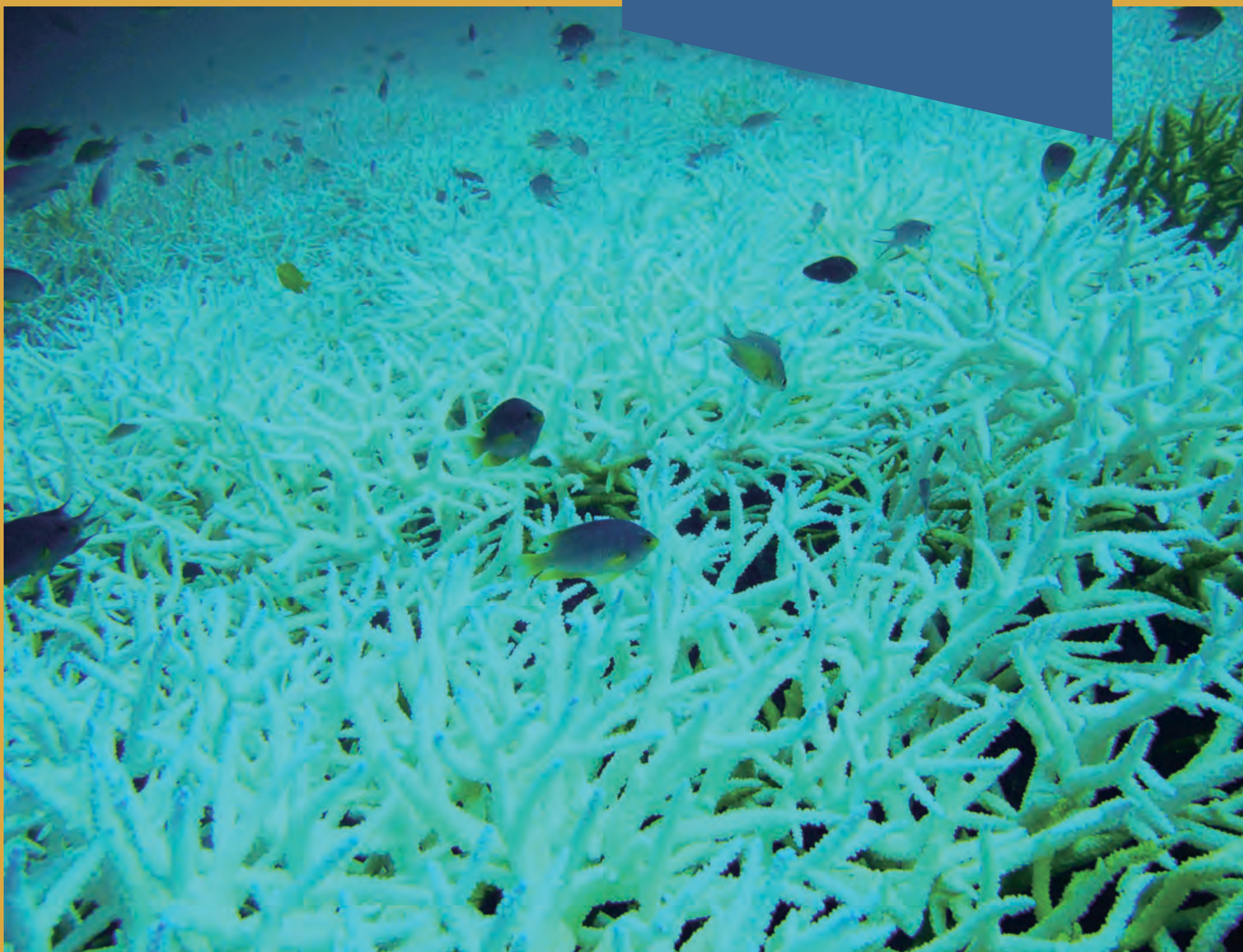
GCRMN

GLOBAL CORAL REEF MONITORING NETWORK

Status of Coral Reefs in East Asian Seas Region: 2010



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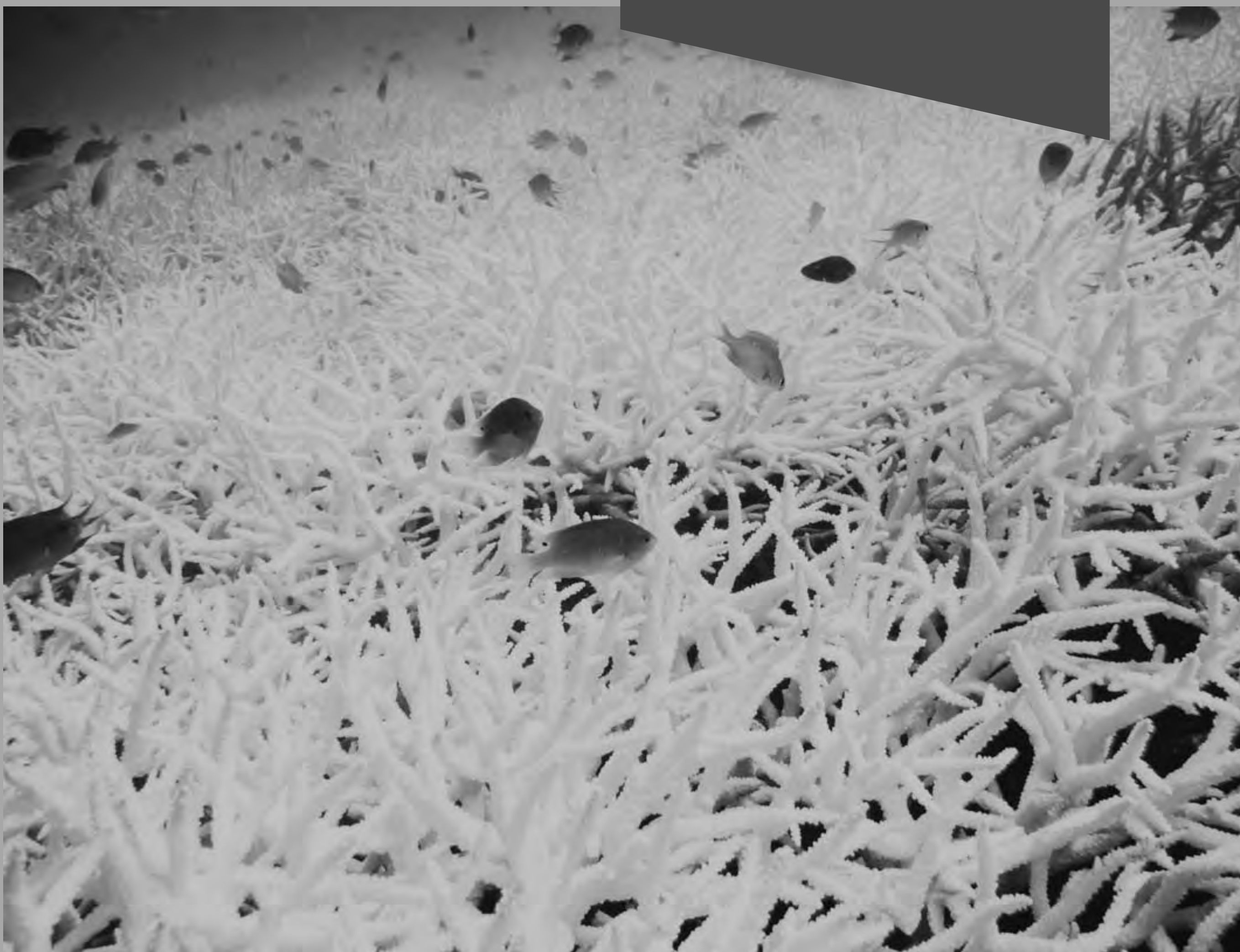

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Front Cover: Bleached Corals in Phuket, Thailand (Thamasak Yeemin © 2010)
Back Cover: Healthy coral community in Similan Island, Thailand. (Thamasak Yeemin © 2010)

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This Report has been edited and organized by Japan Wildlife Research Center by contract with the Ministry of Environment. However, the analyses and recommendations in this Report are the fruit of collaborative efforts by the GCRMN National Coordinators of countries in East Asian Seas Region and do not necessarily reflect views of the Ministry of Environment. Each author is responsible for his/her article in the report.

FOREWORD

The East Asian Seas Region, the area including North-East and South-East Asia, bear coral reefs with the world's richest diversity, which is very important in light of biodiversity conservation. These reefs are also indispensable for local communities because they provide livelihoods and economic benefits as fishery and tourism resources and protect the land as a natural breakwater. However, they are at high risk of destruction due to coastal development accompanied with the rapid population growth in the neighboring coastal area.

The Global Coral Reef Monitoring Network (GCRMN) was launched in 1996 with the purpose of collecting information and raising awareness about coral reef for conservation. The Status of Coral Reefs of the World is one of the most successful outputs from GCRMN for rising people's awareness that has been published every 2 to 3 years since 1998. The first issue highlighted a global crisis of coral bleaching caused by high water temperature.

This book is one of the regional followers for the global report on coral status to share information for enhancing conservation effort in the East Asia. The first regional status book was published and delivered during the first Asia Pacific Coral Reef Symposium in Hong Kong 2006 and this is the second issue of the East Asia regional report edited in 2010. Unfortunately large scale coral bleaching occurred around the Southeast Asia in 2010, this book was published as a special issue of bleaching in this region.

CONTENTS

EXECUTIVE SUMMARY

◆ COUNTRY SUMMARIES ON BLEACHING 2010

1. Brunei Darussalam

Visual assessment by visiting coral reef scientists conducted at two coral reef areas – Two Fathom Rocks by Dr Lyndon DeVantier in June 2010 (Ubaidillah Masli, 2010a) and Pelong Rocks by Dr Gregor Hodgson in July 2010 (Ubaidillah Masli, 2010b) – indicated generally low levels of coral bleaching within both areas, with a possible estimated loss of 10% for the corals at Pelong Rocks.

2. Cambodia

Coral Cay Conservation (CCC), working in partnership with the Fisheries Administration of the Royal Government of Cambodia, initiated the collaborative Cambodia Reef Conservation Project (CRCP) in 2009 to survey the coral reefs of Koh Rong and Koh Rong Semleon Islands in the province of Sihanoukville. As part of the project, baseline surveys were conducted to gather biological and oceanographic data of the area. Since May 2010, coral bleaching was observed at Koh Rong/Koh Rong Semleon, and monitoring continued to assess the impact and subsequent recovery. Preliminary data indicate that bleaching was severe, affecting 75-90% of all hard coral taxa within all reef zones, including other non-hard coral taxa like zoanthids, soft corals and giant clams. There are currently no estimates for bleaching-associated mortality but partial recovery of surviving taxa is expected. However the onset of the northeast monsoon while the corals are still bleached is a cause for concern as increased sedimentation could further worsen the conditions and result in higher coral mortality.

3. Indonesia

Mass coral bleaching occurred across the country in Sabang, Aceh, Padang, Thousand Islands Jakarta, Karimun Jawa, Situbondo, Banyuwangi, Bali (Ngurah Rai Reef, northeast Bali), The Gilis Lombok, Bangko-Bangko, Lombok, Kupang, Wakatobi, Spermonde, Tomini Bay, and Ambon. About 50 different organizations and individuals, ranging from surfers, fishers, divers, dive operators to scientists from government and academic institutions reported the bleaching from mid-March to mid-June 2010. Up to 100% bleaching of susceptible species were reported, and in some areas, severe bleaching also affected the more resistant taxa. In general, severe bleaching was reported in Sumatra and Sulawesi, with milder bleaching observed in Java, Bali, Lombok, Moluccas and West Papua. However, many reports still need to be verified.

4. Malaysia

The earliest bleaching report for Malaysia was in March 2010 for Pulau Tioman, situated along the east coast of Peninsular Malaysia following which, the Department of Marine Parks in Peninsular Malaysia partnered various universities and NGOs to monitor the status of the coral reefs in response to elevated SSTs in the South China Sea and Andaman Sea. Preliminary data indicate severe bleaching at reefs along the eastern coast of Peninsular Malaysia, with 75% to 90% bleaching reported at Pulau Tioman, Pulau Tinggi and Pulau Sibu. Bleaching severity at Pulau Payar along the western coast of Peninsular Malaysia ranged from medium to high, while the bleaching severity at reefs within the East Malaysian state of Sabah was assessed as medium. The bleaching impact along the eastern coast of Peninsular Malaysia is considered more severe than the 1998 event, prompting the Department of Marine Parks to take unprecedented action to close 12 dive sites within three marine parks between July and October 2010 to allow bleached corals to recover.

5. Myanmar

Currently, no information (including anecdotal) on the bleaching event is available for Myanmar's coral reefs, largely concentrated within the Myeik or Mergui Archipelago. However, given its proximity to affected coral reefs in Thailand and the similar SST occurrences within the general area, similar high severity coral bleaching is likely.

6. Philippines

The first signs of coral bleaching in the Philippines began in late May 2010, as elevated SSTs began to move into the South China Sea. Researchers from The University of the Philippines and De La Salle University are currently assessing the bleaching condition in the country. An online moderated bleaching monitoring group was created in May 2010 to provide a platform for bleaching report submissions for the Philippines. Online news articles report at least eight areas where the coral bleaching is severe - the towns of Nasugbu, Lian, Bauan, Mabini, Lobo and Calatagan in Batangas, Calapan in Oriental Mindoro, and Pagbilao in Quezon.There are growing concerns among reef scientists that the affected reefs may not recover well, with recent reports indicating outbreaks of COTs that are further devastating the impacted reefs.

7. Singapore

The first observations of mass bleaching on Singapore reefs were reported in May 2010. Preliminary rapid visual assessment by scientists from the National University of Singapore, the National Parks Board and DHI Water & Environment (S) Pte Ltd indicated moderate to severe bleaching in all reefs and across all reef zones. Bleaching specific quantitative surveys were conducted at four sites in May with a second survey conducted in November 2010 and a third survey planned in the first quarter of 2011 to assess recovery. Besides hard corals, bleaching was also recorded in other zooxanthellate taxa including soft corals, anemones and zoanthids. Data indicate that bleaching severity was highest within the inter-tidal reef flat zones, with almost complete bleaching of all hermatypic taxa. Within the sub-tidal zones, hard coral bleaching was variable, ranging from 30% to 60% between the four sites surveyed. In addition, only 5% to 30% of the bleached corals were completely bleached (white), with most bleached corals retaining some colour within their tissues.

8. Thailand

Elevated SSTs of between 30-34^{o}C were recorded during March and June 2010 within the Andaman Sea and the Gulf of Thailand. The Department of Marine and Coastal Resources, in collaboration with Thai universities and NGOs conducted several reef surveys in both regions and reported widespread and severe coral bleaching of over 80% within all reefs throughout every province. Bleaching in the Andaman Sea was more severe and extensive than in the Gulf of Thailand, with the inner Gulf of Thailand exhibiting the lowest bleaching impact. The most susceptible were *Acropora* spp. and *Pocillopora* spp. Coral mortality following the bleaching event is estimated at about 50-90% within the Andaman Sea, and between 5-50% within the Gulf of Thailand. Some coral species, especially *Porites lutea*, showed good recovery, with an estimated 50-75% of bleached individuals expected to recover in the Andaman Sea. It is estimated that the 2010 bleaching event is similar in extent but with greater severity than the 1998 bleaching event within the Gulf of Thailand, but greater in extent and severity within the Andaman Sea.

9. Timor-Leste

No information on the bleaching event is available for the coral reefs of Timor-Leste. However, given its proximity to the Kupang Bay within the adjacent Pulau Tmor in Indonesia and the similar SST occurrences within the general area, similar medium severity coral bleaching is likely.

10. Viet Nam

Quantitative surveys using the line transect point method with additional bleaching attributes were conducted at 5 areas by scientists from Institute of Oceanography; Phu Quoc, located in the Gulf of Thailand, Van Phong, Nha Trang, Cam Ranh and Ninh Hai, located in the south-central Vietnam. Bleaching severity was assessed as low in south-central Vietnam while reefs in the Gulf of Thailand showed medium severity in response to elevated SSTs. Bleaching was recorded to depths of between 8 to 10m, and affected hard corals, soft corals and sea anemones. Hard coral taxa showed a mixed response; within south-central Vietnam, *Acropora* spp. had the greatest bleaching severity while *Hydnophora* spp., *Montipora* spp., *Acropora* spp., *Pavona* spp. and *Porites* spp. were the most bleached genera at Phu Quoc, within the Gulf of Thailand.

◆ STATUS OF CORAL REEFS IN EAST AND NORTHEAST ASIA

1. China

The coral communities and coral reefs in the mainland China are unprecedentedly degraded over the last 30 to 50 years, overwhelmingly by anthropogenic stressors, such as . mariculture in coral reef areas, over-fishing, and water quality problems 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. In Daya Bay, Weizhoudao, Sanya (Hainan), the percent cover of the live stony corals declined from over 70％ before 1980s to about 30％ in recent years. Infestations of crown-of-thorns-starfish were sustained in Sanya (particularly in Yalong Bay) and large areas of Xisha Islands since 2004, which contributed to mass damage of the coral reefs directly and the promotion of phase shifts. There were very few reports about coral bleaching due to the extreme high temperature in China, except in Weizhoudao (Guangxi), and Nansha Islands, where mass bleaching events were observed and informally recorded in 1997-1998.

2. Hong Kong

Hong Kong is a marginal area for coral growth and thus supports only non-reefal coral communities. Two marine parks, Tung Ping Chau and Hoi Ha Wan Marine Parks, have been designated to protect some of these coral communities. No major or large scale disturbance to Hong Kong corals has been reported in the last five years between 2005-2009, although occasional local outbreaks of gastropod predation and sea urchin bioerosion were observed. Grounding of a large barge during a storm in August 2006 also caused significant damage to the A Ye Wan core area in Tung Ping Chau Marine Park. Patterns of coral reproduction and mass spawning appear to be closely related to temperature change but coral recruitment rate remains very low. Fish diversity and abundance also remain very low in the marine parks, partly attributable to continuous fishing pressures.

3. Taiwan

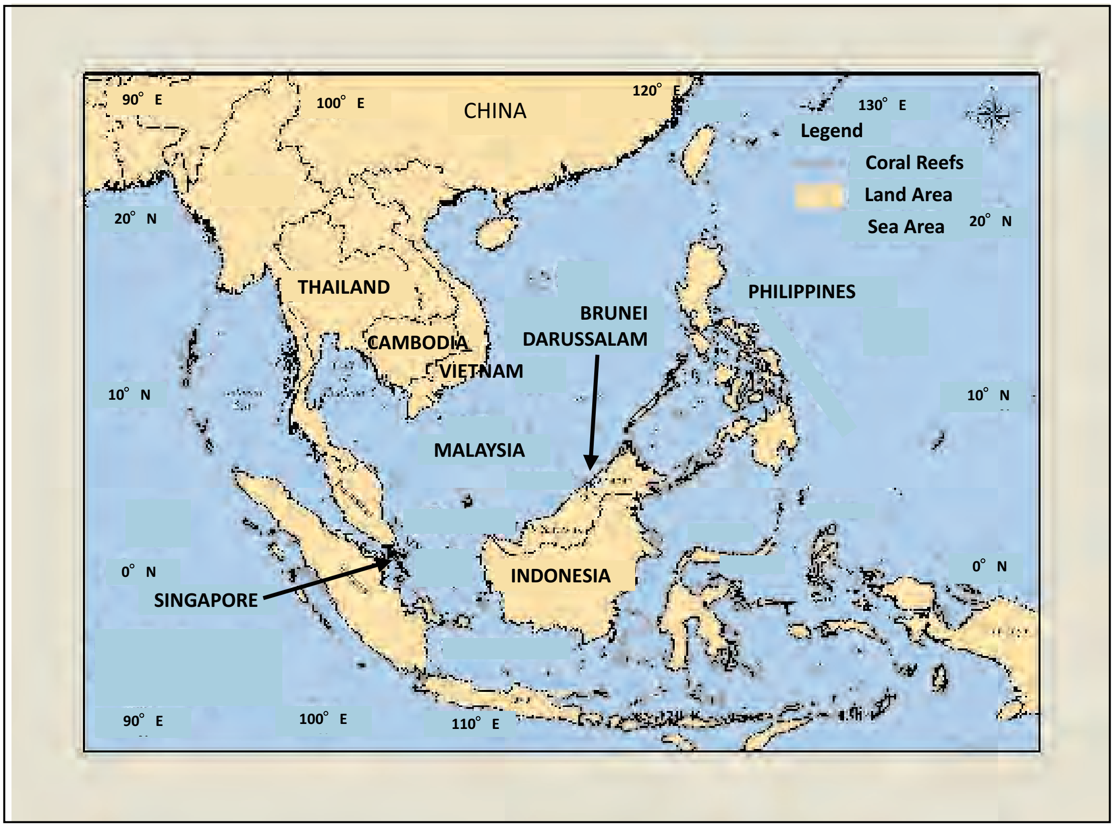
The status of coral reefs in Taiwan based on surveys using the Reef Check methods in June-September, 2009 shouwed that coral cover of the 80 sites varies from 3 to 68%. Among locations, the average coral cover was higher in Penghu Islands (40%) and Lutao (41%) indicating these reefs to be in relatively good condition. Coral cover was very low at Hsiaoliuchiu (15%) indicating these reefs to be severely damaged or degraded. The abundance of fish and invertebrate indicators at most of the sites was very low suggesting that reefs in Taiwan were under the stress of overfishing. Most of the coral reefs in Taiwan are within national scenic areas or national parks, but most of these areas are not effectively managed. It is recommended that adequate laws should be established or revised for the authorities to enforce management policies and to protect the reefs.

4. Japan

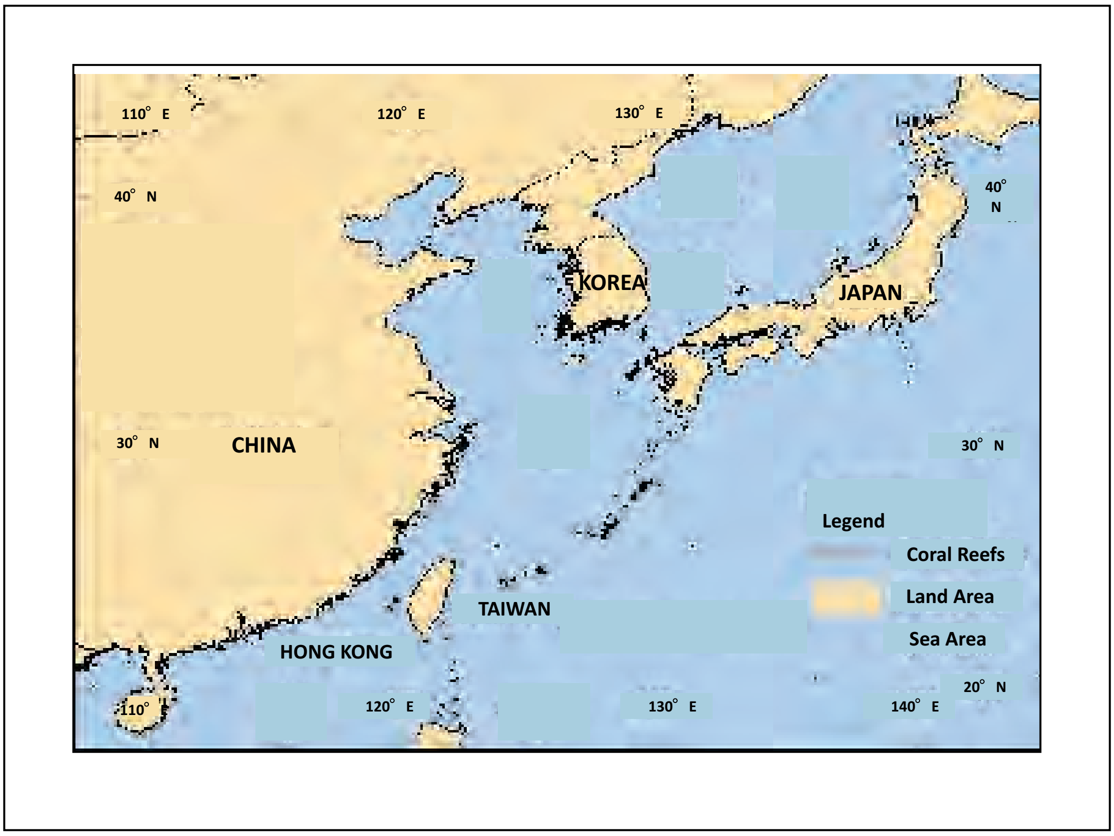
Overview of the coral status from 2004 to 2010 shows that there was no significant increase of coral cover until 2006 in the coral reef area including Amami, Okinawa and Ogasawara islands because of the disturbances by Acanthaster outbreak and typhoon. Serious coral bleaching by high water temperature occurred in Ishigaki, Iriomote islands and Sekisei Lagoon in 2007 and coral cover was decreasing. In addition to the coral bleaching, Acanthaster outbreak precluded coral recovery from bleaching in Miyako, Ishigaki, Iriomote islands and Sekisei Lagoon. Acanthaster outbreaks were dispersed in non reef area and coral cover did not show clear increase until 2009. However, coral cover slightly recovered in 2010. Coral bleaching by high water temperature was observed around Kushioto and Shikoku sites in 2008 and 2010 without mass mortality.

5. Korea

Reef building coral (*Favia* sp.) were recently found around Jeju Island in the southern parts of Korea. They colonize on the bare rocks and compete successfully with macro-algae for space. The population size has also developed gradually. A total of 145 octo-corals have been identified in Korea including nine new species recorded in the past 2 years. It appears that tropical species could recruit under the influence of the Kuroshio Current, which may intensify with global warming. The famous soft coral beds of Jeju Island face threats from coastal development to expand the port and land reclamation close to the MPA in Seogwipo area. Ministry of Land, Transport and Marine affairs (MLTM) started two new programs concerning the corals. One was to monitor the corals around Korea focused on coral ecology and the related environment for five years. Another was the management and restoration of soft corals in the MPA area in Jeju Island.



. A map of Southeast Asian countries.



A map of East and Northeast Asian countries.

1. STATUS OF CORAL REEFS IN SOUTHEAST ASIA 2010

1.1 A REGIONAL OVERVIEW ON THE 2010 CORAL BLEACHING EVENT IN SOUTHEAST ASIA

Karenne Tun[1], Loke Ming Chou[2], Jeffrey Low[3], Thamasak Yeemin[4], Niphon Phongsuwan[5], Naneng Setiasih[6], Joanne Wilson[7], Affendi Yang Amri[8], Kee Alfian Abdul Adzis[9], David Lane[10], Jan-Willem van Bochove[11], Bart Kluskens[12], Nguyen Van Long[13], Vo Si Tuan[13] and Edgardo Gomez[14]

ABSTRACT

The 2010 coral bleaching in Southeast Asia occurred in response to elevated sea surface temperatures (SST) caused by the intense La Niña event that started in early 2010 within the region and continued into late 2010. Coral bleaching was widespread, affecting many reefs within the region, with countries reporting severe bleaching comparable to, and in some cases, more severe, than the 1998 bleaching event that resulted in an estimated 18% coral mortality. Although SSTs have generally declined and returned to normal seasonal levels in most areas by November 2010, the aftermath of the bleaching event was still noticeable with bleached corals prevailing on many reefs, and with initial mortality estimates of 10% to 90% reported in Indonesia, Malaysia and Thailand. In the Philippines, COT outbreaks observed in some areas are expected to reduce the overall resilience of the reefs and possibly compromise their recovery. However, despite the general doom and gloom for the reefs of the region, there is some glimmer of hope; reports by diver operators in the province of Manado in Northeast Sulawesi indicated no occurrences of coral bleaching, with temperatures lower than normal seasonal levels. Reefs within the Raja Ampat archipelago in the province West Papua were similarly spared the bleaching although large temperature fluctuations were reported in the central Dampier Straits region. In addition, repeat surveys in Singapore indicated rapid recovery of bleached corals, with less than 10% mortality attributed to bleaching in November 2010. In an unprecedented move to minimize stress and allow bleached coral to recover, the Malaysian Department of Marine Parks closed 12 of 83 dive sites within various marine parks in Peninsular Malaysia from July to October 2010, where coral bleaching

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exceeded 60%. Thailand implemented a similar measure in January 2011, closing 18 popular tourist dive sites for up to 14 months to minimize diving pressure and allow severely bleached corals to recover. Bleaching is still occurring at the present time (January 2011) and continued monitoring efforts are implemented in many countries. Full estimates of realized impacts of the 2010 bleaching event on the coral reefs of Southeast Asia will only become clearer in the next few years.

OVERVIEW OF 2010 EL NIÑ0-LA NIÑO EVENTS

The year 2010 is set to be among the three warmest years since measurements began in 1850 and 2001-2010 is the warmest decade on record (WMO, 2010). The El Niño event, which began in July 2009, continued into early 2010 before transitioning into the strongest La Niña event known since the mid-1970s (NOAA, 2009), with the Southern Oscillation Index reaching its highest monthly value in September 2010 since 1973. WMO estimates that the El Niño to La Niña transition in 2010 is similar to that which occurred in 1998, the difference being a weaker El Niño but a stronger La Niña, especially in the second half of 2010 (WMO, 2010).

In addition, NOAA's Climate Prediction Center predicts that the La Niña is expected to last until spring 2011 in the Northern Hemisphere, with a possibility of becoming a strong episode by the November-January season within the central tropical Pacific Ocean before gradually weakening (Climate prediction center/NCEP, 2010).

NOAA'S CORAL BLEACHING DEGREE HEATING WEEK (DHW) AND CORAL BLEACHING HOTSPOTS (HS) IN SOUTHEAST ASIA

Monthly predictions of coral bleaching degree heating week (DHW) and coral bleaching hotspots (HS) by NOAA's Coral Reef Watch (CRW) programme were generated and downloaded from ReefBase's ReefGIS database (http://reefgis.reefbase.org/) to assess the bleaching event in the region from January to November 2010 (Fig. 1.1.1). Methodology descriptions for NOAA's CRW coral bleaching DHW and HS are available from http://coralreefwatch. noaa.gov/satellite/ methodology/methodology.html#dhw.

The coral bleaching DHW and HS indicated that SSTs within Southeast Asia began increasing in January 2010, originating south of Indonesia within the waters of the Indian Ocean and the Timor Sea. By March 2010, elevated SSTs were reported in the Andaman Sea, and expanding to the Gulf of Thailand, the South China and the Philippines Sea. The region as a whole sustained DHW temperatures of above 4˚C-weeks and exceeded the HS threshold temperature of 1˚C from April through November, after which SSTs started to decline and return to normal seasonal levels. Within each major water body (Indian Ocean, Andaman Sea, South China Sea and the Philippines Sea), elevated SSTs remained for 5 to 6 months, with the Andaman Sea and the South China Sea experiencing the highest temperature increases (DHW temperatures >10˚C-weeks and HS temperatures over 2˚C) between April to June and May to July respectively.

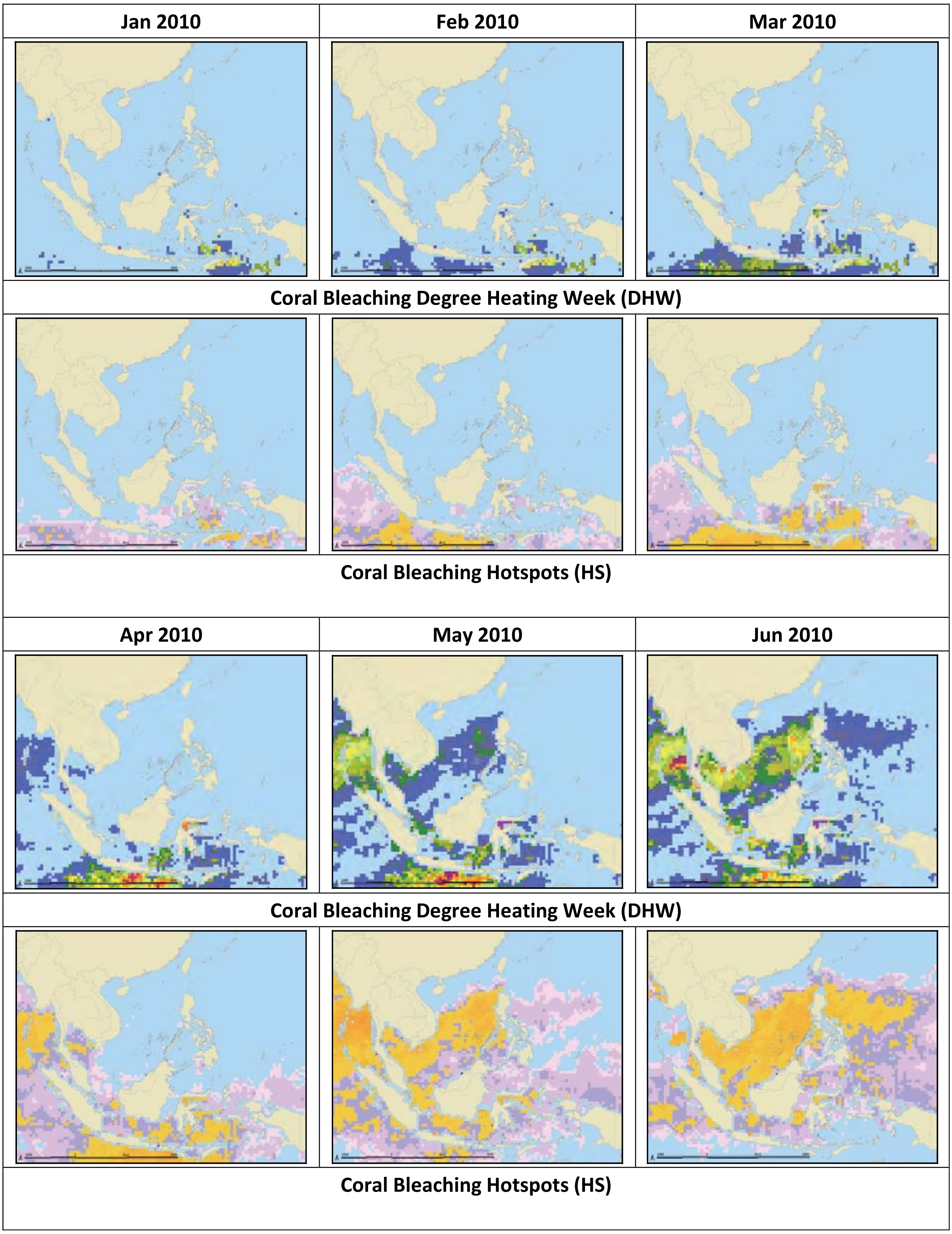

Fig. 1.1.1 NOAA's coral reef watch coral bleaching Degree Heating Week (DHW) and Hotspots (HS) for Southeast Asia's major water-bodies between January and November 2010.

