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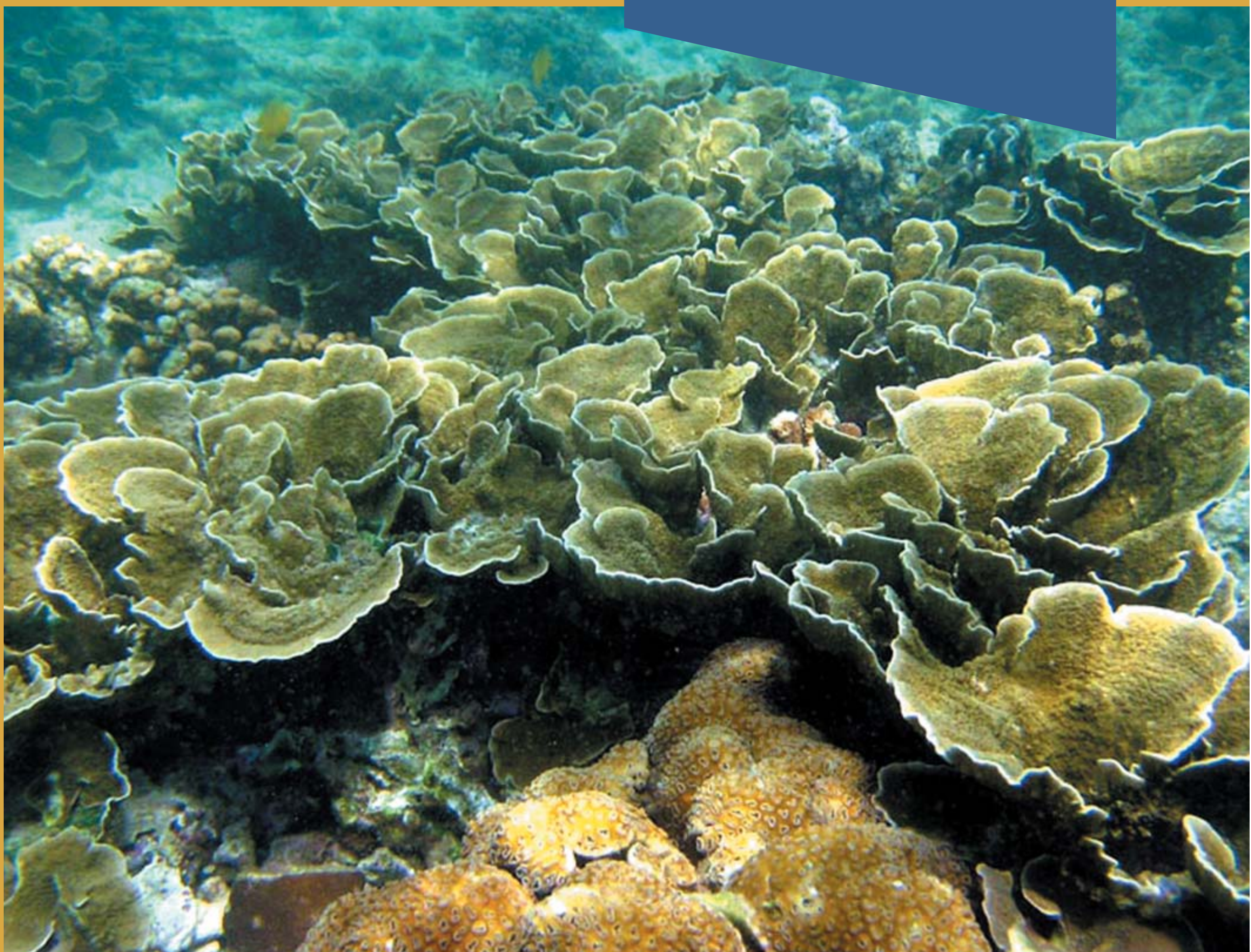
GLOBAL CORAL REEF MONITORING NETWORK

Status of Coral Reefs in East Asian Seas Region: 2004



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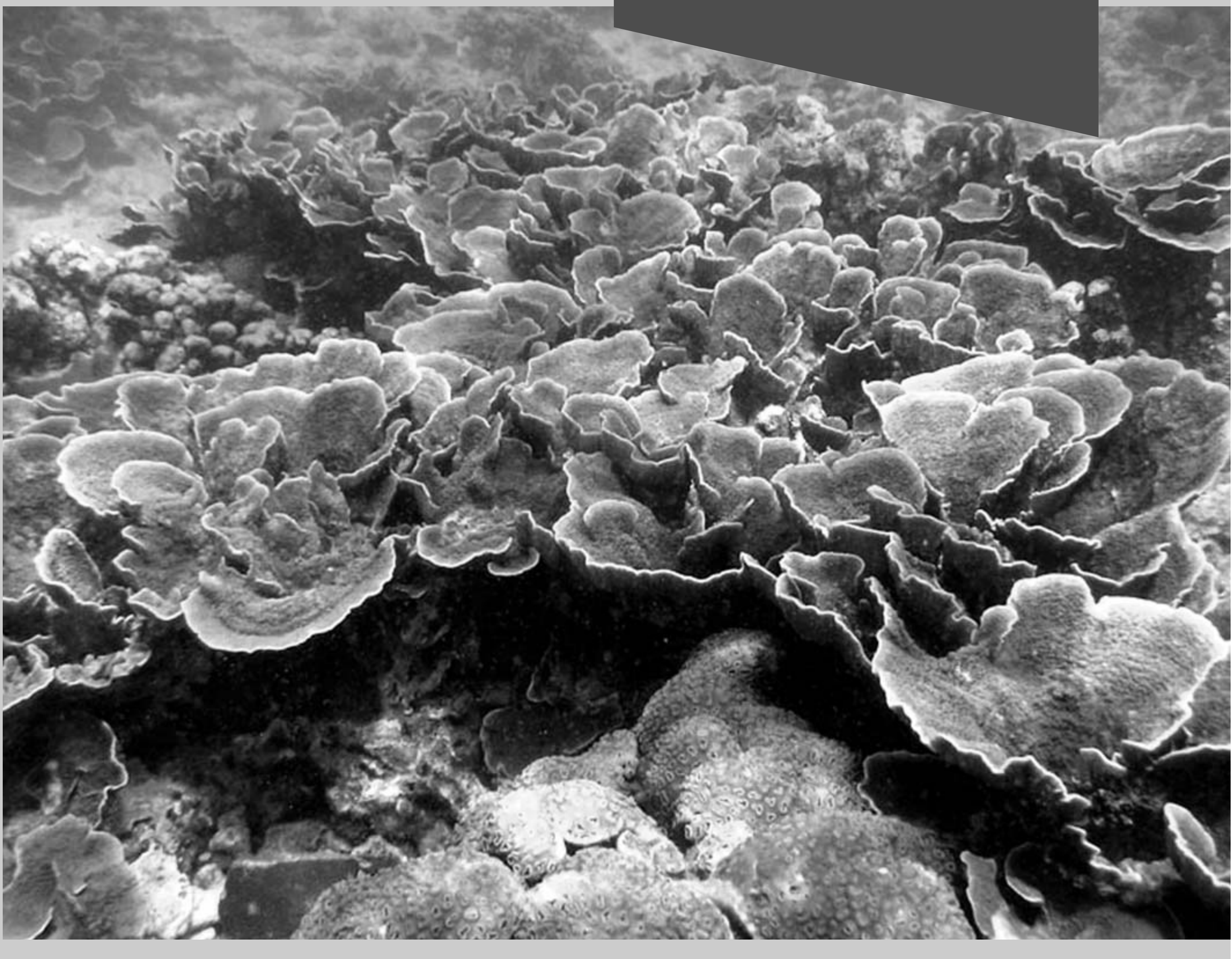

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Front Cover: Coral reefs of Mu Koh Adang Rawi, Satun Province after tsunami (Thamasak Yeemin © 2004)
Back Cover: Damaged corals by tsunami at Mu Koh Phi Phi, Krabi Province. (Thamasak Yeemin © 2004)

GIS Maps for Executive Summary, chapter 2.1. Cambodia, chapter 2.2. Indonesia, chapter 3.4. Japan and chapter 3.5. Korea were produced in collaboration between ReefBase and the Faculty Social Sciences and Humanities, Universiti Pendidikan Sultan Idris.

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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 livelihood and economy as fishery and tourism bases and protect 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 on and raising awareness about coral reef conservation. The Ministry of the Environment of Japan established the International Coral Reef Research and Monitoring Center in Ishigaki Island in Okinawa. The center is strongly promoting the establishment and enhancement of the framework for co-operation to conserve coral reefs in the area, in concert with GCRMN Headquarters and the WorldFish Center, through coordinating and liaison work and regional workshop activities.

This document, "GCRMN East Asian Seas Regional Report", has been produced mainly by the Ministry of Environment and WorldFish Center, working together, in co-operation with national coordinators from relevant countries, under an agreement made on the occasion of the "GCRMN East Asian Seas Regional Meeting" held on the 27th of June, 2004 in Okinawa. As a regional version of GCRMN's "Status of Coral Reefs of the World", this report conveys more detailed information than the global version. I expect the report serves not only as a material for information dissemination but also as a cornerstone for decision making by national governments and aid agencies.

On the 26th of December 2004, before this report was completed, the Sumatra Earthquake Tsunami attacked the area, causing severe damage to Indonesia, Thailand, Malaysia and Myanmar, four countries within the Indian Ocean, out of 10 South East Asian countries. Under the situation, we decided to add information on the damage to coral reefs caused by the tsunami in order to serve as an information base to determine the extent of the damage and to be utilized in post-disaster recovery.

Japan is now co-hosting the International Coral Reef Initiative (ICRI) Secretariat with Republic of Palau for 2 years starting in July 2005. We are prepared to make the utmost effort not only to strengthen the framework of cooperation among East Asian Sea Region but also to deepen cooperation with countries in Pacific and in other areas all over the world.

Finally, I would like to thank all the National Coordinators for authoring the great articles in this Report. I especially thank Dr. Jamie Oliver and Ms. Karenne Tun from WorldFish Center and Mr. Tadashi Kimura from Japan Wildlife Research Center for their impressive cooperation.

Munehiro Abe

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Co-Chair of ICRI Secretariat（2005-2007）

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PREFACE

This regional report is a direct response to the International Coral Reef Initiative (ICRI) strategy on research and monitoring determined in the 'Call to Action' developed in Dumaguete City, The Philippines in 1995. This included a call to: Use regional networks to achieve better coordination and cooperation among national research programs; Promote linkages between regional and global research and monitoring networks ...; Support research and monitoring programs, projects, or activities identified as essential to managing coral reef ecosystems for the benefit of humankind; and Promote the development and maintenance of a global coral reef monitoring network. It is very pleasing to see that Japan and partner countries in the East Asian Seas region are fulfilling this call.

The Ministry of Environment and the Japan Wildlife Research Center, in association with the WorldFish Center worked with national coral reef monitoring coordinators to produce national status of coral reef reports that were presented at the 10th International Coral Reef Symposium in Okinawa, Japan in 2004 and then summarised in the GCRMN global report released in December 2004. This present book contains the full reports from these countries and is intended to provide governments, natural resource managers, NGOs and communities with the latest information on coral reef threats, problems and solutions, along with a series of practical recommendations to improve the health of these reefs. While this North-East and South-East Asian region contains the highest coral reef biodiversity, it also contains large populations of people depending on coral reefs for a livelihood. But an encouraging feature of this report is that this region also contains a wealth of well trained and committed coral reef researchers assessing the status of the reefs and managing them for sustainability. A major objective for governments of the region is to make full use of this human capacity to conserve these valuable resources and their diversity for the peoples of the region and the world. This is possible, but it will require the formation of partnerships of all key stakeholders.

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

Clive Wilkinson
Coordinator, Global Coral Reef Monitoring Network
Townsville Australia

EXECUTIVE SUMMARY

IMPACTS OF TSUNAMI IN 2004 (Updated to May 2005)

The earthquake of December 26 2004 that struck 30km beneath the Indian Ocean off the Northwestern coast of Sumatra, Indonesia, affected 10 countries that share the waters of the Indian Ocean. It triggered massive tsunamis which caused extensive devastation on land and unprecedented loss of lives, and will go down as one of the worst human tragedies in history.

Four out of the 10 Southeast Asian countries were affected by the December 26, 2004 earthquake and tsunami - Indonesia, Thailand, Malaysia and Myanmar, all with coastlines lying within the Indian Ocean.

Indonesia

The northern sections of the island of Sumatra suffered the most severe damage. Pre and post-tsunami satellite images of northern Sumatra show considerable changes to the coastline morphology, including changes to the bathymetry of the surrounding waters. The tsunamis infiltrated several kilometers in to mainland in many areas, destroying not just coastal areas but entire cities and villages. An early estimate of coral reef damage falls in the range of 30%.

Thailand

A total of six provinces were affected by the tsunami – Phuket, Ranong, Phang-Nga, Krabi, Trang and Satun, with Phang-Nga experiencing the greatest impact. A total of 174 sites covering the six affected provinces were assessed. 12% of the sites showed severe impact; with 47% of the sites showing low to moderate impact and 41% of the sites had no visible impact from the tsunami.

Malaysia

The tsunamis reached the northwestern coast of Malaysia 2-3 hours following the earthquake. Coral reefs along the northwestern region of Malaysia were assessed in March 2005, and no tsunami related damage was observed at all sites surveyed, including Pulau Langkawi, Pulau Paya and Pulau Perek.

Myanmar

Official government reports that followed stated that Myanmar was only mildly affected by the tsunami, and subsequent assessments by NGOs and unofficial reports by tour operators and tourists substantiated the government reports. An assessment of the coral reefs of western Mergui Archipelago by Reef Check Europe and WorldFish Center in March 2005 indicated that the reefs were literally untouched by the tsunami waves with little environmental damage.

CURRENT STATUS OF CORAL REEFS

Cambodia

Coral reefs are distributed along the offshore islands and rocky coastlines of Cambodia, covering a total reef area of approximately 28.065 km^2. Seven sites have been identified and established for long term monitoring. Diversity studies have indicated that 111 species of hard coral, 17 species of soft corals and 9 species of seafans and seawhips are present in Cambodian waters. The average live coral cover at the seven monitoring sites range from 23% to 58%.

Indonesia

Indonesia is a large archipelagic nation with about 14% of the world's coral reef area. Results form coral monitoring activities between 1993 to 2003 showed an overall improvement in coral reefs in "poor" condition , while reefs in the good and excellent condition remained relatively stable and unchanged. However, progressive degradation of coral reefs within the last 10-15 years in several areas has been recognized. The best reefs were mostly restricted to remote areas or areas with some level of active management in place.

Philippines

Changes in the percent cover of different benthic lifeform categories on coral reefs in the Philippines that are in excellent condition indicate that the reefs may be experiencing a steady state of decline (from 5% to 3% to >1% of reefs in excellent condition). However, reefs in good condition are still present in the Celebes Sea, Southern Philippine Sea, Sulu Sea and the Visayas biogeographic regions. About 15% of the reefs surveyed in South China Sea and Sulu Sea sustained very high fish biomass.

Singapore

Singapore is a small island state with an estimated 54km^2 of coral reefs. Almost the entire coastline of the main island, particularly the southern half have been altered by land reclamation and many of the southern offshore islands merged by reclamation to form larger islands. Coral reefs, once abundant along the southwest coastline of the main island have been lost to coastal reclamation and are now restricted to narrow fringing bands and patches among the southern offshore islands. Despite the limited reef area and high anthropogenic impacts, some reefs still support good coral cover (50% - 70% coral cover) and diversity (over 150 species of corals).

Thailand

The coastal areas of Thailand between latitudes 6 ° and 13 ° N offer suitable environmental conditions for coral reef development. Three types of coral distribution are recognized in Thailand - coral communities with no true reef structure; developing fringing reefs; and early formation of fringing reefs. The surveys of coral reefs in certain provinces during 2002-2004 showed obvious changes condition of some reefs within the Gulf of Thailand, while the condition of coral reefs in the Andaman Sea have remained relatively unchanged.

Vietnam

Coral reefs are distributed within the shallow waters of the main coastline and around the offshore islands. Coral reefs in better condition are found within the central coastal areas and around the southeastern islands, where temperatures are normally greater than 20℃, and where the reefs experience some offshore influences. Recent coral survey data indicate a dominance of reefs with fair to poor condition (18% and 30% hard coral cover respectively at 50 monitoring sites). Declining abundance of key invertebrate and fish indicators also indicate a reduction of economically important reef organisms. Reefs in better condition were only recorded at some reefs in Ninh Thuan and Phu Quoc.

China

The lack of warm water along much of China's coast has inhibited coral reef growth. Typical fringing reefs occur mainly on part of coasts of Hainan Island and Taiwan Island. Before 1984, coral reefs in China were in good condition with more than 70% in coral cover. In the 1990s, coral reef conditions declined occurred in 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. During the recent surveys in 2002 in China, coral percent cover was still low as 35% in Daya Bay and 19% in Luhuitou. However, some areas have higher coral percent cover such as 68% in Yongxing Island, Xisha Island.

