* and *Prodelphinus malayensis*.

Seagrass beds associated with coral reefs supported some 15 species including *Enhalus acoroides, Halophila decipiens, H. ovalis, H. beccarii, H. minor, Thalassia hemprichii, Halodule pinifolia, H. uninervis, Cymodocea rotundata, C. serrulata, Syringodium isoetifolium, Ruppia maritima, Thalassodendron ciliatum, Zostera japonica and Z. marina*. The richest areas supporting more than 9 species included Van Phong Bay, Nha Trang Bay, Con Dao and Phu Quoc.

CORAL REEF MONITORING SITES

Monitoring activities of coral reefs have been established since 1998 at three areas along Vietnam's coast including Nha Trang Bay, Ca Na Bay and Con Dao islands. These have been expanded with the addition of 5 areas (Ha Long Bay, Cu Lao Cham Islands, Van Phong Bay, Ninh Hai coast and Phu Quoc Islands) in 2000-2002. However, it is noted that no official monitoring programme of coral reefs has been established to the present. Most monitoring activities to date have been conducted under support from provincial, national and international projects working on various aspects. Since no ongoing monitoring programme is established, the number of sites and frequency varied differently between areas and years of monitoring. The number of sites permanently established and monitored at 7 key areas gradually increased from 11 sites in 2000 to 53 sites in 2006 and decreased to 33 sites in 2012 due to lack of these activities in Cu Lao Cham, Van Phong Bay and Con Dao Islands (Table 5.7.3).

Table 5.7.3: Summary of monitoring sites of coral reefs in some key areas in Vietnam. NA: No available data.

Area	**Estimated Coral Reef Area (ha)**	**Within Existing MPA's (ha)**	**No. of monitoring sites**			**Estimated Spread of Monitoring Sites**	**Monitoring Status**	**Parameters Surveyed**	**Survey Methods**	**Monitored By:**
			2000	**2006**	**2012**					
Cu Lao Cham	311	311	NA	10	NA	2	2	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL, F-TG	LIT, REA, RC, MT	IMER, RIMF, IO
Van Phong	1,618	NA	NA	4	NA	3	1	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL	RC, MT	IO
Nha Trang	731	183	NA	8	8	2	2	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL, F-TG	LIT, REA, RC, MT	IO
Ninh Hai	2,330	1,070	NA	10	10	2	2	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL, F-TG	REA, RC, MT	IO
Hon Cau	506	506	NA	5	5	3	1	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL, F-TG	LIT, RC, MT	IO
Con Dao	903	903	8	6	NA	3	1	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL, F-TG	LIT, RC, MT	RIMF, IO
Phu Quoc	474	292	3	10	10	3	2	C-HC, C-SC, C-DC, C-BL, O-RC, O-COT, F-ALL, F-TG	LIT, REA, RC, MT	RIMF, IO
Total	**6,873**	**3,265**	**11**	**53**	**33**					

Year 2000 included data from 1999-2000 *Year 2006 included data from 2004-2006* *Year 2012 included data from 2010-2012*

RIMF: Research Institute of Marine Fisheries IMER: Institute of Environment and Natural Resources IO: Institute of Oceanography

Of these, the four areas with established MPAs (Cu Lao Cham, Nha Trang Bay, Nui Chua in Ninh Hai coast and Phu Quoc) have higher potential to keep ongoing monitoring activities active and into the near future.

Parameters monitored have focused on cover of hard corals (C-HC), soft corals (C-SC), dead coral (C-DC) and bleaching coral (C-BL); other benthos such as Reefcheck counts of macro-invertebrates (O-RC) and crown-of-thorn seastars (O-COT); all species of fish (F-ALL) and target fish species (F-TG); ambient such as physical parameters of impacts (A-PP).

Line Intercept Transect (LIT), ReefCheck (RC) and Manta Tow (MT) have been chosen as the techniques for coral reef monitoring in Vietnam since 1998 while the Rapid Ecological Assessments (REA) technique has also been applied for assessing and monitoring changes of reef communities depending on the requirements of specific studies (Table 5.7.3). However, the RC and MT techniques with addition of some local indicators to suit local condition of coral reefs have been commonly used for the scientific research and the community-based monitoring activities among local stakeholders at various areas in recent years.

Main sources of funding for ongoing monitoring activities are supported by provincial, national and international agencies under the framework of different projects. The main agencies or institutions coordinating monitoring programmes include Institute of Oceanography (IO) and Institute of Environment and Natural Resources (IMER), Research Institute of Marine Fisheries (RIMF) and MPA authorities. The existing activities have not covered sufficient areas with coral reefs and not provided enough data and information for coral reef management in Vietnam. To address these deficiencies, the involvement of local communities in monitoring coral reefs has become an important target. Training for local communities and MPA staff in monitoring of coral reefs has already been conducted at some sites such as Cu Lao Cham MPA, Nha Trang Bay MPA, Van Phong Bay, Nui Chua National Park (Ninh Hai), Con Dao National Park and Phu Quoc MPA, and they will be playing an important role in developing a monitoring network of coral reefs in Vietnam in the future.

SITE CHANGES IN PERCENT HARD CORAL COVER

Monitoring data between periods of time from 1994 to 2012 indicate that overall mean cover of hard corals declined notably from 34.6% in 1994 to 25.6% in 2006 and 21.1% in 2012. In general, the overall decline in hard coral cover during the last 16 years averaged 13.0% with a higher decline in the period of 1994-2000 (16.3%) compared to that in the period of 2000-2006 (3.2%) and 2006-2012 (4.5%). Phu Quoc, Con Dao and Nha Trang had a higher interval decline, ranging between 14.7 to 28.8% while Cu Lao Cham, Ninh Hai and Hon Cau were recorded at 5.3-5.4% (Table 5.7.4). However, the highest degradation rate was found in Con Dao (2.1% per year), followed by Phu Quoc (1.77% per year), while loss of hard coral cover was < 1% per year for Cu Lao Cham, Nha Trang Bay, Ninh Hai and Hon Cau (Table 5.7.5).

Estimation of changes in reef condition with time indicated a negative recovery trend (Table 5.7.4). The overall mean proportion of reefs that are improving averaged 10.8% (range: 0.0-20.0%) whereas reefs that are declining and remained unchanged were 55.4% (range: 30.0-90.0%) and 30.0% (range: 10.0-60.0%) respectively. Of these, Phu Quoc, Cu Lao Cham and Hon Cau supported a higher percentage of reefs that are declining or remain unchanged whereas Cu Lao Cham and Ninh Hai had a higher percentage of reefs that are improving compared to Nha Trang and Con Dao.

Table 5.7.4: Changes in percent hard coral cover at some key areas for Vietnam - Comparison between 1994 and 2012.

Area	1994	2000	2006	2012	Overall interval decline (%)	Degradation rate/year
Cu Lao Cham	21.4	NA	16.0	NA	-5.4	-0.54
Nha Trang	35.1	NA	23.2	20.4	-14.7	-0.92
Ninh Hai	NA	NA	27.5	22.2	-5.3	-0.88
Hon Cau	26.4	NA	21.5	21.0	-5.4	-0.36
Con Dao	41.0	20.1	22.2	NA	-18.8	-2.09
Phu Quoc	49.1	37.5	43.4	20.8	-28.3	-1.77

Year 1994 included data from 1994-1995. Year 2006 included data from 2004-2006.
Year 2000 included data from 1999-2000. Year 2012 included data from 2010-2012.

The significant decline in hard coral cover recorded in Con Dao was mainly caused by heavy impacts from Typhoon Linda (1997) and the coral bleaching event in 1998 (Vo Si Tuan, 2000a) while the decline in Phu Quoc was due to the coral bleaching event in 2010 (Nguyen Van Long et al, 2011). For Nha Trang Bay, degradation of coral reefs has been caused by increase in sediment, outbreak of crown-of-thorns starfish (COTS) and tourism (Vo Si Tuan et al., 2004), especially for coral reefs close to the mainland (Nguyen Van Long & Phan Kim Hoang, 2008).