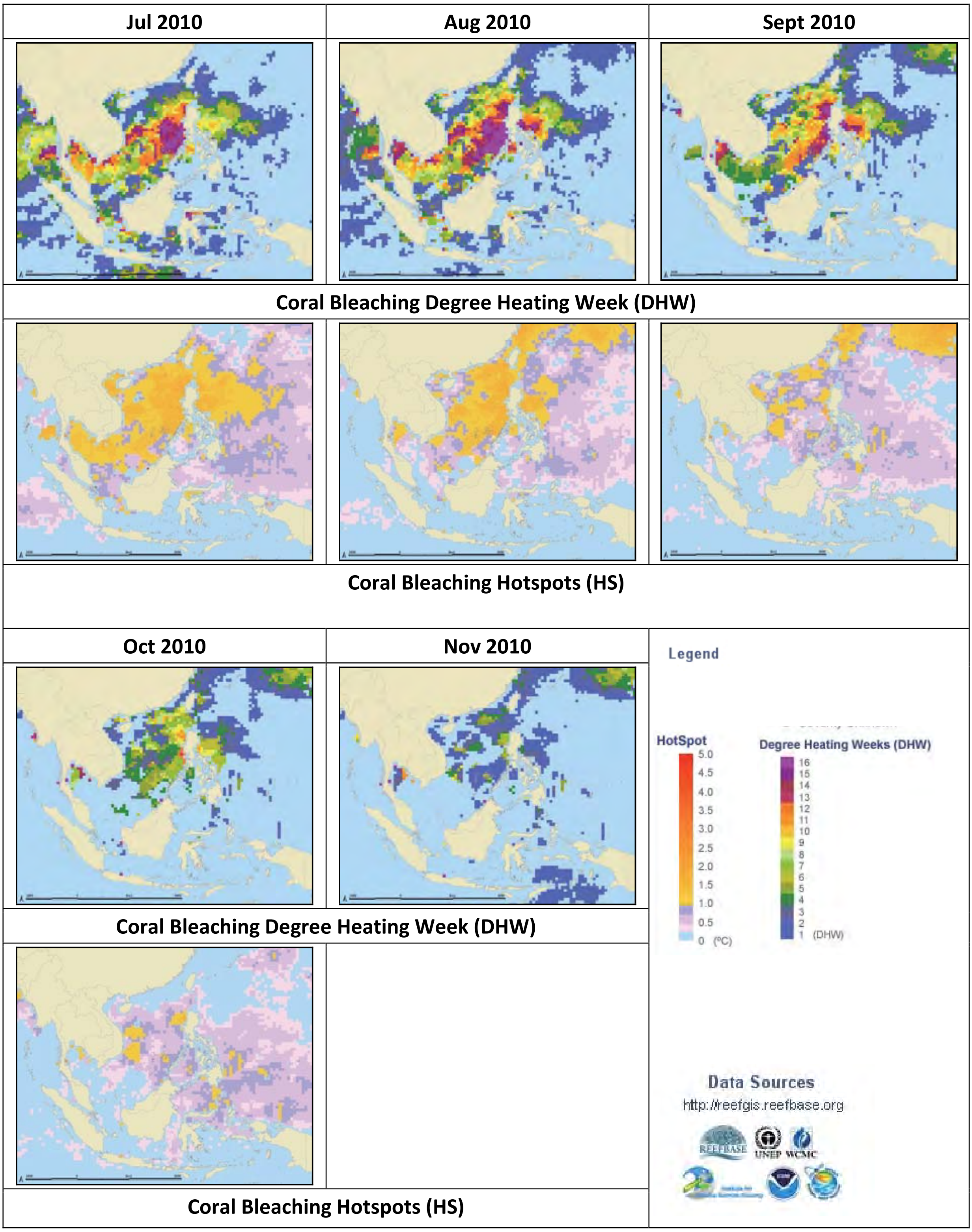

Fig. 1.1.1 (continue) NOAA's coral reef watch coral bleaching Degree Heating Week (DHW) and Hotspots (HS) for Southeast Asia's major water-bodies between January and November 2010.

2010 BLEACHING SUMMARY FOR SOUTHEAST ASIA

Bleaching reports from verified sources were summarized into a regional bleaching map with the estimated onset of bleaching indicated for different areas (Fig. 1.1.2). Reports varied in the amount and type of data collected for different locations, with assessments and observations reported by various agencies and individuals at different periods after the onset of the bleaching. GCRMN country coordinators and/or supporters collated and provided summaries for their countries. However, where country summaries were not available at the time of preparation of this report, online media information, news articles and social media resources were gleaned for bleaching information.

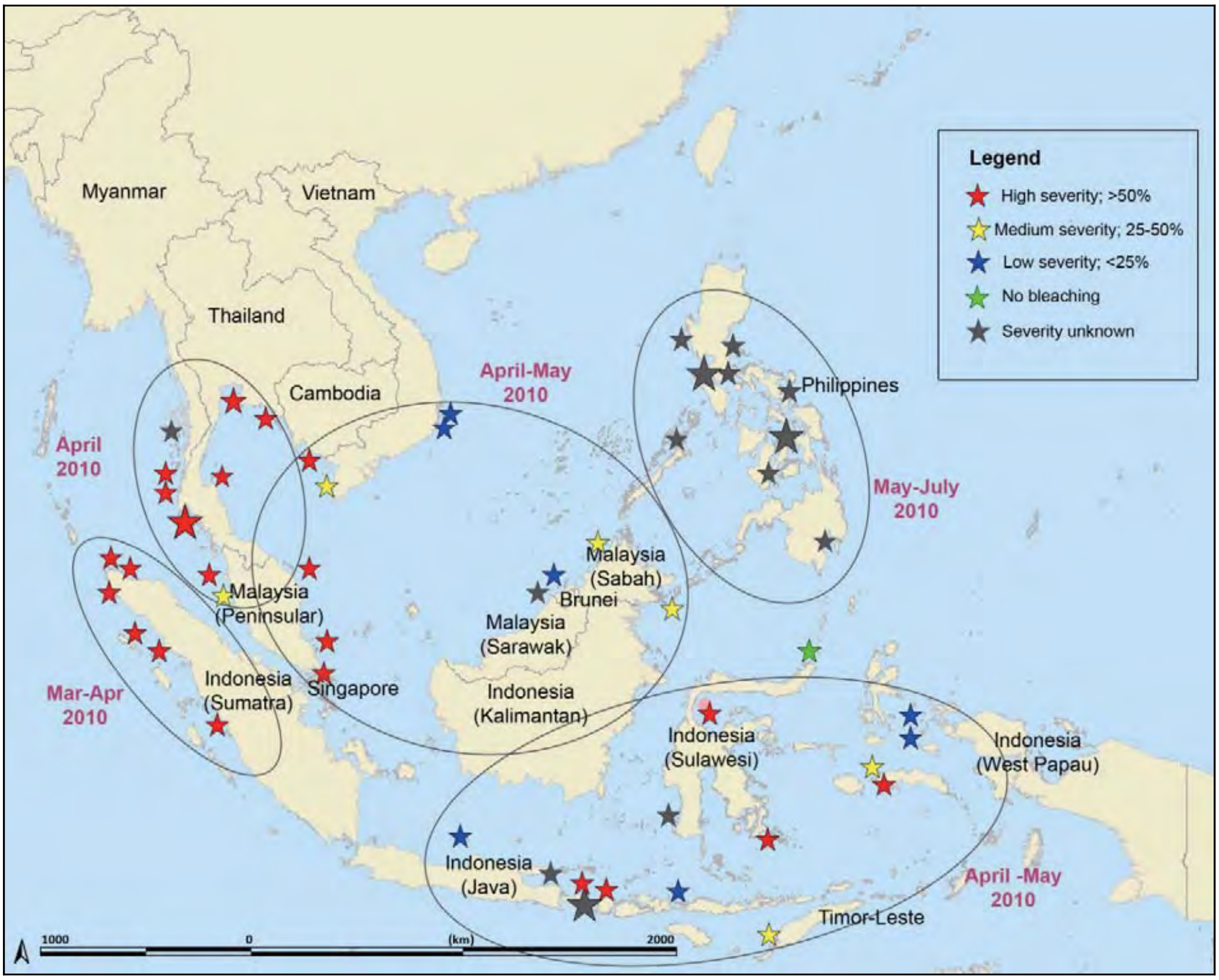

Fig. 1.1.2 Extent and severity of the 2010 coral bleaching event in Southeast Asia. Small stars represent one to five reports per area, while larger stars represent more than five reports per area. Estimated bleaching initiations indicated by the ellipses are only indicative with possibility of earlier onset based on NOAA's CRW SST predictions. By November 2010, SSTs have cooled to normal seasonal ranges in most areas.

The resulting regional bleaching map is thus a synthesis of information from varied sources, and is not intended to be indicative of all reef areas within each country. Table 1.1.1 gives an overall regional summary of the extent, severity, estimated bleaching-associated early mortality and predicted recovery.

Table 1.1.1 Coral bleaching summary for Southeast Asia, based on verified quantitative and qualitative reports and bleaching duration estimated from NOAA CRW's coral bleaching DHW and HS predictions.

Country	**Region/Area**	**Estimated bleaching onset (2010)**	**Estimated bleaching duration**	**Estimated bleaching severity**	**Estimated bleaching-associated mortality**	**Predicted recovery from bleaching**
Brunei Darussalam	Shelf reefs	Mid June to July	May-October	Low to medium	10-25%	Dependent on severity of ongoing COT outbreak
Cambodia	Sihanoukville Province	Early May	May-September	Medium	Unknown	Partial recovery expected
		End April	April-November	High	Low	
Indonesia	Aceh	End March	March-August	No bleaching in a few areas, Mild to high in most others	Unknown	Unknown
	Northeast Java	End April	April-August			
	Bali/Lombok					
	Sulawesi					
	West Papua	Mid May				
Malaysia	East Peninsular	Early March	March-August	High	High to low	Partial to full recovery expected
	West Peninsular	Early April	April-September	Medium	Unknown	Unknown
	Sabah	Mid May	May-October	Medium	Low	
	Sarawak		May-September	Medium	Low	
Myanmar	Myeik Archipelago	Unknown, possibly early April	April-September	Unknown, possibly high	Unknown	Unknown
Philippines	Santa Cruz, Luzon	Mid May	May-November	Unknown	Unknown	Unknown
	Batangas,Luzon					
	Albay, Luzon	Possibly mid May	June-November			
	Palawan		May-November			
	Cebu/Negros					
	Mindanao					
Singapore	Southern Islands	Mid May	May-August	High	Low (<10%)	Fast, full recovery expected
Thailand	Andaman Sea	Early April	April-September	High	High (>50%)	Partial recovery expected
	Gulf of Thailand	End April	April-October	High	Medium (25-50%)	
Viet Nam	Gulf of Thailand	Early May	April-September	High	High (25-92%)	Partial recovery of surviving taxa expected
	South-Central Viet Nam			Low	Medium (5 – 16%)	Full recovery of surviving taxa expected
Timor-Leste	-	Unknown, but possibly April-May	Possibly Jan-June; Nov-?	Unknown, possibly high	Unknown	Unknown

COUNTRY SUMMARIES

1. Brunei Darussalam

Compiled: David Lane (Universiti Brunei Darussalam)

Visual assessment by visiting coral reef scientists conducted at two coral reef areas – Two Fathom Rocks by Dr Lyndon DeVantier in June 2010 (Ubaidillah Masli, 2010a) and Pelong Rocks by Dr Gregor Hodgson in July 2010 (Ubaidillah Masli, 2010b) – indicated generally low levels of coral bleaching within both areas, with a possible estimated loss of 10% for the corals at Pelong Rocks.

Separate assessments by scientists from University Brunei Darussalam at various sites, including GCRMN long-term monitoring sites indicated that significant bleaching was first noted in mid-June at Silk Rock. At Littledale Shoal, 18km offshore from Jerudong, during a series of COT outbreak surveys, bottom temperatures (@~11m depth) increased gradually from 29.8˚C (22 Apr 2010) to 31.0˚C (14th June 2010) without evidence of bleaching. By end July, bottom temperatures remained high (30.2˚C) with extensive bleaching observed, affecting hard and soft corals, particularly the massive *Porites* hard corals and *Dendronephthya* soft corals but not the post-COT table *Acropora* survivors. During the 3-month period from April to July 2010, bottom salinity declined from 34.6 to 29.0 ppt due to high rainfall and the water column became thermally uniform (i.e., no thermal refuge for the submerged reef). Warm water conditions and some bleaching appear to have persisted up to 4th December 2010 with the water column profile even showing a slight thermal inversion. The sustained COT outbreak coupled with the bleaching may compromise the overall recovery of the corals within the area.

2. Cambodia

Compiled: Jan-Willem van Bochove (Coral Cay Conservation)
Bart Kluskens (Song Saa Private Island)

Coral Cay Conservation (CCC), working in partnership with the Fisheries Administration of the Royal Government of Cambodia, initiated the collaborative Cambodia Reef Conservation Project (CRCP) in 2009 to survey the coral reefs of Koh Rong and Koh Rong Semleon Islands in the province of Sihanoukville. As part of the project, baseline surveys were conducted to gather biological and oceanographic data of the area. Since May 2010, coral bleaching was observed at Koh Rong/Koh Rong Semleon, and monitoring continued to assess the impact and subsequent recovery. Preliminary data indicate that bleaching was severe, affecting 75-90% of all hard coral taxa within all reef zones, including other non-hard coral taxa like zoanthids, soft corals and giant clams. There are currently no estimates for bleaching-associated mortality but partial recovery of surviving taxa is expected. However the onset of the northeast monsoon while the corals are still bleached is a cause for concern as increased sedimentation could further worsen the conditions and result in higher coral mortality. Further information of the bleaching event will be in the CCC 2010 annual report that will available in a few months at www.coralcay.org.

In addition to the surveys at Koh Kong, additional surveys at two neighbouring islands – Koh Ouen and Koh Bong - situated within a privately managed marine conservation area, were conducted under the conservation and social program of Song Saa Private Island. The earliest bleaching at these islands occurred in late April 2010, with severe bleaching of 70-85% in the shallow reef flats affecting all hard coral genera as well as soft corals and giant clams. By late September, follow-up surveys indicated that recovery was underway, with various hard coral genera such as *Acropora, Herpolitha* and *Porites* showing partial to full recovery. The overall bleaching severity dropped to 30-60% by late September/October 2010. Bleaching-associated mortality was observed in a few colonies and the overall mortality is expected to be low. Despite the observed recovery, increased monsoon-induced sedimentation is likely to affect the short term recovery of the corals.

3. Indonesia

Compiled: Naneng Setiasih (Reef Check Foundation Indonesia)
Joanne Wilson (TNC)

Mass coral bleaching occurred across the country in Sabang, Aceh, Padang, Thousand Islands Jakarta, Karimun Jawa, Situbondo, Banyuwangi, Bali (Ngurah Rai Reef, northeast Bali), The Gilis Lombok, Bangko-Bangko, Lombok, Kupang, Wakatobi, Spermonde, Tomini Bay, and Ambon. About 50 different organizations and individuals, ranging from surfers, fishers, divers, dive operators to scientists from government and academic institutions reported the bleaching from mid-March to mid-June 2010. Up to 100% bleaching of susceptible species were reported, and in some areas, severe bleaching also affected the more resistant taxa. In general, severe bleaching was reported in Sumatra and Sulawesi, with milder bleaching observed in Java, Bali, Lombok, Moluccas and West Papua. However, many reports still need to be verified.

Rapid coral reef assessments in Sabang by researchers from Syiah Kuala University, Aceh at the end of May showed 80% of hard corals bleached, including species from the genera *Acropora*, *Montipora*, *Pocillopora*, *Seriatopora*, *Favia*, *Favites*, *Goniastrea*, *Fungia*, *Platygyra*, *Hydnophora*, *Galaxea*, *Diploastrea, Lobophyllia*, *Porites* and *Pavona*. Regular coral monitoring in Aceh's West and East coasts revealed 80% and 90% bleaching of soft and hard corals respectively. Observations in Pemuteran (Bali) at the end of April showed 40-60% bleaching of *Acropora* and *Porites.* Manta tow surveys by Reef Check Foundation Indonesia (RCFI) in mid June in the Gilis (Lombok), showed 10-55% bleaching at the reef flat. Genera affected were *Seriatopora*, *Acropora*, *Favia*, *Favites*, and *Porites*. Coral health assessments by TNC in Wakatobi in mid April noted that 60-65% of corals showed signs of bleaching with 10-17% of colonies fully bleached. Almost all *Seriatopora* colonies bleached and other taxa with high percentage of full or partially bleached colonies included *Goniopora*, *Stylophora* and encrusting *Montipora*. Moderately affected (20-30% of colonies bleached) were *Pocillopora*, non-*Acropora* branching corals and *Acropora palifera*. Least affected taxa included branching *Acropora* and massive species (excluding Faviidae). At Lebo Parigi, Tomini Bay, 90% of *Pocillopora* were fully bleached. In Kofiau and Misool, TNC reported mild bleaching with less than 5% of corals affected, predominantly *Seriatopora*. Researchers from the Centre Cendana University also recorded mild bleaching affecting 30% of hard corals at Bolok reef, Kupang. Underwater images from Padang, Ambon, Amed and Spermonde showed over 75% bleaching of branching *Acropora*, as well as the more bleaching-resistant species such as *Lobophyllia* (Spermonde) and *Porites* (Pemuteran). Surfers also reported seeing reefs with patches of white and fluorescent color.

By November 2010, elevated SSTs started declining in many areas but researchers fear that subsequent recovery may be challenged. Resilience surveys in Gili Indah by RCFI showed that some corals perished within one month of the bleaching, while others showed signs of disease. Reports from a joint expedition by the Wildlife Conservation Society, James Cook University, and Syiah Kuala University in Sabang, Aceh indicated that many of the bleached corals observed in May and June were dead by July. *Acropora* corals were the most affected species with up to 80% mortality. Other more resistant species remain bleached, with many of them expected to die within the coming weeks and months. Experts believe that the 2010 coral bleaching in Indonesia is possibly the most rapidly occurring and widespread event with potentially high associated coral mortality.

Coral reef practitioners are currently working with government agencies and community groups to assess the situation in Indonesia and monitor the potential impacts on the livelihoods of coastal communities. Naneng Setiasih (Reef Check Foundation Indonesia [RCFI] Chairwoman), Dr Joanne Wilson

(Deputy Director of Science from The Nature Conservancy's Indonesia Marine Program [TNC-IMP]) and Dr Stuart Campbell (World Conservation Society [WCS]) Indonesia's Marine Director) further emphasized the urgent need for reef managers to implement programmes aimed at reducing and minimizing existing threats to coral reefs to enhance their ability to recover from the bleaching. Coral reefs in Indonesia are already under stress from overfishing, destructive fishing practices, anchor damage, coral mining, pollution, sedimentation and reclamation of reefs associated with coastal development, and such reefs may be more susceptible to coral bleaching. RCFI, TNC-IMP and WCS are working together to identify areas that may be more resilient to bleaching with the aim to include such resilient areas within marine protected areas as a strategy to address climate change. In addition, since 2007, the partnership has initiated a bleaching network in Indonesia to compile reports and studies about bleaching and reef resilience in the face of climate change.

4. Malaysia

Compiled: Affendi Yang Amri (University Malaya)
Kee Alfian (Universiti Kebangsaan Malaysia)

The earliest bleaching report for Malaysia was in March 2010 for Pulau Tioman, situated along the east coast of Peninsular Malaysia following which, the Department of Marine Parks in Peninsular Malaysia partnered various universities and NGOs to monitor the status of the coral reefs in response to elevated SSTs in the South China Sea and Andaman Sea.

Preliminary data indicate severe bleaching at reefs along the eastern coast of Peninsular Malaysia, with 75% to 90% bleaching reported at Pulau Tioman, Pulau Tinggi and Pulau Sibu. Bleaching severity at Pulau Payar along the western coast of Peninsular Malaysia ranged from medium to high, while the bleaching severity at reefs within the East Malaysian state of Sabah was assessed as medium. Bleaching generally affected all zooxanthellate taxa, including hard corals, soft corals, zoanthids, sea anemones and giant clams, and extended to 20m to 25m depth for the deeper reefs at Pulau Tioman and Sabah.

The bleaching impact along the eastern coast of Peninsular Malaysia is considered more severe than the 1998 event, prompting the Department of Marine Parks to take unprecedented action to close 12 dive sites within three marine parks between July and October 2010 to allow bleached corals to recover (Jabatan Taman Laut Malaysia, 2010).

5. Myanmar

Currently, no information (including anecdotal) on the bleaching event is available for Myanmar's coral reefs, largely concentrated within the Myeik or Mergui Archipelago. However, given its proximity to affected coral reefs in Thailand and the similar SST occurrences within the general area, similar high severity coral bleaching is likely.

6. Philippines

Information obtained from the Philippine Coral Bleaching Watch website and summarized by the authors

The first signs of coral bleaching in the Philippines began in late May 2010, as elevated SSTs began to move into the South China Sea. Researchers from The University of the Philippines and De La Salle University are currently assessing the bleaching condition in the country. An online moderated bleaching monitoring group was created in May 2010 to provide a platform for bleaching report submissions for the Philippines. From mid May to mid November 2010, 53 reports were submitted, with 45% (or 24 reports) classified as verified submissions. The verified reports are mostly non-quantitative in nature, and although numerous anecdotal reports and news articles indicate severe bleaching in many affected areas, the current available data are classified as unknown in the regional bleaching map. There are growing concerns among reef scientists that the affected reefs may not recover well, with recent reports indicating outbreaks of COTs that are further devastating the impacted reefs.

Online news articles report at least eight areas where the coral bleaching is severe - the towns of Nasugbu, Lian, Bauan, Mabini, Lobo and Calatagan in Batangas, Calapan in Oriental Mindoro, and Pagbilao in Quezon. In addition, other reports indicate bleaching in Puerto Galera, Lubang Island, Bolinao, Batangas, Iloilo and other parts of Palawan, besides El Nido (Alave, 2010).

7. Singapore

Compiled: Karenne Tun (DHI Water & Environment)
Chou Loke Ming (National University of Singapore)
Jeffrey Low (National Park Board)

The first observations of mass bleaching on Singapore reefs were reported in May 2010. Preliminary rapid visual assessment by scientists from the National University of Singapore, the National Parks Board and DHI Water & Environment (S) Pte Ltd indicated moderate to severe bleaching in all reefs and across all reef zones. Bleaching specific quantitative surveys were conducted at four sites in May with a second survey conducted in November 2010 and a third survey planned in the first quarter of 2011 to assess recovery. Besides hard corals, bleaching was also recorded in other zooxanthellate taxa including soft corals, anemones and zoanthids.

Data indicate that bleaching severity was highest within the inter-tidal reef flat zones, with almost complete bleaching of all hermatypic taxa. Within the sub-tidal zones, hard coral bleaching was variable, ranging from 30% to 60% between the four sites surveyed. In addition, only 5% to 30% of the bleached corals were completely bleached (white), with most bleached corals retaining some colour within their tissues. Data are still being collected and analysed to assess the hard coral bleaching response, but preliminary assessments indicate that *Acropora* corals were the only group that did not bleach throughout the elevated SST period. Among the other hard coral genera, bleaching response was largely variable, but with some indications that the long-tentacled corals (eg, *Euphyllia* spp.), bubble coral (eg, *Physogyra* spp.) and corals with long polyps (eg., *Goniopora* spp.) were less affected by the bleaching than the foliose and massive coral species.

By the second survey in October-November 2010, SSTs had begun to cool and return to normal seasonal levels, with bleached corals showing rapid recovery, regaining much of their colour. Bleaching-associated mortality was estimated at less than 10%, although many bleached corals showed varying degrees of partial mortality. Mortality was generally higher for soft corals and zoanthids, but sea anemones recovered well from the bleaching. The magnitude and severity of the 2010 bleaching event was comparable to the 1998 event, with preliminary data indicating similar mortality and initial recovery rates.

8. Thailand

Compiled : Thamasak Yeemin (Marine Biodiversity Research Group, Ramkhamhaeng University, Thailand)
Niphon Phongsuwan (Phuket Marine Biological Center)

Elevated SSTs of between 30-34˚C were recorded during March and June 2010 within the Andaman Sea and the Gulf of Thailand. The Department of Marine and Coastal Resources, in collaboration with Thai universities and NGOs conducted several reef surveys in both regions and reported widespread and severe coral bleaching of over 80% within all reefs throughout every province. Bleaching in the Andaman Sea was more severe and extensive than in the Gulf of Thailand, with the inner Gulf of Thailand exhibiting the lowest bleaching impact. The most susceptible were *Acropora* spp. and *Pocillopora* spp. Coral mortality following the bleaching event is estimated at about 50-90% within the Andaman Sea, and between 5-50% within the Gulf of Thailand. Some coral species, especially *Porites lutea*, showed good recovery, with an estimated 50-75% of bleached individuals expected to recover in the Andaman Sea. It is estimated that the 2010 bleaching event is similar in extent but with greater severity than the 1998 bleaching event within the Gulf of Thailand, but greater in extent and severity within the Andaman Sea.

A general assessment of the bleaching indicated that within areas where environmental factors were good and coral diversity high with large numbers of colonies, corals were mostly partially bleached with numerous unbleached corals within the same area. In the Andaman Sea , reefs on the eastern coast of the islands showed greater impact than reefs on the western coast, which are subjected to internal waves and generally stronger wave action. Within turbid areas with high water flow, coral colonies showed resistance to bleaching. It is possible that within these areas, reduced light penetration contributed to the overall reduction in the combined temperature/light stressors that induced bleaching. Among hard coral species, there was a mixed response to bleaching, with *Diploastrea heliopora, Heliopora coerulea and Pavona decussata* showing greatest resistance to bleaching. In addition to hard corals, other zooxanthellate taxa including soft corals, zoanthids and giant clams were also bleached.

In January 2011, the National Parks, Wildlife and Plant Conservation Department temporarily closed 18 popular dive sites located in seven marine national parks as a precautionary management measure to reduce diver related impacts and allow the severely bleached corals to recover.

9. Timor-Leste

No information on the bleaching event is available for the coral reefs of Timor-Leste. However, given its proximity to the Kupang Bay within the adjacent Pulau Tmor in Indonesia and the similar SST occurrences within the general area, similar medium severity coral bleaching is likely.

10. Viet Nam

Compiled by Nguyen Van Long (Institute of Oceanography) and
Vo Si Tuan (Institute of Oceanography)

Quantitative surveys using the line transect point method with additional bleaching attributes were conducted at 5 areas by scientists from Institute of Oceanography; Phu Quoc, located in the Gulf of Thailand, Van Phong, Nha Trang, Cam Ranh and Ninh Hai, located in the south-central Vietnam. Bleaching severity was assessed as low in south-central Vietnam while reefs in the Gulf of Thailand showed medium severity in response to elevated SSTs. Bleaching was recorded to depths of between 8 to 10m, and affected hard corals, soft corals and sea anemones. Hard coral taxa showed a mixed response; within south-central Vietnam, *Acropora* spp. had the greatest bleaching severity while *Hydnophora* spp., *Montipora* spp., *Acropora* spp., *Pavona* spp. and *Porites* spp. were the most bleached genera at Phu Quoc, within the Gulf of Thailand.

No data were available from the 1998 bleaching event to compare with. On average, SSTs recorded in Phu Quoc were higher than areas within south-central Vietnam. Full recovery of surviving bleached corals is expected at reefs in south-central Vietnam while partial recovery is expected at reefs in the Gulf of Thailand.

CONCLUSION

The 2010 bleaching event in Southeast Asia is believed to be more severe than the 1998 event in many areas, which resulted in an estimated 18% mortality of the bleached corals. Initial bleaching-related mortality in 2010 ranged from < 10% in Singapore to over 60% in Thailand's Andaman Sea with possibly similar estimates for some areas in Indonesia and the Philippines. Despite the severe bleaching reported in many areas across the region, reefs in Manado in northeastern Sulawesi and within the central Raja Ampat were spared with no reported bleaching within these areaa. Bleaching within West Papua was also reported to be low.

There are growing concerns however that affected reefs may not recover well, with recent reports in the Philippines indicating outbreaks of Crown-of-Thorns starfish that are further devastating already impacted reefs. In Cambodia, recent monsoon rains intensified runoff from land and the elevated sediment load added more stress to the bleached corals, impeding their recovery.

NOAA CRW predictions indicate that SSTs in Southeast Asia will continue to cool in the coming months from January 2011. Monitoring efforts are expected to continue within the region in 2011, and should provide a clearer picture of realized impacts from the 2010 bleaching event in Southeast Asia.

A large proportion of the available data used in this report was based on single surveys/assessments and more data are still being collected and analysed in many countries. Although the report presents a general picture of the 2010 bleaching event, individual country summaries are largely incomplete. Detailed country reports are expected to be available in the later part of 2011 that will provide better insights into the 2010 bleaching event.

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1.2 IMPACT OF BLEACHING IN 2010 – A CASE STUDY IN THAILAND –

Status of coral reefs in Thailand following the 2010 coral bleaching event

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ABSTRACT

Thailand harbors approximately 153 km^2 of coral reefs along its total coastline of 2,614 km and over 300 relatively small islands. Four distinct zones with different oceanographic conditions are recognized, 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. There are three reef types in Thai waters: coral communities with no true reef structure; developing fringing reefs; and early formation of fringing reefs. The 1998 coral reef bleaching event severely affected coral reefs in the Gulf of Thailand. Some reefs showed a declining trend in live coral cover, but other sites exhibited slight increases of live coral cover. However the 2010 coral bleaching event caused coral degradation that was more severe and extensive in the Andaman Sea than in the Gulf of Thailand, with the inner Gulf of Thailand exhibiting the lowest bleaching impact. This paper also provides updated biodiversity data for Thai coral reefs, lessons learned from the Mu Koh Chang Coral Reef Demonstration Site under the UNEP/GEF Project on Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand; a sustainable model for resource management and protection achievable through empowering local communities and businesses in Koh Tao, western Gulf of Thailand; Thailand's Coral Reef Restoration Plan; and includes a perspective for coral reef management under the coral bleaching crisis.

Recommendations for coral reef management under the coral bleaching crisis are to; 1) prevent coral damage from snorkeling in the shallow reefs; 2) prevent illegal fishing in coral reefs; 3) prevent sediment loading from coastal development; 4) prevent wastewater discharge from boats and land-based activities to coral reefs; 5) revise public relation plans and tourist activities at particular sites, such as temporary closure, limited number of divers, controlled activities; 6) establish new diving sites in order to reduce the impacts on natural reefs; 7) conduct research and monitoring program for coral conservation and restoration; 8) inform people and tourists concerning status of coral bleaching; 9) provide sufficient man-power and budget to relevant government agencies, especially Department of National Parks, Wildlife and Plant Conservation, National Research Council of Thailand, Department of Marine and Coastal Resources, Thailand Research Fund, and corporate social responsibility projects of private companies for conservation, research, management and restoration of coral reefs; 10) issue appropriate regulation for coral reef conservation and strong support to implement projects under the national coral reef management plan; and 11) establish effective networks of universities, government agencies, province offices, local administration offices, NGOs, private companies, and conservation groups.

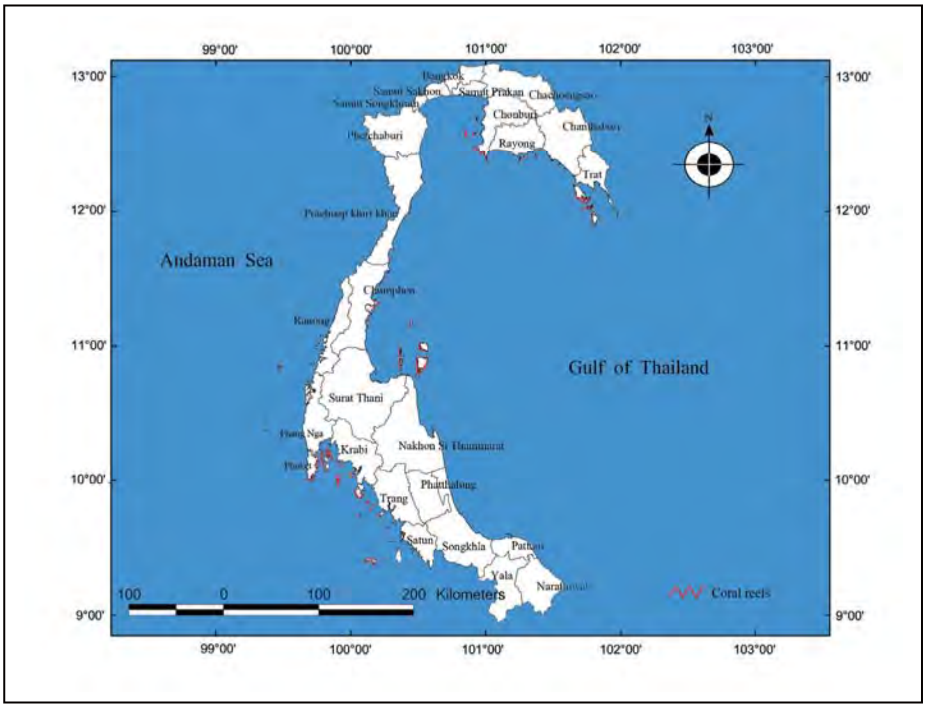


Fig. 1.2.1 Map showing coral reef distribution in Thailand.