Hong Kong

Coral Communities are mainly found in the eastern and northeastern coasts of Hong Kong. There are currently four marine parks and one marine reserve in Hong Kong and all the MPAs are now being monitored for various physical parameters and biodiversity and abundance of corals, fish, other invertebrates and algae. The corals within the marine parks in the northeast are so far, generally healthy and some increase in coral cover has been registered over the last four years.

Taiwan

Coral reefs are found in all the waters around Taiwan except in the sandy area on the west coast. No significant changes in coral cover among years were found between 1997 and 2004, because both increasing and decreasing trends were observed. However, more increasing trends at reef slope and more decreasing trends at reef flat were found, suggesting that the reef flat biota was more frequently influenced by anthropogenic disturbances than that of the reef slope.

Japan

Corals widely distribute from Ryukyu Islands to northern islands of Japan including Kyushu, Shikoku and Honshu. Although most of the coral have been recovered gradually in 10 to 20 years after the outbreak of crown of thorns starfish (COTs), the number of COTs has been increasing again in 2000's. After the catastrophic bleaching event in 1998, relatively small scale bleaching occurred in 2001, 2002 and 2003. On the other hand, coral coverage is increasing in the northern islands because of elevated water temperature in winter relaxing the limits for coral growth in the area.

Korea

Korean waters do not have any typical coral reefs by reef building corals, because of the low water temperature. Only the area around Jeju Island affects the influence of warm current and has temperate, subtropical and tropical marine species. 134 of soft and hard coral species are found in Korea including 15 species of stony corals. Most of researches have been conducted on soft corals mainly in Jeju Island

THREATS TO CORAL REEFS

Cambodia

There are many anthropogenic impacts to coral reefs including destructive fishing practices, over-fishing, coastal development, agricultural run-off, sedimentation and seaweed farming on reefs. Reef fish and invertebrates densities are low due to over-fishing.

Indonesia

Many coastlines are being rapidly degraded mainly through inappropriate land development. Rapid population growth, land-based industry, domestic waste and tourism have resulted in a wide range of environment and resource management problems. The marine resources are severally threatened by destructive fishing methods such as dynamite, cyanide, compressors, fish traps, reef gleaning and over fishing.

Philippines

Philippines has a large coastal population that is highly dependent on reef resources for their livelihoods. Over-fishing and destructive fishing practices are by far the greatest threats to the reefs, followed by coastal development and land-based activities.

Singapore

Ongoing land reclamation since the early 1970's has resulted in elevated sedimentation. Regular dredging of shipping lanes and the offshore dumping of dredged spoils contribute to the sediment load. This chronic impact has resulted in the decline in reef condition since 1986 , with a marked reduction in the vertical growth zone along the reef slopes.

Thailand

The first tsunami disaster in the history of Thailand occurred on December 26, 2004. 13% of the reef monitored showed “high impact”, with around 40% showing “no impact”. 21%, 17% and 9% of the reefs showed “very low”, “low” and “moderate” impact respectively.

Vietnam

There were serious outbreaks of the Crown-of-Thorns starfish in Van Phong and Nha Trang bays, while algal bloom killed almost all the coral reefs in Ca Na bay (Binh Thuan province), with the recovery occurring slowly after the event. Sedimentation continues to have a strong impact in Ha Long and Cat Ba islands.

China

Overfishing and destructive fishing practices have badly damaged coral communities around Hong Kong and Xisha islands, causing most high-value fish species to become locally extinct. Blast fishing has been widely practiced in Hainan Island. Cyanide fishing is carried out by large-scale commercial operators who take fish from remote areas such as Xisha Island and Nansha Island. Cyanides are also used for collecting aquarium fishes. Sedimentation, freshwater incursion, and sewage outflows have adversely impacted China's reefs, particularly near the mainland. Failure in proper managing the land resources have caused problems of siltation. Local governments has bombed out Mabian Zhou, Daya Bay for 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.

Hong Kong

Occasional bleaching, predation, human or storm disturbances have been observed in Hong Kong waters. High sedimentation due to dredging and land reclamation, high nutrients due to effluence of untreated sewage and high heavy metal contents due to industrial effluence are some of the main marine pollution problems in Hong Kong. Extensive mortality of corals was reported in South Ninepin attributable to heavy siltation brought about by dredging in Tung Long Wan Borrow area. Hong Kong waters are generally considered as being overfished.

Taiwan

Soil erosion and landslides frequently occur in coastal areas especially after storms, and these runoffs have carried large amounts of sediment and nutrients to reef areas. Sewage of most towns and villages in coastal areas are often ill-treated and discharged to reef areas. This induces serious nutrient enrichment to reef ecosystems especially in northeastern and southern Taiwan, and Hsiaoliuchiu. Although blast and poison fishing methods have been officially banned, there are still sporadic reports on these illegal fishing methods. Anchor damages could be found sporadically on most reefs. Bottom-trawlers, with their heavy gears sweep over reef surface, have caused severe damage to coral reefs in Penghu Islands. Trampling and mechanical breakage of coral skeleton by divers and tourists have been a serious problem at diving hotspots in Lutao, Penghu, and southern Taiwan. Construction of fishing ports and coastal highway in northeastern and eastern Taiwan has caused damage to coral reefs. Extensive coral bleaching was observed in southern Taiwan, Penghu Is., and Hsiaoliuchiu reefs following heavy rainfalls associated with typhoons in June and July, 2004. Outbreak of a sea anemone, Condylactis nanwanensis, was noticed in Nanwan Bay, southern Taiwan and caused severe damage to coral reefs since it destroys coral tissue and weakens coral skeleton. Typhoon is another disturbance on corals in Taiwan. Coral communities at Chitou, Penghu Islands and Tiaoshi, Nanwan Bay were heavily damaged (up to 90% coral mortality) by Typhoon in 2001, and have not recovered since then.

Japan

The number of COTs has been increasing again in southern part of Japan since 2000’s. After the catastrophic bleaching event in 1998, relatively small scale bleaching occurred in 2001, 2002 and 2003. Soil runoff by the coastal development is also one of the major threats on the reefs in Okinawa and mainland Japan. The corallivorous gastropod, Drupella is still major predator of corals in northern islands.

Korea

The increase of tourists for SCUBA diving and tourist submarine have become the cause of reef destruction.

CORAL REEF MANAGEMENT

Cambodia

The Cambodian government has very limited human resources, infrastructures, and finances for scientific research and monitoring. There are no laws that relate to the protection of coral reefs, with the exception of a Fisheries law. A national action plan that integrates coral reef management and conservation, capacity building and maintenance, infrastructure and institutional development, improved legislations, better administrative framework and enforcement, public awareness, communication, education, and participation, biodiversity assessments and regular monitoring is urgently needed.

Indonesia

The new 1999 legislation (Autonomy laws No. 22/1999 and No. 25/1999) effectively integrated all previous legislations concerning marine management. The ministry of Forestry’s Directorate General for Protection and Nature Conservation (PKA) is the agency responsible for nature conservation in Indonesia. The government has set a target to establish 10 million ha of marine conservation area; however, only some 5.8 million ha has been officially declared, which includes 37 marine conservation area. Coral reef

Rehabilitation and Management Program (COREMAP) have conducted public communication programs for the last two years. All target sites were positively affected by the campaign.

Philippines

The Department of Environment and Natural Resources (DENR) and the Department of Agriculture, Bureau of Fisheries and Aquatic Resources (DA-BFAR) are the two national government agencies that have the mandate to establish MPAs or fishery refuges. Under the 1998 Philippine Fisheries Code, at least 15% of the total coastal areas in each municipality should be identified as fish sanctuaries. Of over 600 MPAs that have been established in the Philippines, only around 10% of these MPAs are actually being managed effectively. A National Coral Reef Strategy is currently being prepared to provide a clear and integrated management framework for the protection, conservation and rehabilitation of the coral reefs in the country.

Singapore

There are no marine protected areas covering coral reefs, although proposals to protect identified reefs have been made. Currently, only two legislated nature areas have marine components, but they do not contain reefs. The establishment of the Biodiversity Center within the National Parks Board in 2004 has increased the focus on the marine environment. Artificial reefs and coral translocation activities have been initiated since the mid-1990's to address the issue of coral reef remediaion.

Thailand

There are numerous institutions involved in coral reef monitoring and management, coordinated through the Department of Marine and Coastal Resources and several universities. A National Coral Reef Strategy: Policies and Action Plan was adopted by the cabinet in 1992. All the major coral reefs in Thailand are assigned to one of four management categories - general use zones, intensive tourism zones, ecotourism zones and ecosystem reserve zones. The majority of coral reefs are classified as ecotourism zones. There have been a few studies on community-based management of coral reefs in Thailand, such as Had Chaolao in Chantaburi Province where local people manage coral reefs for tourism.

Vietnam

National government and international agencies have supported the development of a network of marine protected areas in Vietnam. A national action plan for coral reef management is being developed under the framework of UNEP GEF/SCS project.

China

Coral reefs are protected and managed by the regulations, such as; the State Law of Marine Environment Protection issued in 1983 and new revised edition issued in 2000; the Hainan Province Regulation of Coral Reef Protection issued in 1998; and the State Law of Ocean Use Management issued in 2001 demand that all coastal development programs need accord with the Division of Marine Functional Zonation made by government. There are 3 Marine Coral Reefs Reserves in mainland of China and more MPAs are in the planning process. Marine Coral Reefs Reserves are "no-take" areas where only scientific research is allowed within the boundaries. A program named "Restoration of Coral Reef Ecosystem and Protection and Management of Its Biodiversity in South China Sea of China" is one of the priority programs of 21 Century Ocean Agenda of China.

Hong Kong

The most important legislature that has a direct bearing on the protection of coral communities is the Marine Parks Ordinance that enacted in 1995 and took effect in July 1996. This Ordinance provides for the designation, control and management of marine parks and marine reserves under the Country and Marine Parks Authority of the Agriculture and Fisheries Department (AFD). The Agriculture, Fisheries and Conservation Department (AFCD, former AFD) of the Hong Kong SAR Government is the lead agency overseeing the protection of Hong Kong marine parks. The Authority is advised by the Country and Marine Parks Board that is made up of representatives from different government departments, the academia, NGOs and the public. There are currently four Marine Parks and one Marine Reserve in Hong Kong. AFCD provides the funding for research teams from tertiary institutions to monitor the parks.

Taiwan

Most coral reefs in Taiwan are within national parks, national scenic areas or coastal conservation zones and these areas are protected by the National Park Law and the Coastal Environmental Protection Plan. However, the current laws are inadequate to protect coral reefs. The revision of laws and the planning of MPAs with effective management are currently processing by governmental administrations.

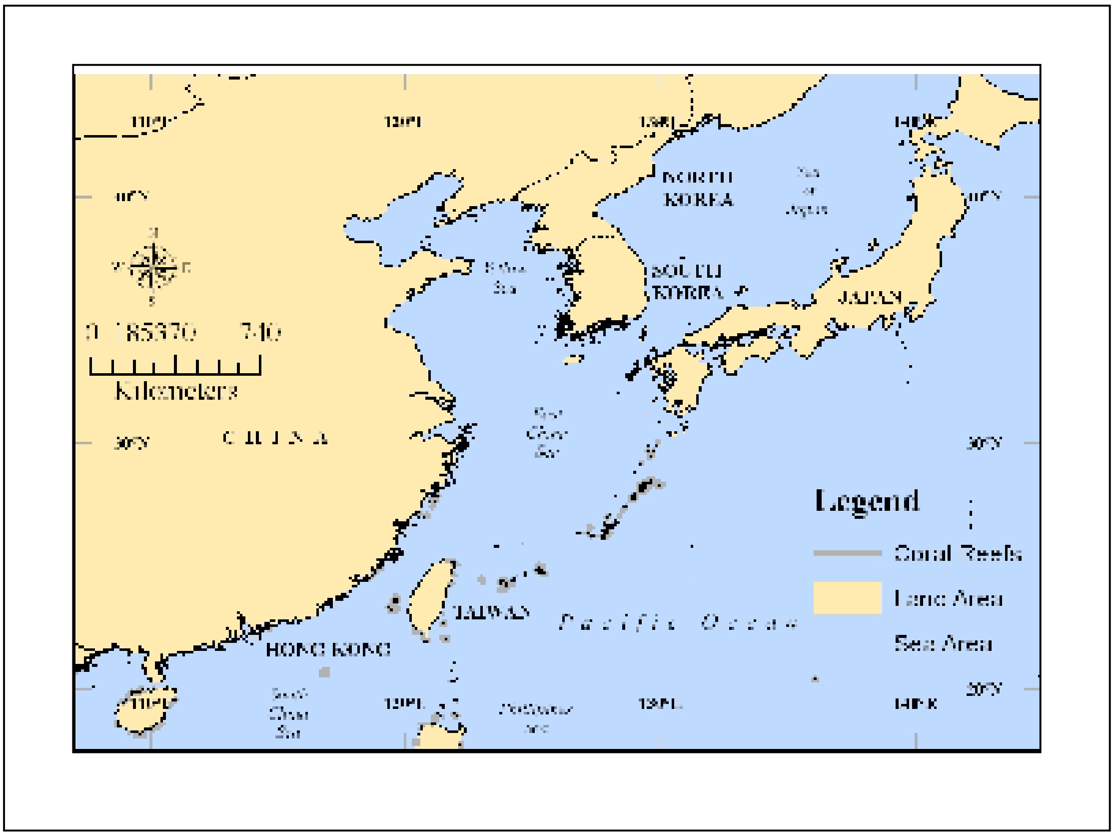
Japan

There are several management practices conducted in the local communities to control the disturbances, such as COTs and *Drupella*. The government has established the Law for the Promotion of Nature Restoration and focus on integrated coastal management involving different stakeholders for coral conservation. There are two programs of Nature Restoration Projects targeting coral conservation.

Korea

Southern coast of Jeju-do were designated as MPA in the name of Wetland Protection Areas by Ministry of Maritime Affaires and Fisheries (MOMAF) as well as Man and Biosphere (MAB) by UNESCO in 2002. There are some overlapping between designation of protected area and development plan in different level (agencies) and they made local stakeholders confused. Legislation in local/national level needs to be well coordinated in complementary integration

. A map of Southeast Asian countries.



A map of Northeast Asian countries.

1. SUMMARY OF PRELIMINARY RAPID ASSESSMENTS OF CORAL REEFS IN AFFECTED SOUTHEAST ASIAN COUNTRIES FOLLOWING THE ASIAN TSUNAMI EVENT ON DECEMBER 26, 2004

Karenne TUN, Jamie OLIVER and Tadashi KIMURA

This report is a joint effort between WorldFish Center, GCRMN and the Government of Japan through the Japan Wildlife Research Center, and will form part of a series of reports under the joint Japan-Palau chairmanship of the ICRI secretariat from 2005 to 2007

ABSTRACT

The earthquake of December 26 2004 that struck 30km beneath the Indian Ocean off the Northwestern coast of Sumatra, Indonesia, affected 10 countries that share the waters of the Indian Ocean. It was the world's most powerful and devastating earthquake since the 1964 Prince William Sound, Alaska earthquake, measuring in at 9.0 on the Richter Scale. It triggered massive tsunamis which caused massive devastation on land and unprecedented loss of lives, and will go down as one of the worst human tragedies in history. The earthquake left the region shaken and geologically unstable, with a further two strong earthquakes measuring between 6.7 and 8.7 on the Richter Scale striking between March 28 to April 10 2005 along the same fault line and south of the December 26 quake, but these did not trigger any tsunami (Figure 1).

Concerns over the environmental impacts and consequences from the earthquakes and the tsunami were highlighted by governments of all countries affected and echoed by numerous international environmental agencies in the immediate aftermath of the events. Concerted efforts have been made by various agencies and groups to address these concerns, resulting in several integrated rapid environmental impact assessments and stand-alone detailed ecosystem assessments conducted in the first quarter of 2005, which have allowed for better understanding of the impacts and responses of the natural environment to the disaster. Results for these assessments have formed the backbone for this report.

This report is a summary synthesis of various post-tsunami environmental assessments that have been conducted, and draws specifically on information related to coral reefs in the affected Southeast Asian countries. This report has drawn from the works of many agencies, groups and individuals, and although efforts have been made to be as thorough and representative as possible, we acknowledge that many gaps still exist in the report. This report will be amended and modified on a regular basis in the next 2 years to incorporate and append new information and results generated from ongoing or future post-tsunami environmental assessments involving coral reefs in Southeast Asia. Information used to develop this report can be found on ReefBase (www.reefbase.org).

Four out of the 10 Southeast Asian countries were affected by the December 26 2004 earthquake and tsunami - Indonesia, Thailand, Malaysia and Myanmar, all with coastlines lying within the Indian Ocean.

Numerous rapid environmental assessments were made within the first quarter of 2005, conducted in all cases with due regard to the sensitivity of the situation and the needs of the survivors. Preliminary coral reefs assessments were conducted in all four countries, either as independent and focused assessments, or part of wider environmental assessment efforts.