Table 5.7.5: Estimation of changes in reef condition at some key areas between time intervals.

Area	Improving	Declining	Remained unchanged	Interval
Cu Lao Cham	20.0	60	20.0	1994-2006
Nha Trang	12.5	37.5	50.0	1994-2012
Ninh Hai	20.0	30.0	27.5	2006-2012
Hon Cau	0.0	40.0	60.0	1994-2006
Con Dao	12.5	75.0	12.5	2000-2006
Phu Quoc	0.0	90.0	10.0	1994-2012

The notable decline in reef condition in Cu Lao Cham was due to the impacts from increased COTS and run-off with low salinity and high sediment discharged from Thu Bon river during the occurrences of Typhoons Xangsane and Cimaron in 2006 (Nguyen Van Long et al., 2008b).

INDEX SCORES OF MAJOR BENTHIC TAXA

Overall status of coral reef benthos surveyed at 89 sites from 10 key areas in the coastal waters of Vietnam during 2010-2011 showed a low overall average value of live coral cover (LCC). No reefs were in excellent condition (> 75% cover), only 2.2% in good condition (range 51-75 % cover), 34.4% in fair condition (26-50% cover) and 63.5% in poor condition (< 25% cover) following the categories in English *et al*. (1997) (Table 5.7.6). Of these, only one site of reefs in good condition was recorded at Nha Trang Bay and Ninh Hai while a higher number of reefs in fair condition were found at Hai Van-Son Cha and Ninh Hai. It is noted that most of reefs at two offshore islands (Ly Son and Phu Quy) were in poor condition.

Table 5.7.6: Numbers and percentage of reefs in different categories of live coral cover surveyed in the period of 2010-2011 at some key areas in Vietnam.

No.	Area	No. of sites with different categories of cover				Total
		>75%	50-75%	25-50%	<25%	
1	Con Co	0	0	4	6	10
2	Hai Van-Son Cha	0	0	8	2	10
3	Ly Son	0	0	0	10	10
4	Van Phong	0	0	0	1	1
5	Nha Trang	0	1	2	7	10
6	Cam Ranh	0	0	1	1	2
7	Ninh Hai	0	1	7	5	13
8	Ca Na	0	0	1	12	13
9	Phu Quy	0	0	0	10	10
10	Phu Quoc	0	0	5	5	10
Total		**0**	**2**	**28**	**59**	**89**
%		**0**	**2.2**	**31.5**	**66.3**	**100**

The index score estimation of major benthic taxa in the period 2010-2011 indicated that hard and soft coral cover at most areas were in poor and fair condition (range: 1.0-2.0), with an exception of moderate condition at Hai Van-Son Cha, Ninh Hai and Phu Quoc (range: 2.10-2.43) for hard corals and Ly Son (2.50) for soft corals (Table 5.7.7). Macro-algae index scores presented good condition for almost all reefs with low nutrient indicated algae (NIA: 4.90-5.00) and coralline algae (CA: 1.00-2.10). Indicators of macro-invertebrates including triton (*Charonia tritonis*), giant clams (*Tridacna*), lobster (*Panulirus s*pp) were also recorded at very low abundance, giving index scores of less than 1.00. Abundance of sea urchins (*Diadema*) were mostly recorded at normal and slightly disturbed conditions (score range: 4.00-5.00) with an exception of disturbed condition at Phu Quoc and Cam Ranh (score: 3.00). Presence of COTS and *Drupella* snails were found at many reefs such as Van Phong Bay, Nha Trang Bay, Cam Ranh Bay, northern part of Ninh Hai, however their abundance was rare (score: 5.00).

Comparison of monitoring data at some key areas between the period of 2002-2003 (Vo Si Tuan et al., 2006) and 2010-2011 showed a decline in density of COTS (Fig. 5.7.1) and *Diadema* (Fig. 5.7.2) at most areas with an exception of increase at Ninh Hai. A significant decline of COTS was recorded at Nha Trang (0.7 and 0.3 ind./100 m^2 respectively) while a similar trend was found at Hon Cau (25.2 and 13.0 inds./100m^2) and Phu Quoc (86.8 and 40.9 inds./100m^2) for *Diadema*. It is hard to explain the notable decline in COTS density due to lack of data and information, which were not collected at the same time of monitoring of biophysical parameters. The significant decline of *Diadema* between the periods mentioned above may be explained by an increase in harvesting to support lobster aquaculture at Hon Cau waters and for tourism at Phu Quoc. Consultation with local tourist boats noted that demand for *Diadema* at Phu Quoc for local consumption from tourists and exports to Ho Chi Minh City has dramatically increased in recent years and driven average cost increase of 50% from 10.000-15.000 VND (about 0.5 USD) per individual in 2006 to 20.000-25.000 VND (about 1 USD) in 2010 (Nguyen Van Long, pers. com.). Comparison of data between 2006 and 2012 showed a stable trend of change in index scores of all fish species and most of key families at most areas with an exception at Phu Quoc (Table 5.7.8).

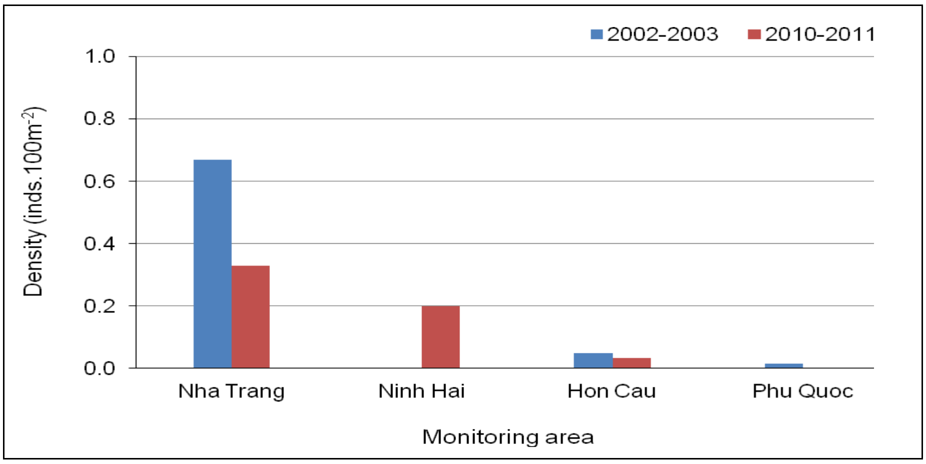

Fig. 5.7.1: Temporal changes in density of COTS at some key areas in Vietnam.

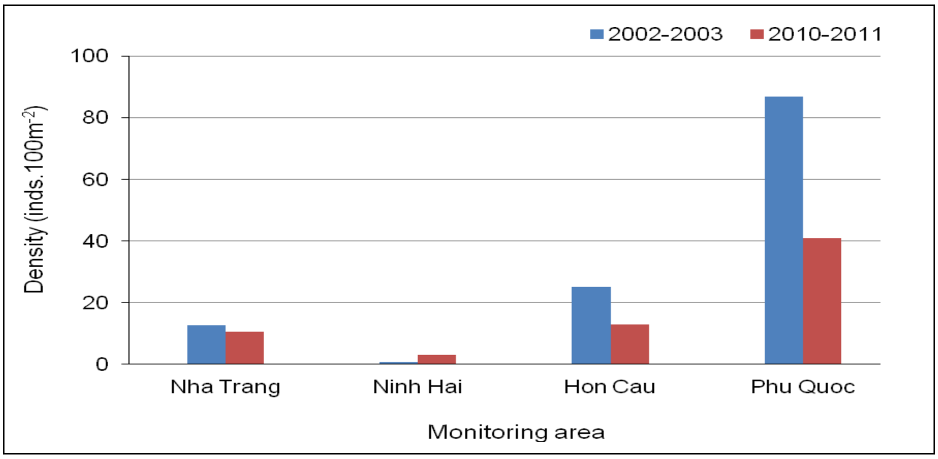

Fig. 5.7.2: Temporal changes in density of *Diadema* at some key areas in Vietnam.