INTRODUCTION

Thailand harbors approximately 153 km^2 of coral reefs along its total coastline of 2,614 km and over 300 relatively small islands. Four distinct zones with different oceanographic conditions are recognized, 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) (Fig. 1.2.1). There are three reef types in Thai waters: coral communities with no true reef structure; developing fringing reefs; and early formation of fringing reefs. The 1998 coral reef bleaching event severely affected coral reefs in the Gulf of Thailand. Some reefs showed a declining trend in live coral cover, but other sites exhibited slight increases of live coral cover. However the 2010 coral bleaching event caused coral degradation that was more severe and extensive in the Andaman Sea than in the Gulf of Thailand, with the inner Gulf of Thailand exhibiting the lowest bleaching impact. In general, the main threats to coral reefs include: overfishing, destructive fishing, eutrophication, sedimentation, coastal development, unsustainable tourism and coral bleaching.

UPDATED BIODIVERSITY DATA

A total of 77 taxa of seaweeds with 10 new records for Thailand and one species new to science are reported (Coppejans et al., 2010). This represents one third of the reported seaweed species of Thailand, indicating the importance of the Mu Koh Samui in the Gulf of Thailand. This checklist is also a significant contribution to the overall inventory of seaweeds in the Indo-west Pacific region.

Invertebrate biodiversity on coral reefs in Thai waters is summarized in ONEP (2008) as follows:

- Prosobranchia 805 species
- Opisthobranchia 134 species
- Bivalves 625 species
- Cephalopods 77 species
- Shrimps, prawns and lobsters 68 species
- Crabs 108 species
- Sea feathers 39 species
- Sea stars 69 species
- Brittle stars 112 species
- Sea urchins 67 species
- Sea cucumbers 94 species

Putchakarn (2006) reported 57 species of demosponges from 8 orders and 29 families, including two new species, i.e., *Cladocroce burapha* Putchakarn, De Weerdt, Sonchaeng & Van Soest, 2004 and *Plakina* sp. nov. Eight species were new records in the South China Sea; namely *Plakina monolopha*, *Plakina* sp. nov., *Craniella abracadabra* De Laubenfejs, *Tetila japonica* Lampe, *Terpios granulosa* Bergquist, *Clathria* (Microciona) *anonyma* Burton, *Dragmacidon australis* (Bergquist) and *Cladocroce burapha* Putchakarn et al. Thirty two species were new records in Thai waters.

Satapoomin (2007) reported that coral reef fishes in Thai waters consisted of about 400 species in the Gulf of Thailand and 880 species in the Andaman Sea (Table 1.2.1).

Table 1.2.1 Comparison of reef fish biodiversity in the Gulf of Thailand and the Andaman Sea.

Family	Gulf of Thailand		Andaman Sea	
	No. of Genera	**No. of Species**	**No. of Genera**	**No. of Species**
Acanthuridae	1	1	4	31
Aulostomidae	-	-	1	1
Balistidae	1	1	8	15
Chaetodontidae	5	7	6	37
Cirrhitidae	-	-	3	3
Holocentridae	2	2	3	12
Labridae	13	29	24	69
Malacanthidae	-	-	2	4
Mullidae	2	2	3	10
Muraenidae	2	4	6	28
Pomacanthidae	2	3	5	13
Pomacentridae	15	40	17	62
Scaridae	2	10	6	20
Serranidae	7	24	14	46
Zanclidae	-	-	1	1

Source: Satapoomin (2007)

STATUS OF CORAL REEFS

Before the 2010 bleaching event

The data obtained from long-term coral reef monitoring programs show different trends between the Andaman Sea and the Gulf of Thailand. Comparison of coral reef condition between the periods 1995-1998 and 2006-2008 showed improvements in the Andaman Sea but a decline in the Gulf of Thailand (Fig. 1.2.2).

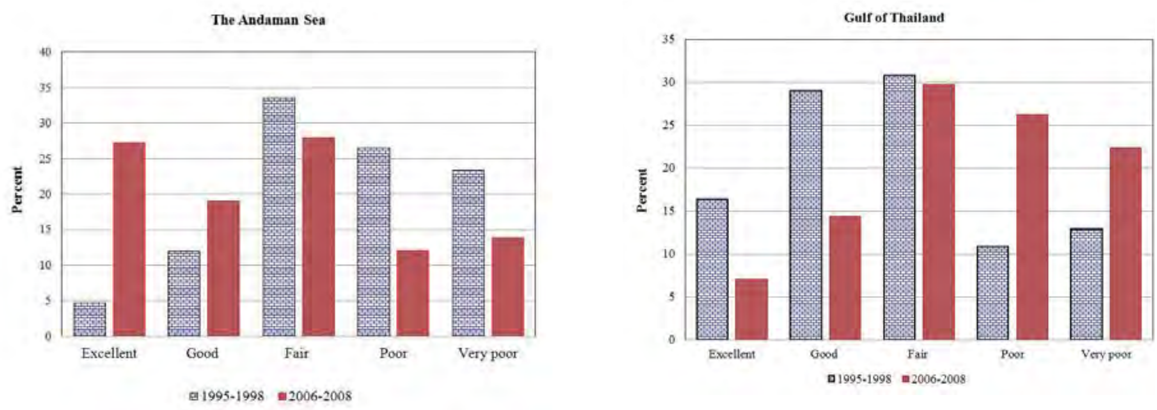


Fig.1.2.2 Condition of coral reefs in the Andaman Sea and the Gulf of Thailand in the periods 1995-1998 and 2006-2008 (PMBC, 2011)

Coral diseases

Pink syndromes were examined on coral communities at Ao Nuan, south of Koh Lan, Chonburi Province in January 2010 (Donsomjit and Yeemin, 2010). The study site is a popular tourist destination in Thailand. The pink syndromes recorded in this study were identified by macroscopic characteristics. The field surveys revealed that most *Porites lutea* colonies exhibited partial mortality which were probably caused by borers, grazers, competitors, encysted parasitic trematodes and some coral diseases. Four types of pink syndrome on *P. lutea* were documented, i.e., pink spot, pink circle, pink patch and pink tumor. Pink circle was the most prevalent syndrome in 60.28% of coral colony numbers, while pink patch and pink tumor were rarely observed, 4.11% and 1.37%, respectively (Fig.1.2.3).

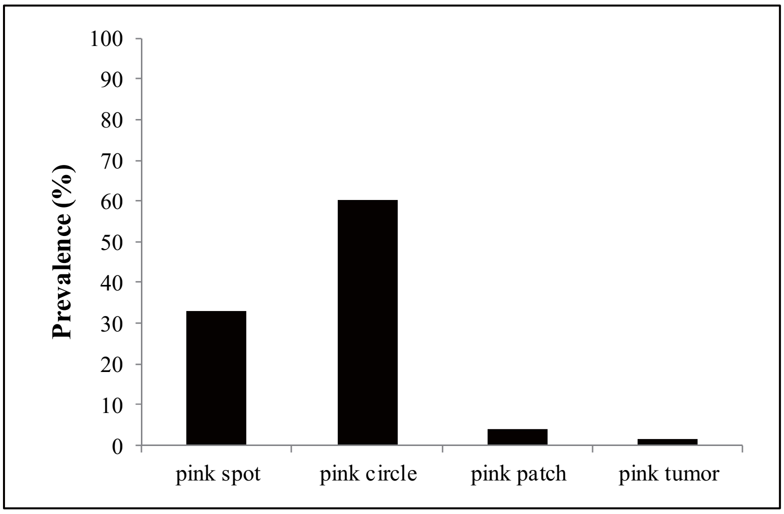


Fig.1.2.3 Pigmentation responses in *Porites lutea* at Koh Lan

The severe coral bleaching event 2010

Average seawater temperature recorded in the inner Gulf of Thailand by data loggers on 8 April 2010 was 31.06±0.23°C and it continued to rise to the maximum on 10 May 2010 (32.70±0.31). However, the average seawater temperatures began to decrease on 27 May 2010 (31.77±0.08) and reached the normal temperature on 2 August 2010 (30.56±0.07) as shown in Fig.s 1.2.4 and 1.2.5 (Pengsakun and Yeemin, 2010).

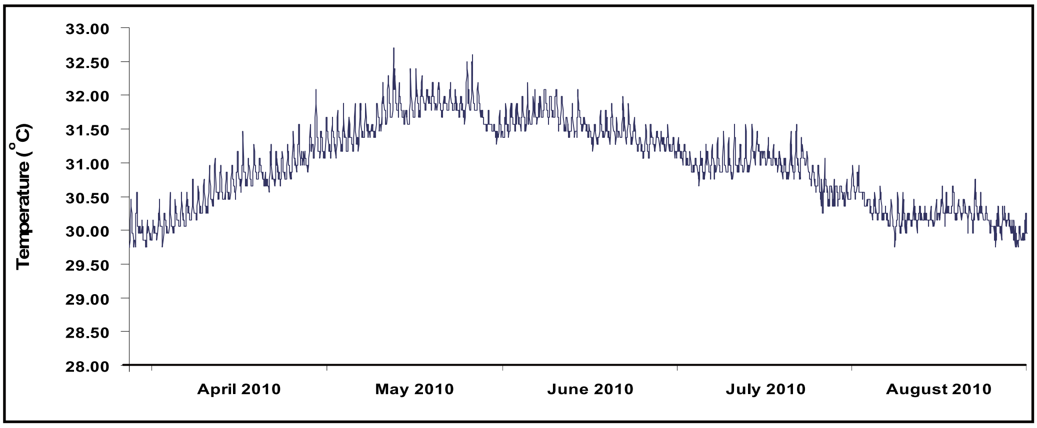


Fig.1.2.4 Seawater temperature recorded by a data logger at Khrok Island, the inner Gulf of Thailand.

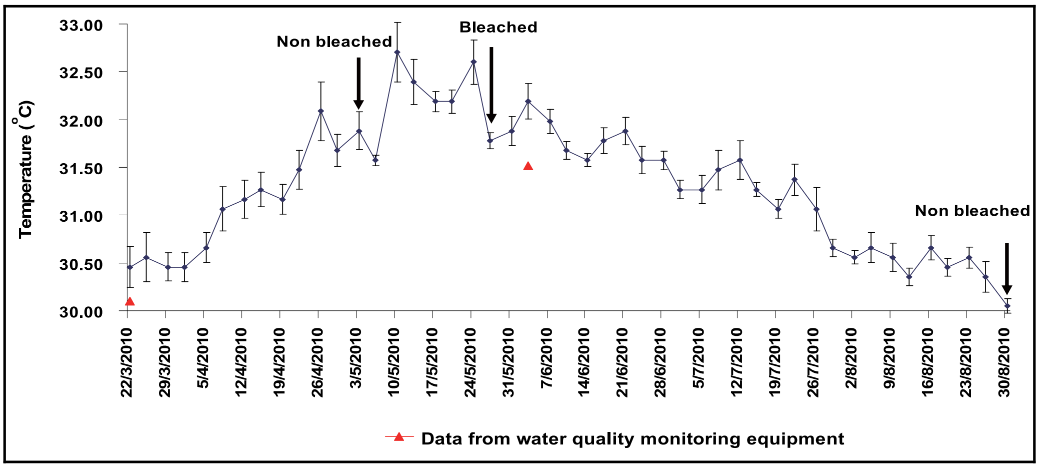


Fig.1.2.5 Seawater temperature anomalies recorded by a data logger at Khrok Island, the inner Gulf of Thailand

The surveys during the 2010 coral bleaching event showed that coral bleaching in the Andaman Sea was more severe and extensive compared to the Gulf of Thailand. The inner Gulf of Thailand exhibited the lowest bleaching extent and severity (Fig. 1.2.6). The most susceptible coral species were *Acropora* spp. and *Pocillopora* spp.

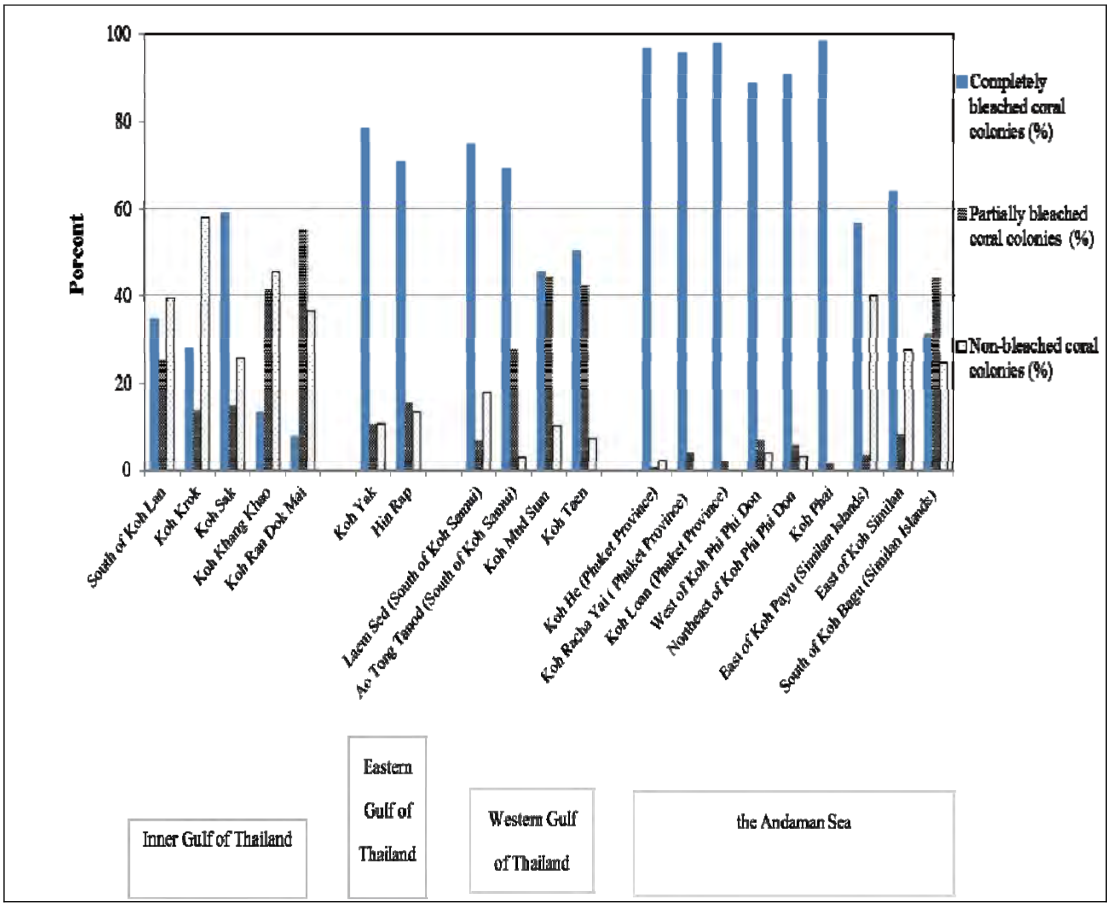


Fig.1.2.6 Coral bleaching in the Andaman Sea and the Gulf of Thailand

The intensive study of bleaching impacts on scleractinian corals at Hin Rap, Trat Province, eastern Gulf of Thailand revealed that a few months after the onset of high seawater temperature anomalies in 2010, over 90% of coral species in the study sites were affected by bleaching, and mortality was about 23% of coral species (Sutthacheep et al., 2010). There were many differences in bleaching response among coral species. *Pavona decussata* and *Oulastrea crispata* were unaffected by bleaching, while *Acropora* spp., *Pocillopora damicornis, Psuedosiderastrea tayami*, *Herpolitha limax, Favites halicora, Goniastrea retiformis* and *Goniastrea pectinata* were relatively highly susceptible. *Pocillopora damicornis* was the most susceptible coral species, with 93% of partial mortality (Table 1.2.2).

Coral reefs and coral restoration sites in Trat Province were among areas severely impacted. The bleaching and subsequent mortality of transplanted corals and juvenile coral colonies on a coral reef restoration site at Koh Kra, Trat Province, the eastern Gulf of Thailand were examined (Sutthacheep et al., 2010). The coral reef restoration site was initiated in March 2007 by using a simple cement block model to provide artificial substrate for coral recruitment and attaching coral fragments collected from the reefs nearby. There were three species of coral recruits on the cement blocks, i.e., *Porites lutea, Pocillopora damicornis* and *Pavona* sp., with an average density 3.8 colonies/m^2. All *Pavona* sp. and *P. damicornis* recruits bleached while 23% of *P. lutea* recruits showed no sign of bleaching. Attached fragments of *Acropora nobilis* and *A. florida* grew well on the artificial substrates, with live coral cover increasing about 120 – 150% in three years. All transplanted *A. nobilis* and *A. florida* died after the severe coral bleaching phenomenon.

Table 1.2.2 Bleaching and mortality of coral species at Hin Rap, Trat Province, eastern Gulf of Thailand

Species	Bleached colony (%)	Pale colony (%)	Partial mortality colony (%)	Unbleached colony (%)
Acropora spp.	88.89	11.11	0	0
Astreopora myriophthalma	25.00	75.00	0	0
Pocillopora damicornis	7.14	0	92.86	0
Plerogyra sinuosa	50.00	0	0	50.00
Pseudosiderastrea tayami	100.00	0	0	0
Psammocora haimeana	12.50	87.50	0	0
Pavona decussata	0	0	0	100.00
Herpolitha limax	100.00	0	0	0
Fungia sp.	50.00	0	0	50
Lithophyllon undulatum	75.00	0	25.00	0
Turbinaria bifrons	41.67	25.00	0	33.33
Turbinaria mesenterina	53.85	46.15	0	0
Turbinaria frondens	66.67	25.00	8.33	0
Favia favus	62.50	37.50	0	0
Barabattoia amicorum	83.33	0	16.67	0
Favites halicora	87.50	12.50	0	0
Goniastrea retiformis	100.00	0	0	0
Goniastrea pectinata	100.00	0	0	0
Platygyra daedalea	75.00	25.00	0	0
Oulastrea crispata	0	0	0	100.00
Leptastrea purpurea	25.00	0	0	75.00
Porites spp.	74.32	12.68	1.00	12.00

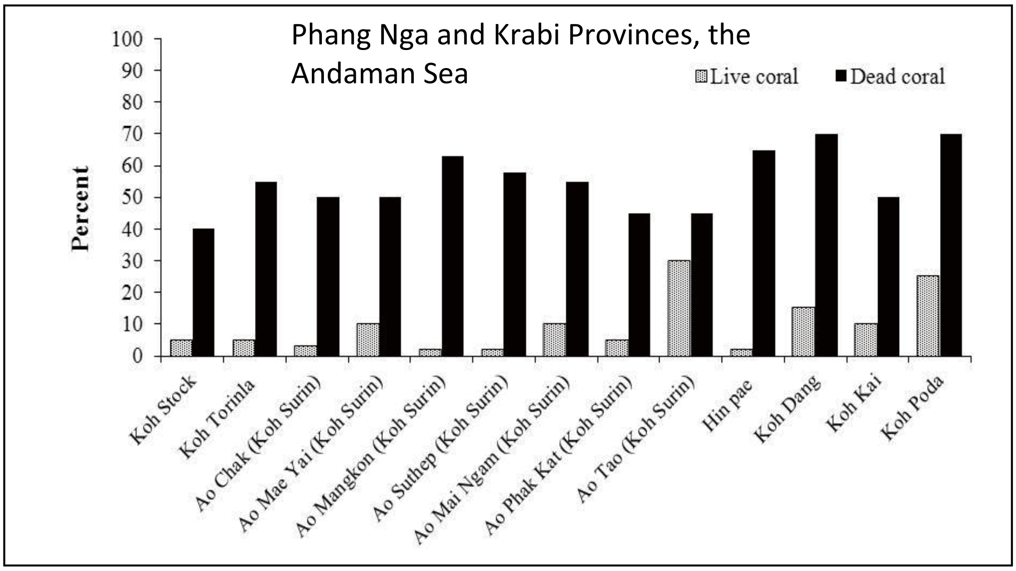
Bleaching of other organisms

A quantitative study on the extent of bleaching in a dominant giant clam *Tridacna maxima* on coral reefs of Phi Phi Islands, Krabi Province, in the Andaman Sea during the severe mass coral reef bleaching event in 2010 was carried out (Saengmanee and Sutthacheep, 2010). The surveys revealed that there were no healthy giant clams at the study sites. All giant clams were affected by the coral reef bleaching event but the impacts varied greatly. Three categories of the giant clams were observed, i. e., recently dead, mostly bleached and partially bleached. Over 70% of giant clams partially bleached while about 25% were mostly bleached.

All colonies of the zoanthid, *Palythoa caesia* at Koh Sak, the inner Gulf of Thailand were also impacted from the bleaching event. Half of the zoanthid colonies had lost their zooxanthellae from over 90% of the colony surface area. Over 80% of *P. caesia* colonies were severely bleached. The results revealed that all colonies were bleached over 50% of their colony surface areas. The dynamic relationship between *P. caesia* and its zooxanthellae in the Gulf of Thailand is required for further studies (Saenghaisuk et al., 2010).

Condition of Coral Reefs Following the 2010 Coral Bleaching Event

Coral mortality following the bleaching event ranged 20-90% for the Andaman Sea, 10-50% for the inner Gulf of Thailand, 10-60% for the eastern Gulf of Thailand and 45-65% for the western Gulf of Thailand. Some coral species, especially *Porites* spp., showed a recovery trend (Fig.1.2.7-Fig.1.2.11).



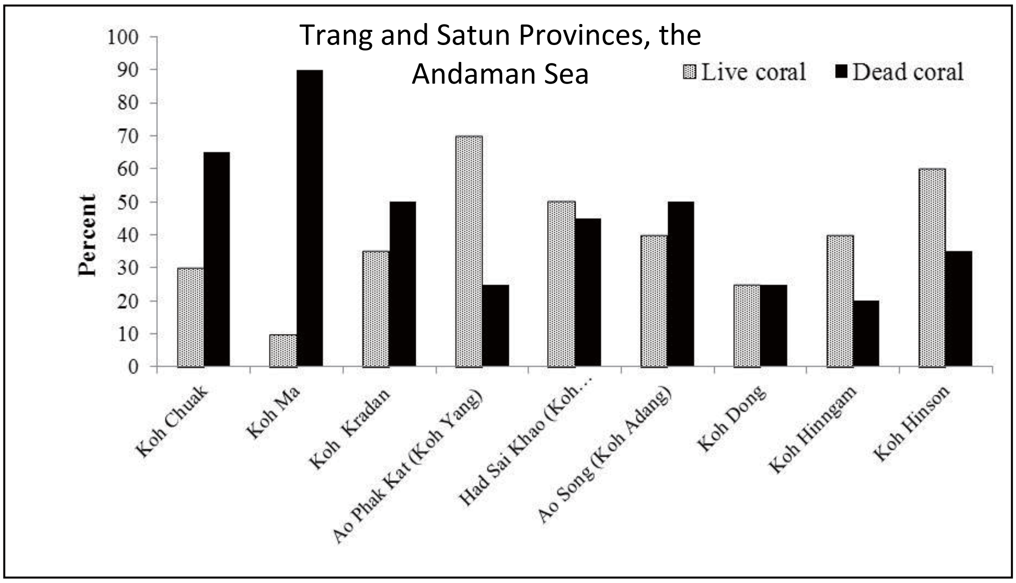


Fig.1.2.7 Conditions of coral reefs in the Andaman Sea following the 2010 bleaching event. Phang Nha and Krabi Province (above) and Tran and Satun Provice (below).

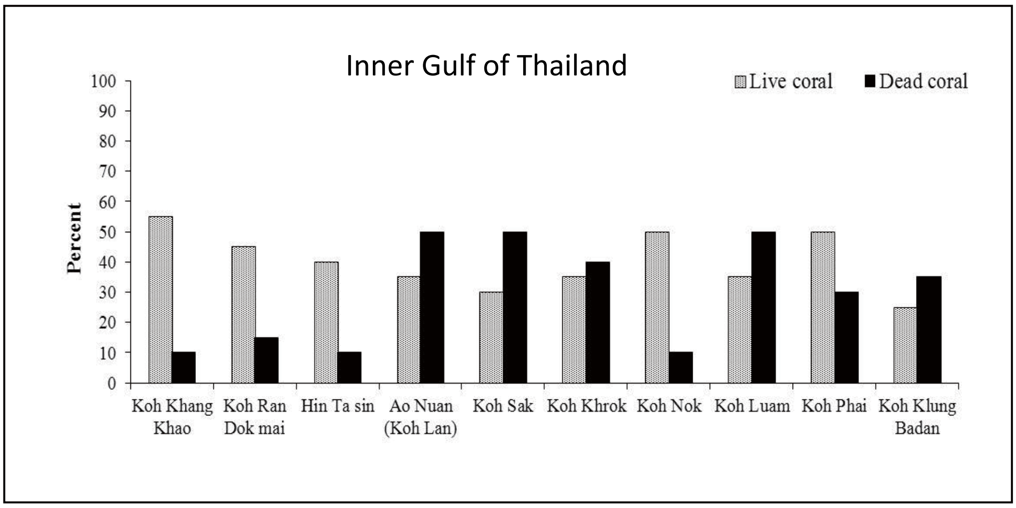


Fig.1.2.8 Conditions of coral reefs in the inner Gulf of Thailand following the 2010 bleaching event.

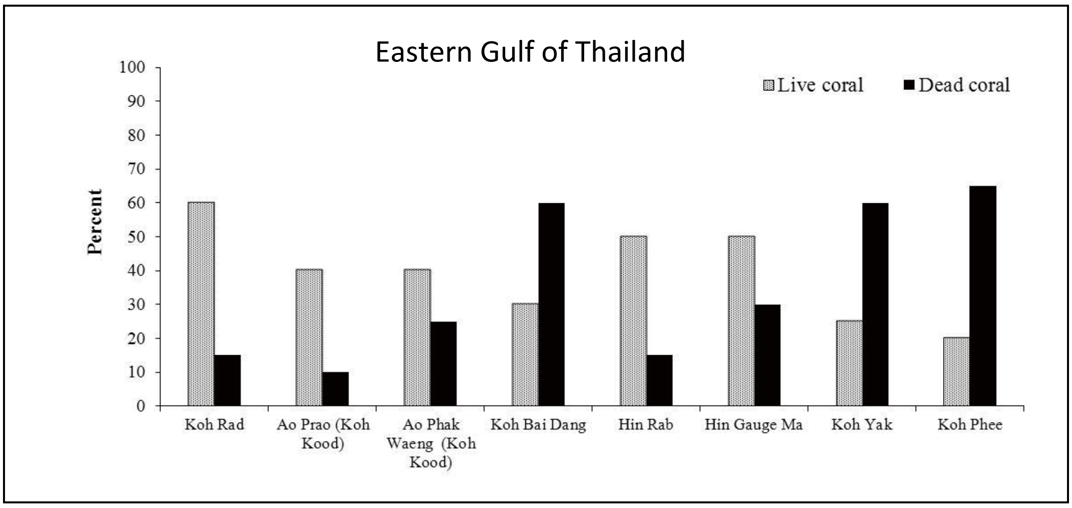


Fig.1.2.9 Conditions of coral reefs in the eastern Gulf of Thailand following the 2010 bleaching event.

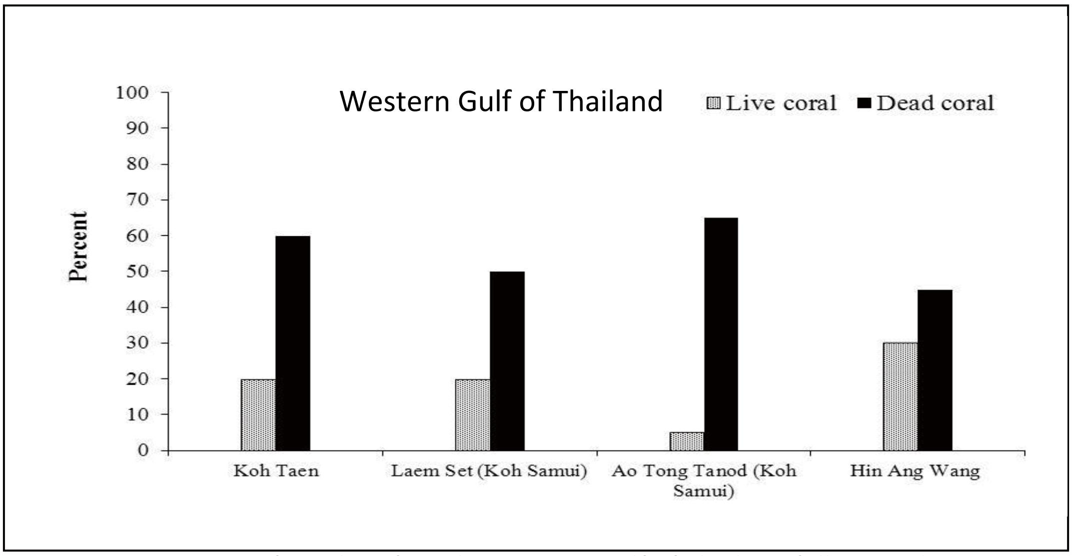


Fig.1.2.10 Conditions of coral reefs in the western Gulf of Thailand following the 2010 bleaching event.

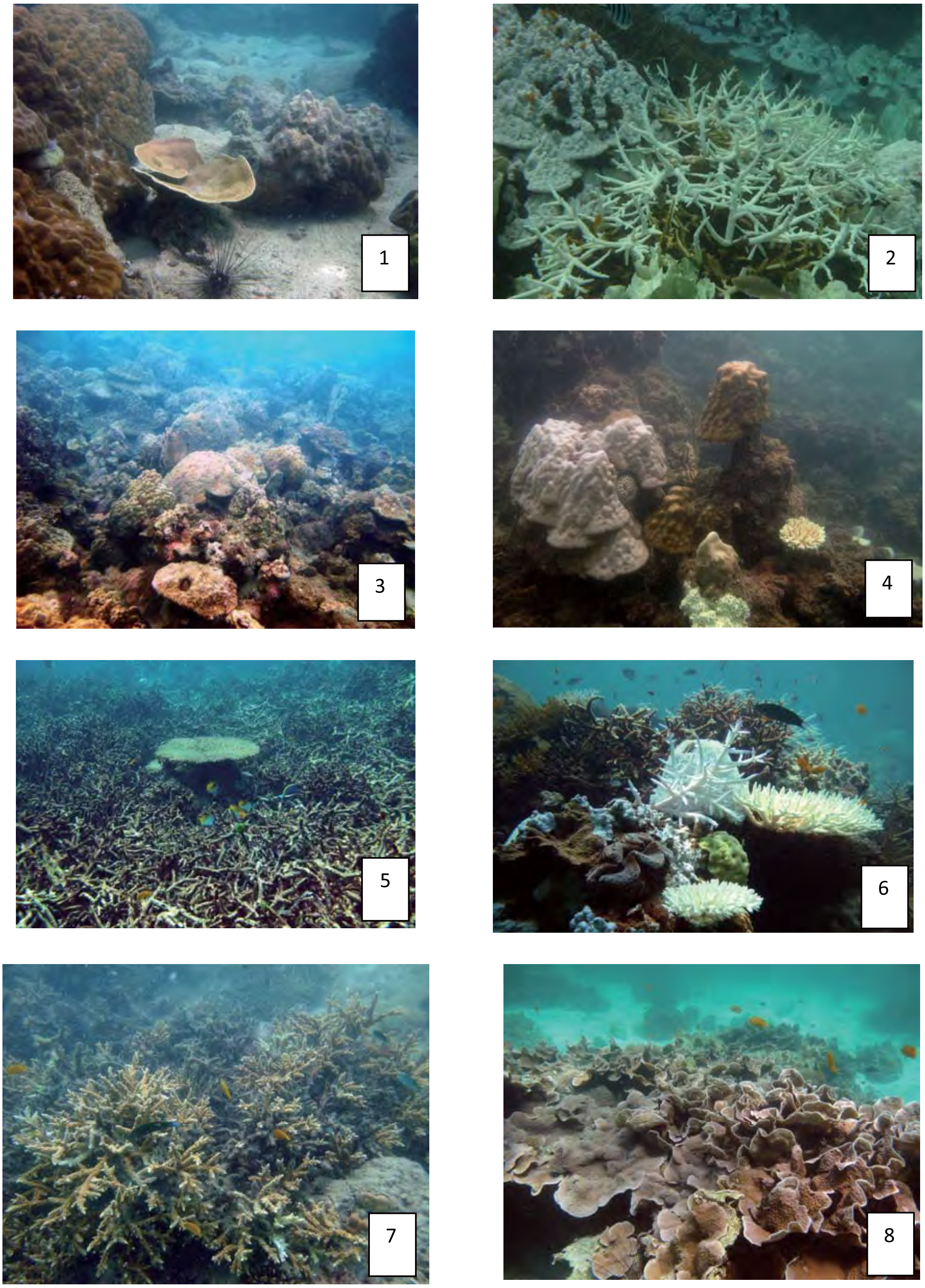
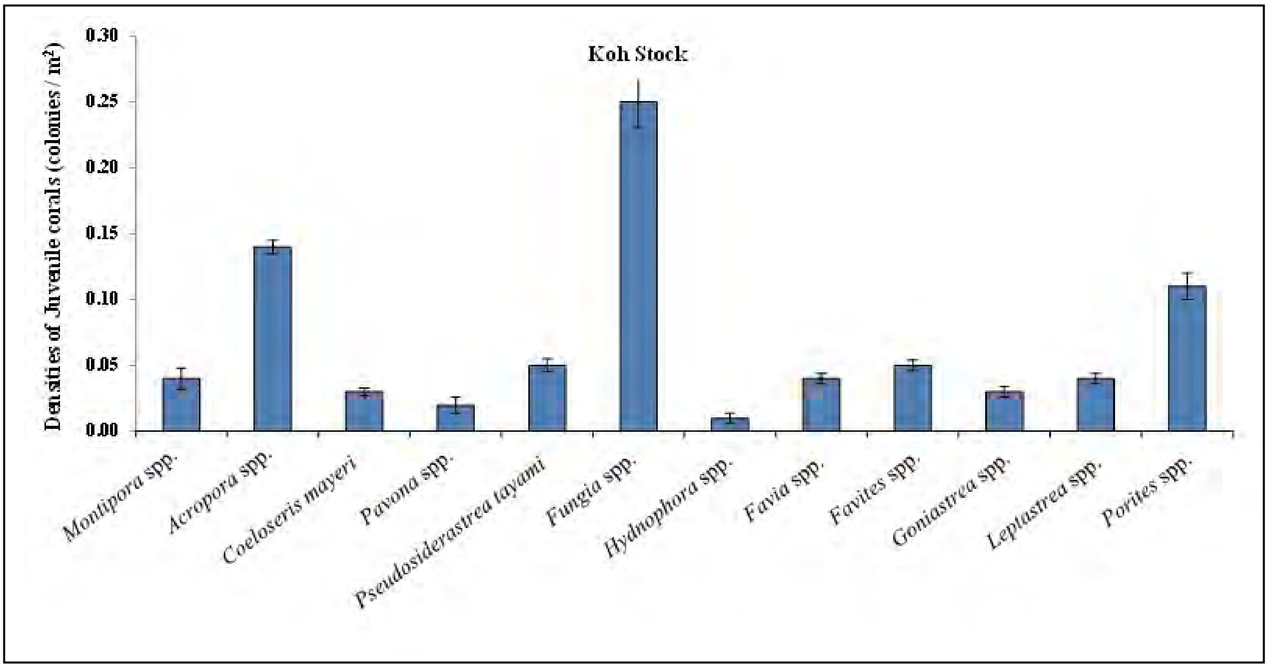


Fig.1.2.11 Coral communities during and after the 2010 coral bleaching event; 1) Koh Lan (GT) after the bleaching; 2) Koh Chang (GT) during the bleaching (GT=Gulf of Thailand); 3) Koh Kood (GT) after the bleaching ; 4) Koh Samui (GT) during the bleaching; 5) Koh Surin (AS) after the bleaching; 6) Koh Phi Phi Don (AS) during the bleaching; 7) Koh Ma(AS) after the bleaching; 8) Koh Yang (AS) after the bleaching (GT=Gulf of Thailand; AS=Andaman Sea).