Preliminary results so far have generated the following general observations:

a. Coral reefs in the region showed varying levels of impact from the earthquakes and tsunami, ranging from total destruction to no visible impacts;
b. Impact on coral reefs from the earthquake and the tsunami had different manifestations, with

the earthquake causing direct physical change to reef systems, while the actual tsunami wave front did not cause as much damage compared to post-wave impacts such as backwash and debris deposition;

c. Severity of impact on coral reefs did not always correspond to severity of impact on adjacent land, as seen at several sites near Patong, Phuket, where damage to reefs were low while adjacent land areas suffered extensive damage;
d. Moderate to high impact on coral reefs from the tsunamis showed positive correlation to anthropogenic influences, as seen by damage to coral reefs in the vicinity Phi Phi island, which were mostly associated with deposition of debris like beach umbrellas, furniture, vehicles and uprooted vegetation;
e. Coral reef fish fauna was not adversely affected, with sites surveyed showing no change in pre- and post- tsunami coral reef fish diversity and abundance;
f. At some survey areas, high proportional tsunami related coral damage were found to correlate with areas that did not have substantial live hard coral cover prior to the tsunami; and
g. Intact and healthy coral reefs (together with associated ecosystems comprising mangroves and seagrass beds) have shown to correlate with shoreline protection and correspondingly less impact on land.

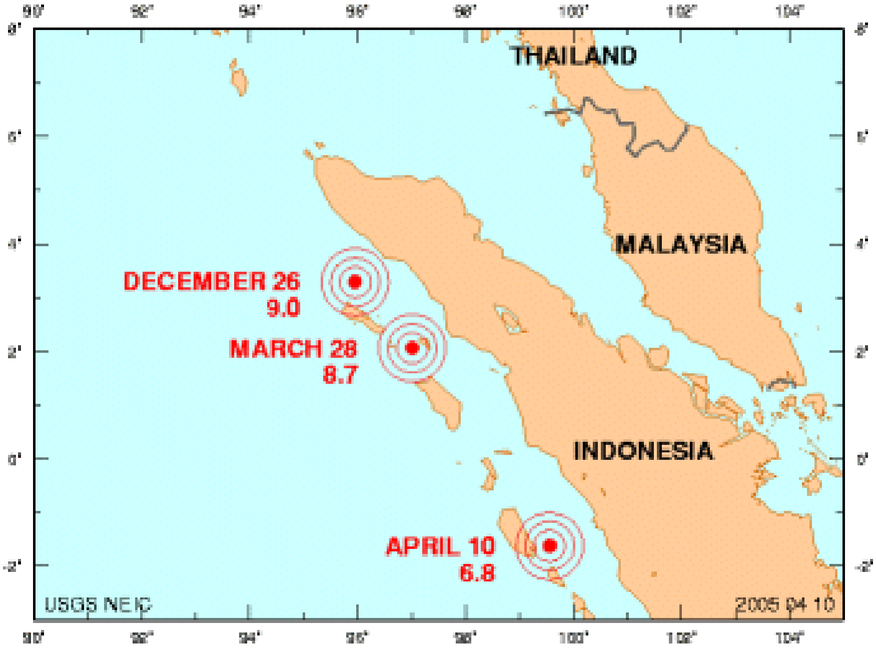


Figure 1. Location of the three earthquakes which stuck along the Western coast of Sumatra, Indonesia between 26th December 2004 and 10 April 2005. (Map and earthquake information from USGS NEIC)

COUNTRY SUMMARIES

1. Indonesia

The northern sections of the island of Sumatra suffered the most severe damage, especially areas lying in the vicinity of the earthquake's epicenter. Pre and post-tsunami satellite images of northern Sumatra show considerable changes to the coastline morphology, including changes to the bathymetry of the surrounding waters. Low lying and cultivated land areas were most drastically affected with vast areas remaining completely submerged three months after the event. The tsunamis infiltrated several kilometers in to mainland in many areas, destroying not just coastal areas but entire cities and villages.

Limited pre-tsunami information on the status of coral reefs in northern Sumatra is available. Much of the information that is available draws from unpublished reports, anecdotal accounts and observations and from pre-tsunami satellite images of the region. Initial rapid assessments indicate that damage to coral reefs varied greatly, with reef areas directly affected by the earthquakes showing visible physical changes while impacts from the tsunami ranged from nil to severe, with the majority of assessments showing moderate impacts.

An early estimate of coral reef damage falls in the range of 30%. Pulo Aceh Islands were identified by Wetlands International as the area most likely to experience serious damage. In Pulau Weh, initial reports indicate that only shallow corals (<3m) showed signs of damage, with deeper corals showing minimal damage. Damage to the Simuelue Island was moderate following the December 26 earthquake and tsunami, but impacts from the subsequent earthquake on March 28 is still not known. Given the geologically unstable nature of the region, it is unlikely that any definite assessment of coral reef damage will be forthcoming in the months to come.

2. Thailand

A total of six provinces were affected by the tsunami – Phuket, Ranong, Phang-Nga, Krabi, Trang and Satun, with Phang-Nga experiencing the most impact.

There is extensive information on the status and condition of coral reefs in Thailand, and regular monitoring and assessments have been conducted for over a decade now. The impact of the tsunami was conducted by a consortium of agencies and institutions within the first 2 weeks of January 2005, and a total of 174 sites covering six affected provinces were assessed. 12% of the sites showed severe impact; with 47% of the sites showing low to moderate impact and 41% of the sites had no visible impact from the tsunami.

Impact on coral reefs resulted from 3 main causes – 1) wave action which dislodged, broke and moved corals; 2) sediment smothering and 3) debris deposition.

An localized assessment of Mu Koh Surin National Park by Coral Cay Conservation between February and March 2005 indicated that areas of high tsunami-related coral damage correlated with areas that did not have substantial live hard coral cover prior to the tsunami. In addition, the assessment indicated that the overall loss in coral cover as a result of the tsunami averaged at about 8%. A separate ReefCheck Europe expedition to Mu Koh Surin National Park from 22 to 27 February 2005 also revealed similar results.

3. Malaysia

The brunt of the December 26th earthquake and tsunami was borne by Sumatra in nearby Indonesia, with the tsunamis reaching the northwestern coast of Malaysia 2-3 hours following the earthquake. Coral reefs along the northwestern region of Malaysia were assessed in March 2005, and no tsunami related damage was observed at all sites surveyed, including Pulau Langkawi, Pulau Paya and Pulau Perek.

4. Myanmar

Limited, if any, information was available from Myanmar in the week following the earthquake and tsunami, and vast areas of coastline were initially believed to have been affected by the tsunami. Official government reports that followed stated that Myanmar was only mildly affected by the tsunami, and subsequent assessments by NGOs and unofficial reports by tour operators and tourists substantiated the government reports. An assessment of the coral reefs of western Mergui Archipelago by Reef Check Europe and WorldFish Center in March 2005 indicated that the reefs were literally untouched by the tsunami waves with little environmental damage.

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Table 1. Summary of Environmental Response to the December 26 2004 Earthquake and Tsunami in Affected Southeast Asian Countries

Country	Assessment Title	Assessment Date/s	Coordinated By	Funded By	Organisation/s Involved	Scope of Assessment	Scale of Assessment	Methods Used	Status of Assessment	Remarks
Thailand	Summary of Rapid Assessment of Coral Reef Damage in Thailand Caused by Tsunami	30 Dec 2004 to 15 January 2005	Department of Marine and Coastal Resources	Government of Thailand	Phuket Marine Biological Center, Kasetsart University, Ramkhamhaeng University, Chulalongkorn Univeristy; Burapha University, Prince of Songkhla University, Walailak University, Mahidol University, Trang Rachamangala Institute, Department of National Park Wildlife and Plant	Visual assessment of coral reef condition. Other ecosystems not assessed.	174 sites across the six provinces of Ranong, Phang-Nga, Phuket, Krabi, Trang and Satun.	Locally developed rapid visual assessment that grouped coral reefs into 3 categories: No Impact (% damage), Low-Moderate Impact (>0-50% damage) and Severe Impact (>50% damage)	Assessment completed and report produced in Thai. Brief summary of assessment completed in English and submitted to GCRMN.	Of the 175 sites surveyed, 12% showed no impact, 47 % showed low to moderate impact and 41% showed severe impact. Results for the six provinces: **Ranong** – 13 sites surveyed; no impact 0%, low to moderate impact 54%, severe impact 46% **Phang Nga** – 52 sites surveyed; no impact 26%, low to moderate impact 52%, severe impact 22% **Phuket** – 22 sites surveyed; no impact 59%, low to moderate impact 41%, severe impact 0% **Krabi** – 29 sites surveyed; no impact 41%, low to moderate impact 55%, severe impact 4% **Trang** – 10 sites surveyed; no impact 40%, low to moderate impact 60%, severe impact 0% **Satun** – 30 sites surveyed; no impact 77%, low to moderate impact 20%, severe impact 3%
	The Impact of the December 2004 Indian Ocean Tsunami on the Coral Reef Resources of Mu Ko Surin Marine National Park, Thailand	February to March 2005	Coral Cay Conservation, UK	British Government through the Foreign and Commonwealth Office	Ramkhanhaeng University, Department of National Parks	Coral reef field assessment and capacity building.	1423 sub-transects equating to over 28km of reef at Mu Koh Surin National Park.	Site specific data using benthic indicator categories adapted from the ICRI/ICRS Tsunami Damage to Coral Reefs Guideline for Rapid Assessment and Monitoring.	Assessment completed and report available online at http://www.coralcay.org/archives/2005/04/06/13.20.43.php	Live hard coral cover high on the north-east coast of the island of North Surin - average value of 75% and maximum value of 90%. Areas of high proportional tsunami related coral damage correlated to areas with substantial lower live hard coral cover pre-tsunami. Only 8% of the pre-tsunami coral quantity or coverage may potentially have been lost to the tsunami if all of this damaged coral subsequently now dies. Signs of coral regrowth were discovered and documented.

	After the Tsunami – Rapid Environmental Assessment	10 to 13 January 2005	UNEP	Unspecified	UNDP, UNHABITAT, ILO, IOM, UNHCR, UNESCO, MONRE	Broad-scale environmental assessments, non-field based, covering all coastal ecosystems.	Entire country.	Synthesis of existing reports and field assessments.	Preliminary assessment completed and report available online at http://www.unep.org/tsunami/tsunami_rpt.asp	Coral reefs summary derived from report from the Department of Marine and Coastal Resources, Thailand, as reflected above.
	ReefCheck Europe – Assessment of Coral tatus and Condition in Mu Koh Surin National Park, Laem Son National Park and other islands	22 to 27 February 2005	ReefCheck Europe	ReefCheck and volunteers	WorldFish Center	Coral reef field assessments.	6 sites at Mu Koh Surin National Park, 1 site each at Ko Khai Yai, Ko Kam Yai, Ko Pai Yam and Ko Khangkao	Reef Check, LIT and Reef Check Plus	Data currently being analysed.	**Mu Koh Surin National Park** - the 6 sites surveyed showed little change in coral cover between pre- and post- tsunami surveys. **Ko Khai Yai** – Overall low to moderate impact from tsunami observed **Ko Kam Yai, Ko Pai Yam and Ko Khangkao** – moderate to high impact from tsunami observed
	Wetlands International Assessment Report to Ramsar STRP12	January 2005	Wetlands International	Unspecified	WWF, IUCN, Birdlife International, IWMI	Broad-scale environmental assessments, non-field based, covering all coastal ecosystems.	Entire country.	Synthesis of existing reports and field assessments.	Preliminary assessment completed and report available online at http://www.wetlands.org/Tsunami/data/STRP12_Asian_Tsunami.doc	Coral reefs summary derived from report from the Department of Marine and Coastal Resources, Thailand, as reflected above.
Indonesia	After the Tsunami – Rapid Environmental Assessment	10 to 13 January 2005	UNEP	Unspecified	UNDP, UNHABITAT, ILO, IOM, UNHCR, UNESCO, MONRE	Broad-scale environmental assessments, non-field based, covering all coastal ecosystems.	Entire country.	Synthesis of existing reports and field assessments.	Preliminary assessment completed and report available online at http://www.unep.org/tsunami/tsunami_rpt.asp	Coral reefs summary derived from report from the Department of Marine and Coastal Resources, Thailand, as reflected above.

	Wetlands International Assessment Report to Ramsar STRP12	January 2005	Wetlands International	Unspecified	WWF, IUCN, Birdlife International, IWMI	Broad-scale environmental assessments, non-field based, covering all coastal ecosystems.	Entire country.	Synthesis of existing reports and field assessments.	Preliminary assessment completed and report available online at http://www.wetlands.org/Tsunami/data/STRP12_Asian_Tsunami.doc	Coral reefs summary derived from report from the Department of Marine and Coastal Resources, Thailand, as reflected above.
	Assessment of Coral Reef at Iboih and Gapang, Pulau Weh	17 January 2005	Center for Wildlife Conservation, Aceh	Unspecified	Unspecified	Coral reef field assessments.	Iboih and Gapang, Pulau Weh	ReefCheck surveys using snorkeling.	Assessment results summarized via email to GCRMN.	90% of coral cover is damaged in Iboih. 15 % coral cover is damaged in Gapang. No shoreline change in either Iboih or Gapang.
Malaysia	Post Tsunami Impact Assessment Reef Survey 2005 (POSTIARS05)	March 2005	Malaysian Society of Marine Sciences	Malaysian Society of Marine Sciences and other sources	WorldFish Center, Universiti Malaya, WWF	Coral reef field assessments.	Pulau Langkawi, Pulau Perak, smaller islands surrounding Penang, Pulau Jarak, Pulau Pangkor,and Pulau Sembilan	Reef Check and visual assessments.	Data currently being analysed.	None of the sites surveyed showed signs of damage specifically from the tsunami.
	Assessment of Tsunami Impact on Coral Reefs in Paya Marine Park, Kedah, Malaysia	Unspecified	Coral Cay Conservation	Department of Marine Parks	Unspecified	Coral reef field assessments.	Pulau Payar Marine Park	Modified ReefCheck and visual assessments.	Preliminary assessment completed and report available from CCC.	The coral reefs of Pulau Payar showed no signs of damage specifically from the tsunami.
Myanmar	ReefCheck Europe – Assessment of Coral tatus and Condition in the southern Mergui Archipelago	1 to 5 March 2005	ReefCheck Europe	ReefCheck and volunteers	WorldFish Center	Coral reef field assessments.	7 sites in the southern Mergui Archipelago	Reef Check and Reef Check Plus	Data currently being analysed.	None of the sites surveyed showed signs of damage from the tsunami.

2. STATUS OF CORAL REEFS: IN SOUTHEAST ASIAN COUNTRIES

2.1. CAMBODIA

KIM Sour, CHOU Loke Ming and Karenne TUN

ABSTRACT

Coral Reefs play a very important role in marine ecosystem in Cambodia as the critical habitat for a lot of marine species, support the fisheries and eco-tourism. Not much is known about Cambodia's coral reefs because of a lack of research capacity. Local people also do not know about this valuable resource because lack of public awareness and extension programs.

Coral reef sites have been completely identified and they are distributed in various localities, generally associated with offshore islands and rocky beds. Totally, seven sites have been identified, and the reef areas accounted for 28.065 km^2 by the study. Diversity studies and review to date indicated 111 species of hard coral, 17 species of soft corals and 9 species of seafans and seawhips. The average live coral cover for the whole coastline accounted for 23% to 58%. Even the percentage coverage is high; coral reefs are generally in not good health, with low species diversity dominated by massive forms. It is dominated by dead coral reefs.

There were many anthropogenic impacts to coral reefs including destructive fishing practices, over-fishing, coastal development, agricultural run-off or sedimentation, seaweed farming on reefs. Reef Fish and invertebrates densities are low due to over-fishing. Reefs appear to be over-fished for both fish and invertebrates.

The absence of policies and laws relevant to coral reef management and conservation, coupled with the lack of enforcement all point to an urgent need to enhance management and research capacity. No single context of the law that mentioned about the protection of coral reefs, and the existing one focused toward the fisheries only. However, reef damaging and removal is not allowed. Most coral reefs have been damaged by mostly military officers or by the one who backed by the military officers. There also are some overlaps of responsibilities among concerned government agencies.

The Cambodia government has very limited human resource, infrastructures, and finance; to regularly and permanently conduct scientific research and monitoring. Therefore; the activities of; a national action plan for coral reef management and conservation, capacity building and maintenance, infrastructure and institutional development, improve legislations, administrative framework and enforcement; public awareness, communication, education, and participation; conduct biodiversity assessment, and regular monitoring; must urgently and carefully be carried out.

A map of Cambodia.