Table 5.7.7: Index scores of major benthic taxa for Vietnam for 2010-2011. NA: No available data.

Area	Coral		Mollusc			Crustacean(Lobster)	Echinoderm			Algae (non-bloom)	
	Hard coral	**Soft coral**	***Tridacna***	**Triton**	***Drupella***		***Diadema***	**Sea cucumber**	**COT**	**NIA**	**Coralline algae**
Con Co	1.70	1.40								5.00	1.00
Hai Van-Son Cha	2.40	1.40								5.00	1.00
Ly Son	1.00	2.50								4.90	2.10
Nha Trang	2.00	1.67	1.00	1.00	5.00	1.00	4.00	1.00	5.00	5.00	1.58
Cam Ranh	2.00	1.00	1.00	1.00	5.00	1.00	3.00	1.00	5.00	4.00	1.00
Ninh Hai	2.43	1.14	1.00	1.00	5.00	1.00	5.00	1.00	5.00	5.00	1.52
Hon Cau	1.15	1.00	1.00	1.00	5.00	1.00	4.00	1.00	5.00	5.00	1.92
Phu Quy	1.50	1.40								4.90	1.40
Phu Quoc	2.10	1.00	1.00	1.00	5.00	1.00	3.00	1.00	5.00	5.00	1.00
Overall mean	**1.84**	**1.40**	**1.00**	**1.00**	**5.00**	**1.00**	**3.80**	**1.00**	**5.00**	**4.87**	**1.40**

Table 5.7.8: Index scores of fish category for Vietnam - Comparison between 2006 and 2012. NA: No available data.

Area	Grouper		Snapper		Sweetlips		Butterflyfish		Fusilier		Surgeonfish	
	2006	**2012**	**2006**	**2012**	**2006**	**2012**	**2006**	**2012**	**2006**	**2012**	**2006**	**2012**
Cu Lao Cham	2.00		1.00		1.00		1.00		1.00		1.00	
Nha Trang	1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	2.00	2.00
Ninh Hai	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00
Ca Na	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Con Dao	1.00		1.00		1.00		1.00		1.00		1.00	
Phu Quoc	5.00	4.00	1.00	1.00	1.00	1.00	5.00	5.00	1.00	1.00	1.00	1.00
Overall mean	**1.83**	**1.75**	**1.00**	**1.00**	**1.00**	**1.00**	**1.83**	**2.00**	**1.00**	**1.00**	**1.33**	**1.50**

Area	Rabbitfish		Parrotfish		Damselfish		Angelfish		Triggerfish		All fish species	
	2006	**2012**	**2006**	**2012**	**2006**	**2012**	**2006**	**2012**	**2006**	**2012**	**2006**	**2012**
Cu Lao Cham	1.00		1.00		1.00		1.00		1.00		1.00	
Nha Trang	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ninh Hai	1.00	5.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Ca Na	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Con Dao	1.00		1.00		1.00		1.00		1.00		1.00	
Phu Quoc	1.00	1.00	2.00	1.00	2.00	3.00	1.00	1.00	1.00	1.00	2.00	3.00
Overall mean	**1.00**	**2.00**	**1.17**	**1.00**	**1.17**	**1.50**	**1.00**	**1.00**	**1.00**	**1.00**	**1.17**	**1.50**

Year 2006 included data from 2004-2006 *Year 2012 included data from 2010-2012*

INDEX SCORES OF FISH CATEGORY FOR VIETNAM - COMPARISON BETWEEN 2006 AND 2012

Analysis of monitoring data at 6 key areas in the coastal waters of Vietnam in the period between 2006 and 2012 show that overall mean densities of all species and most of key families of reef fishes were at occasional and common levels with index scores ranging between 1.00-2.00, with an exception of higher index scores for groupers, parrotfishes, butterflyfishes and damselfishes recorded at Phu Quoc (Table 5.7.8). However, most groupers found in Phu Quoc were small in size (< 20 cm in length) belonging to *Cephalopholis boenak, C. cyanostigma, C. formosa, C. microprion, Epinephelus quoyanus* and *E. fasciatus.*

Index scores for all fish species and damselfishes at Phu Quoc increased from 2.00 to 3.00, equivalent to 447.4 to 739.4 inds./100m^2 and 329.8 to 641.2 inds./100m^2 respectively, whereas a decline was recorded for groupers from 5.00 to 4.00 (5.4 to 1.6 inds./100m^2). Another increase was also found for rabbitfishes at Ninh Hai with index score ranging from 1.00 to 5.00 (1.7 to 59.7 inds./100m^2) and a decline for butterflyfishes at Nha Trang from 2.00 to 1.00 (7.0 to 3.4 inds./100m^2).

INDEX SCORES FOR CURRENT LEVELS AND TRENDS IN CORAL REEF RESOURCE USAGE

Extractive usage

Since a long time ago, coral reefs in Vietnam have been used for multi purposes. Fisheries (reef fish and other reef organisms) have become a major extractive usage of coral reefs with multi-species and multi-fishing gears. Hookah diving, purse seine and gill net, light fishing, drift nets, long line, most trawls and gleaning on tidal flat have been considered as common activities in most of the coastal provinces. Data from Table 5.7.9 indicate that small scale fisheries were common from medium to high levels at most areas (mean index score: 3.64) compared to that at medium for medium to large scale fisheries (2.95) and low for aquaculture (1.77). Of these, Bach Long Vi, Ly Son, Phu Quy and Phu Quoc supported higher levels of small and medium to large scale fisheries while Co To, Ha Long-Cat Ba, Van Phong, Nha Trang and Phu Quoc had higher levels of aquaculture related to coral reefs including groupers (*Plectropomus spp* and *Epinephelus spp*), snappers (*Lutjanus spp*), cobia (*Rachycentron canadum*), pearl oyster (*Pinctada maxima*), spiny lobsters (*Panulirus ornatus* and *P. homarus*), babylon (*Babylonia areolata*), etc.

Many qualitative and quantitative data and information related to reef fisheries have been mentioned in several publications and technical reports at national (Vo Si Tuan et al., 2005; Vo Si Tuan et al., 2007) and local scales (Vo Si Tuan et al., 2005; Nguyen Van Long et al., 2006; Nguyen Van Long et al., 2008b). However, recent analysis of fisheries related to coral reefs in some key areas in Vietnam indicate that coral reefs have provided high production of target resources. Analysis of coral reefs in Phu Quoc in 2010 show that 140 tons of commercial species (mainly fusiliers: 130 tons/year and groupers: 8 tons/year) and 70,000 grouper seeds/year (mainly *Plectropomus maculatus*) with the initial value of 600,000 USD were extracted and this amount was quite low due to over-fishing (Vo Si Tuan, 2013). Coral reefs in Ninh Hai waters annually provided a production of some 500 tons of commercial resources (cuttlefish: 104 tons/year, needlefish: 52 tons/year, parrotfish: 18 tons/year, rabbitfish: 10

tons/year, *Turbo* and *Strombus* snails: 12 tons/year, *Sargassum* and *Gracilaria* seaweed: 155 tons/year) and 220,000 lobster seeds (mainly *Panulirus ornatus* and *P. homarus*) for cage culture, giving a total revenue of 700,000 USD from commercial species and collectors nearly 1 million USD from lobster seeds (Vo Si Tuan & Nguyen Thi Tuong Vi, 2011). Together with the target resources related to coral reefs mentioned above, some other pelagic resources are caught in the waters neighbouring coral reefs in Ninh Hai in seasons of the year with a production of 2,500 tons/year (anchovies: 1,400 tons/year, tuna: 400 tons/year, scads: 300 tons/year, mackerels and flying fish: 200 tons/year for each) with a revenue nearly 2 million USD. On the other hand, catching of ornamental fish such as butterflyfishes, angelfishes, wrasses, scorpionfishes, etc to supply the local and international aquarium trade have been recorded in many areas during the last several decades. The number of ornamental fish collected from Nha Trang Bay for transportation to aquaria in Ho Chi Minh City was around 1,000 fish annually (Chu Anh Khanh, pers. com.).