Coral Recovery Trends

Juvenile coral colonies are an important component of the population dynamics of corals and reef resilience. Densities of juvenile corals varied greatly among the study sites. For example, densities of juvenile corals at Koh Stock following the 2010 coral bleaching event were much higher than those at Koh Daeng (Fig. 1.2.12), thus recovery of coral communities at Koh Stock would require a shorter period of time.



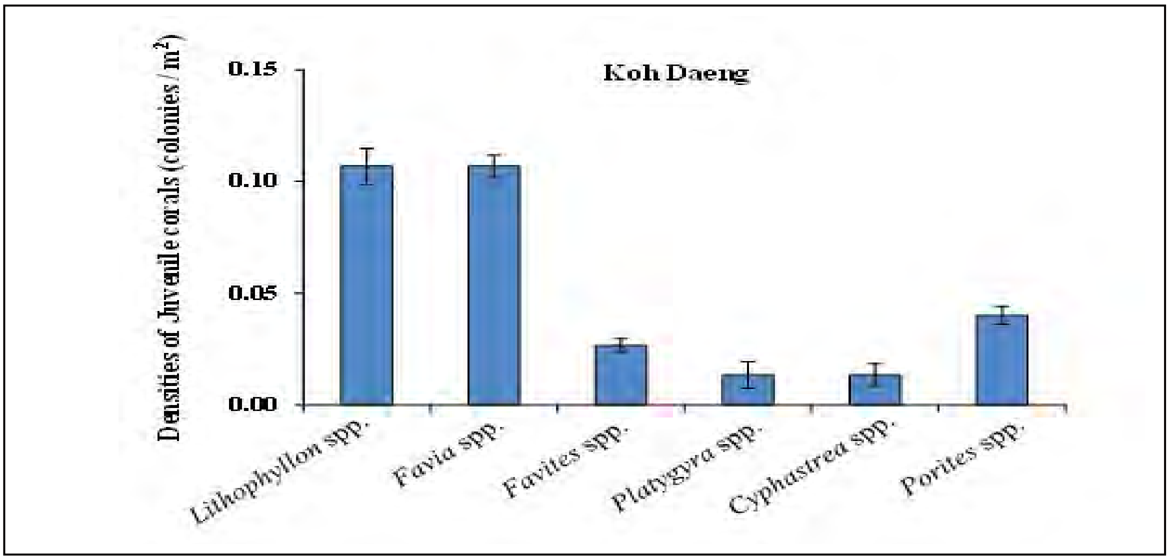


Fig.1.2.12 Juvenile coral densities following the 2010 coral bleaching event at Koh Stock (above) and Koh Daeng (below), the Andaman Sea.

Coral Reef Management under the Coral Bleaching Crisis

Several meetings, seminars and conferences were organized by government agencies, NGOs and universities for solving the coral bleaching problems and providing recommendations for coral reef management. Recommendations for coral reef management under the coral bleaching crisis include the following actions;

1) prevent coral damage from snorkeling in the shallow reefs;
2) prevent illegal fishing in coral reefs;
3) prevent sediment loading from coastal development;
4) prevent wastewater discharge from boats and land-based activities into coral reefs;
5) revise public relation plans and tourist activities at particular sites, such as temporary closure, limited number of divers, controlled activities, etc.;
6) establish new diving sites in order to reduce the impacts on natural reefs;
7) conduct research and monitoring program for coral conservation and restoration;
8) inform people and tourists concerning status of coral bleaching;
9) provide sufficient man-power and budget to relevant government agencies, especially Department of National Parks, Wildlife and Plant Conservation, National Research Council of Thailand, Department of Marine and Coastal Resources, Thailand Research Fund, and corporate social responsibility projects of private companies for conservation, research, management and restoration of coral reefs
10) issue appropriate regulation for coral reef conservation and strong support to implement projects under the national coral reef management plan; and
11) establish effective networks of universities, government agencies, province offices, local administration offices, NGOs, private companies, and conservation groups.

It is necessary to have mechanisms for project implementation under the national coral reef management plan, i.e., establishing a coral reef committee for policy determination, support and evaluation of projects or activities concerning prevention and mitigation of coral reef degradation (under the National Environment Board) and providing regular reports on coral reef status and problems to the cabinet and requesting the cabinet to direct relevant government agencies to implement the proper projects and endorse the National Coral Reef Management Plan.

A list of research needed includes; mechanisms and processes for building reef resilience to coral bleaching, especially coral reef connectivity and social-ecological systems; analysis of long-term data from coral reef monitoring programs for appropriate management; development of indicators for monitoring important ecological processes, such as grazing rate, coral recruitment, and connectivity; biology of introduced organisms on coral reefs, coral bio-eroders and coral diseases; impacts of tourism and fisheries on coral reefs such as sources of sediment on coral reefs and impacts of sewage; stock-recruitment relationships for important species and functional groups; coral reef recovery trends and adaptation; coral symbiosis and coral reef microbes such as genetic diversity of zooxanthellae and microbes, responses of zooxanthellae and microbes to elevated temperature and energy and mass transfer between coral, zooxanthellae and microbes; human dimension on coral reefs such as public awareness on the importance of coral reef, ecosystem services, human impacts on coral reef recovery, alternative artificial reefs for diving, etc.; socio-economic studies on coral reefs such as economic valuation of coral reefs and impacts of degraded reefs on tourism business; economic development, social capital, local history and culture influence resource use and governance systems; assessment of management effectiveness of marine protected areas and networks; maps of coral reef vulnerability and resilience to coral bleaching; coral bleaching monitoring and warning systems including remote sensing applications and coral restoration techniques.

OTHER MANAGEMENT ACTIONS

Recently, central government agencies, provincial governments, local administrative organizations and private sectors have undertaken several projects aimed at improving coral reef conditions through preventive measures, education, public awareness raising and restoration.

◆ ***Mu Koh Chang:*** *Coral Reef Demonstration Site of the UNEP/GEF Project on Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand*

Coral reefs in the Gulf of Thailand support a rich biodiversity of marine organisms and serve as important breeding grounds for species of economic importance in the western part of the South China Sea. However a large area of coral reef is not currently within marine protected areas. One of the specific targets for coral reef management in the South China Sea is that by 2015, at least 70% of the existing area of coral reefs in the target sites be put under an appropriate form of sustainable management. This study provides lessons learned from Mu Koh Chang Coral Reef Demonstration Site under the UNEP/GEF Project on Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand.

The casual chain analysis of coral reef degradation at Mu Koh Chang was carried out during preparatory meetings with stakeholders in the area. The causes of coral reef degradation were identified as being: i) infrastructure development, leading to soil erosion and coastal sedimentation; ii) unplanned expansion of tourism businesses resulting in rapid increase in tourist numbers; iii) unskilled SCUBA divers and snorkelers damaging coral colonies in shallow water; iv) use of anchors by boat operators in reef areas; v) lack of awareness in the local community to the importance of the marine ecosystem to community income from tourism; vi) illegal fishing using chemicals and trawling in prohibited areas and collecting of sea cucumbers and abalones; vii) lack of co-ordination among management agencies; and viii) a lack of manpower and poor law enforcement. The aim of the Mu Koh Chang coral reef demonstration site is to remove or reduce the causes of coral reef degradation through: i) the application of a new model of co-management in the area; ii) restoring certain degraded areas for education and tourism purposes; and iii) assessing the carrying capacity of the reefs for marine based tourism. The project outcomes have highlighted the importance of coordination between and amongst government institutions, the private sector, and local communities in order to promote sustainable tourism development.

Raising awareness of the ecological importance of coral reefs is a crucial output of the project. Public awareness activities have included training for students, tourism operators, government staff and local people on the ecology of coral reefs and how to use these sustainably. Activities to encourage and empower volunteer groups in coral reef conservation were initiated and all activities emphasized stakeholder participation since a high level of public participation is crucial to successful sustainable management. Information has been disseminated using a wide range of methods including radio and television broadcasts, posters and permanent notice boards featuring the coral reefs and coastal resources of Mu Koh Chang. A manual concerning fisheries management and coral reef conservation and a handbook of coral reef and related marine organisms of Mu Koh Chang have also been published. A quarterly Thai Coral Reef Newsletter has been launched and copies are distributed to all stakeholders involved in coral reef conservation both at Mu Koh Chang and throughout Thailand. The webpage "www.thaicoralreef.in.th" provides background to the project, basic knowledge concerning coral reef ecology, a calendar of upcoming events related to coral reef conservation and management and published research papers concerning coral reefs in Thailand.

The demonstration site has established small demonstration sites for coral restoration to raise community and tourist awareness. Each coral restoration site was kept small for ease of control and management for the benefit of tourism, education, public awareness, and research. Natural coral fragments were used in order to increase the survival rate of such fragments that might otherwise be buried. The techniques and methods used were kept simple, using cheap materials available from local suppliers and those that provided a hard substrate for coral recruitment. Four methods are displayed at the sites: i) provision of substrate in the form of pyramids of concrete pipes; ii) attaching branching *Acropora* spp. with screws to PVC pipe frames in the coral nursery area; iii) provision of additional substrate using clusters of concrete blocks to encourage natural coral recruitment; and iv) attaching coral fragments to dead branching corals by means of plastic straps.

Tourism development projects in tropical coastal areas including Thailand frequently result in significant coral reef degradation and unsustainable benefits to local communities. Studies on carrying capacity of tourism sites are critical in order to undertake sustainable tourism planning. An estimated 30% of the coral reef areas are within the jurisdiction of Mu Koh Chang National Park which was established in 1982. The Thai Government also declared Mu Koh Chang a special administrative zone for sustainable tourism development in 2002, as an area having special or unique tourism features and identified as a new tourism destination in Thailand. Most tourists who visit Mu Koh Chang are involved in marine aquatic sports and activities such as snorkelling and SCUBA diving. The number of visitors in 2007 was approximately one million, four times the number in 2003. In order to develop guidelines and measures to control the number of visitors and prevent tourism damage to the natural environment, a study was undertaken to determine the ecological, physical, facility, and psychological carrying capacity of Mu Koh Chang. For the ecological carrying capacity, the national park conservation targets were taken as relative impact indicators, and existing visitor use correlated with existing ecological impacts. The study identified the carrying capacity type that limited the recreation use of each site and the recommendations have been taken into account in planning further development. This enabled identification of an appropriate tourist user fee for visitors to the site. These fees are being used to support and sustain coral reef conservation interventions at the site.

A mooring buoy sub-committee has been established under the Mu Koh Chang National Park Committee to agree on the location of mooring buoys. The committee is composed of boat and dive operators and encourages use of such buoys to prevent anchor damage to sensitive corals. Mooring buoys were installed at sensitive sites. An underwater snorkel trail has been established and mapped with a plastic guide highlighting points of interest along the trail. Underwater guides to the corals, fish and marine benthos of Mu Koh Chang have also been produced.

Changing past practices and developing alternative income sources for fishermen in Mu Koh Chang and its vicinity were particularly focused on. In order to reduce the overall pressure from fishing and use of illegal gears, local fishermen were trained in more sustainable livelihoods such as mariculture and as diving guides and tour boat operators. A local guide centre was established enabling visitors to contact and directly engage local boats and dive operators and this has increased significantly the income of small boat operators. At the same time visitors have gained insight into sustainable management activities being undertaken in the area.

The project sought to encourage collaboration and coordination among government agencies, private sector enterprises, NGOs, and local communities during planning, operation and evaluation of all activities in order to strengthen co-management. Natural resource management in Thailand tends to be through centralized management by government agencies with little decentralization of authority or control. Management of sustainable tourism at Mu Koh Chang, falls under the responsibility of several government entities each of which has its own management body, with little co-ordination between them and a resultant over-lapping of activities. At the time of its designation as a National Park in 1982, few resources were made available to implement management measures. The creation in 2002 of a public organization to maintain a balance between nature conservation and tourism development in Mu Koh Chang resulted in a relatively large amount of funding being spent on tourism infrastructure development and establishing new management frameworks but the local community was involved only in implementation.

The Mu Koh Chang Demonstration Site has developed a management plan and guidelines for sustainable utilization of coral reef resources with participation of all related stakeholders from both local and national levels. This plan indicates appropriate activities, decided by the meetings of all stakeholders that should be implemented in the area and has now been accepted for implementation by the provincial office with support from all responsible agencies. The process has facilitated co-operation between the various government agencies in the area.

Recently, Mu Koh Chang has been visited by several study groups consisting of government officers, researchers, site managers, scientists, mayors and governors from the South China Sea region. The most important objective of those study tours has been to share experiences gained from implementation of the demonstration sites. A group of senior government officials from Viet Nam's coastal provinces visited Koh Chang and have already commenced implementing some of the innovations in Viet Nam. The success of the management model in Mu Koh Chang can be applied to other areas in Thailand, especially Mu Koh Kood and Mu Koh Samui, the largest area of coral reefs in the Gulf of Thailand which are not currently in marine protected areas, and to other countries in the region.

◆ ***Koh Tao, Western Gulf of Thailand:*** *A Sustainable Model for Resource Management and Protection Achievable through Empowering Local Communities and Businesses:*

Resource management in small South East Asian communities is often ineffective due to a lack of support from governmental agencies or non-profit groups. Even where problems are identified or solutions imposed, short or unpredictable funding methods can lead to the non-sustainability of programs or activities aimed at addressing environmental or social problems. A case study of this concept from Koh Tao, Surat Thani Province, western Gulf of Thailand was designed to bring awareness to communities and tourists, decrease human impacts on coastal ecosystems, and revive restoration efforts in the Gulf of Thailand (Scott and Phillips, 2010). This conservation model utilizes consumer interest in environmental activism to provide educational diving courses that also raise money for broader environmental and social projects. This model can potentially provide a framework for the protection and restoration of coastal areas in developing communities where alternative forms of funding are difficult to acquire or less effective than localized efforts. Through more dispersed and localized efforts at the community level, it is possible to create an efficient system to monitor, protect, and restore coral reefs around the world and raising awareness amongst government officials, the public, and tourists. This same funding model can be applied to a wide range of environmental projects to create more localization and community involvement in research and restoration. The utilization of eco-tourism and other funding techniques can help to shift extractive economies and activities towards more sustainable methods of development and growth.

◆ *Thailand's Coral Reef Restoration Plan*

The Department of Marine and Coastal Resources (DMCR) together with the Marine Biodiversity Research Group, Ramkhamhaeng University drafted Thailand's coral reef action plan. Secondary data on status of coral reef, threats and types of use were collected. Various concepts of reef restoration and techniques were discussed in the expert group meetings to formulate the concept of reef restoration for Thailand. The concept and data were then verified and consulted with scientists and stakeholders in four coral reef vicinity areas. Thus, coral reef restoration action plan and priority area were drafted and first approved by DMCR coral reef's committee. The plan was then approved in the final meeting with various stakeholders and government organizations. The coral reef restoration plan focuses on passive restoration by reducing threats from tourism, water pollution, sedimentation and fisheries. There are 4 strategies and 15 measures (Surasawadi and Yeemin, 2010):

Strategy 1: Reduce threats from tourism

Measure 1: Reduce threats from diving activities to coral reefs

1) Control and monitor divers to avoid contact and damage to coral reefs
2) Avoid allowing divers access to risky and fragile reef areas
3) Zoning reef areas
4) Encourage tourist boats to have proper waste and garbage management
5) Apply mooring buoys in all diving areas
6) Encourage use of snorkeling trails

Measure 2: Build awareness, increase local knowledge and capacity

1) Build up tourist centers
2) Train divers before going into the water
3) Train guides and staff for coral reef conservation
4) Train local people in tourist areas for coral conservation
5) Train boat staff for using mooring buoys
6) Produce coral reef conservation media such as posters, video
7) Promote coral conservation through local media

Measure 3: Encourage integrated and co-management

1) Apply carrying capacity limits in tourism sites
2) Encourage using tourist centers
3) Apply code of practice to reduce impacts from tourism activities
4) Create networking between stakeholders for co-management
5) Set up committee responsible for mooring buoy management
6) Create regulation for tourist operators to use mooring buoys and to have proper waste management

Measure 4: Build up monitoring plan for tourism activities

1) Monitor impacts from tourism activities to coral reefs
2) Monitor coral reef status in tourism sites
3) Encourage local participation in monitoring plan
4) Study on improving monitoring techniques related to tourism activities

Strategy 2: Reduce threats from water pollution

Measure 1: Evaluate water quality in coral reef areas

1) Evaluate water quality in coral reef areas

Measure 2: Control water quality within suitable condition

1) Support proper waste water treatment systems for households around coral reef areas
2) Support wetland conservation around coral reef areas

3) Support commercial fishing boats, tourist boats to have waste water holding tanks
4) Encourage fishing piers to have proper waste water treatment
5) Prevent draining of ballast water near coral reef areas
6) Support use of eco-friendly sun protection lotion
7) Promote closed aquaculture system

Measure 3: Build awareness, increase local knowledge and capacity

1) Promote knowledge about impacts from water pollution to coral reefs
2) Campaign and promote water saving through local media
3) Set up youth water conservation groups
4) Display water quality data in the tourism sites

Measure 4: Encourage integrated and co-management

1) Practice on mitigation of water pollution incident between responsible agencies and stakeholders
2) Publish guidelines on mitigating water pollution incidents

Measure 5: Build up monitoring plan for water quality around coral reef areas

1) Monitor water quality in coral reef areas
2) Install online water quality measurement instruments in coral reef sites
3) Monitor and evaluate water discharge from local communities

Strategy 3: Reduce threats from sedimentation

Measure 1: Encourage proper integrated coastal zone management

1) Reduce deforestation and promote reforestation in the coastal area
2) Promote proper crop management to reduce soil erosion
3) Campaign and promote integrated coastal zone management
4) Set up local task force to access ecological mitigation plans in EIA which are done by contractors
5) Legislate local regulation for development and construction
6) Training local staff and stakeholders on coastal zone management

Measure 2: Reduce threats from coastal development

1) Use vetiver grass to prevent soil erosion
2) Legislate regulation to prevent soil erosion and control building during rainy season
3) Control underwater mining to reduce sediment disturbance
4) Monitoring suspended solids and sedimentation in coral reef areas

Strategy 4: Reduce threats from fisheries

Measure 1: Reduce threats from fisheries to coral reefs

1) Inhibit destructive fishing practices in coral reef areas
2) Training illegal fishermen to use appropriate fishing gears
3) Prevent discard trash from fishing boats
4) Use artificial reefs to prevent coral destruction by illegal trawlers and push nets
5) Promote aquaculture of ornamental fish
6) Promote cleanup campaign in coral reef areas

Measure 2: Build awareness, increase local knowledge and capacity

1) Training fishery staff on coral conservation
2) Training fishermen on coral conservation
3) Promote coral conservation through local media

Measure 3: Encourage integrated fishery management

1) Set up local network for integrated fishery management
2) Set up fishery coordination center as information center, receiving complaint and suggestion
3) Zoning fishery areas

Measure 4: Build up monitoring plan for fisheries around coral reef areas

1) Monitor fisheries around coral reef areas
2) Set up local fishery patrol network
3) Study on improving monitoring techniques related to fishing around coral reef areas

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2. STATUS OF CORAL REES IN EAST AND NORTHEAST ASIA

2.1 MAINLAND CHINA

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ABSTRACT

The coral communities and coral reefs in mainland China are unprecedentedly degraded over the last 30 to 50 years, overwhelmingly by anthropogenic stressors. There were very few reports about coral bleaching in China, except in Weizhoudao (Guangxi), and Nansha Islands, where mass bleaching events were observed and informally recorded in 1997-1998. 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 ecosystem from coral-dominated to algal or soft coral-dominated reefs. The most remarkable overall decline of scleractinian corals occurred along the coastal area of southern China in particular, Dongshan (Fujian province), Weizhoudao (Guangxi), Daya Bay and Xuwen (Guangdong province), and Hainan Island. In Daya Bay, Weizhoudao, Sanya (Hainan), the percent cover of the live stony corals declined from over 70％ before 1980s to about 30％ in the recent years. Infestations of crown-of-thorns-starfish were sustained in Sanya (particularly in Yalong Bay) and large areas of Xisha Islands since 2004, which contributed to mass damage of the coral reef directly and the promotion of phase shifts.

INTRODUCTION

Mainland China has an extensive coastline that stretches from its border with Vietnam along the northern South China Sea to the Korean peninsula. However, due to the lack of the mainstream Kuroshio warm-water currents, the coral communities and coral reefs mainly occur along the coast of southen China, and the tropical islands and atolls in the South China Sea. The total area of coral reefs in China, including fringing reefs and atolls, is about 30,000 km^2 (Zhang, 2000, 2001). This report does not include Taiwan and Hong Kong regions, which are covered in separate reports.

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 on the Nansha (Spratly) Islands.

Only a few coral reef surveys were carried out in mainland China when the 'Status 2004' report was prepared. After 2004, extensive surveys have been carried out by our study group, on which this report is mainly based. The number of identifiable species of reef-building corals recorded from these surveys is 210 species.

In China, with the fast growth of the economy, heavy population and intensive land-use have brought severe negative impacts on the marine ecosystems, especially on coral communities and coral reefs. In this report, we selected 6 representative sites with distribution of scleractinian coral communities and coral reefs to demonstrate the present status of coral communities and coral reefs in China. The 6 sites (Fig. 2.1.1) 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) Weizhou Island (21°03′N) in Guangxi Zhuang Autonomous Region. (5) Saya Bay (18°14′N), in China's southmost Hainan Province, (6) Yongxing (Woody) Island, Xisha Islands (16°50′N) in Hainan Province.

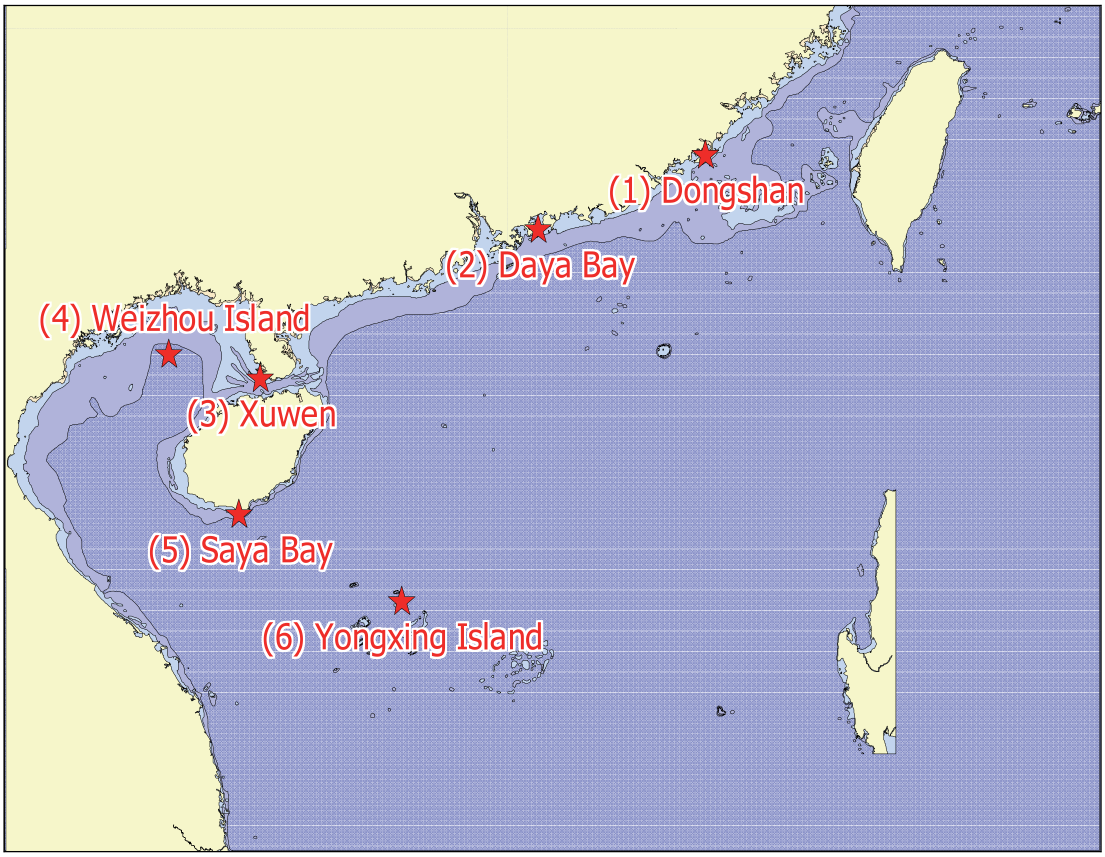

Fig.2.1. 1 Map of the 6 selected sites of representative scleractinian coral communities and coral reefs

STATUS OF CORAL COMMUNITIES AND CORAL REEFS

Coral communities are scattered along southern China's coastal waters, mainly in Guangdong and Fujian Province, typically in Daya Bay and Dongshan (Fig. 2.1.1). The coral community in Dongshan (23°45′N) of Fujian is the north most record of substantive hermatypic corals in mainland China.

Coral reefs in China include fringing reefs along the southmost 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).

From 2005 to 2006, extensive surveys using line intercept transect method were conducted to evaluate the status of coral reefs. Fig. 2.1.2 shows the species richness of scleractinian corals in the six representative sites, and Fig. 2.1.3 shows the average percent cover of live scleractinian corals of the six sites recorded in 2005-2006. These results indicated the low biodiversity and low cover condition in general. The average percent cover of live scleractinians was less than 30% except in the offshore atolls of Xisha Islands. Compared to the historical record of corals in these areas, coral communities and coral reefs are 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, in Sanya and in Xisha Island. In the 1990s, reef conditions 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 recent surveys in 2005-2006 showed the mean live coral cover down to 25% in Daya Bay, 24% in Weizhou Island 29% in Sanya, and 68% and 51% in Yongxing Island, Xisha Island in 2002 and 2006 respectively.

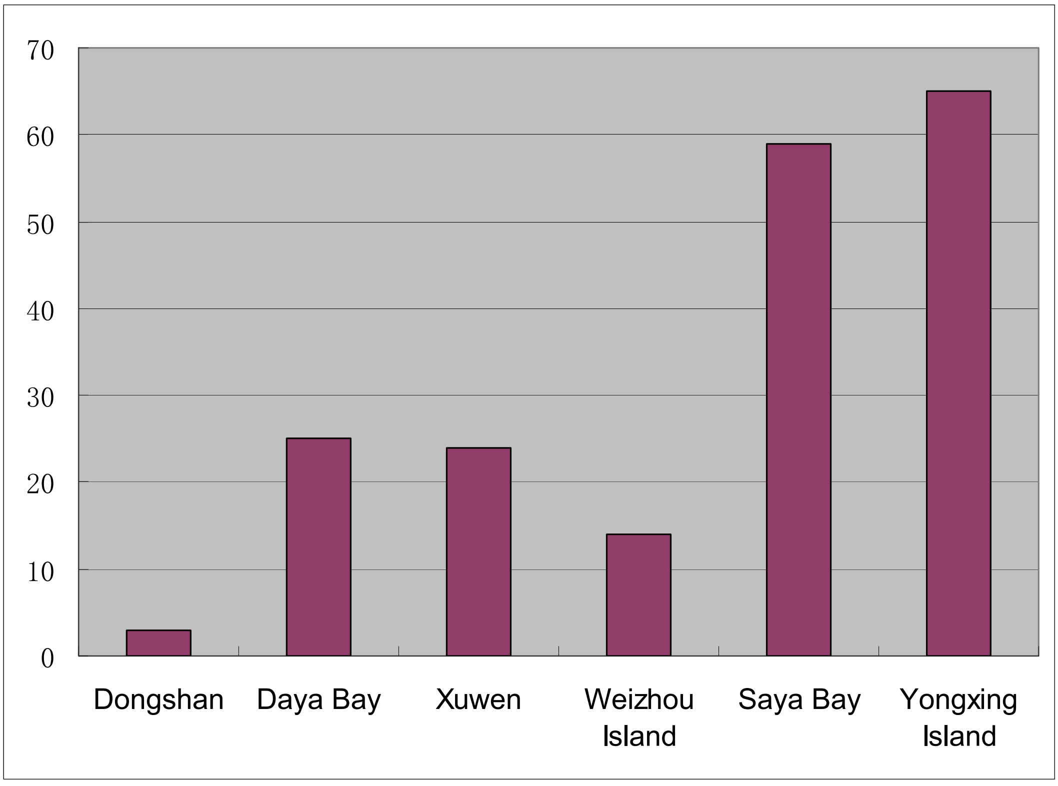

Fig. 2.1.2 Number of scleractinian coral species of the selected 6 representative sites.

The distribution area of stony corals 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 the change of dominant species from branching species to massive corals occurred 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 contributor to the degradation of coral reefs.

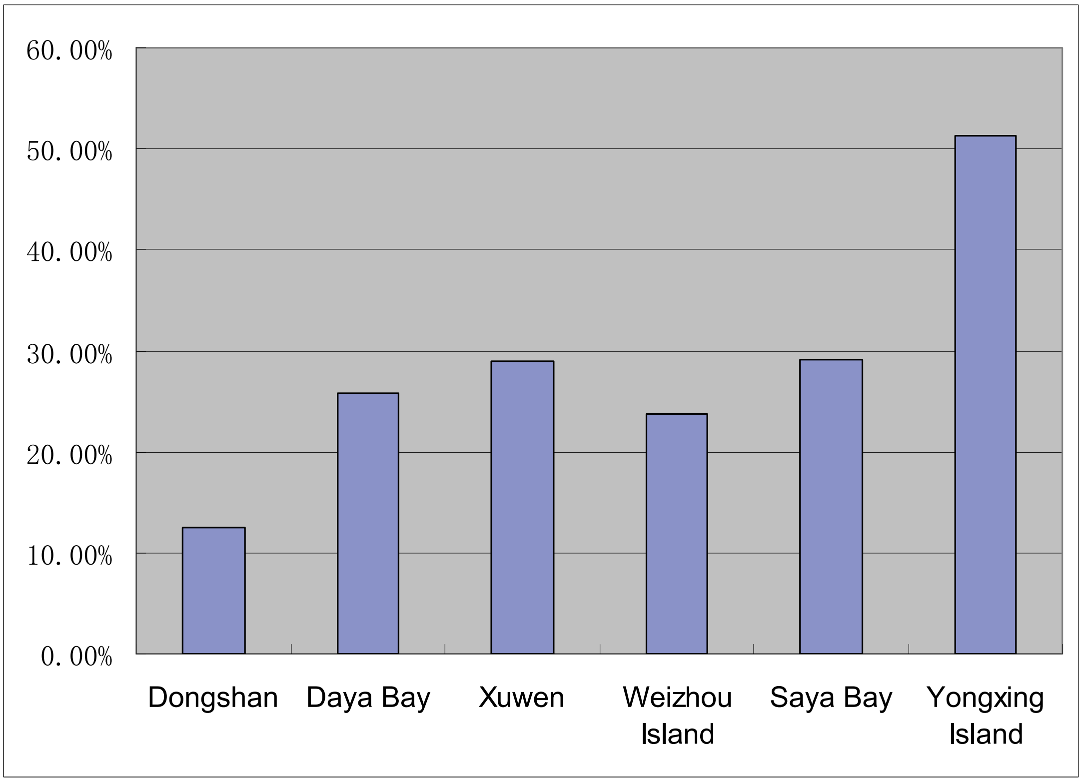

Fig. 2.1.3 Percent cover of live scleractinian corals of the selected 6 representative sites

STATUS OF REEF FISH AND FISHERIES

Commercial reef fishing is primarily conducted using hand-line, small cages made from "chicken-wire" and monofilament nets (single and multi-layer). Long-lining is less frequent. There is also the collection of sea-urchins for their roe by hookah divers operating from mainland China.