Table 1. Summary Coral Reef Status in Cambodia

Location	Koh Kong	Koh Sdach	Koh Rong	Koh Takiev	Koh Tang	Prek Ampil	Koh Pouh
Net CR Area (ha)	72.5	529	468	292.5	439	953	52.5
Live Coral (%)	47.4	29.3	23.1	58.1	38.3	53.8	41.0
Dead Coral (%)	29.6	35.6	44.9	0.6	13.1	0.0	19.2
Other Fauna (%)	4.2	2.2	5.1	3.1	4.2	5.6	2.4
Algae (%)	1.6	17.5	0.6	0.0	0.6	0.6	10.1
Abiotic (%)	17.2	15.4	26.4	38.1	43.8	40.0	27.4
Butterfly Fish/100 m2	1.63	0.47	1.75	0.75	1.25	7.00	0.00
Sweetlips (Haemulidae) /100 m2	0.00	0.33	0.00	0.00	0.00	0.00	0.00
Snapper (Lutjanidae) /100 m2	0.13	0.10	6.50	1.75	0.42	0.00	0.00
Barramundi Cod (*Cromileptes*) /100 m2	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Grouper (Give sizes in comments) /100 m2	2.63	0.23	2.25	0.25	1.67	0.00	0.00
Humphead Wrasse/100 m2	0.00	0.47	0.00	0.00	0.33	0.00	0.00
Bumphead Parrotfish/100 m2	0.13	0.07	0.00	1.25	0.00	0.00	0.00
Other Parrotfish/100 m2	4.38	2.37	0.75	2.00	15.33	0.00	0.00
Moray Eel/100 m2	0.00	0.00	0.00	0.00	0.08	0.00	0.00
Banded coral shrimp (*Stenopus hispidus*) /100 m2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diadema urchins/100 m2	*5.0*	17.0	213.0	17.0	129.8	7.0	4.3
Pencil urchin (*Heterocentrotus mammilatus*) /100 m2	0.0	0.4	0.0	0.0	0.1	0.0	0.0
Sea cucumber (edible only) /100 m2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Crown-of-thorns star (*Acanthaster*)	0.0	0.1	0.8	0.0	0.0	0.0	0.0
Giant clam (*Tridacna*) /100 m2	2.0	1.2	0.3	0.0	0.3	0.0	0.0
Triton shell (*Charonia tritonis*) /100 m2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Lobster/100 m2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coral damage Anchor[1]	0.9	0.2	0.0	0.0	1.4	0.0	0.3
Coral damage : Dynamite	1.8	0.7	0.0	0.0	2.4	0.0	1.3
Coral damage : Others	0.5	0.7	0.0	0.3	1.2	0.0	0.3
Trash : Fish nets	0.4	0.3	0.0	0.0	0.7	0.0	0.8
Trash : Others	0.0	0.3	0.0	0.0	0.2	0.0	0.3

1 From this row to the end explains about General Reef Condition, which meant: None=0, Low=1, Medium=2, High=3.

INTRODUCTION

Cambodia's coastal shoreline is 435 km long. The seaward boundary of the coastal zone has been delimited as the outer limit of the Exclusive Economic Zone with the EEZ, 69,900 sq. miles (Touch, 1995). However, the landward boundary of the coastal zone has not yet been satisfactorily defined. Totally, it has 69 islands.

Administratively, the coastal zone includes two provinces of Koh Kong and Kampot, and two municipalities of Sihanoukville and Kep.

From a functional perspective, Cambodia's coastal zone can be conceptualized as being made up of two inter-related systems such as ecological and socio-economic systems. The ecological system includes the physical, chemical and biological environment parameters that provide natural resources, sequesters pollutants and offers fundamental life-support functions (e.g. clean air and water) for humans and other living organisms. The socio-economic system depends upon many functions and products of complex ecological systems. Ecological systems have abundant living resources but limited capacity to provide fish, timber, coral reefs, seagrasses, clean water and other goods and services to meet the demands of the socioeconomic development. Given that the production capacity of ecological systems is limited, it is not surprising that the final demands by society and new opportunities for multiple uses are the source of increasing conflicts arising within Cambodia's coastal zone.

Marine living resources in Cambodia play a very important role to the national economy and assist the balance of regional or global environment. There are many kinds of marine living aquatic resources namely fishes, coral reefs, inundated forests (mangrove forests) and others2. The article 1 of the Fishery Laws stated clearly that "Fishery resources comprised a live animal and vegetable reproduced itself and abided in the fishery domain", and "Marine fishery domain extends from the coastline to borderline outer of the economic zone of the People’s Republic of Kampuchea. Fishery domain is the property of State." (DoF3, 1990).

Coral reefs, in particular, are critical habitat that supports diversity of both residential and migratory fauna species especially for those are considered to be endangered and vulnerable. The structure of a reef provides homes and food for many types of plants, fish and invertebrates (Nelson, 1999). Coral Reefs are significant for fisheries-many commercially valuable species are dependent on coral reefs and for tourism. Coral Reefs in Cambodia have been very little studied and known due to limitation of resources and interest from the government. Dr. Vicki Nelson, who worked with Danida-funded project on Environmental Coastal Zone Management in Cambodia, firstly led the team to roughly conduct studies in some sites in Kep, Sihanoukville, and Koh Kong Province, the information was collected opportunistically over the period May 1997-March 1999 (Nelson, 1999). Some qualitative and quantitative data were collected. Some species of corals, reef fishes, invertebrates; have been firstly found and recorded by the study.

Table 2 . Summary Country Statistics and Coral Reef Resources

Area	181,035 Km^2
Population in 1998	11,426,223
Coastline	435 Km
EEZ declared in 1978	69,900 square miles
Coastal Provinces/municipalities	4 (Koh Kong, Sihanoukville, Kampot, and Kep)
Marine Fish Catch in 2003	45,850 metric tons
Coral Reef Areas	28.065 Km^2
Coral Species identified	111 species of hard corals, 17 species of soft corals

Sources: National Census, 1998; DoF, 2004; CZM (1999); DoF/SCS (UNEP/GEF), (2004).

Coral Reefs

Coral Reefs in Cambodia are distributing as mostly fringing in parts of mainland and mostly on islands. In Cambodia, coral reefs are found around many islands and headlands (Nelson, 1999). Corals near to shore are those adapted to living in turbid environment, while further offshore a wider diversity of species is found. Seven sites have been designed by the Coral Reefs and Seagrass sub-components of the South China Sea Project for monitoring. The first round of monitoring in Cambodia's history, funded by the South China Sea Project, have been carried out in the whole seven sites by using ReefCheck (refer to the website at http://www.reefcheck.org) and GCRMN Line Intercept Transect (refer to the website at http://www.gcrmn.org) methodologies. Two MPAs have been designed and planned by the Department of Fisheries in order to improve marine fisheries, against the collapse of current fisheries management.

Figure 1. Map of Reef Distribution in Cambodia (UNEP/SCS, 2004)

Biodiversity

In table 2, it was explained the first coral reef species identification in Cambodia by mostly Dr. Vicki Nelson who worked for Environmental Coastal Zone Management in Cambodia. It was found that that there were totally about 67 hard coral reef species and 17 soft coral reef species. Moreover, a brief survey in February 1998 in Koh Tang of Sihanoukville identified at least 70 species in 33 genera and 11 families (Nelson, 1999). The review of by Fisheries Component of the South China Sea Project found 520 marine fish species classified in 202 genera and 97 families with a total stock estimated at 50,000 metric tons (Ing, 2003), but the number of reef fish species and invertebrates are unknown.

Table 3. Estimated Number of Species for Major Group

Group Animals	Estimated Number of Species	References
Hard Corals	70	Nelson, 1999
Soft Corals	17	Nelson, 1999
Marine Fish	520	Ing, 2003
Echinoderms	21	Ing, 2003
Crustaceans	50	Ing, 2003
Mollusks	250	Ing, 2003
Marine Turtles	5	Ing, 2003
Marine Mammals	12	Ing, 2003
Seaweeds	16	Ing, 2003
Seagrass	9	CZM/MoE, 2002

Resource Use

The most direct use of coral ecosystem is marine fisheries. Hundred thousand metric tons of non-reef fish and reef fish have been collected every year. Reef Fishes are the most valuable species in both domestic and international markets. So, reef fishes are the most targeted species by legal and illegal fishers. Collection of coral reefs for souvenir has been popular in Sihanoukville for many years, even now it is still illegally continuing. The main types of corals collected are table coral (Acropora spp.), elephant ear coral (Turbinaria spp.), deer horn corals (Porites spp.), and other species. Before, high rank military officers had enormous amount of corals for their home construction. Diving and snorkeling to see coral reefs and animals are also become interested by mostly foreign tourists in Sihanoukville. This is considered to be the most environmental friendly business, and it is very little impacted to coral reefs. Bringing tourists to see corals and environment are recommended in order to earn income for local people and contribute to public awareness for protecting of the reefs.

Reef Fish and Fisheries

Reef Fish are the most valuable and targeted marine species such as Sweetlips (Haemulidae), Snapper (Lutjanidae), Barramundi Cod (Cromileptes), Grouper (Give sizes in comments), Humphead Wrasse, Bumphead Parrotfish, Other Parrotfish. Fishers used to catch these species by using trap, gillnet and hook and lines. However, some illegal fishers have used dynamite and cyanide to catch these species. No statistical record about these reef fishes. These species have been collected in all sizes including juveniles. Juveniles and pre-adults of reef fish have been collected and re-cultivated in cage along the coast, when they reached commercial sizes they will be mostly sold alive to both local restaurants and international markets in Hong Kong, China, Taiwan.

Tourism

Tourism related to coral reefs seems to be very poor developed in terms of infrastructure and activities. We have very limited resources to encourage tourism sector related to coral reefs. However, compare to lat few years more and more tourists come to Sihanoukville to see coral reefs in Koh Thas, Koh Rong and Rong Salem, and even Koh Tang if they have more time to stay overnight there. Now, we have three private SCUBA diving centers in Sihanoukville, namely, ECO-SEA, Chez Claude, SCUBA NATION; and each center brought about 30-40 divers per month. It is expected the number of divers will be increased in the near future when infrastructure and equipment are put in place.

Other Uses

A part from fisheries and tourism, coral reef resources may play another very important role scientific research and socio-economic use. However, in Cambodia it has very limited scientific research for medicines and/or other purposes. In term of socio-economic use, most local people who live nearby the reef areas are making their living on most the reefs. Most of them are fishers, but some are fishing gear and board's builders. Few of them make their living as tourism services such tourism board operators and guides.

STATUS OF CORAL REEFS

Reef Benthos (especially corals)

In Cambodia's coastline extends 435 Km long, and totally consists of 69 islands. Coral reefs do exist around the islands and the coast of mainland. The distribution of the coral reef are patchy, therefore, the coral reef areas have been merged into 7 main monitoring sites:

- Koh Kong Province: KKCR1 (Koh Kong islands), KKCR2 (Koh Sdach group of islands);
- Sihanoukville: SHVCR1 (Koh Rong and Rong Sanleom), SHVCR2 (Koh Takiev Group of islands) and SHVCR3 (Koh Tang group of islands);
- Kampot Province: KAMPCR1
- Kep Municipality: KEPCR1 (Koh Tunsay group of islands)

All 7 sites have been successfully monitored for the first time in Cambodia's history, in which one site of KKCR2 has been surveyed by National University of Singapore with supported by Singapore International Foundation (SIF) (Chou, L.M., Loh, T.L., Tun, K.P.P., 2003).

In each location, one to three sites were selected for the survey. Prior to the survey, one day was spent for general reef condition to find out the suitable sites. Six people with SCUBA, but they snorkel around the location for the first time to find out the suitable site for laying down transect, then made decision on the selection sites. After transects have been completely laid, then it was time to start up with the real survey.

The coral reef baseline survey was conducted using standard methodologies as outlined by two global coral reef monitoring agencies- the Global Coral Reef Monitoring Network (GCRMN) and the Reef Check.

Six divers from Department of Fisheries and Sihanoukville Fisheries Office, who had been officially trained on Reef Check and Line Intercept Transect (LIT), participated in the survey program.

The Reef Check method is for coral reef survey employ rapid assessment techniques which enable quick and reliable assessment of coral reef health. In this case, the Reef Check was used for the survey reef fishes, invertebrates, general reef condition. Data table from this Reef Check method was used for description general survey site condition, which was made on board. Four replicates of 20 m were used for survey in Reef Check methodology. For detailed description of the Reef Check method, refer to its website at http://www.reefcheck.org.

The GCRMN Line Intercept Transect Method has been widely used within the Asia-Pacific region to survey coral reefs and provide detailed quantitative benthos assessment. For a detailed description of the GCRMN LIT method, refer to its website at http://www.gcrmn.org. Under GCRMN method, LIT was used to survey the reef benthos. A total five replicates of 20 m horizontal transects were conducted for each site at a selected depth around 2 to 5 meters.

Five 20m taps, cloth pegs, ropes, buoys, waterproof drafting papers, pencils, water proof life form identification manuals; were used for the survey.

Regarding mapping of the reef area, a GIS expert with a GPS and snorkels and accompanied by a skillful fisher who exactly know the reef site, went conducting the survey for the reef area of the site. They went around the reef edge and marked way points along the edge and recorded into GPS.

As results, based on GCRMN range, coral reefs are in good and fair condition, as coral cover ranges from 29.3% in Koh Sdach group of island of Koh Kong Province to the highest cover of 58.1% in Koh Takiev group of islands of Sihanoukville.

Dead coral ranges from 0% in Prek Ampil to the highest site of Koh Rong that accounts for 44.9% per square meter. This means the condition of corals within the site is ranged from good to fair.

There are not so many other fauna in most of the sites, it account for 2.2% in Koh Sdach group of islands, where the highest percentage of other fauna was 5.6% in Prek Ampil of Kampot Province.

Maybe there was little impact from run-off pollution, so the reason of no so many dominated algae cover. It is accounted for the lowest coverage of 0% in Koh Takiev, while the highest coverage was 17.5% in Koh Sdach group of islands of Koh Kong Province.

The coverage of sand and rock were considered to be high percentage, which it was found 15.4% in Koh Sdach group of island and 40% in Prek Ampil (see the table 4).

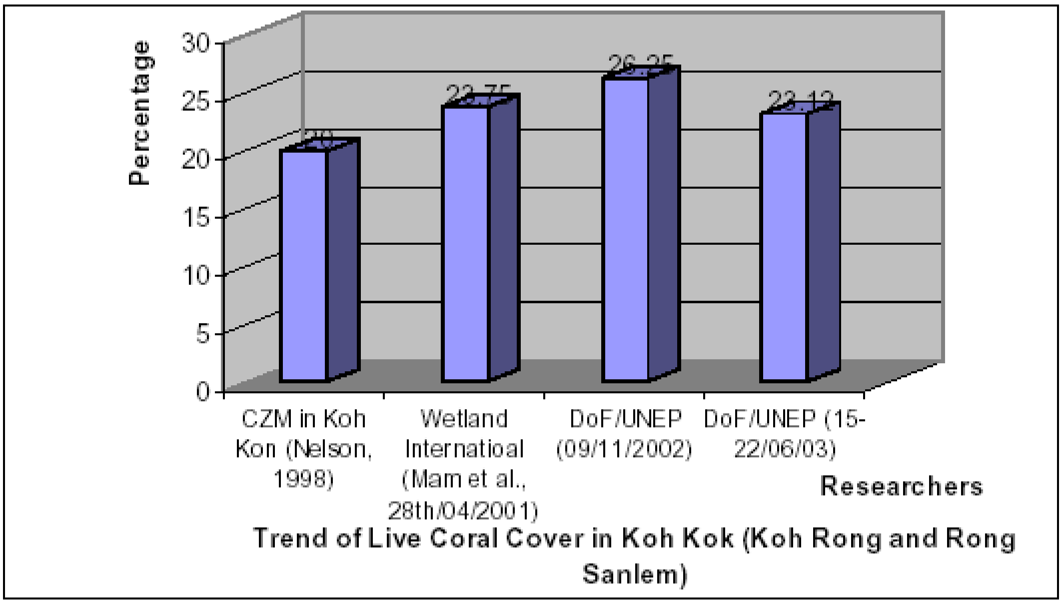
Only one site that has been survey monitored since 1998, which Koh Rong and Rong Sanleom of Sihanoukville. Dr. Vicki Nelson working from the Environmental Coastal Zone Management (CZM) in Cambodia supported by DANIDA, carried out the first monitor within site, and then followed by Wetland International and CZM in 2001. The two final works was carried out by Department of Fisheries supported by UNEP EAS4/RCU5 in 2002 and 2003 for trainings on diving, reef check and GCRMN Line Intercept Transect (LIT) (UNEP, 2003). No exact positions of the transects were plotted by GPS for the last two monitoring programs, however, it was found that all surveys, including the last two ones, were conducted nearly at the same location of transect.

The graph below illustrated that in 1998 the percentage of live coral cover accounted for 20% and slightly increased to 26.25% in 2002. Finally, it is dropped to 23.12% in 2003. Therefore, the trend of live coral cover has not remarkably changed from 1998 to 2003. However, regularly annual monitor should be carried out in order to detect trend in large temporal scale.