Table 5.7.9: Index scores for current levels and trends in coral reef resource usage.

Area	Extractive				Semi-Extractive/Non-Extractive			
	Fisheries (Reef fish and others reef organisms)			Coral mining	Tourism			Research
	Small-scale	Med to large scale	Aqua-culture		Resorts /Hotels	Dive operators	Live-aboard	
Dao Tran	3.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00
Co To	4.00	3.00	3.00	1.00	2.00	1.00	1.00	1.00
Ba Mun	3.00	2.00	2.00	1.00	2.00	1.00	1.00	1.00
Ha Long-Cat Ba	3.00	2.00	4.00	1.00	4.00	2.00	2.00	2.00
Bai Tu Long	3.00	2.00	2.00	1.00	2.00	1.00	1.00	1.00
Bach Long Vi	5.00	5.00	2.00	2.00	2.00	1.00	1.00	1.00
Hon Me	4.00	3.00	2.00	1.00	1.00	1.00	1.00	1.00
Con Co	4.00	3.00	1.00	2.00	1.00	1.00	1.00	1.00
Hai Van-Son Cha	4.00	3.00	1.00	1.00	2.00	1.00	1.00	1.00
Da Nang	3.00	2.00	1.00	1.00	3.00	2.00	2.00	2.00
Cu Lao Cham	3.00	2.00	1.00	1.00	3.00	2.00	2.00	2.00
Ly Son	5.00	5.00	1.00	4.00	2.00	1.00	1.00	1.00
Phu Yen	3.00	2.00	2.00	3.00	1.00	1.00	1.00	1.00
Van Phong	3.00	3.00	3.00	3.00	2.00	2.00	2.00	1.00
Nha Trang	4.00	3.00	3.00	3.00	4.00	3.00	3.00	2.00
Ninh Hai	4.00	3.00	2.00	3.00	2.00	2.00	2.00	2.00
Hon Cau	4.00	3.00	2.00	5.00	2.00	2.00	2.00	2.00
Phu Quy	4.00	4.00	1.00	2.00	1.00	1.00	1.00	1.00
Con Dao	4.00	3.00	1.00	1.00	1.00	2.00	2.00	2.00
Nam Du	3.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00
Phu Quoc	3.00	4.00	1.00	2.00	2.00	2.00	2.00	2.00
Tho Chu	3.00	3.00	1.00	2.00	1.00	1.00	1.00	1.00
Mean	**3.59**	**2.95**	**1.77**	**1.86**	**1.91**	**1.45**	**1.45**	**1.36**

Coral mining for construction materials and making dikes of aquaculture ponds was commonly practiced in several coastal provinces such as Phu Yen, Khanh Hoa, Ninh Thuan in the past (Vo Si Tuan et al., 2007). The problem has been recently improved in many areas, but is still happening at some places. Collection of live coral for souvenirs has been popular at Ca Na bay (Hon Cau MPA). Coral trading including dead corals, souvenir material corals and live corals for ornamental culture has increased around the world. Statistics reported by CITES (1998) show that the yield of corals exploited in 1998 was about 19,327 pieces of live coral for aquaria and 19,327 kg of dead coral for souvenirs. Analysis data based on recent information indicate that levels of coral mining were recorded with low overall index score (1.91), of which Co To, Ha Long-Cat Ba, Van Phong Bay and Nha Trang Bay had a higher levels of coral mining than that of other areas (Table 5.7.9).

Semi-extractive and non-extractive usage

Data from Table 5.7.9 presented low levels of usage for tourism and research in some key areas with overall mean scores ranging between 1.36 and 1.95. A higher number of resorts/hotels was found at Ha Long-Cat Ba, Da Nang, Cu Lao Cham, Nha Trang Bay and Phu Quoc (range: 3.00-4.00).

Tourism has contributed high revenue and provided significant employment in several coastal areas such as Ha Long Bay, Da Nang, Cu Lao Cham, Nha Trang, Nui Chua/Ninh Hai, Con Dao and Phu Quoc. Nha Trang has a long history in development of marine tourism in Vietnam, providing thousands of jobs and income for local communities. The number of diving services in Nha Trang was 13 operators (Khanh Hoa Department of Culture, Sports and Tourism, 2013). The number of tourist boats engaged with marine tourism dramatically increased from 60 boats in 2002 (Vo Si Tuan *et al*., 2007) to 133 boats in 2011 (Statistic data from Cau Da Port Authority). Data collected from Nha Trang Bay showed an increase in number of tourists from 3,000 visitors in 1995 to 40,000 visitors in 2003, giving a total revenue of 400,000 USD/year and approximately 2% of total income from the tourism sector in Khanh Hoa Province (Vo Si Tuan *et al*., 2007). Tourism related to coral reefs in Ninh Hai district (mainly around Vinh Hy lagoon and Hang Rai) during 2010-2013 included 4 tourist operators with 11 boats supporting the marine services. The number of tourists ranged between 60,000-70,000 visitors with a total revenue of 465,000 USD/year (Nguyen Van Long, pers. com.). Phu Quoc has become an attractive destination for marine tourism in recent years. The number of dive operators recorded in Phu Quoc in 2013 was 5 services. The number of tourists participating in marine services reported in 2010 was about 110,000 visitors with an on-boat value of 980,000 USD (Vo Si Tuan, 2013).

Usage of coral reefs for research and education have been commonly conducted in Cu Lao Cham, Nha Trang Bay, Nui Chua/Ninh Hai, Con Dao and Phu Quoc. In recent years, more students from different universities visited these areas for their environmental training and awareness enhancement.

INDEX SCORES FOR CURRENT STRESS AND DAMAGE FOR CORAL REEFS

During the last several years, coral reefs in many areas of Vietnam suffered severe impacts from natural and anthropogenic disturbances. Analysis data given in Table 5.7.10 indicate that overall index scores for most of current stress and damage for coral reefs ranged from low to medium level (2.05-3.00), with an exception of low score for coral diseases (1.43).

Table 5.7.10: Index scores for current stress and damage for coral reefs.

Area	Sediments & Nutrients (land-based)	Damaging Fishing Methods	Anchor, Trawler & Others Kind of Damage (divers, trampling, etc)	Coastal Development Damage (ports, airports, dredging, etc)	Coral Bleaching	Coral Diseases	Outbreaking or Invasive Organisms (COTS, Drupella, Diadema, etc)	Coral Damage from Natural Events (storms, etc)
Dao Tran	2.00	2.00	2.00	2.00	NA	NA	NA	NA
Co To	2.00	4.00	3.00	3.00	NA	NA	NA	NA
Ba Mun	1.00	2.00	2.00	2.00	NA	NA	NA	3.00
Ha Long-Cat Ba	5.00	2.00	3.00	4.00	NA	NA	3.00	2.00
Bai Tu Long	1.00	2.00	2.00	2.00	NA	NA	NA	3.00
Bach Long Vi	1.00	3.00	2.00	3.00	NA	NA	NA	4.00
Hon Me	3.00	2.00	2.00	4.00	NA	NA	NA	4.00
Con Co	1.00	2.00	2.00	3.00	NA	1.00	1.00	3.00
Hai Van-Son Cha	3.00	2.00	2.00	3.00	NA	1.00	2.00	2.00
Da Nang	3.00	2.00	3.00	3.00	NA	2.00	2.00	3.00
Cu Lao Cham	4.00	2.00	2.00	3.00	3.00	2.00	3.00	4.00
Ly Son	2.00	5.00	3.00	4.00	NA	2.00	3.00	4.00
Phu Yen	2.00	2.00	2.00	2.00	NA	2.00	3.00	2.00
Van Phong	2.00	3.00	2.00	3.00	3.00	2.00	3.00	1.00
Nha Trang	3.00	3.00	3.00	4.00	3.00	2.00	3.00	1.00
Ninh Hai	2.00	3.00	3.00	3.00	2.00	1.00	2.00	3.00
Hon Cau	2.00	4.00	3.00	3.00	2.00	1.00	2.00	3.00
Phu Quy	1.00	3.00	2.00	2.00	NA	1.00	2.00	3.00
Con Dao	1.00	3.00	2.00	2.00	3.00	1.00	2.00	3.00
Nam Du	1.00	3.00	2.00	2.00	NA	NA	1.00	2.00
Phu Quoc	2.00	3.00	3.00	3.00	5.00	1.00	1.00	2.00
Tho Chu	1.00	3.00	2.00	2.00	NA	1.00	3.00	3.00
Average	**2.05**	**2.73**	**2.36**	**2.82**	**3.00**	**1.43**	**2.25**	**2.75**

Of these, coral bleaching, coral damage from natural events (storms, etc), damaging fishing methods and coastal development damage (ports, airports, dredging, etc) are considered as major current impacts rather than sediment and nutrients from land-based activities, anchor, trawler and others kind of damage (divers, trampling, etc) and outbreaks of invasive organisms (COTS, *Drupella, Diadema*, etc).