Recreational fishing with hook and line is a popular pastime, and becoming increasingly so despite the often small size of fish caught. Spear fishing with scuba (and re-breather) is also practiced by a small number of enthusiasts. The latter are surprisingly adept at taking groupers, snappers, sweetlips, sea-breams and wrasses at sizes larger than generally caught by the commercial fishery.

Reef fish surveys using belt transect visual census protocol was first done in 2005-2006 and are the first data of its kind from mainland China. The small sized fish (body length <10cm) is the most dominant group, and it is not easy to find those economically important fishery species, such as groupers, lobsters, giant clams (*Tridacna* sp.) and cowries (*Mauritia* and *Cypraea* spp.). These indicate serious over-fishing. The population density of the fish is low, about 1 (0.5-3) ind/m^2. The species diversity is also low, a total of merely 139 species were recorded.

In the coastal area, such as Sanya, the reef fish species are mainly *Pomacentridae*, *Apogonidae, Labridae*, *Chaetodontinae*. The dominant species were *Dascyllus reticulates*, *Pomacentrus* sp., *Apogon* sp., *Stegastes obreptus*, *Abudefduf sexfasciatus* and *Chromis notata*. The mean fish body lengths is 7.0cm, mostly ranged from 1 to 10 cm. Coral reef fish density was low in Sanya, with average fish density being about 0.61 fish per m^2.

In the offshore atolls, such as Xisha Islands, the reef fish species are mainly *Pomacentridae, Blennidae, Labridae, Acanthuridae, and Chaetodontidae*. The dominant species were *Meiacanthus sp, Pomacentridae sp, Chromis margaritifier, Dascyllus reticulates, Chromis ternatensis,* and *Ctenochaetus binotatus*. The mean fish body length is 8.0cm, mostly ranging from 5 to 10 cm. Coral reef fish density was much higher in Xisha than in Sanya, with average fish density being about 1.61 fish per m^2.

STRESS AND DAMAGE TO CORAL REEFS

The heavy population and fast economic growth bring much stress on 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 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 very few reports about coral bleaching due to the extreme high temperature in China, except in Weizhoudao (Guangxi), and Nansha Islands, where mass bleaching events were observed and informally recorded in 1997-1998.

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 1980s. Coral reefs can provide raw materials for building construction. The use of stony coral for limestone has been practised 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. The 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 island and Nansha island. 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 biodiversity survey in Sanya 2007-2008 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 (COTs, *Acanthaster planci*) occurred in Sanya in 2003 to 2004 and in Xisha Islands in 2006-2009. The population of COTs is still high in Sanya and Xisha. Many places were almost denuded by COTs in the recent year. The corallivorous snail (*Drupella* sp. or *Cronia* sp.) was found in most of China's coral area, however, the damage by the snails seems not a serious problem. Special attention should be paid to the crown-of-thorns starfish, which can develop large-scale outbreaks and need artificial clean-up regularly and long-trem monitoring.

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 2.1.1.

Table 2.1.1 Major threats to coral reefs in mainland China.

Region/ Province	**Site**	**Past Direct Damage**	**Destructive Fishing**	**Mari-Culture**	**Over-Fishing**	**Develop-ment**	**Sedimen-tation**	**Pollu-tion**
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

MANAGEMENT

The program 'Restoration of Coral Reef Ecosystem and Protection and Management of Its Biodiversity in South China Sea of China' was one of the priority programs of the 21st Century

Ocean Agenda of China. In the past twenty years, state and municipal governments have passed legislation to preserve the coral reefs. There are a series of laws or regulations involving coral reef protection and management, such as:

(1) The State Law of Marine Environment Protection issued in 1983 and new revised edition issued in 2000.
(2) The Hainan Province Regulation of Coral Reef Protection issued in 1998.
(3) The State Law of Ocean Use Management issued in 2001 demands that all coastal development programs need accord with the Division of Marine Functional Zonation made by government.

Up to 2010, there are only 2 national level and 1 provincial level Marine Protected Areas (MPA) specially for coral reef conservation in mainland China. More MPAs such as Xisha Islands Coral Reef Reserve are in the planning process. Among them, Sanya National Coral Reefs Nature Reserve (5,568ha) in Sanya, Hainan Province was the first coral reef MPA, established in 1990. Xuwen Coral Reef Nature Reserve (15,540ha) in Guangdong Province was officially proclaimed in 2007. Dongshan Provincial Coral Reefs Nature Reserve (11,070ha) in Dongshan, Fujian Province was the north most stony-coral community in China, established in 1998.

There were two cases so far of coral relocation/transplantation for remediation of the coral communities damaged by port construction in Daya Bay, Guangdong Province.

The State Ocean Administration launched a long-term annual monitoring program for the marine ecosystem since 2004, which included the coral reef ecosystem of Xuwen, Sanya, Hainan East, and Xisha Islands. Guangdong Provincial Ocean Administration began collaborating with local diver hobbyists and South China Sea Institute of Oceanology (SCSIO), Chinese Academy of Sciences to implement coral monitoring once a year in Guangdong using the Reef Check protocol since 2006 for increasing public awareness and management enforcement. SCSIO has its own coral reef long-term monitoring program in Daya Bay, Xuwen, Sanya, Hainan East, and Xisha Islands for research purposes using the line transect method and permanent quadrats.

CONCLUSIONS AND RECOMMENDATIONS

The coral communities and coral reefs in the mainland China are 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. There were very few reports about coral bleaching due to the extreme high temperature in China, except in Weizhou Island (Guangxi), and Nansha Islands, where mass bleaching events were observed and informally recorded in 1997-1998. Major stressors driving the degradation of reefs in China were direct reef damage by collecting corals for mining or decoration, and destructive fishing activities before 1980s. 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 problems 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.

The degradation of the coral ecosystem is manifested by the 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 reef (see Table 2.1.2). The overall decline in distribution area of scleractinian corals in China was remarkable along the coastal area of southern China in particular, Dongshan (Fujian province), Weizhoudao (Guangxi),. Daya Bay and Xuwen (Guangdong province), and Hainan Island. In Daya Bay, Weizhoudao, Sanya (Hainan), the percent cover of the live stony corals declined from over 70％ before 1980s to about 30％ in recent years. Infestations of crown-of-thorns-starfish were sustained in Sanya (particularly in Yalong Bay) and large areas of Xisha Islands since 2004, which contributed to mass damage of the coral reefs directly and the promotion of phase shifts.

Table 2.1.2 Degradation status of the coral reefs in mainland China.

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

In the last twenty years, coral reefs in China faced many pressures and problems. Special coordinating efforts from government, local community 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 to 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 efforts are 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 the crown-of-thorns starfish, and various anthropogenic factors such as eutrophication, urbanization, mariculture, and overfishing.

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2.2 HONG KONG

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ABSTRACT

Hong Kong is a marginal area for coral growth and thus supports only non-reefal coral communities. Two marine parks, Tung Ping Chau and Hoi Ha Wan Marine Parks, have been designated to protect some of these coral communities. No new marine park has been set up since 2001, although several sites have been recommended as potential marine parks since the early 2000's. No major or large scale disturbance to Hong Kong corals has been reported in the last five years between 20052009, although occasional local outbreaks of gastropod predation and sea urchin bioerosion were observed. Grounding of a large barge during a storm in August 2006 also caused significant damage to the A Ye Wan core area in Tung Ping Chau Marine Park. Patterns of coral reproduction and mass spawning appear to be closely related to temperature change but coral recruitment rate remains very low. Fish diversity and abundance also remain very low in the marine parks, partly attributable to continuous fishing pressures. A territory-wide octocoral distribution and taxonomic study was carried out since 2004, with 67 species of octocorals and black corals recorded to date. It is recommended that more marine protected areas (MPA) should be set up, and that management of MPA should be integrated at a larger spatial scale. It is further recommended that complete ban of fishing should be enforced within MPAs to ensure recovery of the fish stocks.

INTRODUCTION

Hong Kong is located in the southern part of China. Because of its low winter water temperature (14-16 °C), it is a marginal environment for most coral growths. The influence of the Pearl River to its west makes the western waters of Hong Kong not hospitable for corals. Hence, only scattered non-reefal coral communities are found mostly in the east to northeastern shores where waters are more oceanic. Larger patches of the coral community, mainly around the island of Tung Ping Chau and within the bay of Hoi Ha Wan, are now protected as part of the Tung Ping Chau Marine Park (TPCMP, established in 2001) and Hoi Ha Wan Marine Park (HHWMP, established in 1996) respectively (Fig. 2.2.1). An extensive survey of scleractinian coral communities was carried out in 2002 by the Chinese University of Hong Kong Marine Science Laboratory (CUHK MSL), commissioned by the Agriculture, Fisheries and Conservation Department (AFCD) of Hong Kong SAR Government, to verify the species of hermatypic corals found in Hong Kong waters (Ang et al. 2003). This study identified a total of 84 hermatypic scleractinian corals, with a number of non-hermatypic species remaining to be verified. This present report is an update of activities carried out in Hong Kong to monitor its coral communities from 2005 to 2010. A more detailed review of earlier studies on Hong Kong corals and coral communities is given in Ang et al. (2005).

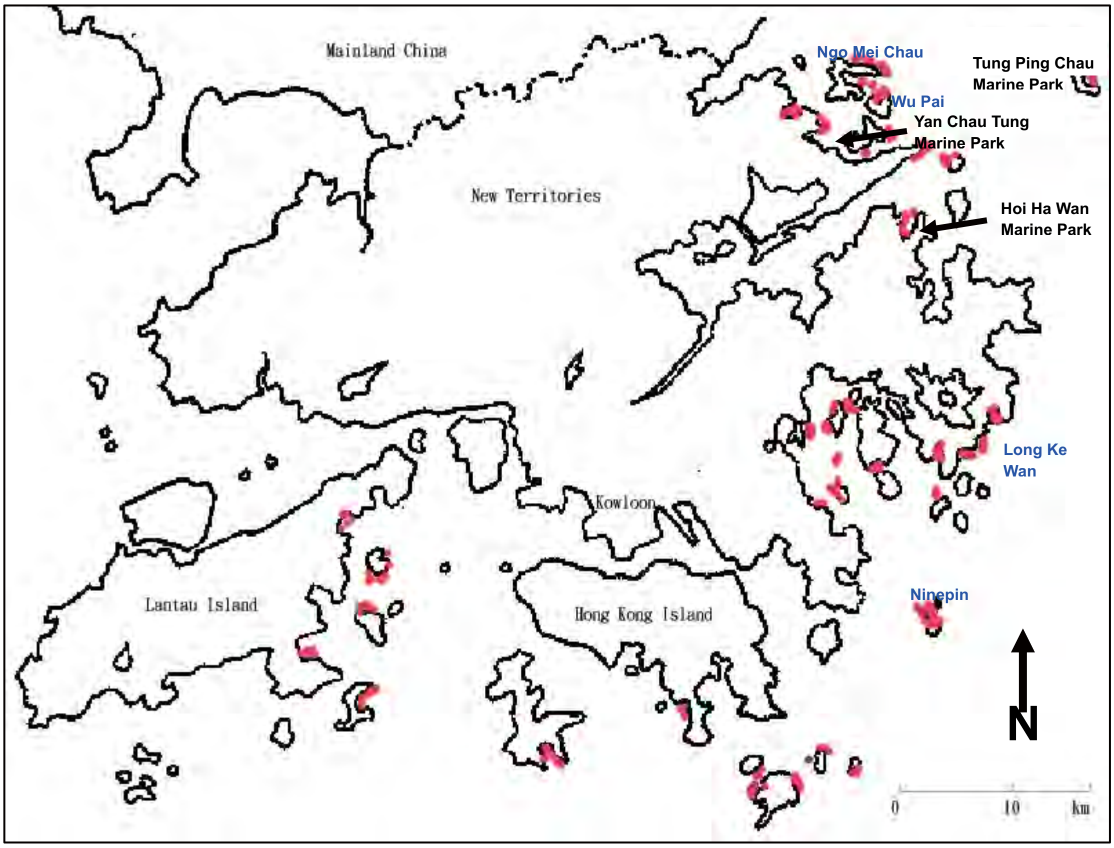

Fig.2.2.1 Map of Hong Kong showing the location of Tung Ping Chau and Hoi Ha Wan Marine Parks. Red shaded areas are areas known to support coral communities. Other potential marine parks with significant coral covers are shown in blue.

STATUS OF CORAL COMMUNITIES

Corals

Permanent transects and quadrats were set up in two sites, A Ma Wan and A Ye Wan, in TPCMP since 1998 and the team from the CUHK MSL continues to monitor coral cover and fish abundance in these sites over the last 12 years. Monitoring was carried out on a monthly basis at the beginning of the monitoring programme (Tam and Ang 2008a), and then twice or once a year since 2000. Monitoring was conducted once in the spring and once in autumn in order to evaluate the potential impacts of physical disturbance, mainly storms, on these coral communities (Tam and Ang 2008b). A comparative monitoring programme was also set up in HHWMP in 2004-2005 for biodiversity mapping as well as to evaluate visitor impact (Ang et al. 2006) as this marine park became popular to local visitors in the early 2000's. Subsequent monitoring of the coral cover of HHWMP was carried out by AFCD through reef check activities. While no major bleaching event occurred, corallivorous gastropod predation and storm damage to corals were found in TPCMP since 2005. Grounding of some fishing vessels occurred but the damage to corals was not very serious. On the other hand, a major grounding of a barge during a storm in 2006 crushed extensive cover of hard corals in A Ye Wan, one of the core coral areas in TPCMP. Coral recovery in this core area was extremely slow with no significant recruitment observed to date.

Octocorals

Systematic studies on Hong Kong octocoral communities were initiated by CUHK MSL in 2004 (Lee and Ang, 2006; Lee 2007). A subsequent study was commissioned by AFCD to cover the whole territorial water of Hong Kong and was carried out by the same team from CUHK MSL (Ang et al. 2010a, 2010b). This commissioned study covered a two-year period from October 2006 to October 2008, followed by a shorter extension of three months from January to March 2010, and is the most extensive study to examine the distribution and diversity of Hong Kong octocorals and black corals. A total of 125 sites were surveyed throughout the northeastern to southwestern Hong Kong waters (Fig. 2.2.2) with a total of 67 species of octocorals reported. These included 29 species of soft corals in 14 genera (Alcyoniidae: *Cladiella, Elbeenus, Lobophytum, Paraminabea, Sarcophyton* and *Sinularia*), Clavulariidae: *Carijoa*, Nephtheidae: *Chromonephthya, Dendronephthya* and *Scleronephthya*, Nidaliidae: *Chironephthya* and *Nephthyigorgia*, Paralcyoniidae: *Studeriotes* and Xeniidae: *Sansibia*) and 38 species of gorgonians in 19 genera (Acanthogorgiidae: *Acanthogorgia, Anthogorgia* and *Muricella*, Ellisellidae: *Dichotella, Ellisella, Junceella, Verrucella* and *Viminella*, Gorgoniidae: *Guaiagorgia* and *Leptogorgia*, Plexauridae: *Astrogorgia, Bebryce, Echinogorgia, Echinomuricea, Euplexaura, Menella*, *Paraplexaura* and *Parisis*, Subergorgiidae: *Subergorgia*). Six species of black corals in two genera (Antipathidae: *Antipathes* and *Cirripathes*) were also found in the same study. A field guide is now being prepared to help disseminate information on the conservation values and biodiversity of Hong Kong octocoral fauna to the general public.

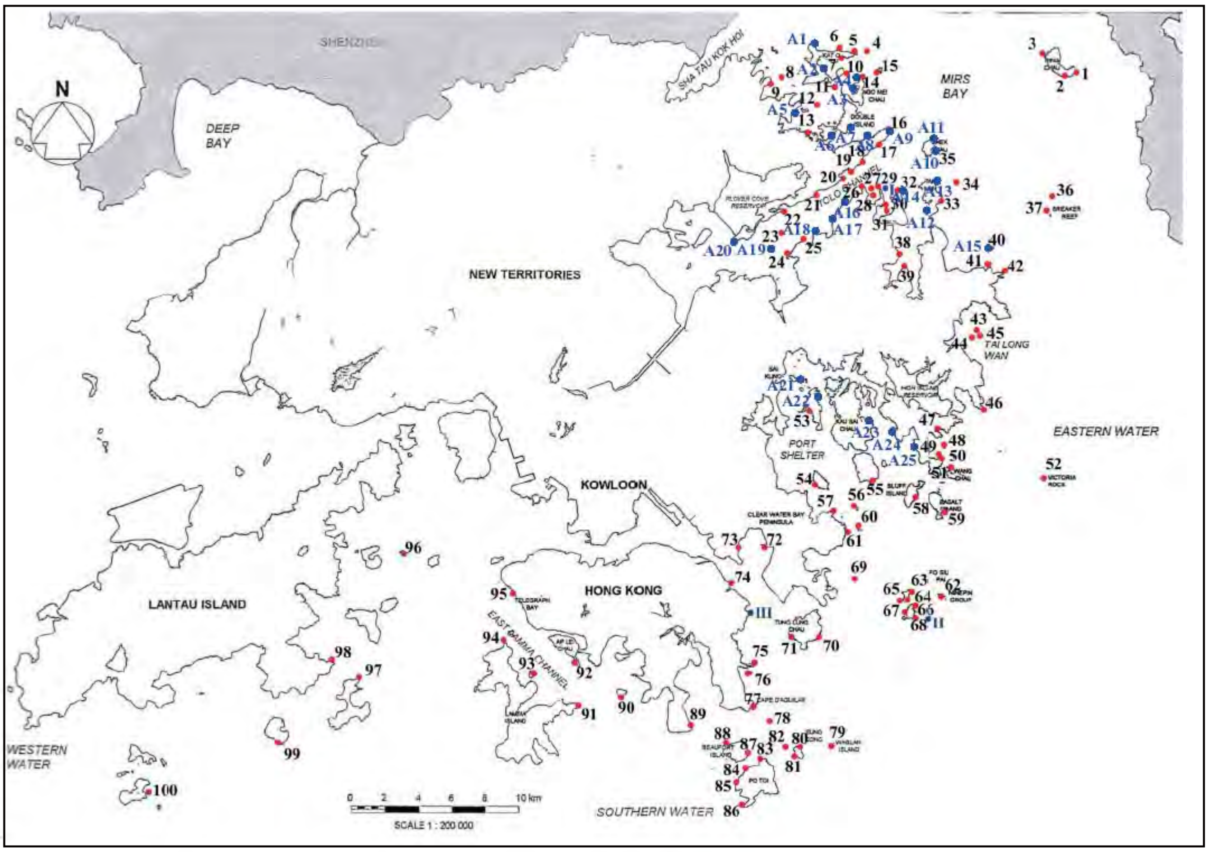

Fig2.2.2 Map of Hong Kong showing the sites surveyed in the octocoral study carried out by the Chinese University of Hong Kong Marine Science Laboratory. Red dots indicate the original 103 sites surveyed in 2005 to 2006, and blue dots the additional 22 sites surveyed in 2010. Refer to Table 2.2.1 for a complete listing of all these sites and Ang et al. (2010a; 2010b) for more details of this study.

Table 2.2.1 Complete listing of study sites surveyed in the octocoral studies. Refer to Fig. 2.2.2 for the location of these sites.

Site No.	Name		Site No.	Name		Site No.	Name
A1	Cheung Tsek Tsui		19	Fung Wong Fat		62	Lung Suen Pai
A2	Kat O Inner Bay		20	Light House		63	Ma Wan
A3	Wu Pai		21	Check Point		64	Sai Chau Mei (N. Ninepin)
A4	Ngo Mei Chau Tsui		22	To Tau Tsui		65	Hoi Tam Hau (N. Ninepin)
A5	Au Yue Tsui		23	Che Lei Pai		66	Kwo Chau Wan (S. Ninepin)
A6	Wong Wan Tsui		24	Sham Chung Kok		67	Tai Chau Mei (S. Ninepin)
A7	Tai Shek		25	Tai Pak Kok		68	Stone Wall
A8	NW of Wong Chuk Kok Tsui		26	Gluff Island		69	Steep Chau
A9 (= 16)	Wong Chuk Kok Tsui		27	Artificial Reef HHW4		70	Tung Lung Chau East
A10 (= 35)	Chek Chau		28	Artificial Reef HHW6		71	Tung Lung Chau South
A11	Chek Chau Chau Tau		29	Hin Pai (HHWMP)		72	Fat Tong Chau
A12	Tit Shue Pai		30	Flat Island (HHWMP)		73	Chiu Keng Wan
A13	Lung Kang Kun		31	Artificial Reef HHW3		74	Heng Fa Chuen
A14	Ocean Point		32	Ocean Point (HHWMP)		75	Tai Tau Chau
A15 (= 40)	Wong Mau Chau		33	Grass Island		76	Ng Fan Chau
A16	SW of Heung Lo Kok		34	Kung Chau		77	Cape d' Aguilar
A17	O Keng Tsui		35	Chek Chau		78	Bokhara Rock
A18	Pak Yue Tsai		36	Shek Ngau Chau		79	Branch Shoal
A19	Tang Chau		37	Breaker Reef		80	Sung Kong North
A20	Tai Mei Tok		38	Sze Tei		81	Sung Kong South
A21	Cham Tau Chau		39	Tung Sam Kei Tsui		82	Fury Rock
A22	Tsek Ku Wan		40	Wong Mau Chau		83	Pak Lau Koh
A23	Kap Lo Kok		41	Mai Fun Tsui		84	Po Toi Northwest
A24	She Wan Kok		42	Tuen Tsui		85	Po Toi West
A25	Lam Fung Chau		43	Lan Tau Pai		86	Po Toi South
1	Chau Tau (TPCMP)		44	Tsim Chau		87	Beaufort Island East
2	Lung Lok Shui (TPCMP)		45	Tai Chau		88	Beaufort Island
3	Chau Mei (TPCMP)		46	Conic Island		89	Stanely
4	Kai Kung Pai		47	Pak Lap Tsai		90	Ngan Chau
5	Kai Kung Tau		48	Wong Nai Chau		91	Picnic Bay
6	Northern Kat O		49	Kong Tau Pai		92	Ap Lei Chau
7	Chung Wan		50	Wang Chau		93	Luk Chau
8	Ap Tau Pai		51	Town Island		94	Pak Kok
9	Kau Ma Shek		52	Victor Rock		95	Pok Fu Lam Sandy Bay
10	Wong Nai Chau		53	Sharp Island		96	Siu Kau Yi Chau
11	Wong Kok Mei		54	Shelter Island		97	Cheung Chau
12	Fu Wong Chau		55	Ma Tsai Pai		98	Chi Ma Wan
13	Pak Hoi Tuk		56	Ping Min Chau		99	Shek Kwu Chau
14	Yeung Chau		57	Pak Pai		100	Tai A Chau
15	Round Island		58	Bluff Island		I	Moon Island
16	Wong Chuk Kok Tsui		59	Basalt Island		II	One Foot Rock
17	Tolo Channel (1)		60	Trio Island		III	Cape Collinson Cemetery
18	Tolo Channel (2)		61	Po Keng Teng			

Fish

Comparison was made between the diversity and abundance of fish fauna in the two core areas (A Ye Wan and A Ma Wan) of TPCMP before and after its establishment as a marine park in 2001 (Tam, 2005; Tam and Ang, 2006; Tam and Ang 2009a). Subsequent studies were also carried out to monitor changes in fish abundance thereafter. In general, using ratio of post-protection (2003-2004) to pre-protection (1998-1999) fish densities as an indicator of response to protection, a ratio ranging from 1.19 in fall 2003 to 1.60 in summer 2003 in A Ye Wan, and 1.11 in winter 2004 to 2.91 in summer 2003 in A Ma Wan was detected, suggesting some increase in fish abundance two to three years after protection. But this increasing trend was not sustained with fish diversity and abundance remaining low even eight years after the setting up of the marine park (Tam T.W., unpublished data). Similar studies on HHWMP also showed no increase in fish abundance 10 years after the establishment of Hoi Ha Wai as a marine park from 1996 to 2006 ((http://www.wwf.org.hk/en/news/press_release/2007_press_release.cfm?1385/Research-shows-Marine-Parks-in-Hong-Kong-failing-to-protect-reef-fishes.mht). This lack of recovery of fish diversity and abundance in the marine parks was partly attributed to the failure to completely ban fishing activities within the parks, as traditional fishers are still allowed to fish in the parks albeit under a licensing system.

Studies have also been carried out to examine the habitat and social structure of fish in the marine park (Liu and Sadovy, 2005). The chocolate hind *Cephalopholis boenak* was found to be closely associated with corals, especially *Pavona decussata*. Both juveniles and adults of this species share the same habitat, with the home range being positively correlated to the body length of the larger fish (≥90 mm). Habitat protection should be an essential part of the population management of fish species associated with the coral communities.

STATUS OF DISTURBANCES ON HONG KONG CORAL COMMUNITIES

Bleaching

Low level bleaching of Hong Kong corals is normally recorded in summer and winter because of exposure to high summer (28°C) and low winter (14-16°C) temperatures (Choi, 2003; Tsang and Ang, 2008). No major bleaching event was reported on coral communities in Hong Kong over the last five years (2005-2009). The last five winters were also very warm (>16°C) and no serious winter bleaching was observed. Even though a very cold February (13°C) was recorded in 2009, this lasted only for about two weeks and did not cause major bleaching nor mortality of corals in Hong Kong.

Biological Disturbance

The major predators of Hong Kong corals are the corallivorous gastropods *Drupella rugosa* and *Cronia margariticola* (Tsang and Ang, 2006). While no extensive outbreaks of coral predators were recorded in the last five years, local outbreaks could sometimes be observed (Lam et al. 2007). Sea urchins were also observed to cause damage to corals in HHWMP (Lam et al. 2007). In TPCMP, a huge increase in the density of the sea urchins since 2006 has grazed down the *Sargassum* beds in Lung Lok Shui, on the southwestern part of the marine park (Ang, 2008). Up to now, no recovery of the *Sargassum* bed is in sight.

Storms

Tropical cyclone (typhoon) is a major physical disturbance to Hong Kong coral communities although Hong Kong corals appear to be quite resilient (Tam and Ang 2008a; 2009b). While occasional overturn of corals can result from typhoon impact, in general, no major damage to coral communities within the marine parks can be attributed to typhoon impact in the last five years.

Sedimentation

Detailed monthly changes in sedimentation rate are being monitored in TPCMP by CUHK MSL since 1998. Within a year, sedimentation rate is highly correlated with the frequency of storms so that sedimentation rate is normally higher during summer, coinciding with the typhoon season. Over the years, however, there appears to be an increase in sedimentation rate, from a maximum of 275.9 mg cm^{-2} day^{-1} in June 1999 to a maximum of > 1,000 mg cm^{-2} day^{-1} in Sept 2006 and July 2008. Extensive coastal development in Shenzhen, just opposite the TPCMP, in the last 10 years may have partly contributed to this increase. Although no immediate impact of this increasing sedimentation on coral colonies seems apparent, there could be some effects on coral recruitment.

Pollution

Heavy metal and organic pollution continue to be a major source of environmental disturbances to Hong Kong marine environment. More detailed studies on pollution effects on Hong Kong corals have now been initiated both by CUHK MSL and the University of Hong Kong. More information on pollution effects on Hong Kong corals are expected to become available in the near future.

Tourism

The number of tourists / divers (both skin and SCUBA) visiting the marine parks on weekends has stabilized since the peaks in 2002 to 2003. Although no actual data were collected, anecdotal observations as well as interviews with local stores providing services to visitors did indicate such a trend. Nevertheless, increased number of visitors did pose some disturbance to the coral communities in the marine parks and some management strategies, like installation of boundary buoys to restrict access to the coral areas by small motorised boats carrying holiday visitors, have to be put in place in HHWMP (see also Part V.3 below).

Boat Grounding

The pier at TPCMP has been in use since the 1960's and the Civil Engineering Department (CED) of the HK SAR Government deemed it necessary to renovate it in the late 1990's. The actual work was carried out in 2006. In August 2006, a large barge used in the reconstruction of the pier drifted ashore during a typhoon and crashed into the A Ye Wan core area, causing extensive damage to the corals. Although AFCD commissioned a contractor to try to repair some of the damaged corals, many large colonies (60 to 80 cm tall) of mainly *Platygyra* spp. were reduced to rubble and beyond repair. Many of these colonies were estimated to be > 60 years old. The damaged area was more extensive in the shallower zone (-1 m CD) (see Tam and Ang 2008a for more details on the coral cover of this core area), and was estimated to be at least 50m in width parallel to the shore. This is one single major disturbance to TPCMP since its establishment in 2001. The coral bed has not recovered since.

MANAGEMENT

Marine Protected Areas (MPA)

No new MPA was established in Hong Kong since 2001. Several potential sites, including Wu Pai, Ngo Mei Chau, Long Ke Wan and Ninepin (Fig. 2.2.1) have been recommended as future marine parks since the early 2000's because of high (>20%) cover of hard corals in these sites (Ang et al. 2005). Other than hard corals, several sites with high diversity of soft corals, gorgonians and/or black corals, including Breaker Reef, Beaufort Island East and Fury Rock (Site nos. 37, 87 and 82 respectively in Fig. 2.2.2) were also recommended to be established as MPAs (Ang et al 2010a).

Monitoring:
Coral Reproduction

Monitoring on seasonality of coral reproduction and mass spawning continues to be a major research focus of CUHK MSL. Reproductive patterns of both the hard and soft corals (Yeung and Ang, 2010) are being closely followed. Additional works on coral reproduction have also been carried out at the Swire Institute of Marine Science, the University of Hong Kong, and at the WWF Marine Life Centre. In general, May to July is the main season for coral spawning to occur. Some coral colonies were observed to spawn only once in each season. On the other hand, some species could spawn more than once in each season but each time involving different colonies (Lin and Ang, 2006). To better understand the pattern of coral reproduction, histological studies as well as underwater observation were employed. Temperature appears to be the most important environmental factor that triggers coral spawning.

Coral Recruitment

Coral recruitment rate is very low in Hong Kong. Several attempts had been made to monitor coral recruitment patterns using natural or artificial substrata. Thus far, the pioneering *Oulastrea crispata* has been shown to recruit continuously throughout the year (Ma and Ang, 2006a). On the other hand, recruitment of other species showed some periodicity, with peaks in some years but not the others (Liu and Ang, 2006). Coral recruits, whether at the settlement or post-settlement stages, need to compete with other benthic organisms like algae (Ma and Ang, 2006b) and barnacles (Chui and Ang, 2010) for space. Heavy sedimentation rate is also detrimental to coral recruitment success (Chiu P.Y., unpublished data).

Reef Check

AFCD of the Hong Kong SAR Government, in collaboration with Hong Kong Reef Check Foundation, continue to sponsor the annual reef check activities in Hong Kong, now on its 12^{th} year. As of 2009, 41 reef check teams participated in this campaign, comprising more than 410 divers from different sectors of the community. These teams surveyed 33 sites, including sites within the marine parks. Based on these survey results, Hong Kong corals were generally found to be healthy. The public pier and Coral Beach at HHWMP and A Ma Wan at TPCMP continued to show the highest coral coverage that ranged from 72% to 74% (http://www.afcd.gov.hk/English/publications/publications_press/pr1459.html). These sites have consistently shown to support the highest cover of corals in Hong Kong over the years.

Dynamite Fishing Detection

World Wildlife Fund Hong Kong (WWF HK) collaborated with Teng Hoi Conservation Organization and Hong Kong University of Science and Technology to install and test a dynamite fishing detection system at WWF's Marine Life Centre in HHWMP in 2007. The detection system hopes to be able to locate dynamite blasting in real time and to assess the extent of blast fishing around Hong Kong waters (http://www.wwf.org.hk/en/news/press_release/?1381/Dynamite-Fishing-Detected-at-the-Professor-Ridzwan-Fish-Blast-Detection-Station-in-Hoi-Ha-Wan.mht).

Management of Marine Parks

In HHWMP, because of an increase in the number of people visiting the marine park, AFCD had to install boundary buoys to restrict access to the coral areas by small motorised boats. This undertaking was shown to be effective as a visitors' impact study carried out by CUHK MSL showed no further significant impacts on the corals at Coral Beach within HHWMP (Ang et al. 2006). A more recent study to evaluate the impact of diving on Hong Kong corals and coral communities is now being undertaken by the Baptist University of Hong Kong with funding from the Hong Kong Environmental Conservation Fund (HK ECF).

In 2006, part of HHWMP was also closed down because of a local outbreak of the coral predator *Drupella rugosa*, followed by bioerosion by the sea urchins *Diadema setosum* (Lam et al. 2007).

Scientific Meeting and Education Campaign:

◆ ***The First Asia Pacific Coral Reef Symposium***

The Chinese University of Hong Kong Department of Biology Marine Science Laboratory hosted the First Asia Pacific Coral Reef Symposium (APCRS) from June 18 to 24, 2006. This was a major gathering of reef scientists, conservationists, managers, fisheries and relevant government officials from the Asia Pacific Region and was co-hosted by AFCD, The Environmental Science Programme of The Chinese University of Hong Kong, The City University of Hong Kong, The University of Hong Kong and the Hong Kong University of Science and Technology. The theme of the First APCRS was "Coral Reefs: Cooperation and Collaboration for Better Conservation". The meeting was attended by 260 participants from 27 countries / regions. A total of 221 abstracts were presented in 8 keynote addresses, 12 mini-symposia, 4 student competition sessions, 11 oral and 3 poster contributed sessions.

◆ ***Ocean Summit 2008***

WWF HK organized the Ocean Summit on March 8 2008. This was attended by various sectors of the Hong Kong community, including academics, government officials, green groups, fishers and legislators. The summit aimed at finding a solution to address Hong Kong deteriorating marine environmental conditions, especially its declining fisheries (http://www.wwf.org.hk/en/news/press_release/2008_press_release.cfm?1299/Hong-Kongs-First-Ocean-Summit-to-Find-Solutions-for-a-Healthy-Sea.mht).