Table 4. Benthos Cover of Coral Reefs in Cambodia

Location/site	Koh Kong	Koh Sdach	Koh Rong	Koh Takiev	Koh Tang	Prek Ampil	Koh Pouh
Live Coral (%)	47.4	29.3	23.1	58.1	38.3	53.8	41.0
Dead Coral (%)	29.6	35.6	44.9	0.6	13.1	0.0	19.2
Other Fauna (%)	4.2	2.2	5.1	3.1	4.2	5.6	2.4
Algae (%)	1.6	17.5	0.6	0.0	0.6	0.6	10.1
Abiotic (%)	17.2	15.4	26.4	38.1	43.8	40.0	27.4

Figure 2. Trend of Live Coral Cover in Koh Kok (Koh Rong and Rong Sanleom) of Sihanoukville



Reef Fish

Base on ReefCheck method, about 17 groups of reef fishes and invertebrates have been recorded in all 7 locations. They are butterfly fish, sweetlip, snapper, barramundi cod, grouper, humphead wrasse, bumphead parrotfish, other parrotfish, moray eel, banded coral shrimp, pencil urchin, sea urchin, sea cucumber, crown-of-thorn star fish, giant clam, triton shell, and lobster. The table below shows the number of each animal group per 100 square meters. Reef fishes have been found in nearly all sites except Koh Pouh of Kep Municipality. However; sweetlip, barramundi cod, moray eels, lobster, triton shell, and banded coral shrimp; were rarely seen in nearly all sites. For banded coral shrimp, this is because of their small body so it could not have seen by researchers.

Table 5. Site Summaries of Major Fish Groups

Location	Koh Kong	Koh Sdach	Koh Rong	Koh Takiev	Koh Tang	Prek Ampil	Koh Pouh
Butterfly Fish/100 m^2	1.63	0.47	1.75	0.75	1.25	7.00	0.00
Sweetlips (Haemulidae)/100 m^2	0.00	0.33	0.00	0.00	0.00	0.00	0.00
Snapper (Lutjanidae) /100 m^2	0.13	0.10	6.50	1.75	0.42	0.00	0.00
Barramundi Cod (*Cromileptes*) /100 m^2	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Grouper (Give sizes in comments) /100 m^2	2.63	0.23	2.25	0.25	1.67	0.00	0.00
Humphead Wrasse/100 m^2	0.00	0.47	0.00	0.00	0.33	0.00	0.00
Bumphead Parrotfish/100 m^2	0.13	0.07	0.00	1.25	0.00	0.00	0.00
Other Parrotfish/100 m^2	4.38	2.37	0.75	2.00	15.33	0.00	0.00
Moray Eel/100 m^2	0.00	0.00	0.00	0.00	0.08	0.00	0.00
Banded coral shrimp (*Stenopus hispidus*) /100 m^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diadema urchins/100 m2	*5.0*	17.0	213.0	17.0	129.8	7.0	4.3
Pencil urchin (*Heterocentrotus mammilatus*) /100 m^2	0.0	0.4	0.0	0.0	0.1	0.0	0.0
Sea cucumber (edible only) /100 m^2	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Crown-of-thorns star (*Acanthaster*)/100 m^2	0.0	0.1	0.8	0.0	0.0	0.0	0.0
Giant clam (*Tridacna*) /100 m^2	2.0	1.2	0.3	0.0	0.3	0.0	0.0
Triton shell (*Charonia tritonis*) /100 m^2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Lobster/100 m^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Resource Use

Base on government official but not reliable statistics, about 42,000 to 45,000 metric tons of marine fish and invertebrates have been harvested every year. However, it was estimated that it could be 10 to 20 times of the official figure. Also, how much of resources that have been used from the reefs, are unknown.

Only one interviewee admitted to using dynamite, and claimed that a profit of up to 14,7 million riel per day was possible (CZM, 1999).

Coral collection and selling for tourists do occur in Sihanoukville. The trade is not profitable and is most often a secondary business for most collectors and sellers (CZM, 1999). The corals collected are Acropora, Turinaria and Porites species. Of these, Acropora and Turbinaria are fast growing and abundant recruits on reefs, while Porites is a slow-growing coral that often forms the fundamental building blocks of Cambodian reefs (CZM, 1999).

Physical Environment

Due to limitation of research resources, information about physical environment is completely lacked. However, it conducted some parameters such as sea surface and air temperature, depth, turbidity and/or visibility. Usually, visibility is very low near mainland and high in offshore islands. In further offshore islands the visibility is 20m, while near shore is visibility is poor (2m).

STRESS AND DAMAGE TO CORAL REEFS

There were many development activities being carried out on or toward coral reefs ecosystem.

Sediments and Nutrients (land-based)

Coastal agriculture and development have enormously contributed to the damage of coral reef in Cambodia in terms of sedimentation and land-based pollution. Without any prompt mitigation, enormous quantity of agricultural run-off and soil are washed from up stream to the coastal reefs every year. But, the figure is unknown. This has caused high turbidity near shore coral reef area.

Damaging Fishing Methods

No actual data on over-fishing and damaging fishing methods. However, based on some reefcheck data and other studies indicated that dynamite fishing is the main threat. It was also pointed out that the main problem for coral reefs in Cambodia is dynamite fishing (CZM, 1999).

Information about cyanide fishing is equally lacking. The raw chemicals came from Vietnam and were very cheap (US$36/kg). Groupers and cod were caught using this method for grow-out in cages at Tumnup Rolork and Stoeng Hav (CZM, 1999).

Coral collection and selling for tourist do occur in Sihanoukville Souvenirs made from corals were sold on one of the beach of Sihanoukville. The coral collected were Acropora, Turbinaria and Porites species. Acropora w s no longer abundant on Cambodian coral reefs and should be protected (CZM, 1999). However, this activity has been reported to be reduced due to prohibition by the provincial government and unprofitable business.

Figure 3. Land Removal in Sihanoukville, and a lot of sediments were washed away the most to the nearby reefs.

Figure 4. Reef Rubles from dynamite fishing in Koh Tang, one of beautiful reef areas in Cambodia.

Figure 5. Souvenirs made Acropora sp were on sale in one of the Sihanoukville beach (left) and Anchor damage (right)

Anchor and Trawler Damage, Others Kind of Damage (divers, trampling, etc)

Coral damages from fishing boat Anchoring do occur in every reef in Cambodia because there is not mooring buoys being set and the fishers are not aware or even care about the damage. Cambodia has very few local tourists visiting the reefs, so, impacts from divers and trampling are considered to be least. However, this could be a potential threats in the future when tourism industry become booming.

Table 6. Anchor and other damages to the coral reefs in Cambodia

Location	Koh Kong	Koh Sdach	Koh Rong	Koh Takiev	Koh Tang	Prek Ampil	Koh Pouh
Coral damage Anchor[6]	0.9	0.2	0.0	0.0	1.4	0.0	0.3
Coral damage : Dynamite	1.8	0.7	0.0	0.0	2.4	0.0	1.3
Coral damage : Others	0.5	0.7	0.0	0.3	1.2	0.0	0.3
Trash : Fish nets	0.4	0.3	0.0	0.0	0.7	0.0	0.8
Trash : Others	0.0	0.3	0.0	0.0	0.2	0.0	0.3

6 From this row to the end explains about General Reef Condition, which meant: None=0, Low=1, Medium=2, High=3.

Seaweed cultivation in Cambodia started in 1999 with an introduction of Eucheuma cottonii. It is a lucrative cultivation and more people who live along the coast of Kampot province have been being involved in this kind of cropping. It has enhanced a lot of local livelihood. Coral Reefs in Koh Pouh group of islands have been seriously damaged by seaweed farming.

However, local people have cultivated their seaweed directly on corals. So, corals are now under severe threats from seaweed farming and are disappearing from many sites in the area (Mam, 2001). It is contributing to the destruction of the once healthy corals. Major of coral communities on Koh Pouh have now been turned to rubble and dead corals are subsequently washed away by waves thus leaving only small area which is exposed to strong waves and is still under some threats from the farming site.

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

There were many construction activities on the beach, but the impacts to coral reefs were unknown. The construction activities included commercial port expansion, five-star hotel, and golf court; have been carried out in Sihanoukville. No EIA has been conducted before any construction. Even the government has policy of conducting EIA, but limitation of resources in terms of research facility and finance causes the problem.

Coral Bleaching

Regarding coral bleaching was equally unknown. However, similar to the other places in the region, coral bleaching did occur in 1998. Bleaching from the 1997-1998 ENSO event affected Cambodian reefs, with one survey indicating that 80 percent of corals in Sihanoukville bleached during 1998 (Burke et al., 2002). Nelson (1999) has noted that bleaching occurred elsewhere in Cambodia, including other sites on Koh Rong Sanleom, Koh Rong, Koh Tang, Koh Damlong, and Koh Thas. Statistics about coral bleaching at national level is not available.

Coral Diseases

Similar to bleaching, there was no data and information about coral diseases in Cambodia. However, it was assumed that there were some diseases which required scientific research on these.

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

Crown-of-thorns were abundant in 1998. At one site on Koh Tang, crown-of-thorns starfish (COTS) were abundant, with more than 20 large starfish found in an area approximately 100 m^2 CZM (1999). Also, based on last survey, it was found crown-of-thorns, but not as many as in 1998, which was nearly 1 animal per 100 m^2 (table 5). However, the most concerned was the outbreak of Diadema setosum. It was accounted for until 218 in an area of 100 m^2in Koh Rong and Rong Sanleom (table 5). So, this might be an outbreak even of Diadema setosum when removal of its predators.

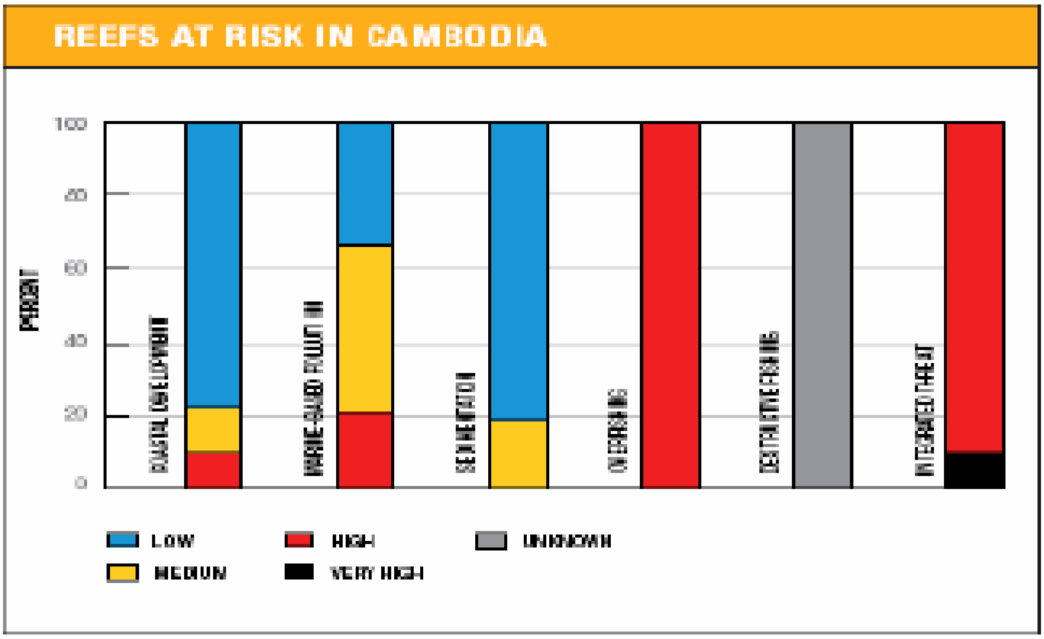
Coral Damage from Natural Events (storms, etc)

There was no scientific evident of coral damage from natural events. However, there was report about a big damaging event in 1998 by Linda storm to Southeast Asia.

POTENTIAL THREATS TO CORAL REEFS (REEF AT RISK THREAT INDICATORS)

There are many impacts contribute to coral reef ecosystem in Cambodia. Reefs at Risk of Southeast Asia's Indicators 2002 indicated that there were many main threats coming from many sources of development such as coastal development, marine-based pollution, sedimentation, overfishing, and destructive fishing; which showed in figure 6 below.

Figure 7. Potential Threats to Coral Reefs in Cambodia (Burke et al., 2002).



Coastal Development

Less quantity of coastal development causes medium and high impacts to coral reef, and a majority of development contributes to low threats. However, in the future a lot of development will be carried out along the coastline of Cambodia and will be high threats to coral reef ecosystem if strictly environmental assessment and mitigation are not taken into consideration.

Marine-Based Pollution

Marine-based pollution was considered to be low threats to coral reefs; however, the data is not available. Advanced counting measures are not available, and in case of oil spill the government does not have facility to tackle.

Sedimentation and Nutrient-Inputs

Sedimentation was considered to be low by Burke et al in 2002. However, a lot of land clearing occurs upstream of rivers and estuaries.

Over-fishing

Even there was not comprehensively statistical data; over-fishing is considered to be one of the highest threats to not only coral reef ecosystem but also local livelihood. Most reef fishes and invertebrates have been locally extinct, while others are still in fewer amounts.

Destructive Fishing

Destructive fishing has been occurred since last decade, and over-fishing and destructive fishing are very high threats in 2004. Reef fishes and invertebrates are highly targeted species for both local and international markets; so, local fishers try to use all means to collect these species, including dynamite and cyanide fishing practices. The main problem for coral reefs is dynamite fish, which is very destructive practice (CZM, 1999).

MANAGEMENT

The management of coral reefs in Cambodia has been nearly forgotten because there is little understanding and awareness of significances and advantages of this ecosystem at all levels of stakeholders. The management for conservation of coral reefs in Cambodia is still rudimentary (Burke et al, 2002).

The Department of Fisheries of the Ministry of Agriculture, Forestry and Fisheries; is responsible to manage and use of marine living resources as whole. Day-to-day management of natural resources and resource use on the coast is the responsibility of the Ministry of Agriculture, Forestry and Fisheries (MAFF), particularly the Department of Fisheries (Nelson, 1999). There are fisheries staffs at district level as well as provincial, whose responsibility is to patrol and manage commercial as medium scale marine fisheries, and to protect critical fisheries habitats such as mangroves, seagrasses and coral reefs.

However, there are overlaps of responsibilities among concerned government agencies, particularly Ministry of Environment and Department of Fisheries of MAFF, and also between National Level and Provincial Level. The remit of the Ministry of Environment overlaps with that of MAFF to a certain extent. The Ministry of Environment is responsible for the management of protected areas and for overseeing environmental protection. This includes protection of coral reefs, seagrasses and mangroves, particularly when they are in a protected area. This overlap does not seem to be problematic for managers on the ground, but needs to be clarified legally. Reef management is a shared responsibility between many departments-the Department of Fisheries, the Provincial Government and District Government to name a few-and this appears to be a source of conflict (Chou et al., 2002).

Proper management and conservation of these natural resources are thus important for the area’s future (Chou et al., 2003).

It is also important to empower the local communities with knowledge for the natural heritage and the various impacts of developing a tourism industry, as they live most closely in association with the environment around them (Chou et al., 2003).

Coral collection, an important threat from 1995 to 1997, is declining because the Fisheries Department has tightened controls and confiscated coral from vendors (Burke et al, 2002).

Marine Protected Areas

Legally, only one marine protected area has been established, which is called “Ream National Park”. Originally, it was designed to protect land and mangrove forest upstream river. There was no intention to protect coral reef. However, it was later extended to some part of coral reef area. The first project was community based fisheries management at Ream National Park, which was a demonstration project funded by ADB in July 1999. It consisted of 8 organized villages for fisheries resources management. Regulations at community level were developed, and participatory enforcement was initiated.

Monitoring

The government of Cambodia is interested in management and conservation of marine resources in sustainable manner. Therefore, information on the extend and present health of coastal and marine ecosystems as well as coral reefs is needed to provide basis for long term management strategy. To use the marine living resources (marine fisheries) in sustainable manner, proper management and continuous monitoring of the resources are significant, and the assessments will provide the information that important for coastal/marine resource management plans. There have been some projects and/or program supported for coral reef monitoring activities since 1998.

Environmental Coastal Zone of Cambodia (CZM)
This is the biggest ever done in Cambodia in terms of coastal zone and resources management and conservation in Cambodia, which financially supported by DANIDA. The project started in 25 November 1998; and it had carried out coral reefs baseline survey for the first time in some reef areas.

National University of Singapore (NUS)
The National University of Singapore and supported by the Singapore International Foundation, Youth Expeditions Projects (SIF, YEP) have organized three expeditions to assess the marine biodiversity of the reefs off Koh Kong Province, Cambodia. Three research activities have been carried out in Koh Sdach group of islands using the methods of Reef Check and Line Intercept Transect (LIT).

Proposed Marine Protected Area in Koh Rong and Rong Sanleom
In June 2002, the MPA project was started to implement by the DoF and supported by UNEP/ICRAN (International Coral Reef Network). The project supported DoF staff for SCUBA diving, Reefcheck and LIT Training courses.

Wetland International Asia Pacific and Lower Mekong Basin Program
A team from the Ministry of Environment, Wetlands International Asia Pacific, Lower Mekong Basin Program and other agencies conducted field survey of both coral reefs and seagrasses along the coast of Cambodia from April 26 to May 26, 2001.

DoF's Coral Reef and Seagrass Sub-component of the "South China Sea Project, UNEP/GEF"
Activities carried out by the Department of Fisheries with financial support from UNEP/GEF include under the project called "The South China Sea Project", in which Cambodian Coral Reef and Seagrass Sub-component is responsible to do the job in order to:

- To determine the general distribution of coral reefs along the Cambodia's marine water, and to conduct baseline quantities surveys to determine the abundance and distribution of the coral reef benthos, reef fishes, and invertebrates;
- To determine the general condition of the coral reefs by visible impacts;
- To identify areas with good coral reef for preparation of demonstration sites for sustainable management and conservation.
- To map coral reef areas for preparation of demonstration sites of sustainable resources management.