Coral bleaching has been recorded with high frequency at several areas such as Cu Lao Cham, Van Phong Bay, Nha Trang Bay, Ninh Hai, Con Dao and Phu Quoc in recent years (Table 5.7.10). The 1998 bleaching event in Con Dao had caused a high frequency of bleached coral colonies with an average cover ranging from 0.0 to 74.2% (overall mean: 37%), of which *Sinularia* and fire corals *Millepora* were most heavily bleached (with > 80 % of all colonies bleached), *Porites* (57%), *Symphyllia* (42%), *Leptastrea* (40%), *Favia* (36%), *Goniastrea* (30%), *Lobophyllia* (25%), *Montipora* (22%) and *Acropora* (19%) (Vo Si Tuan, 2000b). Extensive assessments of coral beaching in 2010 at some areas indicate that cover of beached corals varied between sites and areas. Of these, Phu Quoc had a higher overall cover (mean: 23.5%, range: 10.0-62.5%) (Nguyen Van Long et al., 2011) than at Nha Trang Bay (mean: 6.5%, range: 0.7-26.7%) and Ninh Hai (mean: 10.8%, range: 2.4-40.0%) (Nguyen Van Long et al., 2013). It is noted that the level of bleached corals was also different even at small spatial scales with a higher cover in the northern part (Ganh Dau: 62.5%) compared to the further southern part (An Thoi islands group: 10.0-28.8%) of Phu Quoc. Some genera had a higher cover of bleaching including *Hydnophora* (38.5%), *Acropora* (24.4%), *Montipora* (13.0%), *Seriatopora* (7.9%), *Fungia* (5.7%), *Favites* (4.0%) and *Cyphastrea* (3.3%). Data from two permanent sites (Hon Gam Ghi and Hon Xuong) in Phu Quoc in August 2010 showed a high mortality of 30% on average after the bleaching event (Vo Si Tuan, unpublished data). Two bleaching events were recorded at Phu Quoc, however the level of corals bleached in 2013 (range between sites: 2-10%) and 2014 (< 5%) were much less than that in 2010 (Nguyen Van Long, unpublished data).

Coral damage from natural events (storms, etc) have not been studied in recent years. However, impacts from typhoons had caused serious problems to coral reefs at several areas in the past and were noted from medium to high levels at Bach Long Vi, Hon Me, Cu Lao Cham, Ly Son, Con Dao and Tho Chu (Table 5.7.10). Results from 23 surveyed reefs at Con Dao in 1994-1995 showed an average of 43% coral cover and nearly 70% of the reefs were categorized as having high to excellent cover. After Typhoon Linda in 1997, most of the reefs were seriously destroyed and live coral cover of some reefs were at values near to zero (Vo, 2000b). Data from 10 permanent monitored reefs at Cu Lao Cham show a notable decline in overall mean cover of hard corals from 20.0% in 2004 to 13.5% in 2008, and this had been caused by heavy impacts from Typhoons Xangsane and Cimeron through increase of freshwater and high sediment discharged from Thu Bon river during the typhoons in 2006 (Nguyen Van Long et al., 2008b). Similar problems had caused a high mortality of corals at Con Dao in October 2005 (Hoang Xuan Ben et al., 2008).

Coastal development damage from development of ports, airports, dredging, etc were recorded between low and high level, especially at Ha Long-Cat Ba, Hon Me, Ly Son, Nha Trang Bay and Phu Quoc (Table 5.7.10). The development of coastal cities has affected coral reefs in Vietnam. The construction of large infrastructure projects such as harbours, airports, and dikes, has directly and/or indirectly damaged coral reefs. Survey results indicate that recent increases in sediment concentration in the water has a connection with coastal development, dredging, soil exploitation, forest cutting and other unplanned agricultural activities. The Ha Long–Cat Ba coastal area is an illustrative example that clearly demonstrates the strong impact of sedimentation on coral reefs. Previous studies showed that the suspended sediment concentration in the water in these areas is high, as compared to other areas. Coral reefs inside Cat Ba National Park were damaged by sedimentation as a result of coal mining activities in Quang Ninh province (Nguyen Huy Yet at al., 2011). Studies of coral reefs in Central Vietnam show that these reefs are also threatened by sedimentation from rivers in the rainy season, but to a lesser degree than those in Halong-Cat Ba area. There is concern that high water turbidity has not only occurred locally, but has also increased over a larger area where corals are currently distributed.

Damaging fishing methods had caused heavy problems for coral reefs in the past and have been considered as a major impact to coral reefs at most of central and south Vietnam, especially at Co To, Ly Son and Hon Cau (Table 5.7.10). Vo Si Tuan et al. (2007) indicated that marine resources are being exploited everywhere in coastal Vietnam. As these resources decline, harvesting efforts increase, leading to increasing use of destructive fishing methods. Low returns from inshore harvesting efforts are due to declining marine resources, primitive fishing methods and increased competition. The declining marine resources are in turn linked to the overall poverty of inshore marine harvesting households, to fishing methods and to changes in the marine environment. The situation is further exacerbated by competition and conflicts for provincial territorial resources by outsiders, especially fishermen from other provinces, but also to some degree by non-resident marine harvesters from Hong Kong and China. The dimensions of illegal and inappropriate harvesting include indiscriminate killing of small fry and seedlings necessary for stock regeneration and environmental damage. The proliferation of destructive harvesting methods has made coastal residents aware of the overall ineffectiveness of government agencies to control violations and to enforce regulations. Live trade in groupers and other fish species for the Hong Kong and Chinese markets operates with impunity in the northern and central parts of Vietnam, and even in the productive waters near the Con Dao National Park. Capture methods employ divers and cyanide poisoning to stun the fish, which in turn kill coral and other biota outright. Collecting live coral for souvenirs and displays has also occurred in many places such as Cu Lao Cham, Hon Mun, Cu Lao Cau. Corals, particularly staghorn varieties of *Acropora*, are most sought after for the tourist and aquaria trade, and are now becoming rare in places such as Nha Trang Bay, the center of the coral trade in the country. A serious impact of tourism is the increase in demand for animal products as souvenirs, and does lead to wild animal exploitation. Marine turtles (e.g. hawksbill turtle, green turtle) have been exploited in an uncontrolled manner with free trade taking place in large tourism centers such as Nha Trang and Vung Tau.

Land-based sediments & nutrients have become major impacts to coral reefs in recent years. Natural situation has been exacerbated in recent times in many areas by increased river pollution including upland silt run-off, and domestic and industrial discharges which now poses a serious threat to the marine environment. For example, the coral reefs in Cat Ba National Park are being killed by the increased sediment load of terrestrial mining in Quang Ninh province. Pollution from ports and ships which are routed through the waters of the park is also having a negative impact. All these impacts are now placing serious stress on coastal coral reefs and seagrass beds in many parts of Vietnam, particularly along the coast of western Tonkin Gulf and the eastern gulf of Thailand. The development and expansion of industry along the coast is beginning to add to the pollution load, particularly poisonous heavy metal waste, which is often released into the sea without attempt to reduce toxicity. The expansion of ports and unregulated bilge cleaning is now becoming a more frequent source of coastal pollution, in particular in the northern areas of Quang Ninh and Hai Phong. This poses very serious threats to proposed MPAs in northern part of Vietnam.