◆ ***Jockey Club HSBC WWF Hong Kong Hoi Ha Marine Life Centre***

WWF HK opened its Marine Life Centre at HHWMP on Jan 19, 2008. The centre is equipped with an exhibition room, a 2,000-litre aquarium and two new multifunction rooms to conduct various educational activities. This centre also operates a glass bottom boat that will allows visitors and students to view the underwater coral communities in HHWMP at closer range (http://www.wwf.org.hk/en/news/press_release/2008_press_release.cfm?1322/WWF-officially-opened-the-Jockey-Club-HSBC-WWF-Hong-Kong-Hoi-Ha-Marine-Life-Centre.mht).

Marine Parks Visitor Service

AFCD of the Hong Kong SAR Government provides free guided ecotour services for visitors to the marine parks on Sundays and public holidays. These tours will normally include not just an introduction to the marine environment but also other sites of interests within the park.

RECOMMENDATIONS

As early as 2002 (Ang, 2002), suggestions have already been made to manage the coral communities in Hong Kong at a larger spatial scale involving the whole northeastern region of Hong Kong waters, rather than at the level of individual marine park units. Several local sites in the northeast and eastern waters of Hong Kong have been surveyed in 1997 to 2002 as part of the feasibility study to identify potential sites for future marine parks or reserves. Establishment of marine parks or reserves in Hong Kong has been met with support from green groups, but strong opposition from the fishers' groups and other special interest groups. Conflict resolution to address concerns from different interest groups remains difficult and a greater commitment from the Hong Kong SAR government would be needed to expand the number of marine protected areas in Hong Kong.

On the other hand, WWF HK had launched a "Save Our Seas Campaign" in March 2008 to advocate the implementation of long-term marine conservation measures in Hong Kong. Its targets include 1) to stop fishing in Hong Kong existing marine parks to turn them into real sanctuaries to protect marine lives, 2) to designate 10% of Hong Kong waters as "no-take zones" banning any form of fishing so fish stocks can recover, and 3) to stop uncontrolled fishing by licensing all commercial fishing boats and setting catch quotas (http: //www.wwf.org.hk/en/news/press_release/2008_ press_release.cfm?1292/WWF-and-almost-60000-People-demand-immediate-actions-to-bring-life-back-to-Hong-Kong-seas.mht).

Hong Kong, as part of southern China, is some of the few places in the world where potential expansion of coral distribution could occur in the light of global warming. It is therefore important that more detailed studies on the dynamics of Hong Kong coral communities be carried out to ensure that sound strategies could be planned and put in place for their greater conservation and protection.

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2.3 TAIWAN

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ABSTRACT

The status of coral reefs in Taiwan is based on surveys using the Reef Check methods in June-September, 2009. Eighty sites in 7 locations including Northeastern coast, Eastern coast, Sourthern Taiwan, Lutao, Lanyu, Hsiaoliuchiu, and Penghu Islands were surveyed. Coral cover of the 80 sites varies from 3 to 68%. Among locations, the average coral cover was higher in Penghu Islands (40%) and Lutao (41%) indicating these reefs to be in relatively good condition. Coral cover was very low at Hsiaoliuchiu (15%) indicating these reefs to be severely damaged or degraded. The abundance of fish and invertebrate indicators at most of the sites was very low suggesting that reefs in Taiwan were under the stress of overfishing. Most of the coral reefs in Taiwan are within national scenic areas or national parks, but most of these areas are not effectively managed. It is recommended that adequate laws should be established or revised for the authorities to enforce management policies and to protect the reefs.

INTRODUCTION

Coral Reefs

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. Most of the reef areas are located in southern, eastern, northern Taiwan, and most offshore islands around Taiwan. The main reef area is located on the coast around the southern tip of Taiwan where well-developed fringing reefs can be found in most places. The northern and eastern rocky coasts have flourishing or patchy coral communities with scattered reef development.

Coral reefs in Southern Taiwan are characterized by diverse and abundant scleractinians and alcyonaceans (Dai, 1991). Coral reefs are also found in shallow waters of several offshore islands including Lutao (Green Island) and Lanyu (Orchid Island) off southeastern Taiwan, Hsiaoliuchiu off southwestern Taiwan, and Penghu Islands (the Pescadores) in the Taiwan Strait. These coral reefs also have diverse and abundant scleractinians and alcyonaceans. The status of coral reefs in eight reef regions around Taiwan has been monitored by the Reef Check method from 1997 to the present.

Biodiversity

Species diversity of reef organisms on the coral reefs around Taiwan is relatively high. 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.

Resource Use

Coral reefs in Taiwan are important for both fisheries and tourism. Approximately 150,000 people rely on coral reefs, at least in part, for livelihood. Fish and invertebrates collected from waters adjacent to coral reefs comprise considerable portion of the total catch of nearshore fisheries. In addition, coral reefs are major attractions for tourists and are popular for recreational fishing. Currently, most coral reefs in Taiwan are within national parks or national scenic areas. These include Kenting National Park in southern Taiwan, Dongsha Atoll National Park, the Northeast Coast National Scenic Area, the East Coast National Scenic Area, Tapengwan National Scenic Area, and Penghu National Scenic Area. Various marine recreation activities including scuba diving, snorkeling, glass bottom boat trips and recreational fishing depend on coral reefs.

STATUS OF CORAL REEFS

Status of coral

Coral reefs at 80 sites in 7 locations (Fig. 2.3.1) were surveyed using Reef Check methodology in June-September, 2009. These surveys were conducted by members of the Taiwanese Coral Reef Society and volunteers of local diving clubs.

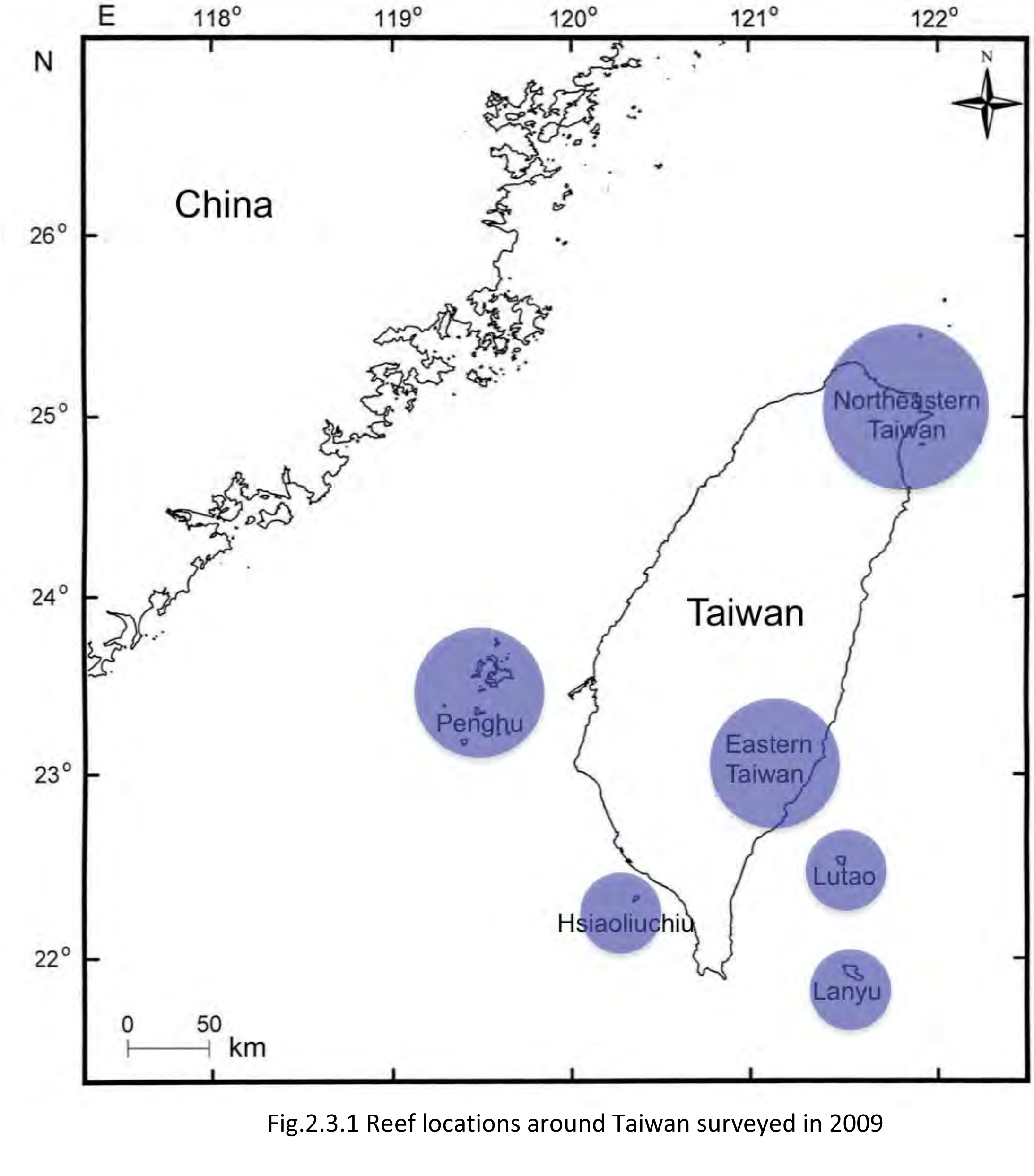

Fig.2.3.1 Reef locations around Taiwan surveyed in 2009

The percentage of hard coral cover varies from 3 to 68 %, with a mean value of 32 % (Fig. 2.3.2). The highest coral cover was found at Siyuping Island (68%) and Dongyuping Island (67.3%) in southern Penghu Islands. Hard coral cover at approximately half of the sites (39/80) were lower than 30%

indicating that most reefs were under severe stress or heavily damaged. The results also showed a dramatic decrease of coral cover at Lutao and Lanyu, comparing with the data in 2004. Coral cover remains low (around 15%) at Hsiaoliuchiu.

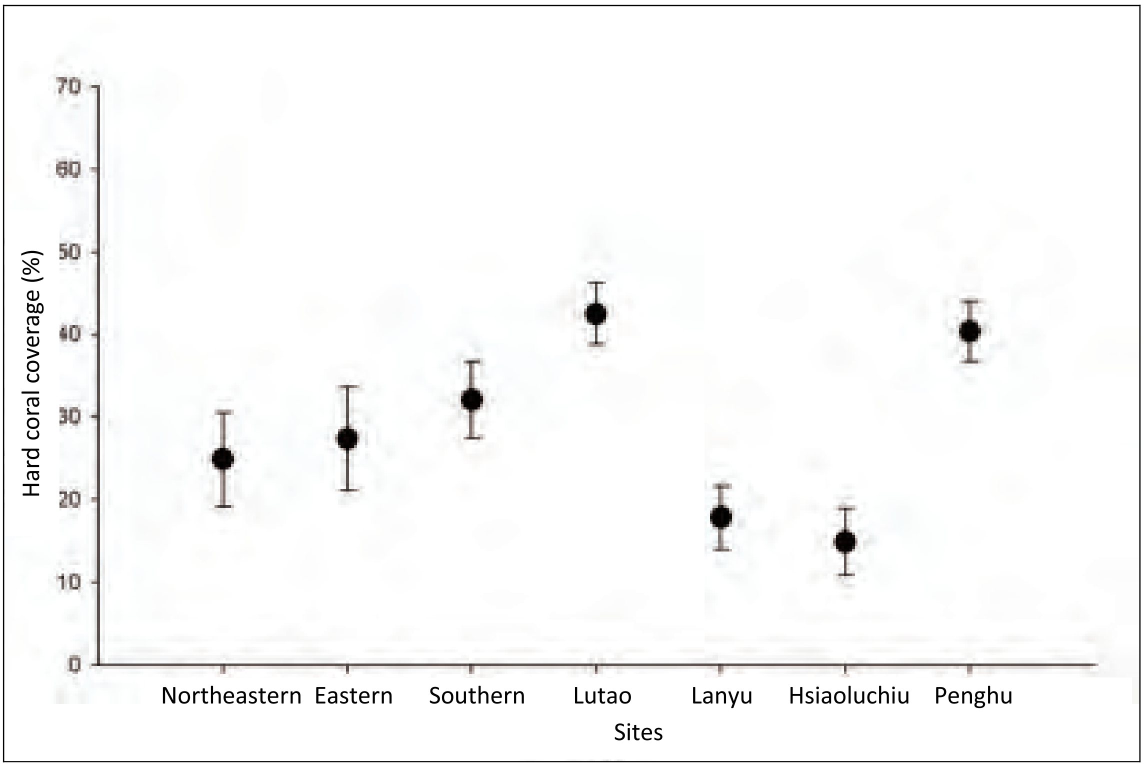

Fig.2.3.2 Percentage of hard coral cover at 7 locations in Taiwan, 2009.

The percentage of dead corals was high at several sites, mainly due to the damage caused by Typhoon Morakot in August 2009. The percentage of bare rock is high at a few sites, mainly in northeastern coast, Lanyu, southern Taiwan, and Hsiaoliuchiu (Table 2.3.1), suggesting that reef destruction in these areas possibly occurred several years ago. The cover of fleshy algae at 17 sites was greater than 10%, mostly in northern, southern Taiwan, and Penghu Islands.

Status of Reef Fish

Among 80 sites surveyed, 56 sites had reef fish data. The abundance of fish indicators remained very low at most sites. Humphead wrasse was absent at all of the 56 sites monitored. Bumphead parrotfish was only recorded at 2 among 24 sites in southern Taiwan. Moray eel was found in one site at Lanyu and 3 sites at Hsiaoliuchiu. Barramundi cod was not recorded at 91% of the reef sites; it was only recorded in northeastern Taiwan and Penghu Islands. Groupers were relatively common in southern Taiwan where they were recorded at 12 among 24 sites, although the population density was very low and their body sizes were small. Groupers are heavily fished by a variety of methods in the waters around Taiwan due to their high commercial value. The abundance of snappers was also very low and none was recorded at

68% of the sites. The extremely low densities of groupers, Haemulidae and snappers indicate that most reef sites have been heavily influenced by overfishing.

The abundance of butterfly fish was relatively higher than other indicator organisms. The density of butterfly fish at most sites is 2-4 individuals per 100 m^2. This is much lower than most Indo-Pacific reef sites where the majority had 6-8 individuals per 100 m^2. The low density of butterfly fish indicates that the reefs are under the stress of aquarium fish collection.

Table 2.3.1 Average cover of substrate categories in 7 locations surveyed by the Reef Check method in 2009.

Location	Hard coral	Soft coral	Dead coral	Macro-algae	Sponge	Other	Rock	Rubble	Sand	Silt/ clay
Northeastern Taiwan	25	6	0	24	0	4	32	3	5	0
Eastern Taiwan	35	6	0	1	0	5	46	0	1	7
Southern Taiwan	32	5	7	10	0	0	31	2	11	0
Lutao	43	3	0	4	2	3	33	1	8	2
Lanyu	18	0	0	2	0	0	68	9	2	0
Hsiaoliuchiu	15	7	1	1	1	0	66	2	12	0
Penghu Islands	40	10	3	5	0	6	12	11	5	6

Status of Invertebrate

Among 80 sites surveyed, 56 sites had data on invertebrates. The abundance of invertebrate indicators remained very low at most sites in 2009. The crown-of-thorns starfish was absent at all the 56 sites surveyed. Giant clams, collector urchins, lobsters, pencil urchin, and banded coral shrimp were recorded at 10 sites only. Sea cucumbers were found at 16% of the sites, and high density was found at one site in Penghu Islands. Triton was found at 34% of the sites but was absent in northeastern Taiwan. The density of triton was about 1-2 individuals per 100 m^2 and the shell length was usually less than 20 cm. Long-spined urchin (*Diadema* spp.) was recorded at half of the sites but with low density (<1 individual per 100 m^2). The very low densities of invertebrate indicators suggest that most reefs are under the stress of both overfishing.

Status of Resource Use

Most reef areas in Taiwan have been overfished and the fishery resources have been depleted in the past two decades. The results of Reef Check from 1997 to 2009 showed that the abundance of all fish indicators was very low and very few commercially valuable fishes now exist on the reefs. Most reefs also suffered from intensive aquarium fish collections. Marine recreation activities, mainly scuba diving and snorkeling, have flourished during the past two decades. Reefs on the northeastern coast, southern Taiwan, Lutao, Lanyu, and Penghu Islands are frequently visited by large numbers of tourists every year. The trend for tourism development is accelerating due to the growing demand for marine recreation, putting even more pressure on these reefs.

Physical Environment

Coral reefs in Taiwan are frequently influenced by typhoons. Sedimentation from terrestrial runoff has been one of the major impacts on coral reefs particularly for those around Taiwan and Penghu Islands. In June-September 2009, Typhoons Linfa, Morakot, and Barma impacted southern Taiwan and caused severe damage to the coral reefs, especially on windward reefs (western coast) where approximately 50% of hard coral cover was removed.

STRESSES AND DAMAGES ON CORAL REEFS

Sediments and Nutrients (land-based)

Coastal areas around Taiwan have been intensively exploited for various uses including aquaculture, road construction, resort building, and agriculture. Soil erosion and landslides repeatedly occur in some coastal areas, especially after storms. These runoffs carry large amounts of sediment and nutrients to the reef areas. In addition, the capacity of sewage treatment in most coastal villages is still limited. The discharge of sewage from towns or villages in coastal areas has been one of the major threats to coral reefs in Taiwan.

Abandoned fishing gears

Fishing practices mainly occur in southern Taiwan and offshore islands including Hsiaoliuchiu, Lutao, Lanyu, Penghu Islands and Dongsha Atoll. Gill nets are commonly used for fishing in many reef areas and discarded nets entangling coral reefs are frequently observed. This causes long-lasting threats to reef organisms.

Other damages to coral reefs

Damage caused by anchoring was found occasionally on most reefs. Bottom-trawlers, with their heavy gear sweeping across the reef surface, have caused severe damage to coral reefs in Penghu Islands. Trampling and mechanical breakage of coral skeletons by divers and tourists have been a serious problem at diving hotspots in Lutao, Penghu and southern Taiwan.

Coral Bleaching

Coral bleaching was sporadically observed in northeastern Taiwan and southern Taiwan, but did not cause noticeable mortality of corals. The sea temperature in summer remained in the normal range and was cooled by the rainfall associated with typhoons in June-September, 2009.

Coral Diseases

Extensive black disease, caused by an encrusting sponge, *Terpios hosinota*, was discovered at Lutao in 2006. The occurrence of this disease was also noticed at few sites in Lanyu. Research on the physiological and ecological mechanisms of black disease is on-going. Other coral diseases including various types of tissue or skeleton abnormality were noticed in northeastern, eastern, southern Taiwan, and offshore islands. There is an urgent need for studies on coral diseases in Taiwan.

Coral predators

The occurrence of COTs on the reefs around Taiwan was not recorded in 2009. Aggregations of *Drupella* were observed at several sites which might cause damage to corals at a local scale. The outbreak of sea anemones in Nanwan Bay, southern Taiwan, caused severe damage to coral reefs (Chen and Dai, 2004). However, the abundance of sea anemone decreased and the reefs recovered gradually in the past few years (Tkachenko et al. 2007).

Coral damage from natural disturbances

Coral damage, mainly mechanical breakage and sediment burial, caused by typhoons have been occasionally observed at monitoring sites. These damages caused by typhoon disturbances are highly variable among sites since the impacts are often spatially heterogeneous. Coral communities in protected habitats are particularly vulnerable to typhoon disturbances. For example, coral communities at Chitou, Penghu, suffered serious damage (up to 90% coral mortality) from Typhoon Chibi in September 2001, and had not recovered since then.

MANAGEMENT

Marine Protected Areas

Most of the reef areas in Taiwan are within national parks or national scenic areas. The management is entrusted to the following authorities: 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. However, the management effectiveness of these areas is still weak, due to lack of adequate laws and the enforcement of management policies to protect the reefs. The revision of laws and establishment of MPAs with effective management are under planning and discussion by governmental administrations.

Monitoring

Monitoring of coral reefs has been conducted by Taiwanese Coral Reef Society by using Reef Check surveys from 1997 to the present. This long-term monitoring is sponsored by the Fisheries Agency of the Taiwanese government. Another long-term ecological research program was launched in 2001 to monitor the changes of coral reefs in southern Taiwan. This program is sponsored by the National Science Council of the Taiwanese government and data are managed by National Taiwan Ocean University. In 2009, two NGOs (Taiwan Environmental Information Center, and Taiwan Association for Marine Environmental Education) were involved in Reef Check surveys.

Legislation

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. This law may strengthen the legal basis for the management of coastal areas in Taiwan.

CONCLUSIONS AND RECOMMENDATIONS

Data shows that coral reefs of Taiwan are under intense pressure of overfishing and destructive fishing, pollution and nutrient enrichment from terrestrial sedimentation, and marine recreational activities. The results of Reef Check in 2009 conducted on 80 sites around Taiwan showed that only 16% of the reef sites in Taiwan were in “good conditions”, with coral cover higher than 50%. About 34% of the sites were in “stressed conditions”, with coral cover between 30% and 50%. Another half of the reef sites were in “degraded conditions”, with coral cover lower than 30% (Fig. 2.3.2). The low abundance of fish and invertebrate indicators revealed that marine organisms with commercial values were very rare and the coral reefs of Taiwan are in overfished situation.

In order to protect coral reef resources, the following measures are recommended: the establishment of more effective MPAs, marine pollution control, development of coral nurseries, sustainable management of marine resources, restoration of endangered species, raising public awareness, and initiating integrated research on coral reefs and marine ecological conservations.

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2.4 JAPAN

Tadashi Kimura
Japan Coral Reef Monitoring Network

ABSTRACT

Status of corals

Ministry of the Environment has started a national program on coral monitoring since 2004 to collect information of coral status from 24 sites in coral reef area and non reef area of Japan (Fig. 2.4.1).

Overview of the coral status from 2004 to 2010 shows that there was no significant increase of coral cover until 2006 in the coral reef area including Amami, Okinawa and Ogasawara islands because of the disturbances by Acanthaster outbreak and typhoon. Serious coral bleaching by high water temperature occurred in Ishigaki, Iriomote islands and Sekisei Lagoon in 2007 and coral cover was decreasing. In addition to the coral bleaching, Acanthaster outbreak precluded coral recovery from bleaching in Miyako, Ishigaki, Iriomote islands and Sekisei Lagoon (Fig. 2.4.2).

Acanthaster outbreaks were dispersed in non reef area and coral cover did not show clear increase until 2009. However, coral cover slightly recovered in 2010. Coral bleaching by high water temperature was observed around Kushioto and Shikoku sites in 2008 and 2010 without mass mortality (Fig. 2.4.3).

In the non reef area, coral distribution has been increasing and *Acropora hyacinthus*, a popular tabulate species of Acropora in coral reef area, invaded coral communities previously dominated by *A. solitaryensis*. These phenomena indicated that the temperate environment was going to shift to sub-tropical environment with sea water temperature rise. This phase shift also brought bleaching and Acanthaster, popular disturbances on corals in coral reef area and non-reef areas.

Management

As short-term counter measures against Acanthaster outbreak, extermination programs were conducted by the Ministry of the Environment, Fisheries Agency, Okinawa Prefecture and the City governments in Ishigaki, Iriomote islands and Sekisei Lagoon. Acanthaster extermination was also conducted by the local scientiets, managers and volunteers in the non-reef area to protect coral communities.

To challenge the land based disturbances, Okinawa prefecture has been trying to reduce red soil runoff from farm area, based on their experiences in controlling red soil runoff from the development construction by prefectural ordinance. Conservation committees of multiple stakeholders were established in Kochi, Tokushima, Kagoshima and Okinawa prefectures for an integrated approach to long-term management of corals.

The central and prefectural governments have worked on providing overall plan for coral conservation. The Mministry of the Environment formulated an action plan for conservation of coral reef ecosystem in 2010 and Okinawa prefecture has been processing a draft plan for conservation, restoration and sustainable use of coral reefs from 2009 to 2011.

WWF Japan conducted a project on evaluation of biological diversity of Nansei Islands and selected Biodiversity Priority Area of several different taxa in the region contributing to further discussion for regional strategy on conservation of biodiversity. WWF Japan also has a local project on coral conservation to reduce soil runoff in Kume Island in Okinawa involving multiple stakeholders and harmonizing with local development events.

Coral transplanting programs for public awareness or tourism have been focused in Okinawa prefecture. The Ministry of the Environment has conducted a nature restoration project in Sekisei Lagoon and Okinawa Prefecture has also started a restoration project of corals in 2011.

Recommendations and challanges

To link management plans by government and/or prefectural government with individual local conservation programs for improving and integrating effective coral conservation. Challenge is to assess and evaluate the social and economic impact from the change of community structure of corals and ecosystem shift.

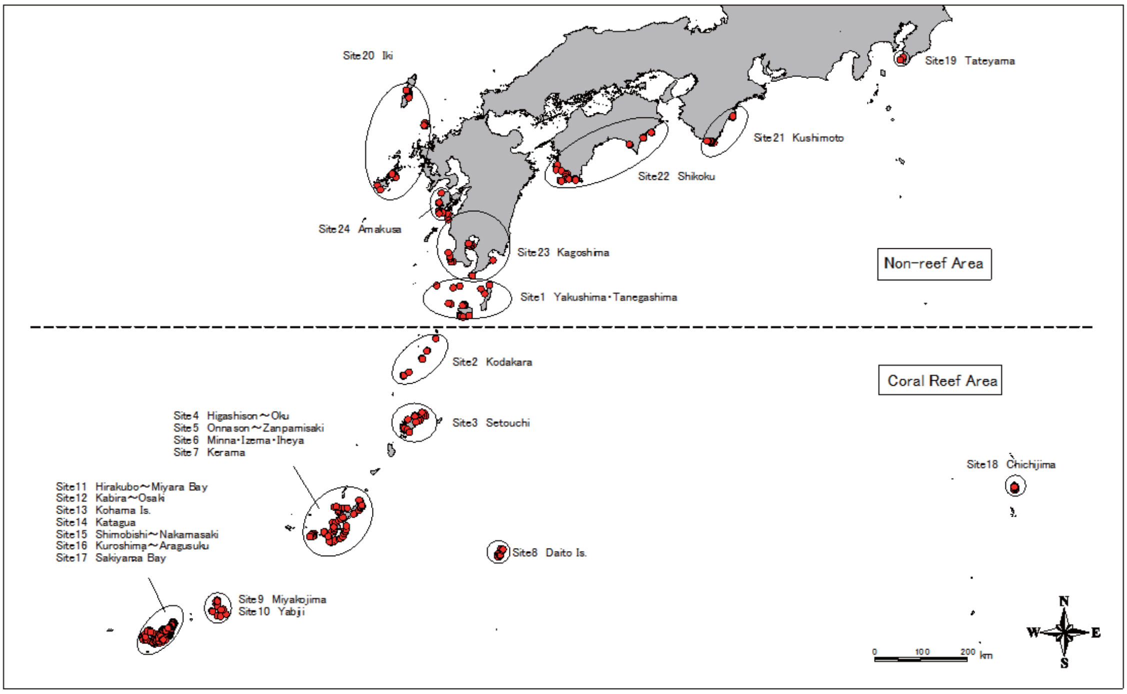

Fig. 2.4.1 Location of the monitoring sites of the national coral monitoring program by the Ministry of the Environment (red circles) and areas where integrated management projects with the local committee are ongoing (blue triangles).

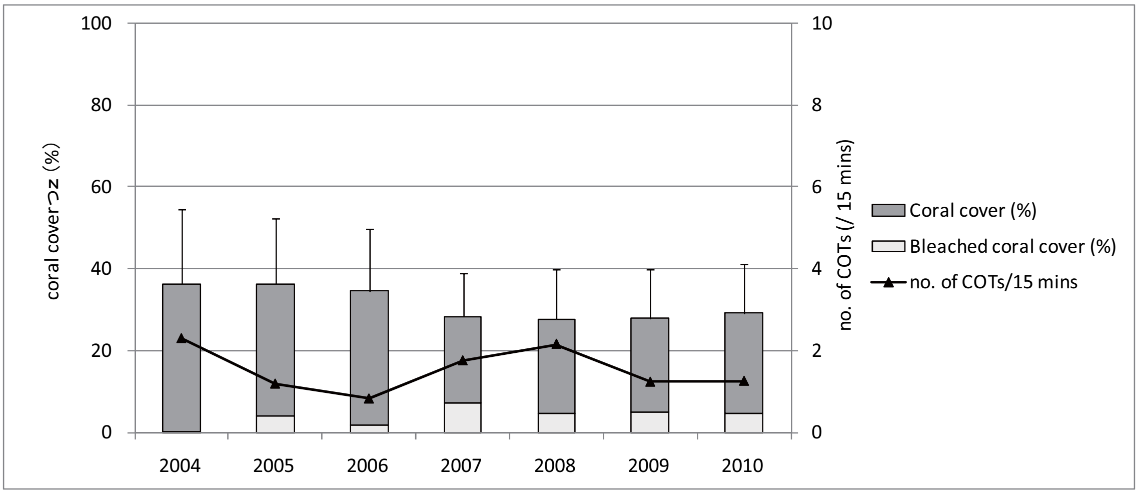

Fig. 2.4.2 Average coral cover (%), percentage of bleached corals and Acanthaster count (per 15 min.) in reef building area from 2004 to 2010. Error bar on each column indicates standard diviation of the average coral cover.

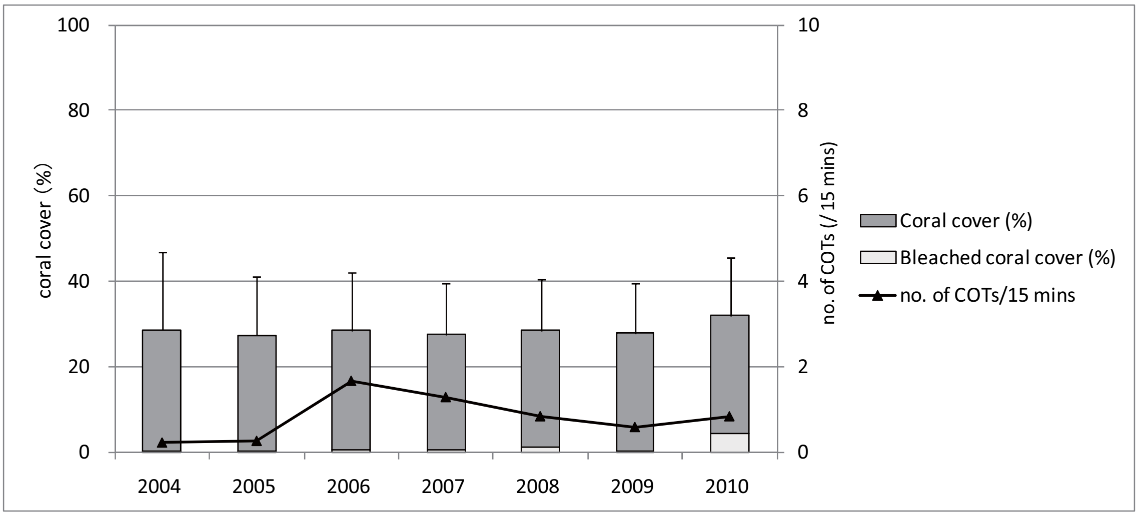

Fig. 2.4.3 Average coral cover (%), percentage of bleached corals and Acanthaster count (per 15 min.) in non reef area from 2004 to 2010. error bar on each column indicates standard diviation of the average coral cover.

INTRODUCTION

Coral distribution is divided into two areas which is the coral reef area from Tokara islands to Yaeyama waters and Ogasawara islands and the non reef area from Tateyama to Yakushima and Tanegashima islands. There are 7 monitoring sites located in non reef area and 17 monitoring sites in coral reef area for national coral monitoring program by the Ministry of the Environment (Fig. 2.4.1). This program has been conducted every year since 2004 except for Daito and Tokara islands where the monitoring is conducted every 5 years because of their remote location. The researchers of this monitoring program form a national monitoring network (Table 2.4.1) for information exchange on coral monitoring and conservation.

In 2010, COP 10 was held in Nagoya, Japan and intensive discussion was made on Marine Protected Areas. A Strategic Plan of the Convention on Biological Diversity ("Aichi Target") was adopted during the meeting. An East Asia Regional Strategy on Coral Reef MPA network was formulated during the ICRI regional workshop in Phuket, Thailand in 2010 which emphasized regional collaboration on coral reef MPA. A Coral Reef Conservation Action Plan has been established by the Ministry of the Environment and related sectors of the government in 2010 to improve conservation actions on corals at tha national and prefectural levels comprehensively.

For the national coral monitoring program, surveys used timed swim methods called "Spot Check method" to estimate coral cover, record coral life form categories in 7 life form, number of Acanthaster and bleaching rate.

Table 2.4.1 Members of Japan Coral Reef Monitoring Network

Monitoring Area (prefecture)		member	Monitoring Area (prefecture)		member
High Latitude Non Reef Area	Tateyama (Chiba)	Masahito Kiyomoto	Coral Reef Area	Amami Is (Kagosima)	Katsuki Oki
		Tomoki Sunobe		Okinawa Is (Okinawa)	Tomohumi Nagata
	Kushimoto (Wakayama)	Keiichi Nomura		Kerama Is (Okinawa)	Kenji Iwao
	Ootuki Chou (Kochi)	Humihito Iwase		Miyako Is (Okinawa)	Kenji Kajiwara
		Takuma Mezaki			Hisashi Matsumoto
	Southern Kagoshima	Shinichi Dewa		Ishigaki Is (Okinawa)	Minoru Yoshida
	Amakusa (Kumamoto)	Satoshi Nojima		Sekisei Lagoon (Okinwwa)	Tadashi Kimura
	Suou Chou (Yamaguchi)	Masaaki Hujimoto			Mitsuhiro Ueno
	Yakushima (Kagoshima)	Takeshi Matsumoto		Ogasawara (Tokyo)	Tetsuro Sasaki
	Iki & Tsushima (Nagasaki)	Kaoru Sugihara			

STATUS OF CORAL REEFS

Coral Reef Area

Around the Amami Islands located in the northern most coral reef area, the coral cover showed a decreasing trend before 2007 because of Acanthaster outbreak in many areas. But the outbreak ended in 2007 and declining coral cover was stopped since 2008. However, in 2010 corals were damaged by soil erosion after heavy rain and coral cover decreased again (Fig. 2.4.4).