Further coral reef management schemes will be of great use and at least one survey per year will help to monitor coral reef in all identified sites.

Legislation
There was no real law to protect coral reefs, but there is fisheries law that mentioned about protection of marine living resources. Most laws relate to the protection of fisheries rather than coral reefs, however, the government is making strides in some areas (Burke et al., 2002).

The Fisheries Department claims not to be able to enforce the law prohibiting dynamite fishing practice because of corruption, lack of financial and other resources, and lack of political support (CZM, 1999).

Coral collection and selling is unregulated but only a small business at that time.

CONCLUSIONS AND RECOMMENDATIONS

Due to the fact that Cambodia had a very long period of civil war, the study of coral reefs seems to be forgotten. Therefore, it has had very little information and data about her coral reefs. In 1998 a roughly baseline survey in some parts for the first time in Cambodian history was carried out. In 2004, it was found that total reef areas accounted for 28.065 km^2. Diversity studies to date indicated 111 species of hard coral, 17 species of soft coral and 9 species of seafans and seawhips. The average live coral cover for the whole coastline of Cambodia accounted for 23% to 58% of coral cover. Good reefs in further offshore islands, visibility 20m, dynamite and cyanide also used illegally. Reefs near shore were in poor condition because of poor visibility (2m).

The policy and plan for long-term monitoring has not been in place. The existing law focused toward the fisheries only. No single context of the law that mentioned about the protection of coral reefs. However, reef damaging is not allowed. The law enforcement is not really effective. There also are overlaps of responsibilities among concerned government agencies.

Cambodia government has very limited human resource, infrastructures, and finance; to regularly and permanently conduct scientific research and monitoring.

This value of the resources has not been well aware, understood and interested from all stakeholders at all levels; because it lacks public awareness and extension program.

Recommendations:

- Establish national action plan for coral reef management and conservation: Start up with national policy and plan of action for coral reef monitoring and sustainable uses of the reef ecosystem.
- Capacity building and maintenance, infrastructure and institutional development: Build up capacity and infrastructure of the institution for coral reef management and sustainable uses.
- Improve legislations, administrative framework and enforcement: Improve the current legislations to make them applicable for coral reef management and conservation.
- Public awareness, communication, education, and participation: To make it be aware and understood about the significance of coral reef ecosystem among all stakeholders at all levels.
- Conduct biodiversity assessment, and regular monitoring: To understand coral reef biodiversity, and to get reliable assessment of changes in reef health.

REFERENCES

Burke, L., Selig, E., Spalding, M. (2002). Reefs at Risk in South East Asia. World Resource Institute. 10 Street, NE Washington, DC 20002, USA.

Chou, L.M., Loh, T.L., Tun, K.P.P., (2003). Status of Coral Reef of the Koh Sdach Group of Islands, Koh Kong Province, Cambodia, Part II. Marine Biology Laboratory, Department of Biological Sciences. National University of Singapore. Blk S1, 14 Science Drive 4. Singapore 1175 43.

Chou, L.M., Tun, K.P.P., Chan, T.C., (2002). Status of Coral Reef and Socio-economic Evaluation of the Koh Sdach Group of Islands, Koh Kong Province, Cambodia. Marine Biology Laboratory, Department of Biological Sciences. National University of Singapore. Blk S1, 14 Science Drive 4. Singapore 1175 43.

CZM, (1999). Case Study: Coral Reefs of Sihanoukville, Destruction by Dynamite and Coral Collection. Environmental Coastal Zone in Cambodia. Danida/Ministry of Environment. Phnom Penh, Cambodia.

CZM, (2002). Coastal Resources of Cambodia. Environmental Coastal Zone in Cambodia. Danida/Ministry of Environment. Phnom Penh, Cambodia.

DoF (1990). Compiled Theme of Fishery Laws. Department of Fisheries. Phnom Penh.

Ing, T. (2003). National Report on Fish Stocks and Habitats of Regional, Global and Transboundary Significance in the South China Sea, Cambodia. The Cambodian Fishery Component of Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand. Department of Fisheries. Phnom Penh, Cambodia.

Mam, K. (2001). CORAL REEF AND SEAGRASS SURVEY IN CAMBODIA. Lower Mekong Basin Program of Wetlands International Asia Pacific. Ministry of Environment. Phnom Penh.

Nelson, V. (1999). State of Coral Reefs Cambodia. Environment Coastal Zone Project, MoE/Danida, Phnom Penh, Cambodia.

Touch, S.T. (1995). Present Status of Fisheries in Cambodia and the Development Action Plans. The Department of Fisheries. Phnom Penh.

UNEP, (2003). Report of the Training Programme in SCUBA Diving and ReefCheck Technique in Cambodia (30 pages), and Report of the Training Programme in Coral Reef Survey Using Line Intercept Transect (LIT) Method (24 pages). United Nations Environmental Program, UN Building, 9th Floor Block A, Rajdamnern Avenue, Bangkok 10200, Thailand.

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2.2. INDONESIA

SUHARSONO

INTRODUCTION

Indonesia is the world largest archipelagic nation with 17,805 islands and fourth most populous country with population of over than 210 million people. Coastal length and the area of coral reefs have been variously estimated at between 80,791 km (Moosa 1995) and 204,000 (Tomascik et al ,1997), while the official estimate for the area of coral reefs is 7500 km^2 (KLH 1992) and 85,707 km^2 (Tomascik, et al, 1997) which represents about 14% of the world's corals. The mapping coral reef habitat throughout Indonesia has been done since last two years using a satellite image processing to more accuracy calculate area of coral reef, the number of islands and the Indonesia coastal length. The results of these worked will be announced soon.

Indonesia is also the world's largest shallow water which consists of Sunda shelves in the west and Sahul in the east. In the middle part is a deep seas basin, through and deep sea trench. The numerous large and small islands divided the marine waters of the region into different seas connected by many channel passages and straits. These unique and complex set of physical, chemical and biological interaction related to the geological history and results the Indonesian archipelago becoming one of the richest marine diversity of the world. This diversity arose in the ancient Tethys seas. Results from several studies shows that Indonesia can justify claim to be location of the world's greatest diversity. At least 2,500 species of fish, 590 species stony corals (Veron, 2002), 42 species of mangrove, 13 species of sea grass, 782 species of algae, 850 species of sponge, 2,500 species of mollusk, 1,500 species of crustacean and 745 species of echinoderm (Moosa, 1998).

A map of Indonesia.

Distribution of coral reefs in Indonesia

Western Indonesia Reefs

The coastal environment of West Sumatera consists of a chain of islands and shallow water reef, separated from the mainland of Sumatera by deep water. It extends from Simuelue Island in the north to the Enggano Islands in the southeast. The eastern site of those islands in some places covered by mangrove. Some coral species such as Porites spp. and Goniastrea can often be found adjacent to Rhizophora roots. Further seaward more corals appear and among the most abundant are massive *Porites* which can form microatolls. They are mostly dominated by coral boulder of *Porites* and big column of *Goniastrea*. The reef flats are very wide and they slope gently down to 5-10 m depth. The soft bottom substrate coral communities are dominated by various species of *Acropora*, *Seriatopora* sp. and *Pocillopora*. From the depth of 5-10 m a steep reef slope goes down to more than 100 m depth. Coral reef communities are dominated by *Acropora* spp. and *Montipora* spp.

There are two chains of small islands running parallel to the coast of Sumatra at a distance of about 10 and 30 km respectively. The inshore chain is situated on the continental shelf with depth around 50-80 m while the outer chain is in 200 m isobath right on the continental slope. The reef flats are relatively narrow and gently sloping down to 10 m depth. On the western side of the island spurs and groves are well developed. The eastern sides of these islands are relatively protected from strong wave actions. On the western side, the coral communities are dominated by *Acropora formosa* group and *Montipora* while in the eastern side they are dominated by massive corals such as *Porites* spp., and *Diploastrea*. A steep reef slope is found in the 10-40 m depth with Octocoral and gorgonian being the most common, some reaching as large as 3 m. The coral reefs communities are subject to heavy sedimentation from rivers in Sumatera. Some 49 genera were found from this study area whose condition ranges from good to poor.

Reefs are poorly developed on the northern part of the east coast of Sumatera but are widely spread around the offshore island to the south of Riau Kepulauan as far as the islands of Bangka and Belitung. Mangroves are well developed on the inshore and offshore islands due to many large rivers which flow into the sea bringing high sediment and decreasing the salinity. The reef flats in the offshore island are relatively narrow, terminating at their seaward edge in shallow reef slope down to approximately 5-7 m. Coral reef communities are well developed at the upper reef slope down to 7 meter depth. Coral growths are dominated by branching coral *Acropora*, *Echinopora* and massive coral such as *Favites* and *Favia* in which the larger size is up to 1-2 m. In the soft bottom substrate coral communities are dominated by various species which are adapted to turbid areas such us Trachyphyllia and Goniopora.

The fringing reefs along the south coasts of Java develop only in certain areas such as Panaitan Island, Pangandaran, Pangumbahan, and Parangtritis. The most extensive reef developments on East Java occur along the coast of Grajagan, Watu Ulo to Blambangan Peninsula. Coral reefs in this area are subject to high-energy waves and are dominated by digitate *Acropora* such as *Acropora digitifera* and *Acropora humilis*. The north coast of Java by contrast is lacking of fringing reef except in Banten Bay and Jepara Bay. Millions of tons of sediments are deposited along the north coast of Java every year. Coral reefs are developed well on the offshore islands in the Java Sea such as the islands of Karimunjawa, Bawean, Kangean and Kepulauan Seribu. Coral reef structures on the ofshore islands north of Java are patch reefs or fringing reefs which slope down gradually to the depth of 15-20 m. The reef flat of the subtidal patch reefs are dominated by branching corals in the windward side while in the leeward sides *Porites nigrescens* is the commonest species. The reef slope has mainly encrusting and foliaceous corals as Mycedium, *Echinophylia*, *Oxypora* and *Pachyseris*. A total of 56 genera containing 193 species have been recorded in the Kepulauan Seribu (Moll and Suharsono, 1986).

Central Indonesian Reefs

Very few studies have been carried out around the west and southern Kalimantan so far. In these areas mangroves are well developed. Many large rivers flow into the sea. The east coasts of Kalimantan are almost covered by pristine mangrove swamps, followed by sea grass beds and then fringing reefs. Fringing reefs are well developed along the offshore island at a distance of about 20-40 km from the mainland. *Porites* spp. and large foliaceous species *Montipora* spp. and *Turbinaria* spp. are the most dominant scleractinian corals in these areas.

Nusatenggara is situated on the border of Indian Ocean and Banda Sea. It consists of several thousand of islands, stretching east to west, with coastlines dominated by rugged, rocky shores sloping relatively steeply into the sea. Reef flats are mostly narrow, with the slope varying from gently to steep down to 30-50 m. The southern coast are exposed to oceanic swell throughout the year and the corals here are dominated by encrusting or low branching species such as *Seriatopora* sp., *Stylopora* sp. and *Acropora humilis*. In some places there are relatively sheltered bays with mangrove. There are several places with very strong tidal current, flowing through the straits. Coral developments is greatest in the west and north coast of the islands. The reef formation in Nusatenggara reaches approximately 30 m depth and corals species are very diverse reaching their maximum richness. The underwater topography of Nusatenggara is very rugged and known as refuge areas for coral species (Best et al., 1989). A total of 225 coral species belonging to 61 genera were recorded. Coral species are mostly dominated by branching *Acropora* spp., *Seriatopora* sp.. In the sheltered areas large stand of *Echinopora* spp. and *Montipora* spp. are found.

Oceanic reefs such as Takabonerate, Lucipara Islands and Tukang Besi Island are found in the Banda Sea. These rise from great depths and are remote from major influences of continental processes such as land runoff, siltation, turbidity etc. Lucipara Island has the widest reef flat and the greatest reef development. The reef contains a variety of habitat related to different degrees of exposure to prevailing winds, waves and currents. The sheltered areas or lagoon are dominated by *Anacropora* sp., *Acropora* spp., and *Galaxea* fascicularis. In the more exposed areas the dominant species are Favia speciosa, *Montipora verrucosa*, *Platygyra daedalea*. A total of 198 coral species belonging to 68 genera were recorded in Takabonerate (Best et al. 1989).

The seas surrounding Sulawesi Island are the main reef areas in Indonesia and well known as the global center of coral species diversity and coral reef associated biota. The coastlines of Sulawesi are bordered by almost continuous fringing reefs. The deep seas surrounding Sulawesi generally remain extremely clear and favour reef development. Coral communities are typically diverse and mixed. Four major reef types can be found in Sulawesi waters: barrier reefs, fringing reefs, patch reefs and atolls. Takabonerate is the largest atoll in Indonesia and the third largest in the world.

Eastern Indonesian Reefs

Maluku has numerous large and small volcanic islands. Generally these islands are situated within zones of high tectonic activity and earthquakes. Maluku is surrounded by deep seas and is located between Sunda shelf in the west and Sahul shelf in the east. Several volcanic islands with fringing reefs are found in Banda and Halmahera. The coastlines are usually rugged with narrow and steep beaches. The reef flats are narrow and gently sloping down to seaward to about 2-5 meter depth, followed by a drop down at an angle of 80-90o to a depth greater than 100 m or sometimes down to where the ocean floor can not be seen. The sub tidal reefs flats are dominated by acroporoid assemblages or Millepora, while vertical wall is densely covered by massive and encrusting coral, soft coral and gorgonian.

The southern coast of Irian Jaya is continuously covered by mangrove. These rivers cause high sedimentation and salinity fluctuation. Reefs here are poorly developed. Irian Jaya coral reefs are the most develop in Teluk Cendrawasih, Padaido Island, Auri Island, Mapia Island and Raja Ampat Island. Many reefs in Irian Jaya have not been surveyed but are thought to be in good to excellent condition. Coral reefs in Teluk Cendrawasih are still in good conditions and have achieved their highest development and diversity here. Generally offshore islands have narrow fringing reefs with steep reef slope down to great depth (200 m).

STATUS CORAL REEFS

There are four major types of island and reef system in Indonesia: 1) A fringing reefs, 2) barrier reefs, 3) atoll and 4) patch reefs. Each reefs have many derivates. Indonesia has at least 76 barrier reefs, 55 atolls, and 40 patch reefs, with total reefs area is estimated at more than 85.707 km^2 (Tomascik et al. 1997). Coral cover and generic richness have been measured and counted of several locations throughout Indonesia. We use live coral cover as an indicator for coral reef health. Although some people question the assertion that high coral cover (more than 50 %) is an indication of a healthy coral reef and low coral cover (less than 50%) being an indication of unhealthy reef, one thing is surely clear coral growth depends upon where the reef is located. Coral cover can definitely be used as an indicator for the coral reefs adjacent to human settlement. In remote areas lower coral cover is not necessarily indicative of unhealthy reefs. For example, most areas that are exposed to strong and small wave action like those in the south of Java and Nusatenggara Islands, and some areas which have windward facing reef margin, such as ridges spur and grove, show reduced coral cover but high coralline algae cover or soft coral cover. In western Indonesia, coral reefs are subject to greater anthropogenic impact compared with those in the central and eastern Indonesia. For example 70 % of coral reefs in the Seribu Islands near Jakarta are in poor condition. In this case percentage of coral cover can be used as indicator of reef health.

The total area of coral reef area in Indonesia is about 85.700 km^2 or about 14 % of the world's total. This area of coral reef consist of fringing reefs 14.542 km^2 barrier reefs 50.223 km^2, oceanic platform reef 1.402 km^2 and atolls 19.540 km^2 (Tomascik et al. 1997)

A total of 585 stations from 55 different locations of reefs have been surveyed throughout Indonesia. The results showed that 39.5% of the reefs were in poor condition, while 5 % are in excellent condition, 21 % in good condition and 34.5% in fair conditions. The clear water of the central and eastern part of the Indonesian seas permits corals to develop to a depth of more than 30 m. In the western Indonesia, in contrast, coral growth is limited to an average depth of no more than 20 m. At shallow water coral reefs in Indonesia are dominated by *Acropora* spp., *Montipora* spp. and *Porites* spp.. In greater depth coral growths is dominated by *Echinopora* sp., *Mycedium* sp., *Oxypora* sp. and *Turbinaria* sp. This difference in coral domination can be related to the degree of exposure to water movement. Certain species can function as indicator for either sheltered or more exposed biotopes. For example *Porites* sp. survives better in sheltered and turbid water and becomes the dominant genera of a less diverse community. Alternatively *Acropora* sp. and Montipora sp. flourish in a habitat more exposed to water movement and clear water.