Outbreaking of invasive organisms of COTS, *Drupella* snail, *Diadema* sea urchin, etc were recorded in high density at many reefs in the past, especially in the period of 2000-2004 (Vo Si Tuan et al., 2006; Nguyen Van Long & Vo Si Tuan, 2014a). These impacts were considered as problems at several areas including Ha Long-Cat Ba, Cu Lao Cham, Phu Yen coast, Van Phong Bay, Nha Trang and Phu Quoc (Table 5.7.10). Data from the manta tow survey in 2002 in Nha Trang Bay showed that numbers of COTS (*Acanthaster planci*) exceeded 100 individuals per hectare on several reefs (Vo Si Tuan et al., 2006). Comparison of data monitored at some key areas in the coastal waters of Vietnam in the period 1994-2007 indicate that density of COTS increased in 2000-2004 and gradually decreased in 2005-2007, with a higher density in Van Phong Bay, Nha Trang Bay and Cu Lao Cham (Nguyen Van Long & Vo Si Tuan, 2014). Another analysis from this study also showed an increase in ratio of reefs with active outbreak from 0% in 1998 to 45.5% in 2002 and 35.7% in 2007 while the number of reefs with no recent outbreak of COTS decreased from 100% in 1998 to 64.3% in 2007.

MPA ATTRIBUTES AND MANAGEMENT EFFECTIVENESS SCORES

In 2010, a list of 16 MPAs was approved by the Government of Vietnam under Decision 742/QD-TTg dated 26 May 2010 with a total area of 270,271 ha and 169,617 ha of marine area. The individual area of most MPAs was less than 30,000 ha, combined to form 87.5% of total coral reef area and only 2 MPAs (Nam Yet and Phu Quoc) had more than 30,000 ha (12.5%) (Table 5.7.11). Basically, all of the approved MPAs support coral reefs and more than 57% of coral reef area falls inside the declared MPAs.

No MPAs were established before 1994 and only two (6.3% of total) were established between 1994 and 2006 (Nha Trang Bay in 2001 and Cu Lao Cham in 2004) and four (37.5% of total) declared after 2006 (Phu Quoc in 2007, Nui Chua in 2008, Con Co in 2010 and Hon Cau in 2011). Of these, 16.7% of MPAs had good management (Cu Lao Cham), 50.0% moderate (Nha Trang, Nui Chua/Ninh Hai and Phu Quoc) and 33.3% poor (Con Co and Hon Cau) (Table 5.7.11). Several new MPA initiatives are now under way or in the planning stages. These will be test cases for the new legislation and management approaches.

Institutional and administrative complications have been an impediment to effective protected areas design and management in Vietnam. The planning process is sectoral-driven and centrally oriented which often results in planning conflicts at the provincial level and little recognition of real on-the-ground needs at the district level. With respect to marine protected areas, MARD is the designated management authority in the country and the Agency for Fisheries Exploitation and Protection under MARD is responsible for protection of marine resources.

Table 5.7.11: MPA Attributes and Management Effectiveness Scores.

Total number of MPAs - Declared		16
Total number of MPAs – Proposed		19
% of Declared MPAs with Coral Reefs Represented		100
Total % of Reefs Within Declared MPAs		> 57
% of Declared MPAs that have management effectiveness rating of:	Unknown	0.0
	Poor	16.7
	Moderate	66.7
	Good	16.7
	Very Good	0.0
% of Declared MPAs with Areas that are:	<10, 000 ha	37.5
	Between 10,000 & 30,000 ha	50.0
	Between 30,000 & 50,000 ha	12.5
	Between 50,000 & 100,000 ha	0.0
	> 100,000 ha	0.0
% of Declared MPAs established:	Before 1994	0.0
	Between 1994 & 2006	6.3
	After 2006	37.5

PRINCIPLE ACTS AND REGULATIONS AFFECTING CORAL REEFS

At the present time, there are no special laws and regulations at national level specifying the process and materials required for coral reef conservation and management in Vietnam. Most activities relating to protection and management of coral reefs and MPAs have been mainly based on some laws and regulations as follows:

- The Law on Environmental Protection was passed by the National Assembly on 29 December 2005. It is broad and includes strategic direction for environmental protection. The law contains a broad mandate for environmental impact assessment, and it establishes environmental quality standards specifying the provisional environmental quality criteria that are to be used for monitoring and inspections of projects and activities. The law has been effectively implemented, making great strides in environment protection, especially enhancing the people’s awareness on the environment and ecology.

- Law of Fisheries was adopted on 26 December 2003 by the National Assembly of Socialist Republic of Vietnam. This law came into force from July 1st 2004. The Law stated that fisheries resources shall be subject to the ownership of the people and under the integrated management of the State. Organizations and individuals shall have rights to exploit the fisheries resources as provided for by legislation. Following the law, fisheries activities shall ensure the economic effectiveness in accordance with the protection, rehabilitation and development of fisheries resources and biodiversity; shall protect environment and natural landscape. The development of fisheries activities in all aspects shall be done in accordance with the development master plan and plans of fisheries sector nationwide and in specific provinces. The articles related to coral reefs included contents on sustainable fisheries development; prohibited activities in fisheries activities; habitat protection, conservation, protection, rehabilitation and development of fisheries resources, and Planning and management of protected areas and marine parks.

- The Ordinance on the Protection and Development of Fisheries Resource was approved by the Government of Vietnam on 25 April 1989. It contains 29 article stipulating national fishery resource protection and development in inland water bodies, territorial waters, transitional areas, EEZs and national continental shelf areas. Article 3 states in details that the fishery resources protection and development must be integrated with their living environment protection. Article 8 also stipulates to strictly ban any harmful acts to damage fishery resources, to pollute living environments of aquatic organisms by uses of dynamites, toxic substances, electric pulse, waste discharge and destruction of coastal habitats, etc. Although no specific provision is provided for marine conservation by the Ordinance, it has become an important legal instrument for supporting fishery resources management for both inland and marine resources.

- There are some other legal documents supporting enforcement of the above-mentioned laws, including: Decree No. 195/HDBT, dated 2/6/1990 issued by Minister Council on executing Ordinance on the fishery protection and development; Decree No. 48/CP, dated 12/8/1996 issued by Government on stipulation of administrative violation on the protection of fishery resources; Decree No. 26/CP, dated 12/8/1996 issued by Government on stipulation of administrative violation on environment protection; Decree 43/2003/ND-CP of Vietnam government dated 2 May 2003 authorized MARD (former Ministry of Fisheries) to declare list of species needed to be protected, restored and giving solutions for protection of aquatic ecosystems, genetic diversity, aquatic biodiversity. Ministry of Fishery were also authorized to give regulations on no-take zones, catch limited areas and list of non-imported and non-exported species, and manage domestic aquatic reserves, marine protected areas; Decree No. 27/2005/ND-CP of the government of Vietnam dated 8 March 2005 on detailed definition and guidance for implementation of Law of Fisheries.

- Decision 08/2003/QD-BTS of Minister of Fisheries signed on 5 August 2003 authorized the National Directorate of Aquatic Resources Exploitation and Protection (NADAREP) to oversee and monitor implementation of regulation on species needed to be protected, non-imported, non-exported species (except aquaculture seed), seed conservation and manage domestic aquatic reserves, marine protected areas. Decision 742/2010/QD-TTg was adopted by the government of Vietnam dated 20 September 2010 on the strategy to develop marine protected area system of Vietnam to 2020.

- Directive No.1/1998/CT–TTg dated 2/1/1998 issued by the Prime Minister on banning of using explosive, striking-electricity, poison for fishery exploitation.