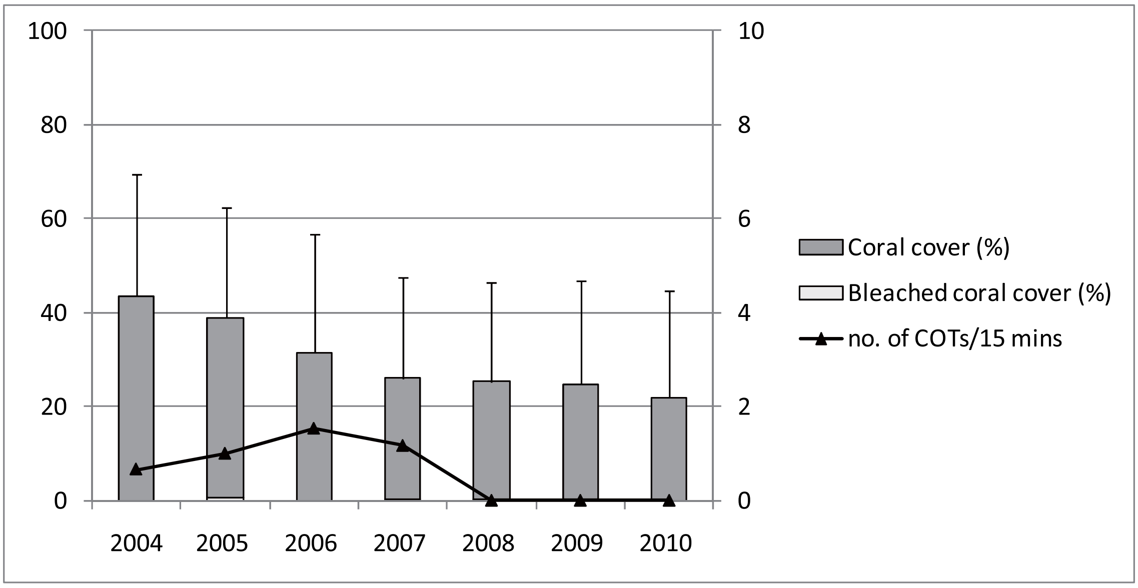

Fig. 2.4.4 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at Setouti site in Amami Islands from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

Although average coral cover around the Okinawa Island sites was less than 10 %, a very low in 2004, it gradually increased by 2009 because of the increase of coral cover at relatively healthy stations at reef edge. But the trend of increase stopped and average coral cover of all the stations showed no further increase in 2010 (Fig. 2.4.5).

At the Amami Islands site, Kerama Islands site was damaged by the predation of Acanthaster outbreak and the average coral cover decreased since 2004. The outbreak of Acanthaster ended in 2007 and the coral cover began to recover. Coral cover decreased again in 2009 from unknown cause and showed little recovery in 2010. Some individuals of small size Acanthasters and coral disease were observed (Fig. 2.4.6).

In Miyako Island and the outer reefs, Acanthaster outbreaks continued since 2004 and average coral cover tended to decrease by 2009. Coral bleaching by high temperature was observed in 2010 with no mortality and coral cover has increased (Fig. 2.4.7).

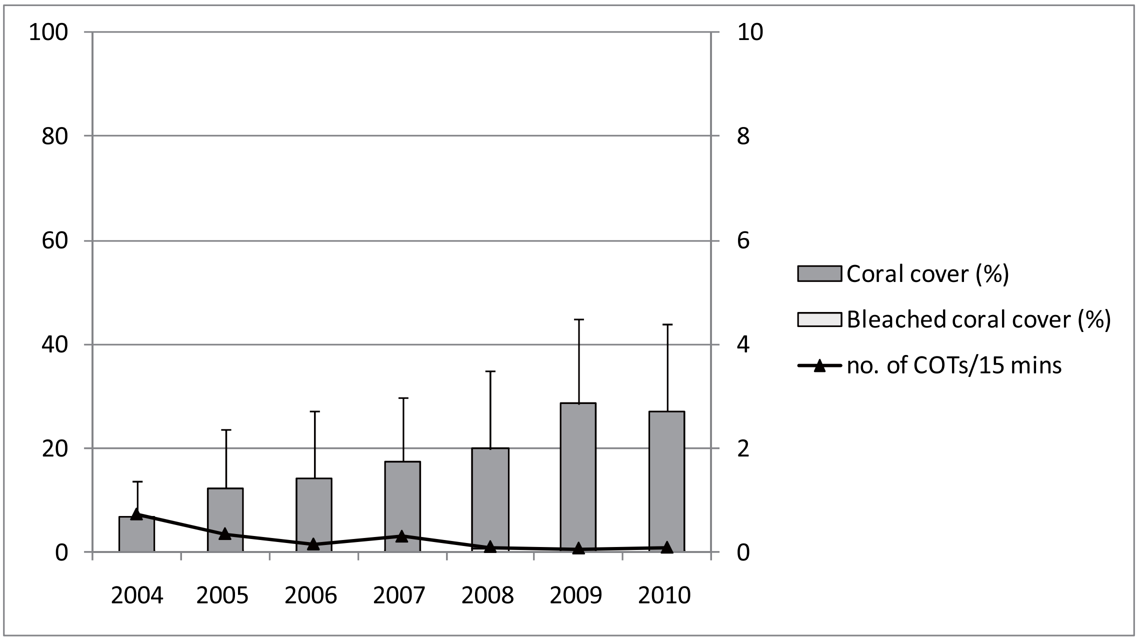

Fig. 2.4.5 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at Okinawa Island sites (Okinawa Island east coast, west coast and neighbouring islands) from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

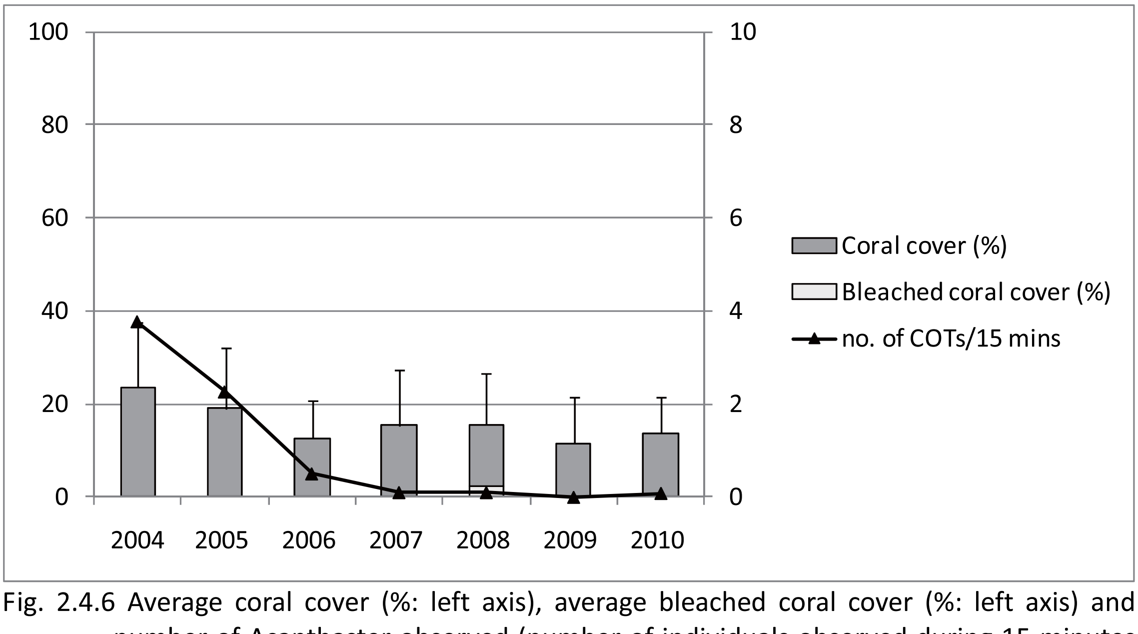

Fig. 2.4.6 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at Kerama Islands site from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

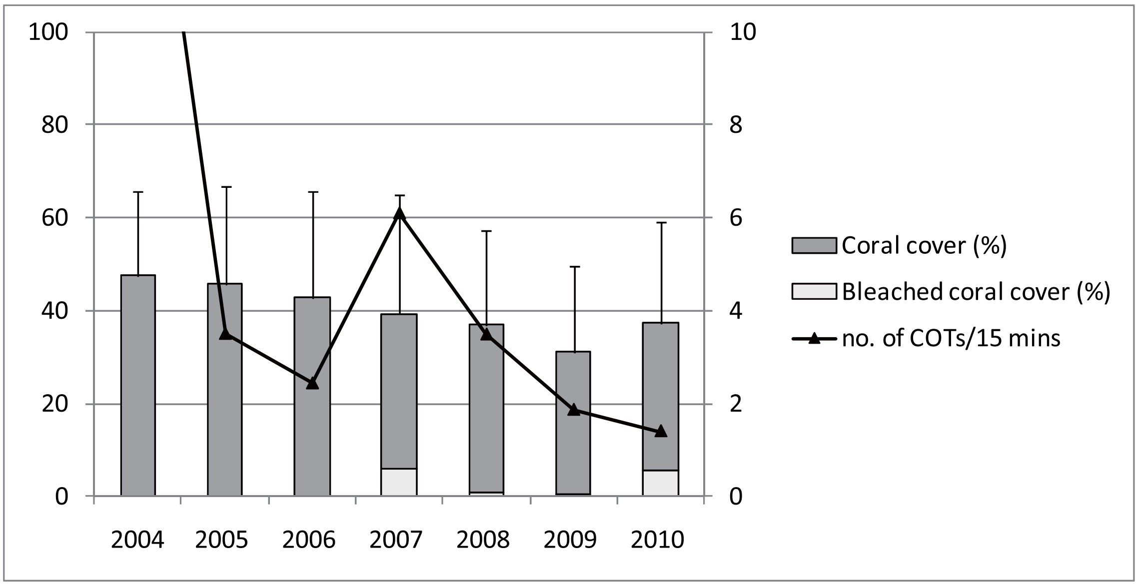

Fig. 2.4.7 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the site of Miyako island and the outer reefs from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

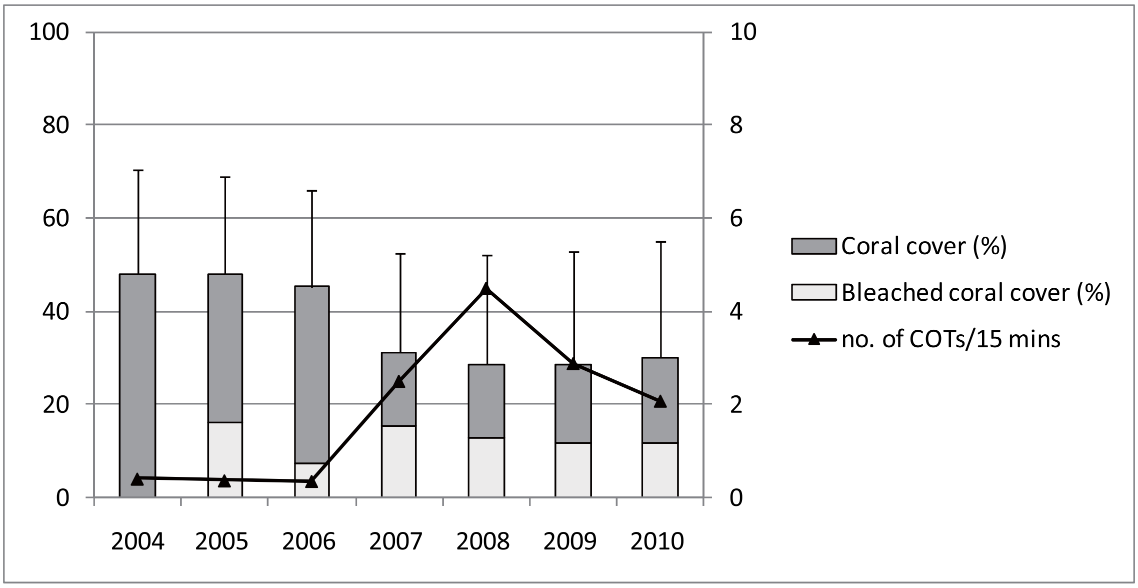

Fig. 2.4.8 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the site of Sekisei Lagoon and Iriomote Island from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

As the sites around Sekisei Lagoon were damaged from the coral bleaching by high water temperatures (2005, 2006) and typhoon (2005), the average coral cover showed slight decrease from 2004 to 2006. In 2007 severe coral bleaching was observed in the area and the average of coral cover significantly decreased. Acanthaster outbreak was also continuing in many stations of these sites and coral recovery has not been observed since 2008 (Fig. 2.4.8).

The average coral cover of Ishigaki island, a neighbouring sites of the Sekisei Lagoon slightly increased from 2004 to 2006 but decreased significantly in 2007 because of a large-scale bleaching event by high water temperature. Acanthaster outbreaks were observed at some stations in 2010 and the coral cover declined after gradual recovery in 2008 and 2009 (Fig. 2.4.9).

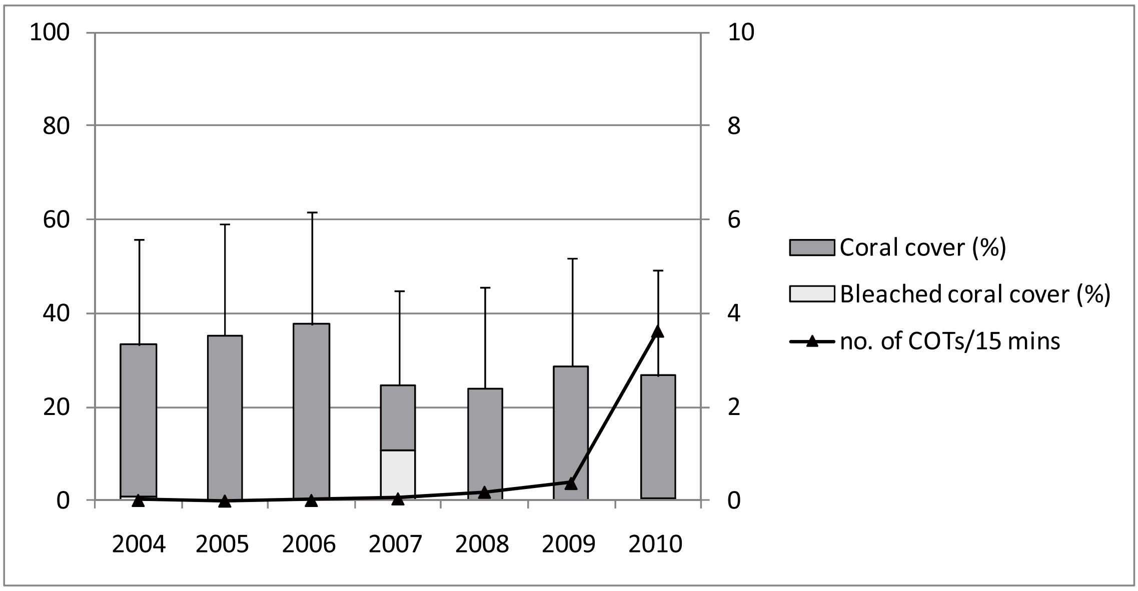

Fig. 2.4.9 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Ishigaki Island from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

At the site of Ogasawara Islands, average coral cover tended to increase slightly from 2004 to 2006 and decreased in 2007 due to typhoon damage. Although it showed a recovery in 2008, large scale coral bleaching was observed in 2009 and coral coverage decreased. In 2010, recovery was not yet observed (Fig. 2.4.10).

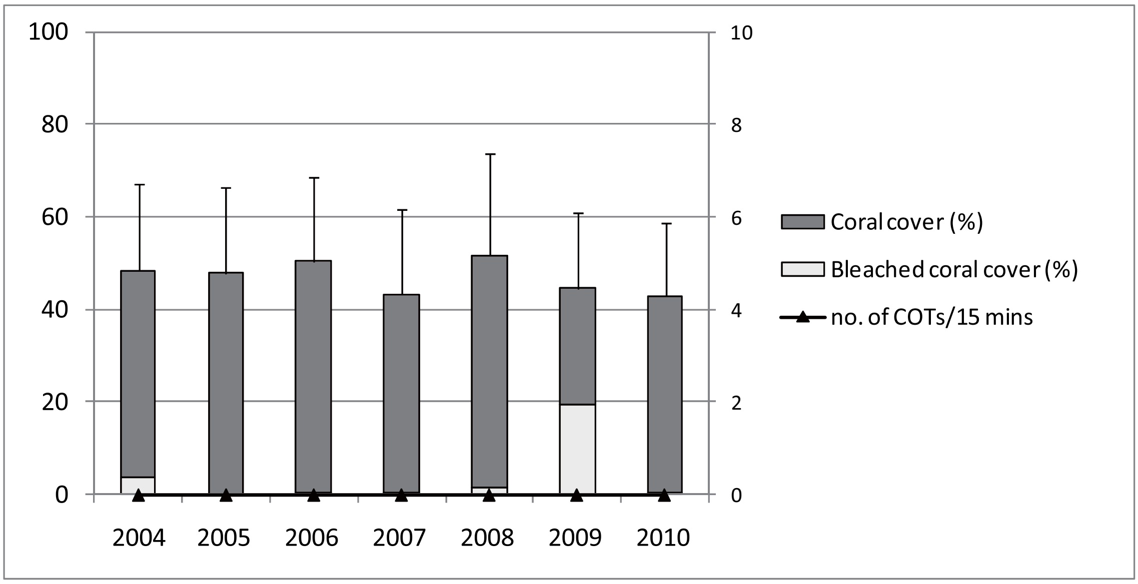

Fig. 2.4.10 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Ogasawara Islands from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

Non Reef Area

The site of Tateyama is located at the highest latitude of the coral distribution along the Pacific coast. There are small paches of coral colonies of *Alveopora japonica*, *Acropora tumida* and other Favia species observed in this site. Average of coral percent cover of all the stations of this site has been low and stable from 2004 to 2010 without major disturbances on corals like Acanthaster and coral bleaching except a little predation by Drupella (Fig. 2.4.11).

At the site of the Sea of Japan, average coral cover decreased until 2008 due to predation by Diadema in 2005 and coral bleaching by high water temperature in 2007. The corals recovered after those events and showed a increase of coverage in 2009 and 2010 (Fig. 2.4.12).

Acanthaster outbreak occurred around Kushimoto site in Wakayama Prefecture in this period. As typhoons (in 2006 and 2009) and coral bleaching by low water temperature (in 2009) also damaged corals in this site, the average coral cover decreased in 2005, 2006 and 2009. Although large-scale coral bleaching occurred in this site due to high water temperature in 2010, corals recovered and the average percent cover showed increase in 2010 (Fig. 2.4.13).

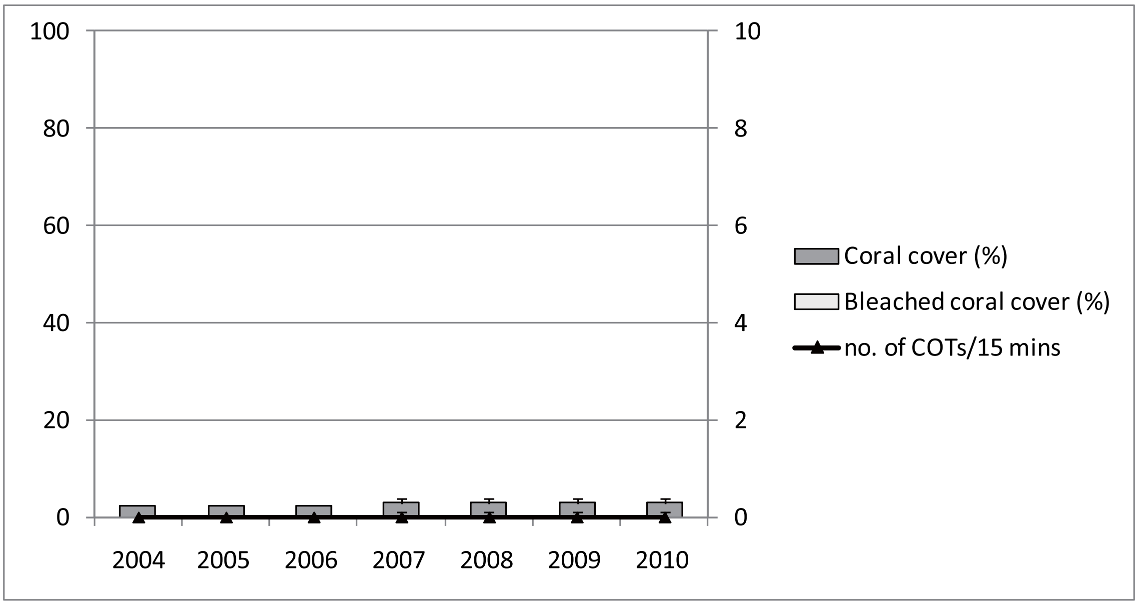

Fig. 2.4.11 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Tateyama site from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

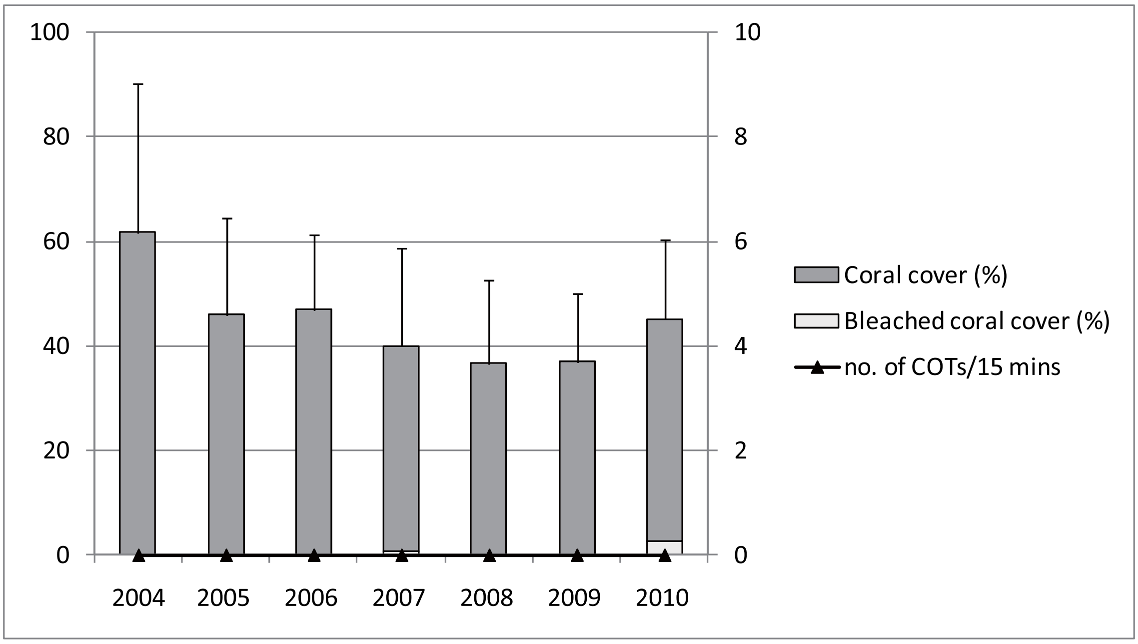

Fig. 2.4.12 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of the Sea of Japan from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

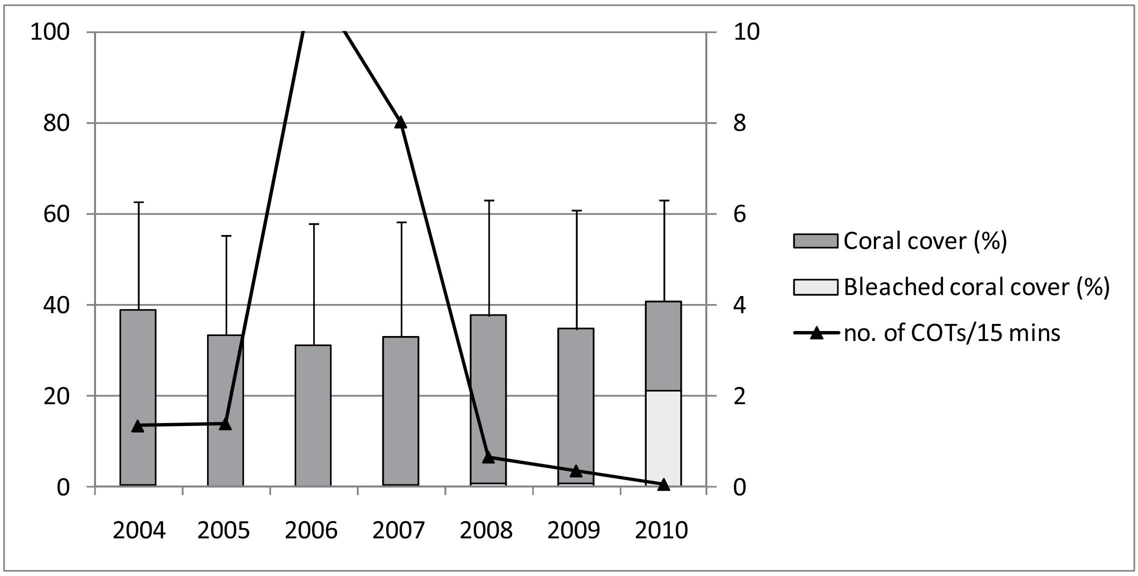

Fig. 2.4.13 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Kushimoto in Wakayama prefecture from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

The average coral cover of the site of the southwest coast of Shikoku has increased slightly since 2004 in spite of the starfish increase since 2008 and its outbreak at some stations in 2010. In addition, coral bleaching event by high water temperature was observed in 2008 and 2010 (Fig. 2.4.14).

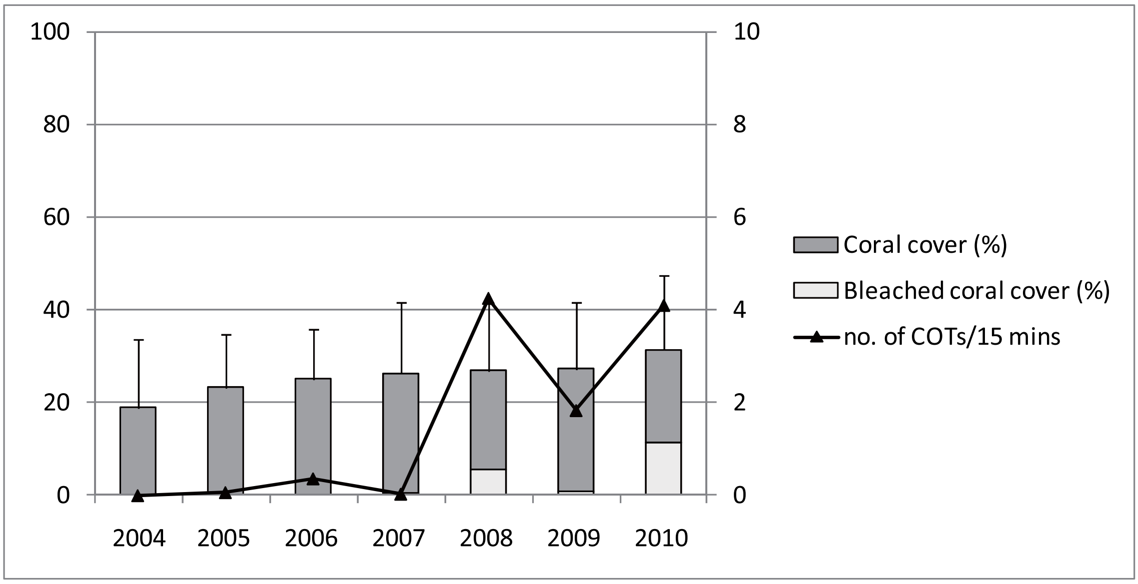

Fig. 2.4.14 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Southwest Coast of Shikoku Island from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

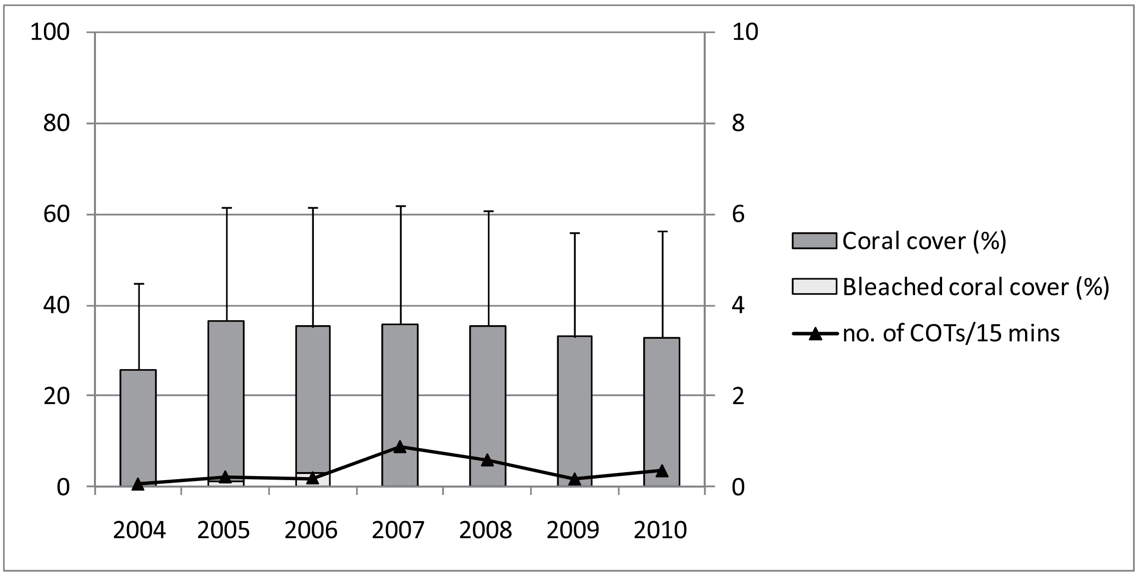

Fig. 2.4.15 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Southcoast of Kagoshima Prefecture from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

At the site of the southern coast of Kagoshima Prefecture, aggregation of Acanthaster has been observed in many stations since 2006, average coral cover has not increased (Fig. 2.4.15). The explosions of Sakurajima volcano began in 2009 and it had been observed that the volcanic ash covered and killed corals in 2009 and 2010.

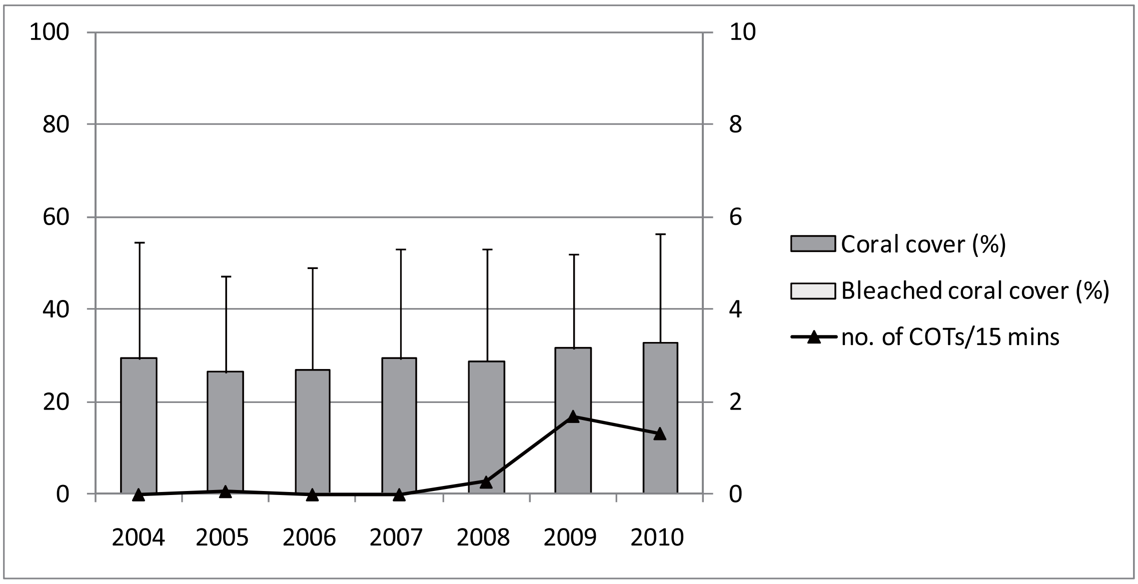

Fig. 2.4.16 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Amakusa in the western Kyushu from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

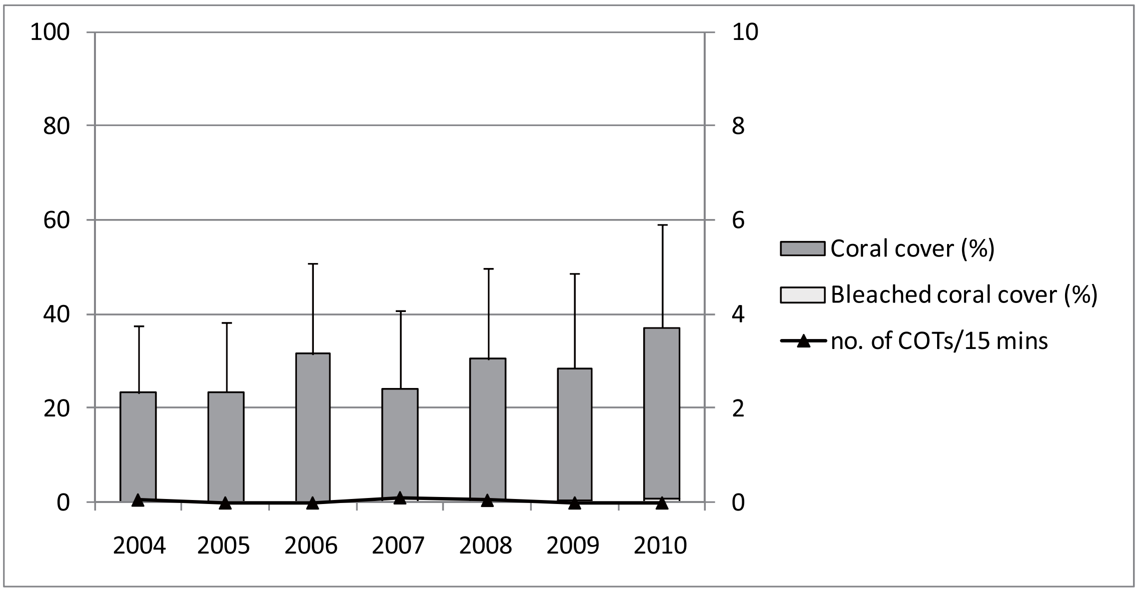

Fig. 2.4.17 Average coral cover (%: left axis), average bleached coral cover (%: left axis) and number of Acanthaster observed (number of individuals observed during 15 minutes swim: right axis) at the sites of Osumi Islands (Yakushima and Tanegashima) from 2004 to 2010. The vertical bars at the top of columns indicate the standard deviation in the coral cover.