Table 1. The Status Of Coral Reef In Indonesia (%) (Based On 648 Stations, 2004)

	No.Of Location	Excellent	Good	Fair	Poor
West	243	5.76	20.99	33.33	39.92
Central	210	6.19	31.43	45.24	17.14
East	195	9.23	29.23	33.08	28.46
Indonesia	648	6.69	26.59	37.56	29.16

• Excellent : 75-100 % living coral cover	•Fair : 25-49 % living coral cover
•Good : 50-74 % living coral cover	•Poor : 0-24 % living coral cover

Coral reef monitoring conducted in 648 stations of 58 different localities throughout Indonesian waters revealed that in terms of its condition the corals of this waters could be classified into four categories, namely: excellent (6.69 %), good (26,59 %), fair (37.56 %) and poor (29.16 %). Detailed examination of the results indicated that the condition of corals in the western Indonesia was the worst compared to those in the central and the eastern Indonesia (Table 1).

Evaluation of results of coral monitoring that have been done during 1993 to 2003 showed that there was the trend of improvement from poor to fair condition. In the meantime corals in the good and excellent categories were relatively stable during these years. It was noted that coral condition in Indonesia varied highly from one locality to another, while the best condition was most frequently found either in the remote areas or in properly guarded places.

It has been accepted worldwide that Indonesia serves as the origin of world corals as well as the center of marine biodiversity of the world. This distinction is justifiable taking into account the high number of coral species that live in Indonesian waters, which consists of 590 species and 82 genera. The distribution of genera and species is presented in Figure 4 & 5. Of the 113 species of *Acropora* recorded in the world, 91 species are found in Indonesian waters. This fact strongly confirms the denomination of Indonesia as the center of coral biodiversity. Tomini bay (Central Sulawesi) is the place where the highest number of *Acropora* sp (78 species) is recorded (Wallace et al., 2000). The West Sumatra waters, by contrast, have a low number of *Acropora* species, i.e. 40 species. For comparison, the Great Barrier Reef has 60 species of *Acropora* (Wallace 1997). Presently 40 species of *Fungidae* are recorded in the world, and all of them are found in Indonesian waters.

Results of observations indicate that species composition differs from one site to another, in the mean time some localities exhibit to have endemic species. To acquire accurate data on the wealth of coral species at certain locality, an in-depth and long-term study requiring quite an amount of fund will be needed. This state of affairs explains why only a few areas have sufficiently accurate data of corals. Species composition of coral reef in eastern Indonesia is commonly richer than in western Indonesia. As stated earlier, the total number of coral species in Indonesia amounts to 590 species, and the locality that have the highest number of species is Raja Ampat Isles in Papua which harbors 456 species belonging to 77 genera. Coral population in Banda, Spermonde (South Sulawesi) and Derawan Isles (East Kalimantan) was 330, 262 and 444 respectively (Veron 2002, Suharsono et al. 2002, Moll 1983, Teraki 2003). Meanwhile the species composition of corals in western Indonesia is usually less than 250 species.

The total number of coral genera in the world is presumed to be 109, while currently the number of coral genera in Indonesia is 82 or about 75 % that of the world. Observation on coral genera is less difficult compared to that on coral species. Therefore, data on coral genera distribution in Indonesia is much better than that of coral species. Certain species of corals in Indonesia have been studied in a greater detail than others. Togean isles and Tomini bay represent the localities that are rich in *Acropora* species. In the Caribbean sea, United States Florida, only three species of *Acropora* are recorded, while in the Great Barrier Reef there are only 60 species (Wallace 1997). Some species of *Acropora* are endemic to certain localities, such for instance *Acropora togeanensis*, found only in Togean waters and *A. suharsonoi*, found only around Bali and Lombok. Adequately detailed study has also been done on the distribution of Fungidae. This family has 41 species worldwide, 40 of which are found in Indonesia (Hoeksema and Putra 2000). Another example showing the Indonesian status as the center of coral biodiversity, is the distribution pattern of *Millepora*. The total species of *Millepora* in the Indo-Pacific waters is 7 species, and Indonesia harbors 6 of them. The rich coral species of Indonesia is closely correlated with the geographic position, habitat variation and geological history of the Indonesian seas which provide an optimal condition for evolutionary growth of corals.

NATURAL AND ANTHROPOGENIC DISTURBANCHES

Bleaching is a major natural disturbance affecting coral reefs in some areas of Indonesia. In 1983 bleaching events were recorded in Karimunjawa Islands, Seribu Islands and Sunda Strait. Coral mortality reached 80-90 %, extending from the reef flat down to a depth of 15 m. Oceanographic data collected during the bleaching event indicated that sea surface temperature reached 2-3oC above normal during March – June 1983 (Brown and Suharsono 1990). That coral bleaching event and subsequent mass mortality of Scleractinian and other zooxanthellae reef organisms has been linked to synergistic effect of increased temperature, unusually cloud free and calm weather during that time.

Estimates of coral community recovery from various environmental disturbance such us harricane, volcanic eruption and bleaching of different intensities range from 10-70 years (Pearson, 1981, Colgan, 1987, Done et al. 1991: Dollar and Tribble, 1993). However disturbance and recovery of scleractinian coral communities following volcanic eruption in Gunung Api, Banda Island only take 5 years (Tomascik, 1997). Tomascik suggested that the radial skeletal extension rates of tubulate acroporid on the Gunung Api as high as 30 cm/year. These growth rates are among the highest known for this group (Tomascik et al. 1996). While the Porites spp. can exceed 2.5 cm/year.

Growth rates of reef in the archipelago follow similar patterns and reef in the Kepulauan Seribu complex, Indonesia grew at rate of 5-10 mm year-1 from 8000 yr BP to 4500 yrs BP since 4500 yrs BP and sea levels in this region have been relatively stable and reef growth has been largely outwards (Tomascik, 1997) while vertical growth rates of submerged oceanic platform reefs in the Banda Sea are relatively high for reef flat, reef crest and reef slope.

Human impacts, direct and indirect, have been recognized as higher threat than natural disturbances. Many stresses on coral reef from human activity have been well documented such as dredging, siltation, organic pollution, oil pollution, sewage, blast fishing, fish poisoning, anchor damage, construction of infrastructure on reef and marine tourism (Gomez et al. 1994, Jameson et al. 1995, Hawkin and Roberts, 1993, Wilkinson and Ridzwan, 1994). The major causes of coral reef degradation in Indonesia are blast fishing, sewage, industrial pollution and cyanide fishing. The majority of the Indonesian population is concentrated along the coast. Rapid economic development in particular those closer to major population center resulted in large amount of sewage and industrial pollution, which have caused the decline of many reef areas especially the reef in front of the growing cities such as Jakarta, Ambon and Ujung Pandang. Umbgrove (1929) noted that the reef in Nyamuk Besar (Jakarta Bay) was characterized by a prominent Montipora ramosa and M. foliosa facies today none of those remains. Recent studies show that living coral cover in Jakarta bay and Ambon Bay ranged from 2.5-24.01 % respectively.

Muroami fishing and blast fishing are considered major factor contributing to physical damage to the reefs. These fishing techniques cause corals to break and damage the bottom habitat. There are at least two types of fishermen using blast fishing: (1) small scale fisherman use self constructed bombs made from fertilizer in order to catch fishing by blowing up small reef areas at shallow water near by their house; (2) medium scale to large scale bomber using big bomb and detonator. They fish in remote areas (about 7-10 day trips), destroying vast area of reef, from reef slope to about 20 m depth. They also use tire compressor to supply air to diver who collect the fish.

The demand for reef dwelling grouper and humperhead wrase has risen dramatically over the past few years and Indonesia is now the largest single industry to supply living reef fish into Asian market. It is estimated that- more than 50 % of the total wild caught living reef fish are currently supplied to Hong Kong and Singapore (Johannes and Riepen, 1995). Cyanide is a broad-spectrum poison causing damage to the liver, intestine and reproductive organ of the fish and causing extensive damage to corals. Blast fishing and cyanide fishing have caused irreversible damage to many Indonesian reefs. These destructive fishing techniques continue to practice throughout Indonesia water.

Marine activities and coastal resources account for about 20.6 % of Indonesia Gross Domestic Product (GDP) and employ over 30 million people, about 7 % of the total population. These area perform important functional as gene bent, stabilizing coastal areas or preventing coastal erosion and storehouse of marine species. At least 2.500 species of reef fish, 400 species stony corals, 42 species of mangrove, 13 species of seagrass, 782 species of algae, 850 species sponge, 2500 species of mollusk, 1503 species of crustacea and 745 species of echinoderm (Moosa, 1978).

Marine and coastal resources are high economic values and are capable of sustainable long-term management. Therefore a new approach to marine and coastal resources management is urgently needed.

THREAT AND IMPACT

Over the past 10-15 years, progressive degradation of the reef in several areas has been recognized. Many reef have less living coral cover and smaller fish they did before as a results of combined human and natural factors. Many coastlines are being rapidly degraded mainly throught inappropriate land use development. Rapid population growth, land base industry, domestic waste and tourism all resulted a wide range of an intractable environment and resources management problems. In general coastal resources located with large human population have suffered the most serious degradation. Remote areas that were previously protected from human pressure by deep water and distance are now becoming expored to destructive fishing method using dynamite and cyanide fishing. Destructive fishing practice combain with uncontrolled rural and coastal development are severally damaging coastal resources, putting at risk the livelihood of thousands of fisherman villages. Human threats to the coastal resources have intensified over the last 4 years as a result of the economic crisis. They are pushed marine habitat beyond sustainable level and reef fish stocks are declining as a result of over fishing and destruction of habitat. The marine resources are severally threatened by destructive fishing methods such as dynamite, cyanide, compressors, fish traps, reef gleaning and oner fishing. The fisherman with compressor has been destroying more coral reef and depleting more demersal resources. Fishermen break down and turn over the corals and leave the field of dead coral behind them. The used of compressor by dynamite fisherman, cyanide fishermen, fish trap fishermen resulted a large of destruction of marine habitat, deep water coral reef and distance are becoming exposed to destructive fishing practice. Cyanide fishing with targeting live reef fish has been physically and chemically destroying coral reefs. In the capture of a single grouper, poisoning and breaking of coral destroy more than a square meter of corals. In the areas where cyanide fishing has been practiced intensively the reefs is mostly dead, over grown with algae and with only few animals still living on it. The use cyanide not only results in the high valued food fish but also in the death of numerous small and juvenile fish and invertebrates.

Some of the traditional fishing methods may have led to the degradation of the marine rsources. It becomes imperative therefore to introduce new more environmental friendly fishing technique as part of the management of a sustainable coastal fishery. Lift net fishing “Rompong” and hand line fishing are currently considered non-threatening to demersal and sedentary marine resources. Lift net is mainly used to catch squid and anchovy fish. “Rompong” or fish aggregating device are made from palm leave and bamboo rafts anchored in deep water which attract pelagic fish. These types of fishing method have already been established among reef fishing coastal communities to catch Spanish mackerel and tuna.

MANAGEMENT

Monitoring

In the marine protected area usually have a small vilages and the majority of people are fisher from Bajo, Bugis and local people. Fisherman working in the marine protected area use a variety of fishing technique and equipment. Some methods and types of equipment are destructive and degrade the marine resources. The major fishing method of inhabitats are hook and line, reef gleaning to collect marine invertebrate at low tide, especially for sea cucumber. Other method include lift net which is mainly used to catch squit, development of bamboo traps to catch reef fish and diving with “hokahor” or compressors to catch lobsters, groupers, and mother of pearl. The threats to the marine protected area are mostly fisheries related especially by a variety of destructive methods including the use of compressors, dynamite and cyanide fishing, fish traps and reef gleaning. The use of compressor combination with both dynamite and cyanide fishing must be banned. Dynamite and cyanide fisherman have damaged most of the marine resources at a rapid rate. Dynamite fishing are not only killing fish and other marine organism but also live coral in the upper slope have been reduced to rubble. Dynamite fishing has also caused major reef degradation, loss of sustainable fishing marine, coastal protection and tourism.

Monitoring of marine resources utilization program is determine which community groups are involved in which fishing activities where they fish and when they fish. Is there any changes in the behavior of fisherman due to management measures and it will indicated which groups of fisherman it may need extra attention.

Management authority have implemented coral reef, fish and resources utilization monitoring programs to assess the impact of fishing and other activities in the marine protected area. The monitoring program has been developed to obtain feedback on the effect of management activities. The fish monitoring program focuses are chosen since they are heavily targeted by the live reef fish trade. By monitoring the size frequencies of a number of both species on a number known aggregration sites, it is possible to evaluate developments in the fish population in cost effective manner and also can be used as indicators for the impact of these fisheries.

The coral reef monitoring program are also applied to obtain information on spatial and temporal pattern in reef status inside and outside the marine protected area manta tow and intercept transect was used to identify for the percentage of damaged coral, live coral cover and mapping of damage coral due to destructive fishing method and other causes.

Marine recreation and dive tourism is becoming increasingly popular in the marine protected area. Such as in Komodo National Park, Pulau Seribu National Park and Bunaken National Park. Without careful planning monitoring and management tourism growth may also result in disturbed and damaged habitat.

Pollution is an emerging problem in Komodo, Pulau Seribu and Bunaken due to land base sediment erosion and run off from wathershed. Sewage from egacity of Jakarta especially for Pulau Seribu is becoming obrious.

Public awareness program

The achievements of the COREMAP (Coral reef Rehabilitation and Management Program) for the public communication program conducted for the last two years has a positive impact but that it is not yet reaching enough people compare the vast area of Indonesia. Activities and materials that were developed or supported as part of the public communication program included TV and Radio spots, and programs, posters, stickers, campaign songs, billboards, a children's game, exhibitions, a field guide to coral reefs, newsletters, press releases, web site, interpersonal contact, entertainment-education events, community meetings and a variety of workshops. A communication impact evaluation was carried out in the main COREMAP areas shows that 63% of the general public and 71% of coastal community resident were aware of program of save the coral reef now. People more exposure to Coremap communication were more likely to recognize the seriousness issues such as they could do something to help protect coral reef, more likely to think that coral reef destruction will affect them personally. All Coremap locations were positively affected by the campaign and Coremap should continue to reinforce and support people who are beginning to support community-based resource management so that their positive attitudes can spread to others over time.

Legal Basis

Until 1990 there is no single law concerning marine protected area in Indonesia. We have adapted general legislation on marine environment without specific provision for marine protected area. In 1983 Indonesia signed the Indonesian Exclusive Economic Zone law No. 5, this accepting responsibility for the exploration, utilization, management and conservation of approximately 6 million km^2 of marine area with on Exclusive Economic Zone (ZEE) within 200 mile. In 1986 the Department of Forestry passed the marine nature preserver decree (Kemmen, 123) which initiated the production of a growing body of legal instrument necessary for the sustainable management of the marine and coastal resources. In 1988 the marine and coastal sector was recognized for the first time in GBHN (Broad Guideline for State Policy) where the effective utilization of coastal area, sea areas, and land waters should be continued and improved without destroying the quality and sustainability of the environment and its natural resources. In 1990 law No. 5 1990 was enacted concerning conservation of living natural resources and their ecosystem which links sustainable resources utilization with ecosystem integrity and the type of conservation areas in Indonesia. The new 1999 legislation (Autonomy laws No. 22/1999 and No. 25/1999) spatial utilization management effectively integrated all previous legislation concerning marine management. Schemes by specifically delegating power to the provincial and local authorities operate within a national environmental legislative framework. The law provided the opportunity for provincial and local government to regulate the use of coastal and marine area to fit their needs. The allocation of responsibility for managing coastal and marine ecosystems to provincial and local government was one important step towards the effective coastal zone management framework. For the time being, the urgent need is to begin the implementation of the existing policies and regulations in the most appropriate way.

Development

The government of Indonesia has set a target to establish 10 million ha marine conservation area in the foreseeable future. Currently only some 5.8 million ha are officially declared and consist of 37 location of marine conservation areas. The ministry of Forestry's Directorate General for Protection and Nature Conservation (PKA) is the agency responsible for nature conservation in Indonesia. Although the plans for 10 million ha of marine conservation are impressive, unfortunately they remain in essentially plans, very few that the gazetted conservation areas have actual management plans prepared or put into operation.

The Indonesian law concerning the conservation of living resources and their ecosystem (ACT No 5 of 1990) recognizes 4 different types of marine protected areas. Strict nature reserves which are strictly protected are allowed to develop naturally, wildlife sanctuaries which habitat were managed are allowed to ensure their continuity of existence, National park which are managed through zoning system allows different activities to take place in different part of the park. Natural recreation areas mainly intended for recreational and tourist purposes. While KSDA (Conservation of Implementation Unit) is the principle management agency for most day-to-day management activities of Marine Protected Area. Human use is integral to the approach and managed to be ecologically sustainable and commercial or recreational use is allowed in the general use zone.

REFERENCES

Best. M.B.; B.W. Hoekseuma; W. Moka; H. Moll; Suharsono and I.N. Sutarna 1989. Recent scleractinian coral species collected during the Snellius II expedition in Eastern Indonesia. Net. Jour. Sea Res., 23(2): 107-115.

Brown, B.E. and Suharsono 1990. Damage and recovery of coral reefs affeted by El Nino related sea water warming in the Thousand Islands. Indonesian coral reefs, 8: 163-170.