- Legislations on tourism have considered concerns on impacts of tourist activities to resources and environment in general and to coral reefs in particularly. On 22/6/1993, the government has enacted Resolution 45/CP on management reform and development of the tourist sector. In the Resolution, the government has confirmed that Vietnam has large potential to develop tourism activities, is endowed with natural beauty, places of interest, historical, religious and architecture relics. In order to codify regulation on tourism, the National Assembly Standing Committee (2000) has approved the Ordinance on Tourism. The Ordinance stipulates that: "the State ensures tourism development toward cultural tourism and ecological tourism" (Article 2), "Organizations, individuals operating tourism business are responsible for protecting, reasonably and effectively exploiting and utilizing tourist resources and protecting the environment in tourism areas, routes, and sites" (Article 14), "The state invests in basic surveys on tourist resources; placing priority on projects that protect and restore tourism resources, utilization and development of tourist resources" (Article 16). If tourism is managed in this direction, coral reefs in tourist sites will be reasonably exploited and conserved.

- Biodiversity Action Plan for Vietnam (BAP) was approved by the Prime Minister of the Government under Decision 79/2007/QD-TTg dated May 31, 2007. The major tasks of BAP are: Conservation and development of terrestrial biodiversity; Biodiversity conservation and development in wetlands and coastal areas; Agricultural biodiversity conservation and development; Sustainable use of biological resources; and Improvement of state management capacity for biodiversity and control over genetically modified organisms, and products and commodities originating from genetically modified organisms for effective protection of people's health, the environment and biodiversity.
- The 1991-2000 National Plan of Environment and Sustainable Development is a framework plan that outlines inter-sectorial key priorities on environment protection, and it also exhibits Vietnam's environmental commitment to the international community. Chapter 11, par 3.4 of the Plan emphasized on integrated coastal zone management and planning, and the details are to: Protect estuaries and coral reefs; Protect and reforest mangrove forest; Carry out investigations of sea weeds and grass; Manage coastal lagoons in Central Vietnam; and Protect the coast from erosion and undertake technical solutions for coastal protection.

RECOMMENDATIONS AND CHALLENGES ON CORAL REEF CONSERVATION AND SUSTAINABLE RESOURCE USE

Challenges:

- ***Coral reef monitoring activity*****:** Coral reef monitoring has been carried out in many countries around the world, in some places over several decades, the results of which are important for effective coral reef management. In Vietnam, reasonably comprehensive and standardised coral reef monitoring surveys have been conducted in some coral areas along the coast by the Institute of Oceanography, Institute of Marine Environment and Resources since 1998 and recently by Research Institute of Marine Products. Data collected from monitoring sites in Nha Trang Bay and Con Dao since 1998 have shown that changes in coral reef organism population structure are due to natural and human impacts. However, the data collected at permanent monitoring sites are not always regular and consistent due to lack of financial and human resources, resulting in limited overall effectiveness of monitoring. The active participation of local communities in coral reef monitoring is considered necessary and important in order to increase future coral reef research capacity and management in Vietnam. Only with local community support and awareness of the livelihood benefits, as well as the biodiversity values of coral reefs, will Vietnam's coral reef resources be sustained.

- ***Financial sources for management*:** One of the key issues for coral reef management, in general, and marine protected areas (MPA), in particular, is finance. The finance being supplied for those activities is still inadequate. Even large national parks and MPA such as Con Dao, Cat Ba and Phu Quoc received very limited financial resources. The funds received do not sufficiently cover basic management activities, let alone for comprehensive programmes of research and monitoring, education, and enforcement. Protected areas not classified as national parks receive even less funds. Due to limited funds and inadequate workforce, natural resource management effectiveness is low. Moreover, poor infrastructure, lack of equipment, low awareness of personnel working in marine resources conservation and management, and weak participation of local communities in planning and management of protected areas, also contributes to the overall weakness in management.

- ***Lack of typical management model*:** Few coral reef management models exist in Vietnam, and are still in the pilot stage. In recent years, coral reef management has been became a more important issue and has received greater attention in workshops at national and local levels. Vietnam has also been increasingly represented at the international level at relevant forums. At the central level, the MADR has been assigned to set up a development programme for a national MPA system and to appeal to investment projects in establishing MPAs. The declared MPAs have gradually increased capacity in marine resources management in recent years and has achieved considerable results. At the local level, some provinces have built up a plan of coral reef management and protection for their own provinces. A model of coral reef management with multiple uses was established in Ninh Hai district, Ninh Thuan province to harmonize the benefits of all stakeholders in usage and conservation of local coral reefs. A plan of setting up a small scale no-take zones and habitat protection areas has been developed in Ninh Hai (Ninh Thuan) and Van Phong Bay (Khanh Hoa). These are trial models designed to find effective solutions towards sustainable integrated management of coral reefs in particular and MPAs in general over the long term.

- ***Lack of database management*:** No effective national coral reef database has been established. In general, data on Vietnam's coral reefs has been stored in various databases, research publications, and scientific reports at research institutions, and has not yet been effectively utilised to contribute to comprehensive coral reef management. A centralised database would improve access to information sources for coral reef research scientists and managers in Vietnam.

- ***Inadequate resource management framework*:** Currently, the national framework for natural resources management is still inadequate and over complicated in Vietnam, particularly at the central level. The decentralization process and details of functional responsibilities of ministries involved in natural resources management and protection is unclear, with many gaps and overlaps in mandate, as well as a lack of management in some fields. Institutional capacity and policies relating to coral reef management in Vietnam are inadequate and unsystematic. Resource management effectiveness is ineffective due to lack of detailed and clear jurisdictional guidelines and directives. In addition, community awareness and understanding of appropriate use and conservation of natural resources, including coral reefs, is very low and continues to negatively affect coral reef management and conservation.

Reccomendations:

- *Establish a scientific basis for sustainable use and management of priority coral reef areas along the shoreline of Vietnam.*

    - Although studies on coral reefs in Vietnam have been undertaken for many years, the understanding of coral reefs is still limited. Most of the studies have focused on coral reef taxonomy, while a few studies have focused on biodiversity, resources exploitation, and conservation potential at major sites. Thus, coral reef distribution and values of coral reefs in Vietnam are not yet fully understood. Enlarging the scope of study to improve understanding and build a scientific basis for coral reef management at a range of locations is urgently needed. Moreover, better understanding on structure, functions, ecological processes, and causes of coral reef degradation, are important for increasing coral reef management effectiveness. Providing and updating information on coral reef physiology, ecology, and socio-economic data relating to coastal areas will be vital to help managers and policy makers make better informed decisions for establishing MPAs. It is also important for forming fisheries management and coastal development regulations in order to minimise impacts of coral reef degradation at specific sites and over time. The aim of this issue is to supply and update sufficient scientific information for a database (scientific significance and socio-economic values) for coral reef management and sustainable use in Vietnam.

    - Recent studies within the framework of the project entiled "Studies and Establishment of Fisheries Refugia in Vietnam" under financial support from Ministry of Agriculture and Rural Development of Vietnam (MARD) in the period of 2012-2014 recorded several nursery grounds of barred-cheek coral trout (Plectropomus maculatus) found in the waters surrounding most of the islands group (An Thoi) in the southern part of Phu Quoc (Fig. 5.7.3) (Nguyen Van Long & Vo Si Tuan, 2014b). Among them, Hon Kim Quy and Hon Roi located outside the restricted zone supported much higher density of juveniles of groupers than other islands.

- *Establish a coral reef monitoring system to monitor coral reef status and to evaluate and improve management effectiveness.*

    - The assessment and monitoring of coral reef status is important to increase awareness and to support the minimization of negative impacts to coral reef ecosystems. Effective coral reef management is dependent on how appropriate the management solutions being applied are, and how management decisions are adapted to environmental and socio-economic changes (adaptive management). The monitoring programme will be an important process to detect changes in coral reef health and status prior to, during, and following negative impacts. Monitoring also plays a vital role in planning and ensuring a good approach to sustainable management strategies, and to minimize negative impacts on coral reefs. Furthermore, long-term monitoring programmes are useful tools for evaluating the effectiveness of management strategies designed to conserve and improve coral reef ecosystems. The aim of this recommendation is to monitor coral reef status over time to improve effectiveness of coral reef management.