The average coral cover at the Amakusa site in the western Kyushu decreased significantly in 2005 due to typhoon damage, but gradually recovered after the event. However, the Acanthaster has increased since 2008 and their predation has also been observed (Fig. 2.4.16).

The site of Osumi Islands (Yakushima, Tanegashima) is located in the southernmost latitude in non reef area that borders the coral reef area. A highly dense community of *Acropora formosa* at the station of Mageshima Island in this site was damaged in 2009 and the average coral cover here decreased in 2009. In 2010, coral cover has increased because of the increase of coral cover at the other stations, but the Acropora community was destroyed by unknown cause (Fig. 2.4.17).

DISTURBANCES ON CORAL REEFS

Acanthaster planci

The survey by visual observation, the number of starfish observed per 15 minutes is evaluated as: less than 2 individuals indicates the normal distribution; less than five and more than 2 individuals indicates alert for possible increase; less than 10 and more than 5 individuals indicates pre-outbreak level; and more than 10 individuals indicate outbreak.

A large group of Acanthaster was observed at the sites of Amami, Kerama and Sekisei Lagoon in the coral reef area since 2000 and some stations showed outbreak level of individuals in those sites and Miyako Islands and outer reefs in 2004. However, the number of Acanthaster observed rapidly decreased in Amami and Kerama islands from 2006 to 2008 and it seemed that the outbreak had ended in these 2 sites (Fig. 2.4.4, Fig. 2.4.6). Meanwhile the number of

Acanthaster increased around Sekisei Lagoon since 2007 (Fig. 2.4.8) and some of the stations showed high number of the individuals indicating outbreaks in 2010. Also at the sites of Ishigaki Island, which are adjacent to the Sekisei Lagoon, Acanthaster was rapidly increasing in 2010 (Fig. 2.4.9) and high number of individuals of Acanthaster indicated their outbreak in some stations. Large numbers of Acanthaster were also observed at the sites of Miyako Island and outer reefs since 2004 and outbreaks have continued in 2010 (Fig. 2.4.7). The sites of Okinawa (Fig. 2.4.5) and Ogasawara Islands (Fig. 2.4.10) showed normal level of Acanthasters from 2004 to 2006.

While Acanthaster outbreak increased in the coral reef area, Acanthaster predation was spreading over the southwest coast of Shikoku, Kushimoto, southern coast of Kagoshima Prefecture and Amakusa, downstream of the Kuroshio Current flowing through the Pacific Ocean. The number of Acanthaster observed rapidly increased at Kushimoto site from 2006 through 2007. The number decreased to normal level after 2008 (Fig. 2.4.13), but their predation appeared in the surrounding area of the monitoring and their extermination program have been conducted in those areas. At the southwest coast of Shikoku site, the number of Acanthaster observed increased rapidly in 2008 and high number of individuals indicated their outbreak in some stations of the site in 2010 (Fig. 2.4.14). At the site of the southern coast of Kagoshima Prefecture, the growing number of starfish was observed in 2007 (Fig. 2.4.15) and predation by large populations of Acanthaster was observed in some stations. The Amakusa site showed an increasing trend in the number of Acanthaster since 2008 (Fig. 2.4.16) and extermination program was conducted around the monitoring stations. There has been no predation by the Acanthaster at the sites of Tateyama in Tokyo Bay and around Iki Island of the Sea of Japan (Fig. 2.4.11, Fig. 2.4.12).

The outbreaks of Acanthaster on coral reefs began from coral reef area and has spread to high-latitude regions and remain a significant disturbance on corals in Japan except at Kerama and Amami Islands where the outbreaks seemed to have ended.

Coral Bleaching

In the coral reef area, large-scale coral bleaching from high water temperature occurred around Sekisei Lagoon and Ishigaki Island in 2007 and the average of coral cover of these sites decreased (Fig. 2.4.8, Fig. 2.4.9). However, small scale coral bleaching without mortality was observed in Sekisei lagoon annually since 2005. Coral bleaching was also observed at the sites of Miyako Island and outer reefs in 2007 and 2010 (Fig. 2.4.7) but coral cover did not show any decreasing trend (reduced coral cover in 2007 was due to the predation by Acanthaster). In 2009, the first coral mass bleaching was observed around Ogasawara Islands site and led to decreasing average coral cover (Fig. 2.4.10).

In the high latitude non reef area, coral bleaching by high water temperature was observed at the southwest coast of Shikoku in 2008 and 2010, and around Kushimoto and Iki Island in 2010 (Fig. 2.4.12, Fig. 2.4.13, Fig. 2.4.14). Especially, the bleaching around Kushimoto in 2010 was a large-scale event which was never recorded before in this site. However, corals have recovered and no motality was recorded.

Soil runoff

In 2010, coastal soil runoff due to heavy rain occurred at the site of Amami Islands and the sediments covered and killed coral colonies. It caused decrease of average coral cover of this survey site (Fig. 2.4.4). Similar events occurred at Kochi prefecture of the Shikoku site in high-latitude non reef area in 2000 and at Ishigaki Island in coral reef area in 2001.

Damage caused by volcanic Ash

At the site of southern coast of Kagoshima Prefecture, the ash deposited on the sea bottom by the explosion of Sakurajima volcano has been reported in 2010 and 2009, caused damage and coral death. Another volcano, Shin-Moetake erupted in January 2011 in Miyazaki Prefecture and corals were also killed by the ash deposited.

OTHERS

Ecosystem shift

At the sites of Kushimoto, Shikoku and Kagoshima prefecture, distribution of *Acropora hyacinthus*, a common tabulate acropora species in sub tropical waters, has been growing around and among the colonies of *A. solitaryensis*, which is a common tabulate Acropora in the high latitude non reef area. Also, around the Iki island in the Sea of Japan, colony of tabular Acropora was recorded which had never been reported. These phenomena possibly indicate the expansion of the subtropical species into the high latitude non reef areas. Distribution of *Alveopora japonica* was observed near Suou Ooshima, Yamaguti prefecture facing the Seto Inland Sea that has less influence from the Kuroshio Current.

Huge coral community in the Mesophotic Area in Kume Island

In 2010, a large coral community was found at a depth of 15m to 30m off Kume Island located approximately 100km west of Okinawa Island (Fig. 2.4.18). The community is distributed over more than 1km, but the whole area has not been measured yet. Most of this community was dominated by the single branching Acropora species, *Acropora horrida.* Futher research on relationship between this community and the neighbouring shallow reefs is needed to identify the roles of this community for the surrounding coral reef ecosystem (Kimura et. al. 2010).

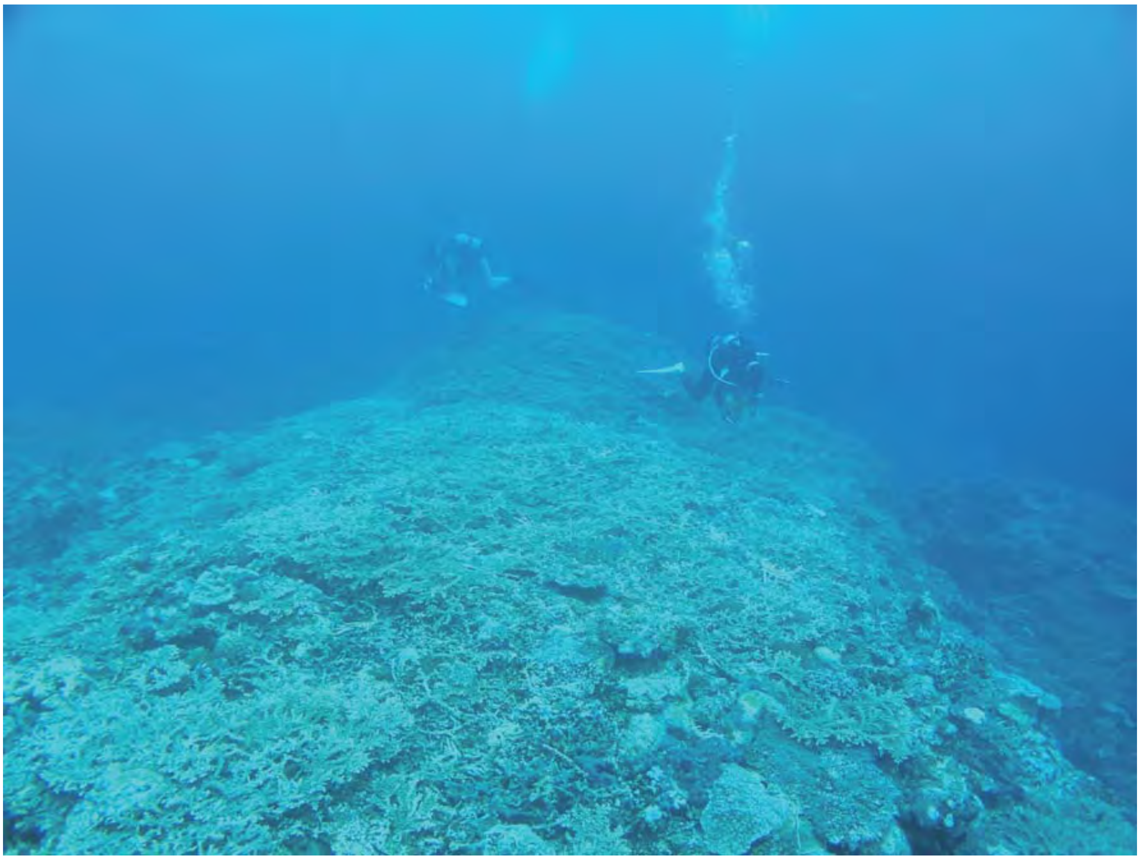

Fig. 2.4.18 Huge community of branching Acropora at 25m depth off Kume Island. The community was observed approximately 200 m in width (vertical direction in the shoreline) and more than 1,000 m in length (parallel to the shoreline). However, the total area of the community has not been measured yet.

CORAL REEF MANAGEMENT

Monitoring

The Ministry of the Environment has started a national monitoring program on corals and coral reefs since 2004 and a mechanism has been established for collecting information on corals from the high latitude non reef area and coal reef area to identify the status of corals in Japan.

Countermeasure for individual issues

As one of the short-term conservation programs against the disturbances on corals, Acanthaster extermination projects have been conducted around Ishigaki Island and Sekisei Lagoon by the Ministry of the Environment, the Fisheries agency, Okinawa prefectural government and Ishigaki city government. Similar projects have also been made by the government and volunteers in Kushimoto, Shikoku, southern coast of Kagosima and Amakusa.

To prevent red soil runoff, Okinawa Prefecture has controlled the soil runoff from the development construction by the prefectural ordinance and been implementing counter measures to prevent soil runoff targeting the farm areas. In Kochi prefecture, a government project on coral restoration has conducted for rehabilitation of the damaged coral communities by soil runoff after the heavy rain.

Integrated approach with local committee

As a long-term effort, integrated approach on coral conservation including land based program has been implemented in Kochi Prefecture, Tokushima Prefecture, Kagoshima Prefecture and Okinawa Prefecture with establishing local committee on conservation in each target area.

Conservation and management plan by government and local government

As conservation programs by the administration, a "Coral Reef Ecosystem Conservation Action Plan" has been formulated by the Ministry of the Environment in 2010 as national policies and directions on conservation of coral reefs. Okinawa prefectural government has also processed a draft of "Prefectural Plan on conservation, restoration and sustainable use of coral reefs in Okinawa" from 2009 to 2011.

Challenges by NGO/NPO

As one of the efforts by NGO/NPO, WWF Japan has implemented a comprehensive coral reef conservation project on preventing red soil runoff in Kume Island involving local government, scientists, managers and local communities. This project also targets to link conservation actions to the economic development of the island.

Enhancement of Marine Protected Areas

The promotion of marine protected areas was highlighted at the 9th Meeting of the Parties of the Convention on Biological Diversity held in Nagoya, Japan in 2010. Ministry of the Environment amended the Natural Parks Law in 2009, including restrictions on motor boats and expanding the target area to strengthen the marine protected areas. The Fisheries Agency has started the program on supporting and promoting environmental and ecosystem conservation based on the concept of Fisheries resource management extending to cover the conservation of coastal ecosystems such as seaweed and seagrass beds, tidal flats and coral reefs.

In addition, WWF Japan conducted a biodiversity assessment project of Nansei Islands including Ryukyu Island from 2006 to 2010 and selected Biodiversity Priority Areas (BPA) of major important organisms including corals.

Challenge for Coral restoration

The Ministry of the Environment is challenged to restore coral communities in the Sekisei Lagoon, a part of the Iriomote-Ishigaki National Park, through a Nature Restoration Project in Sekisei lagoon since 2006. Okinawa prefecture government also planned to conduct a coral restoration project in 2011 using transplanting of corals. Private and Fishery Cooperatives in Okinawa also implemented coral culture and transplanting as environmental conservation programs.

Collaboration with East Asian region

The Ministry of the Environment hosted an International Coral Reef Initiative (ICRI) Regional Workshop in Phuket, Thailand in 2010 to develop an East Asia Regional Strategy on MPA Networks 2010 with Cambodia, East Timor, Indonesia, Philippines, Singapore, Thailand, Vietnam, China for enhancing coral reef conservation in cooperation with the East Asian countries in the region.

RECOMMENDATIONS

- Promote conservation efforts through the conservation and management plans of the prefectural and national governments and linking them to the local action and challenges for improving overall effects of coral conservation throughout Japan;
- Compile and evaluate the effects of exsisting activities such as Acanthaster extermination and reef restoration for utilizing the results for other areas and considering further process of the coral conservation;
- Develop intensive research and projects to minimize stresses from terrestrial and coastal areas for enhancing resiliances of corals against the natural disturbances such as coral bleaching and typhoon;
- Address the social, economic and cultural impacts from the change of the ecosystems due to the expansion of corals and degradation of seaweed communities, creating new resources for tourism and changes of the fish species used for the fisheries resources.

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2.5 KOREA

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ABSTRACT

Reef building coral (*Favia* sp.) were recently found in the southern parts of Korea. Around Jeju Island, located in the south *Favia* sp. could be found more easily than before on hard bottom at 0m depth. They colonize on the bare rocks and compete successfully with macro-algae for space. The population size has also developed gradually. A total of 145 octo-corals have been identified in Korea including nine new species recorded in the past 2 years. It appears that tropical species could recruit under the influence of the Kuroshio Current, which may intensify with global warming. The famous soft coral beds of Jeju Island face threats from coastal development to expand the port and land reclamation close to the MPA in Seogwipo area. In addition, a new huge development plan starts in the neighboring area. The government will try to construct a naval base close to the MPA area. NGOs announced the effects to the coral beds by drilling and reclamation. Ministry of Land, Transport and Marine affairs (MLTM) started two new programs concerning the corals. One was to monitor the corals around Korea focused on coral ecology and the related environment for five years. Another was the management and restoration of soft corals in the MPA area in Jeju Island.

INTRODUCTION

Typical coral reefs with reef building stony corals were believed to be absent from Korean waters since 1974, surveys on the geographical distribution of corals around the Korea peninsula revealed 145 species (nine of which were found in 2009). The seas around Korea can be divided into three parts; Yellow Sea, East Sea and Southern Sea. Corals are found in all three areas but species richness differs because of different environmental conditions. The Yellow Sea had 7 species, East Sea 12 and the Southern Sea 103. Among them, 102 species are distributed in Jeju Island, of which 73 species are restricted to Jeju Island. This includes 18 species of stony coral. Fifteen coral species are designated as preservation species by the Natural Environment Preservation Act (Ministry of Environment).

Coral distribution in Korea is limited to the few areas influenced by the Kuroshio warm current. Although corals occur in Uleungdo and the southern coast of Korea, the abundance and number of species are limited. The Southern coast of Jejudo represents important habitats for coral. Jeju Island also affected directly by tropical and subtropical elements because of a branch of the Kuroshio, which passes mainly through the southern part of the island. As climate change induces prevalence of warm water, subtropical species including stony corals are recruiting in the southern sea, and distribution of *Favia* sp. has expanded. A total of 14 areas have been designated as MPAs in Korea, but only the southern parts of Jeju Island are they focused on corals.

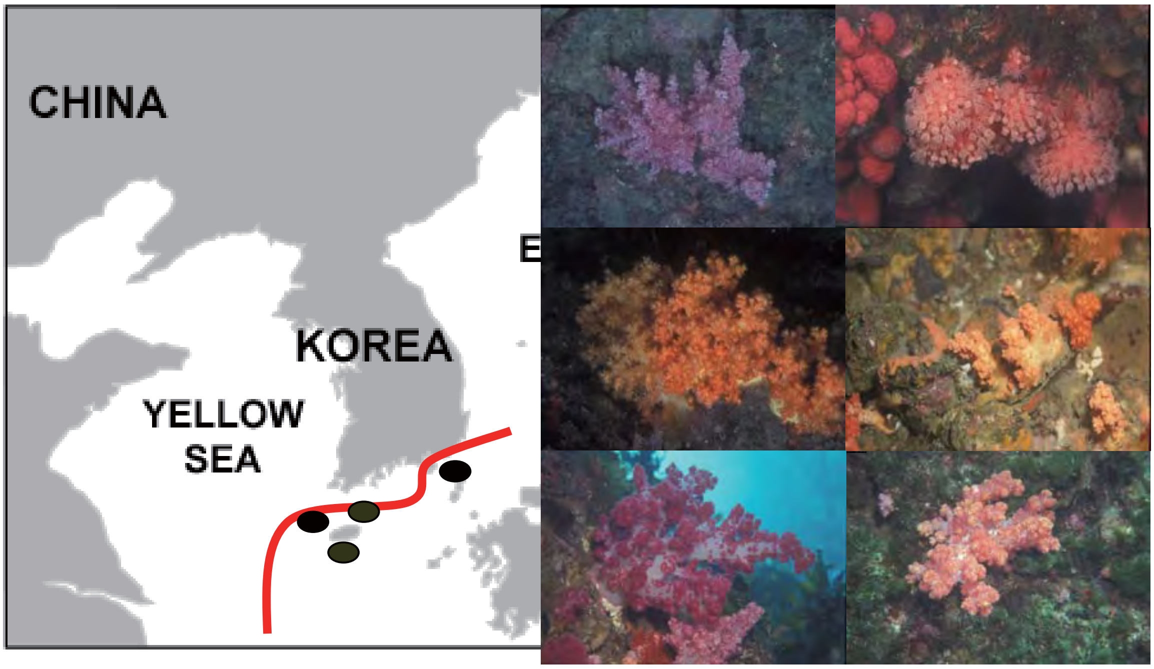

Fig.2.5.1 Bio-geographical boundary of soft coral beds in Korea

STATUS OF CORAL REEFS

Corals

Korea's coral reefs were believed to be mainly soft corals beds (Fig. 2.5.1), but recent surveys increased the diversity more than previously known adding nine new species, two of soft coral and four of stony coral. It appears that warm water prevalence of the Kuroshio currents is favoring the establishment of more species including stony corals, especially in the Southern Sea including Jeju Island. Macro-algae, *Undaria pinnatifid* and *Ecklonia cava* that dominated the hard bottom now has to compete for space with stony and soft corals. About 10 year ago, rock bleaching around the coastal area occurred, after which coralline algae recruited massively, and new algal recruitment proceeded with stony coral recruitment. The abrupt succession of the hard bottom ecosystem presented the opportunity for the recruitment of other species including stony corals.

Reef Fish

Fishes identified in the Jeju Island MPA were approximately 250 species (ME, 2009). It includes commercial species such as food and aquarium species. From 1993, tropical fishes were identified in Jeju Island. Until now Korea has about 1,200 species of marine fish excluding larval fish. An increase is expected as the seas warm from climate change.

Resource Use

Traditionally, *Antipathes japonica* was widely used for the ornament trade. Turned into belts or pendants and hung on the top of house doors, they were believed to drive away evil spirits. Local fishermen hang these on their boats believing that they will be safe for the year, and they do this normally during the lunar New Year. Soft corals are attractive as aquarium specimens and are important sources of natural chemical compounds.. As part of marine technology, soft corals and other sessile invertebrates are investigated for new materials. Soft corals enhance underwater scenery making it attractive to dive tourists. The unique assemblage of temperate, tropical, and subtropical species in Jejudo, which enriches contributed to the biodiversity and colorful scenery under water is of high interest to dive tourists. In particular, the southern coastal area of Jejudo is important for the habitat of corals and fisheries. The underwater scenery around Munseom is one of the grandest sights imaginable with colorful soft corals and various benthic organisms. Since 1988 the areas have been used for tourist submarine. Since then, more than one million people visited for the submarine tours. The increase of tourists for SCUBA diving and tourist submarine can cause destruction problems.

Physical Environment

In southern Jeju Island's coast, the soft corals were dominant only on vertical walls whereas the brown algae dominate horizontal bottoms from 5m to 25m depth. Since 2000, the soft corals appear to replace algae. Recently, some soft coral species already covered all horizontal rocks at 15m depth close to Seogwipo, located in southern Jeju Island. It might be caused by a change of current speed due to construction for a harbor extension.

STATUS OF DISTURBANCE ON CORAL REEFS

Development Damage to Coral Reefs (ports, airports, dredging, etc)

Extension of harbor construction indirectly changes the current patterns, which cause change in distribution of coral in and around MPAs. The Government has plans to construct a naval base close to the MPA in Jeju Island. For a long time, NGOs and the Navy tried to coordinate preserving the soft coral bed from the impact of the new port construction.

Coral Bleaching

Coral bleaching have not been reported in Korea.

Coral Diseases

Coral diseases have not been reported in Korea.

Sediments and Nutrients (land-based)

Major threats on the marine life including corals are suspended material from coastal development and construction, and land-based organic pollution including wastewater. Other threats are unsustainable fishing and tourism. Also, recreational divers and the tourist submarine sometimes physically impact the habitats of marine organisms, especially of soft corals on sub-tidal cliffs. Due to the extension construction of Seogwipo harbor, currents between the main island (Jejudo) and Munseom islet are unexpectedly changing as reported by local divers.

Outbreaking of Invasive Organisms (COTS, Drupella, Diadema, etc)

Outbreaking of invasive species has not been reported in coral habitats of Korea. Only the soft coral grazer, *Armina* sp. was found in soft coral beds for the first time.

Coral Damage from Natural Events (storms, etc)

Annually, typhoons occur around the Korean peninsula, but there were no strong typhoons from 2008 to 2010. Measurable stress and damage were also not surveyed at regional or national level.

POTENTIAL THREATS TO CORAL REEFS (Reef at Risk Threat Indicators)

It is difficult to make an assessment using the five RRSEA indicators recommended, as a regular monitoring system is not established or integrated. Each item can be commented briefly.

a. Coastal Development: increasing
b. Marine-Based Pollution: decreasing
c. Sedimentation and Nutrient-Inputs: increasing
d. Over-fishing: decreasing or no actual data
e. Destructive Fishing: N/A

MANAGEMENT

Marine Protected Areas

In 2001, the southern parts of Jejudo were designated as Natural Monument Protection Areas. These managed areas along Jeju Island were the first kind of protected areas for marine life including corals. They were investigated for designation as a Biosphere Reserve Area by UNESCO and a Marine Protected Area by Ministry Lands Transport and Marine affairs (MLTM). A coral monitoring program in Jeju Island started in 2009 and proceeded for 5 years until 2014. The Hot Spot Program, also carried out in 2009 looked for candidate sites for MPAs focusing on hard bottoms (Fig. 2.5.2). Only Seogwipo coastal area is mainly protected for the purpose of coral and underwater scenery. Overlapping of protection designation will lead to public awareness for local stakeholders and conservation planning in local government as well as the central government. The draft of management plan for wetland protected area by MLTM is being reviewed for budget and planning. MPAs in Korea involve multiple ministries involved with different name and level such as Natural Monument Protection Areas, Wetland Protection Area, Seogwipo City Marine Park and MAB. As the MPA sites for coral conservation were designated recently and management plan is in progress of draft reviewing, calculation of score for management effectiveness (recommended by World Bank) is difficult to carry out.

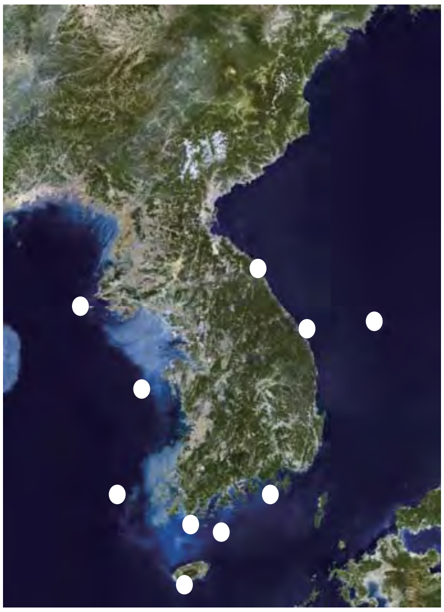

Fig. 2.5.2 A map showing the candidate sites of new MPA areas
(About 2 of area considered to corals)

CONCLUSIONS AND RECOMMENDATIONS

Overlapping of designation of protection area and development plans at different levels cause confusion to local stakeholders. They want for themselves a lot of benefits from their space. They also have a conservative attitude, but the new generation is more practical and open to development of their environment. Legislation in local / national level needs to be well coordinated in a complementary integrated way. For efficient management, all of the stakeholders must realize the importance of protecting the ecosystems in terms of marine resources and socio-economic value for local communities. Sustainable fishing and tourism as well as environmental education are suggested and should be implemented. Even though many surveys have been carried out in these areas, solutions and identification of the ecological/biological/socioeconomic issues have not yet been found. There is, therefore, a great need for long-term research and monitoring projects focusing on the ecosystem. A network system is needed for all protected areas relating to marine ecosystems for efficient management and conservation through sharing of information and experiences, although the protected areas are managed by different departments and local governments in Korea. Also, it may be necessary to develop a collaborative work among the East Asian countries on following research and monitoring fields; biogeography of corals and inhabitants on coral community, exotic species including temporary visitors carried by currents, solutions for major environmental threats of coral species and their habitats.

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3. MONITORING NETWORTK IN EAST ASIA

3.1 REGIONAL CORAL REEF MONITORING AND REPORTING THROUGH AN INFORMAL MECHANISM – THE EXPERIENCE OF SOUTHEAST ASIA

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BACKGROUND OF MONITORING CAPACITY

Coral reef research progressed at various levels in the different countries of Southeast Asia well before the 1980s. The region's interest in coral reefs surged with the Fourth International Coral Reef Symposium organized in Manila in 1981 with an increase in reef monitoring activities. An attempt to review monitoring capacity and the methods used was made through a UNESCO workshop in 1982 held at the Phuket Marine Biological Center. Various methods were being used and monitoring scale and scope was diverse.

The ASEAN-Australia Living Coastal Resources Project (1987-1994) focused on a common monitoring methodology that could be used by the participating countries (Indonesia, Malaysia, Philippines, Singapore, Thailand) with the rational that cross-country comparisons could be made together with a regional analysis. This marked the first time that such a capacity was developed and the method used (Line Intercept Transect - LIT) has remained the most commonly used since. Reef monitoring capacity extended to other Southeast Asian countries like Brunei Darussalam, Cambodia and Vietnam through later regional or bilateral projects.

The ReefCheck monitoring method was also introduced and also widely used. Both the LIT and ReefCheck methods have provided useful information regarding reef condition throughout the region.

With the conclusion of the ASEAN-Australia Living Coastal Resources Project, the five participating countries continued with reef monitoring on their own through national or institutional arrangements. A significant achievement of the project is the network of coral reef researchers that continued to expand and include younger people.

REGIONAL REPORTING

The network made it possible for the region to contribute to the "Status of Coral Reefs of the World" reports compiled for the Global Coral Reef Monitoring Network (GCRMN), which started in 1998. The status of Southeast Asia's coral reefs has been reported since then and done on an informal arrangement supported by the network. A lead author will coordinate the activity and request for information from network members from the various countries.

In 2003, funding was available to appoint a Coordinator for Southeast Asia. Ms Karenne Tun took up the appointment and drove the process for the regional report in 2004. After funding ceased, she continued to discharge the responsibility on a voluntary basis as is the case with the network members who continued contributing to the regional reports.

The informal process has its advantages and disadvantages. Based on goodwill, members give time and effort to compile national status reports to feed into the regional report. However, it is difficult for members to keep doing this voluntarily because of other commitments and there is little to compel them to deadlines.

A meeting was organized for the network members in April 2004 at the WorldFish Center in Penang, where members discussed the development of a network identity and agreed to form SEACORM Net (Southeast Asia Coral Reef Monitoring Network). The aim was to attract sources of funding to regularize the reporting process. However, that identity has not been fully exploited and regional reporting continues to depend on volunteers from the network willing to contribute each time.

CHALLENGES

The informal arrangement has been able to deliver so far to all the status publications. It is apparent that some cannot continue to contribute and other members have to be recruited. Those who have been coordinating the reports are finding it increasingly difficult to get continued commitment and the present arrangement has to be re-evaluated.

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3.2 PRESENT SITUATION OF GCRMN SOUTHEAST ASIA, AND EAST AND NORTHEAST ASIA REGION

Tadashi Kimura
GCRMN Coordinator of East and Northeast Asia Node

BACKGROUND

The GCRMN Southeast Asian (SEA) region has been formed with 7 countries (Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) based on a network of key coral scientists for research and/or conservation programs in the ASEAN region. This network was leading by Professor Chou Loke Ming, the National University of Singapore and he prepared regional reports for the Status of Coral Reefs of the World 1998, 2000 and 2002. He had been transferring his task of GCRMN SEA region to Karenne Tun, the National University of Singapore, and she has taken over his duty as a GCRMN regional coordinator of the SEA since 2004.

The GCRMN East and Northeast Asian (ENEA) region consists of 5 countries and states which are China, Hong Kong, Taiwan, Japan and Korea. Initially the information of coral monitoring in this region was collected by Shuichi Fujiwara, Marine Parks Center of Japan, for 2000 global report with his personal network. His colleague, Tadashi Kimura took over his task and has developed a network of national coordinators of this region since 2002.

In 2004 the regional coordinators of SEA and ENEA organized regional meeting of GCRMN national coordinators during the 10th International Coral Reef Symposium in Okinawa. The participants of this meeting agreed to strengthen the networking of these two regions as one larger region for sharing information on coral reef research and conservation. Then the coordinators decided to organize “Asia Pacific Coral Reef Symposium (APCRS)” as a regular meeting (every four years) for coral reef scientists and managers in the region.

The regional coordinators and national coordinators in the SE and ENE Asia were working as an organizing committee for the symposium and the first APCRS was held in Hong Kong in 2006 inviting over 200 participants. The committee members also prepared a regional status report (Status of Coral Reefs of the East Asian Seas Region, 2006) delivered during the symposium for sharing the situation of coral reefs in the region. The second APCRS will be held in Phuket, Thailand in June 2010.

PRESENT STRUCTURE

The Southeast Asian region consisted of Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam.

Countries and national coordinators of the GCRMN Southeast Asian Region
Cambodia: Ouk Vibol, Fisheries Administration, Cambodia
Indonesia: Suharsono, COREMAP, LIPI
Malaysia: Affendi Yang Amri, University of Malaysia
Philippines: Alino, University of the Philippines
Singapore: Karenne Tun, National University of Singapore
Thailand: Thamasak Yeemin, Ramkhamhaeng University
Vietnam: Vo Si Tuan, National Oceanography Institute

The East and Northeast Asian Region consist of 5 countries and states that are China including Hong Kong and Taiwan, Japan and Korea. The regional coordinator of this region is Tadashi Kimura, Japan Wildlife Research Center.

China: Huang Hui, SOA, Chinese Academy of Science
Hong Kong: Put O. Ang, Chinese University of Hong Kong
Taiwan: Chang-feng Dai, National University of Taiwan
Japan: Tadashi Kimura, Japan Wildlife Research Center
Korea: Heung-sik Park, Korea Ocean Research and Development Institute

MOVING TOWARD FOR A STRONGER NETWORK

After the fist APCRS in Hong Kong, the GCRMN regional coordinators and national coordinators have continued to discuss the sustainable mechanism for maintaining GCRMN activities in SE and ENE Asian region. The main activities of coordinators relied on their voluntary work besides doing their own job. As most of the coordinators are belonging to the scientific institutes, one of the acceptable reasons for spending their time for side work is to contribute some activities regarding to scientific meeting, symposium and/or societies.

So the coordinators are considering pushing forward the GCRMN regional network to stronger scientific network. The draft idea is that the members of national and regional coordinators formulate a steering committee and establish a regional scientific society as a wider and stronger GCRMN regional network. However, this idea is still under discussion and will be finalized during the regional GCRMN meeting at the APCRS in Phuket in June, 2010.

The success of the first APCRS in Hong Kong also showed that this kind of scientific event stimulated to raise fund for special publications of the event from governments and/or privates sponsors. The regular symposium held every four years could give a possible opportunity to publish regional status report in this region.

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