- *Strengthen research capacity and sustainable management of coral reef resources at national and local levels.*

  - Resources for sustainable coral reef management include personnel, property, and finances for supporting research activities and management. Currently, coral reef researchers are mainly based at research institutions such as Institute of Oceanography, Institute of Marine Environment and Resources, and Research Institute of Marine Products. Coral reef inventory data have largely been collected as part of small projects; therefore there remain large gaps in knowledge. Management officials from fisheries resources protection branches and departments, functional management departments of related Ministries such as MARD and MONRE are few and have not been supplied with sufficient information. Technical facilities and equipment for coral reef research is inadequate and is largely concentrated at the two leading research institutes: Institute of Oceanography, Institute of Marine Environment and Resources, and Research Institute of Marine Products. Government coral reef management and research budgets remain inadequate and there is often a reliance on foreign donors. The aim of this part is to build capacity for existing coral reef management and research offices in Vietnam by modernizing research equipment, recruiting additional research personnel, and enhancing management capacity for agencies at all levels.

- *Complete legislation and institutional arrangements for comprehensive national coral reef management.*

  - Coral reef management policies in Vietnam do not adequately provide for the implementation of a comprehensive national coral reef management strategy. Coral reef management has not been considered as urgent priority in the existing policies and legislation on fisheries protection and development. There are no existing strategies on coral reef resources conservation and management. The current status of coral reef management at the site level demonstrates the inadequacy of current policies. There is a lack of collaboration and supportive mechanisms to implement coral reef resources management laws between national and local levels, and among agencies (Fisheries, Agriculture and Rural Development, Resources, Environment, Construction, etc.) as well as between provincial agencies and other local areas (e.g. no take areas, exploitation and trade areas) including international trade in coral reef organisms. No guidelines exist for MPA establishment. There is a need to highlight the importance of including governmental management structures and policy systems related to coral reef ecosystems into other management structures relating to the coastal ecosystem policy system, which is also currently being developed. The aims of this issue are to establish an integrative policy on coral reef resources management.; develop a national strategy on coral reef resources protection; to amend and improve policy for fines for fisheries resources, environmental protection, and trade infringements, and other regulations on personnel recruitment, and investments to enhance legislation formulation; and to etablish guidelines for MPA management and establishment.

- *Increase awareness of managers and communities on the ecological roles and economic values of coral reefs.*

    - In recent years, the government has issued basic laws and ordinances for conserving resources. Although coral reefs have been specifically mentioned, detailed guidelines for application in the field are severely lacking. In addition, while there are several Ministries, coastal provincial governments, technical research institutions, and international projects with interests in coral reef conservation and management, the implementation of sustainable coral reef use models is largely ineffective because of a lack of education and awareness of laws, management strategies, and general understanding of marine resource management issues. The aim of this issue is to increase the awareness of all stakeholders at all levels in order to promote sustainable use of all coral reefs in Vietnam.

- *Establish management models to ensure the sustainable use of coral reefs, and the maintenance of economic benefits derived from coral reef use.*

    - To date, no appropriate frameworks for coral reef ecosystem management have been provided in Vietnam, thus, there is an urgent need to establish such a management approach. Previous coral reef management projects in Vietnam should be evaluated for their effectiveness and potential as management models. There is a need to test proposed approaches to coral reef management and to consider lessons learned in previous projects so as to avoid unnecessary duplication of mistakes. The long term goals should also be to harmonize conservation and development needs in Vietnam's current stage of development. The aim of this part is to suggest appropriate management models for specific coral reef areas with suitable ecological functions and management status in Vietnam. Parallel with establishment and management of MPAs, it is important to take consideration in development of a network of fisheries refugia in order to protect spawning and nursery grounds of target species in coral reefs at specific period of critical stages of life cycles. These will contribute to conservation and sustainable use of habitats and associated marine resources in the coastal waters of Vietnam in the future.

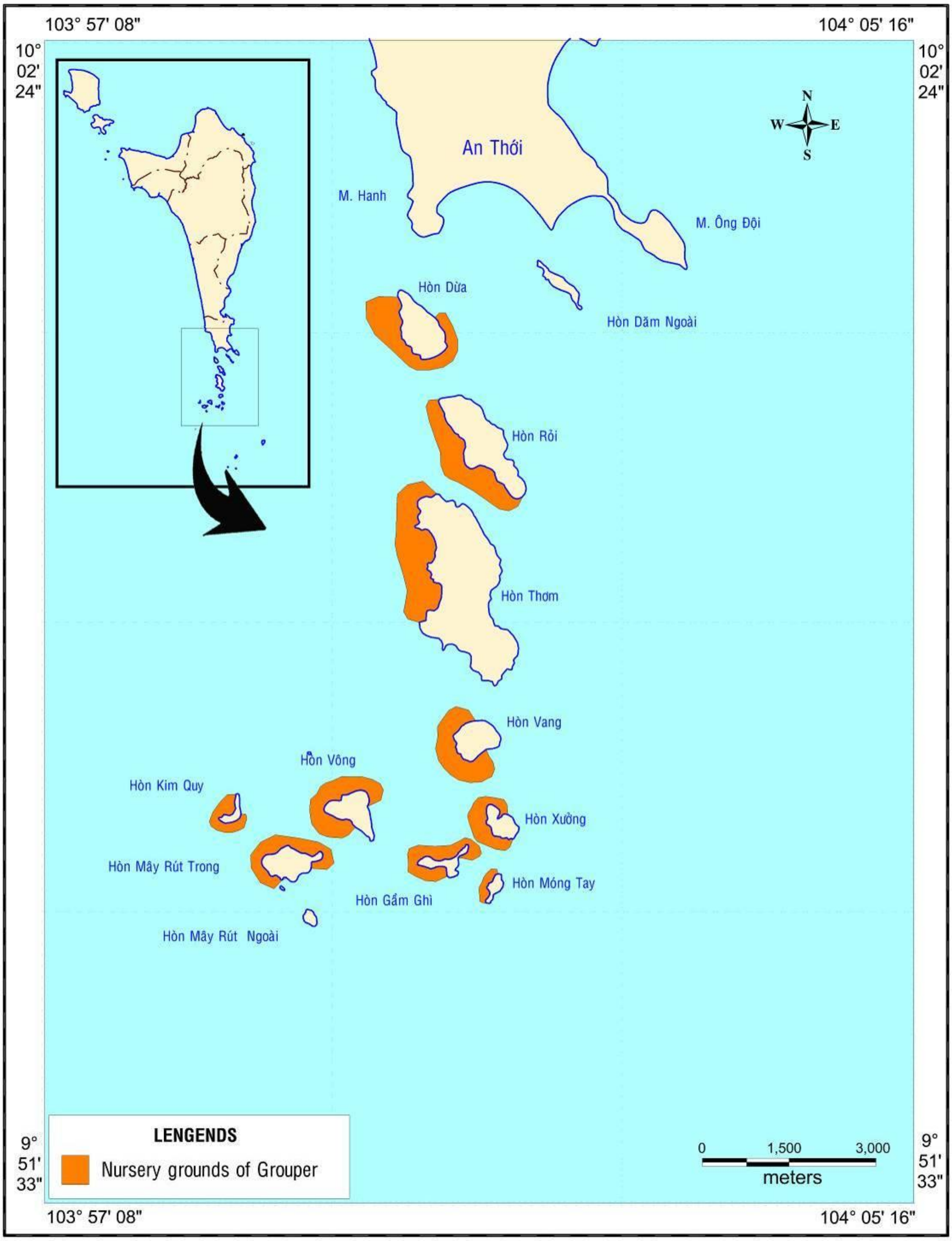

Fig. 5.7.3: Distribution of nursery grounds of barred-cheek coral trout in coral reefs in Phu Quoc islands.

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