De Vantier, L.M. 1986. Studies in the assessment of coral reef ecosystems. In: Brown, B.E. (ed). Human induced damage to coral reefs results of a regional UNESCO workshop with advanced training Diponegoro University and National Institute of Oceanology. Jakarta, 40: 99-111.

English, S., C.R. Wilkinson and V. Baker, 1994. Survey manual for Tropical Marine Resources ASEAN-Australia. Marine Science Project Living Coastal Resources. AIMS-Townsville.

Gomez, E.D., P.M. Alino, H.T. Yap and W.Y. Licuanan 1994. A review of the status of Philippine reefs. Mar. Poll. Bull. 29: 62-68.

Halim, M. and R.H. Djohani 1992. Pulau Seribu ten years later. A marine protected area in Indonesia. Proc. 4th World Congr. National Parks, Caracas, Venezuela.

Harger, J.R.E. 1986. Responses of coral reef communities to environmental variables in the Kepulauan Seribu Island chain. In : Brown, B.E. (ed.) Human Induced damage to coral reefs Results of a regional UNESCO (COMAR) workshop with advanced training Diponegoro University, Jepara and National Institute of Oceanology, Jakarta, Indonesia. UNESCO Reports in Marine Science 40: 164-173.

Hawkins, J.P. and C.M. Roberts 1993. Effect of recreational Scuba diving on coral reefs: trampling on reef flat communities. J. Appl. Ecol. 30(1) : 25-30.

Jameson, S.C., J.W. McManus and M.D. Spalding 1995. State of the reefs: Regional and global perspectives. International coral reef initiative (ICRI) Scretariat background paper. Washington: 32 pp.

Johannes, R.E. and M. Riepen 1995. Environmental, Economic and Social Implications of the live Reef Fish Trade in Asia and the wester Pacific, 78 pp.

Moll, H. and Suharsono 1986. Distribution, diversity and abundance of reef corals in Jakarta Bay and Kepulauan Seribu. In: Brown, B.E. (ed). Human induced damaged to coral reefs: Results of regional UNESCO (COMAR) workshop with advanced training. Unesco reports in Marine Science 40: 112-125.

Ongkosongo, O.S.R. 1986a. Background to the study sites in the Bay of Jakarta and Kepulauan Seribu. In ; Brown, B.E. (ed.) Human induced damage to coral reefs Results of a regional UNESCO (COMAR) workshop with advanced training Diponegoro University, Jepara and National Institute of Oceanology, Jakarta, Indonesia. UNESCO Reports in Marine Science 40: 56-79.

Ongkosongo, O.S.R. 1986b. Some harmful stresses to the Seribu coral reefs, Indonesia. Proc. MAB-COMAR Regional Workshop on coral reef ecosystems: their management practices and research /training needs. UNESCO, Jakarta, pp. 133-142.

Suharsono 1990. Ecological and physiological implications of bleching at Pari Island, Thousand Islands, Indonesia. Ph.D. Thesis, University of Newcastle upon Tyne, 279 p.

Suyarso 1995. Atlas Oseanologi Teluk Jakarta. Lembaga Ilmu Pengetahuan Indonesia Pusat Penelitian dan Pengembangan Oseanologi Jakarta, 160p.

Tomascik, T., Suharsono and A.J. Mah 1994. Case histories: A historical perspective of the natural and anthropogenic impacts in the Indonesian Archipelago with a focus on the Kepulauan Seribu, Java Sea. In: Ginsburg, R. (ed.) Proceedings of the colloquium on global aspects of coral reeffs Health, hazards and history. University of Miami, Rosenstiel School of Marine and Atmospheric Science, pp. 304-310.

Tomascik, T., Suharsono and A.J.Mah, 1993. Case Histories: A historical respective of the natural and anthropogenic impacts in the Indonesian Archipelago with a focus on the Kepulauan Seribu, Java Sea. Proc. Coll. Global aspects of Coral Reefs Univ. Miami, 304-310.

Tomascik, T., A.J.Mah, A. Nontji and M.K. Moosa, 1997. The Ecology of Indonesia Seas. Publ. Pariplus Ed. Vol. VII(1) : 136-144.

Umbgrove, J.H.F. (1928). De koraalriffen in de Baai van Batavia. Dienst Mijnb. Ned. Indie, Wetensch, Meded. 7: 1-69.

Umbgrove, J.H.F. (1929). De koraalriffen der Duizen eilanden (Java zee). The coral reefs of the Thousand Islands (Java Sea). Dienst v.d. mijnbouw in Ned.Ind. Wetensch, Meded. 12: 1-47.

Umbgrove, J.H.F. (1929). The influence of the monsoons on the geomorphology of coral islands. Proc. 4th Pacific Sci. Congr. 2A: 49-54.

Umbgrove, J.H.F. (1939). Madreporaria from the bay of Batavia. Zoologische Meded. 22: 1-64.

UNEP and IUCN 1988. Coral Reef of the world. Switszerland and Cambridge UK and UNEP Nairobi 2.

Veron, J.E.N. 1995. Coral in space and time: the biogeography and evolution of the scleractinian. UNSW Press. Sydney Australia.

Verwey, J. 1931. Coral reef studies. III. Geomorphological notes on the coral reefs of Batavia Bay. Treubia 13: 199-215.

Wallace, C.C. 1997. The Indo-Pacific Centre of coral diversity re-examined at species level. Proc. 8th Int. Coral Reef Symp. 1: 365-370.

Wilkinson, C.R. 1992. Coral Reef of the world are facing widespread devastation: can we present this through sustainable management practices?. Proc. 7th Int. Coral Reef Symp. 1: 11-21.

Wilkinson, C.R. and A.R. Ridzwan 1994. Causes of coral reef degradation within Southeast Asia. In: Wilkinson, C.R. (ed) ASEAN-Australia Symposium on Living coastal Resources. AIMS: 18-24.

Wallce, CC., Z. Richards and Suharsono, 2000. Regional distribution patterns of Acropora and their use in the conservation of coral reefs in Indonesia.

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2.3. PHILIPPINES

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ABSTRACT

Regular update of the status report on coral reefs has been ongoing for more than two decades now. Initial report indicated that only 5% were in excellent condition. Based from the proportion of the different benthic lifeform categories, percent cover of the excellent reefs suggests that the reefs in the Philippines may be experiencing a steady state of decline (i.e. from 5% to 3% to >1%). However, better reefs can still be found in Celebes Sea, Southern Philippine Sea, Sulu Sea and the Visayas biogeographic regions. The different categories of estimated fish biomasses derived from fish census showed ways on how these biomasses can be translated to fishing pressure. Fish biomasses ranging from 0 to 10 mt/km^2 (very low to low) are considered as overfished, from 11 to 20 mt/km^2 (medium) as slightly or moderately fished, 21 to 40 mt/km^2 (high) and greater than 40 mt/km^2 (very high) as with very minimal fishing and/or protected. About 15% each of the total reef areas surveyed in South China Sea and Sulu Sea fall under the very high fish biomass category. Various management interventions have been conducted in different forms such as establishment of marine protected areas and strict enforcement of the law on destructive and illegal fishing methods. With these ongoing efforts, the declining trend in coral cover and the status of fish biomass will probably revert back to its previous state. Fishery models can provide different ways on how coral reef resources can be use sustainably.

INTRODUCTION

The Philippines is situated in between 4° to 22°N latitude and 112° to 127°E longitude. It is composed of 7,100 islands and islets with a total coastline of 36,289 km, reef area of 25,819 km^2 (Burke et al. 2002), land area of 298,170 km^2 and a marine area of 679,800 km^2. In 2003, the estimated total population was 84.6M and about 39M are living in the coastal areas.

It is also within the center of the highest marine diversity known as the coral triangle. To date, a total of 464 scleractinian corals were identified (Licuanan and Capili 2003, Veron and Fenner 2002), 736 reef fishes (Allen 2002), 648 species of mollusks (Wells 2002), 16 species of seagrass (Fortes and Santos 2004) and 820 species of algae (Trono 1999).

The contribution of coral reefs to the country's total fishery production ranges from 8-20% and can be high as 70% for some island reefs (see review by Aliño et al. 2004). In 2000, the total annual fish production was estimated at 2,983M mt (BFAR 2001) valued at PhP98.69B (NSCB 2002). About a million small-scale fishers are dependent directly on reefs for livelihood (Barot et al. 2004).

Licuanan and Gomez (2002) have presented the last status report and fully described the sequence of events that took place prior to their report. This status report covers the period from March 2000 to June 2004 involving 424 transects. In the same manner with the previous reports, areas covered were different and dependent on the availability of data. This report has more sites on the Pacific Seaboard, some in South China Sea area and very few in the Sulu Sea, Visayas Region and Celebes Sea areas. This report also put emphasis on the status of coral reef fishes and the efforts on marine protected areas (MPAs).

STATUS OF CORAL REEFS

Reef Benthos

Of all the lifeform benthos categories living coral usually referred to hard corals and soft corals. The percentile scores for living corals was the basis for the quartile condition categories proposed by Gomez and co-workers. The combination of the major lifeform benthic categories provided a combination of these attributes. This brought about other additional types of indices such as the mortality index (Gomez et al. 1994a) and those proposed by Mantachitra (1994). Unfortunately, the manta tow broad area surveys have been underutilized and often are not reported in many country reports. Despite the constraints on using coral cover as the only basis for an indication of the condition of reefs, the other lifeform benthos are helpful in gauging impacts and condition of reefs. The dead coral with algae and their "abiotic" cover might suggest succession stages at ecological scales and geomorphological features of the reef at evolutionary scales. Thus the narrow reef extent can be inferred in the North and South Philippine Sea reefs (NPS, SPS). Likewise these reefs also indicate more frequent higher algal coverage. On the other hand, The Visayas Region (VR), Sulu Sea (SS) and Celebes Sea (CS) regions indicate a wider range of abiotic cover (Table 1).

Table 1. Nationwide percent composition of the different benthic lifeforms covering 424 transects from March 2000 to June 2004. For sites that were repeatedly surveyed, average data was used. (HC = hard corals; SC= soft corals; DC/A = dead corals and dead coral with algae; algae = algal assemblage, coralline, Halimeda, macro and turf algae; Others = other fauna excluding soft corals; and Abiotic = rock, silt, sand, rubble).

% cover	Benthic lifeform category						
	HC+SC	HC	SC	DC/A	Algae	Others	Abiotic
Nationwide							
0-10	2.1	3.3	92.9	80.9	17.2	90.1	20.8
10.1-20	21.2	31.8	5.2	10.1	14.9	8.7	26.2
20.1-30	29.5	29.2	0.7	5.7	9.9	1.2	18.9
30.1-40	27.8	24.3	0.5	2.4	15.8	0	12.3
40.1-50	13.7	7.8	0.2	0.5	17.9	0	8.7
50.1-60	3.8	2.6	0.5	0.5	14.9	0	6.1
60.1-70	1.7	0.9	0	0	6.4	0	3.3
70.1-80	0.2	0	0	0	2.8	0	3.1
80.1-90	0	0	0	0	0.2	0	0.7
90.1-100	0	0	0	0	0	0	0
TOTAL	100	100	100	100	100	100	100

Table 2. Percent live coral (hard and soft corals) cover using quartile categories (see Gomez and Alcala 1979) per biogeographic region covering the period from March 2000 to June 2004. Values in parenthesis represent the live hard coral cover only. For sites that were repeatedly surveyed, average data was used.

Biogeographic region	No. of transects	Living Coral Cover							
		Excellent (76-100%)		Good (51-75%)		Fair (26-50%)		Poor (0-25%)	
		No.	%	No.	%	No.	%	No.	%
South China Sea	124	0	0 (0)	0	0 (0)	67	54.0 (48.4)	57	46.0 (51.6)
Northern Philippine Sea	81	0	0 (0)	0	0 (0)	42	51.9 (44.4)	39	48.1 (55.6)
Southern Philippine Sea	113	0	0 (0)	10	8.8 (7.1)	68	60.2 (53.1)	35	31.0 (39.8)
Visayas Region	42	0	0 (0)	1	2.4 (2.4)	21	50.0 (45.2)	20	47.6 (52.4)
Sulu Sea	25	0	0 (0)	2	8 (0)	9	36.0 (32.0)	14	56.0 (64.0)
Celebes Sea	39	1	2.6 (0)	11	28.2 (12.8)	19	48.7 (41.0)	8	20.5 (46.2)
Total	424	1	0.2 (0)	24	5.7 (3.5)	226	53.3 (46.9)	173	40.8 (49.5)

Better reefs could be found in the CS, SPS, SS and the VR biogeographic region (Table 2, Fig. 1). Some representative sites are still reported in the good to excellent categories. Based on the proportion of the benthic lifeform categories the percent of bottom cover of the excellent reefs (i.e. > 75%) suggests that the reefs in the Philippines are may be experiencing a steady decline (i.e. from 5% to 3% of all the reef transect sites, Fig. 2). This degradation trend is further corroborated by the increasing trends in the poor condition category (i.e. ~ 33 in the 1980's to nearly 40% two decades after).

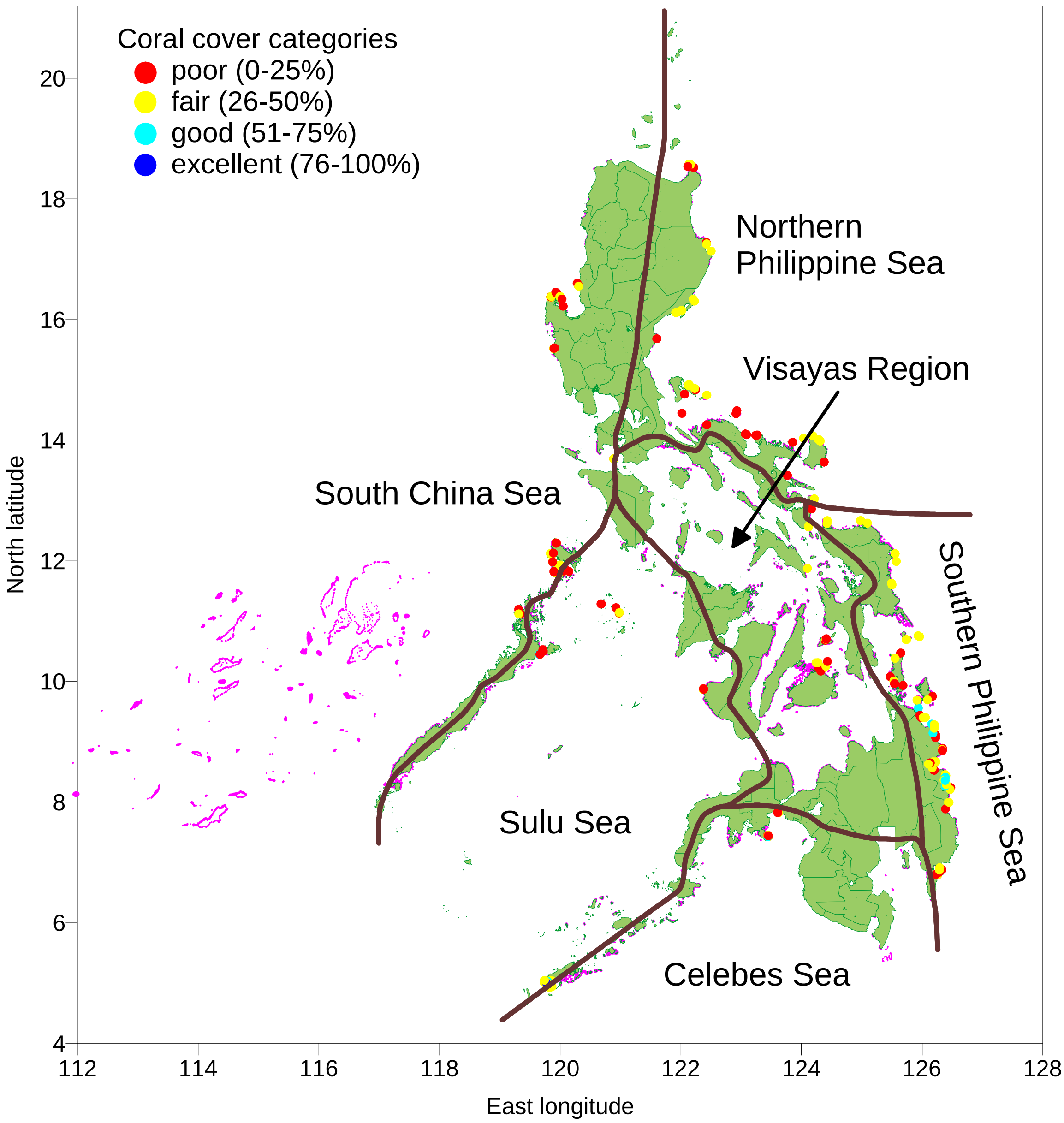

Figure 1. Philippine map and its biogeographic regions (Aliño and Gomez 1994) showing the color coded live coral (HC+SC) cover data that were surveyed from March 2000 to June 2004. For sites that were repeatedly surveyed, average data was used.

Whether future best-case scenarios would elicit a rebound of having more good and excellent reefs derived from recovery and enhancement of fair to good to excellent reefs remains to be seen. At worse, the possible phase shifts observed in many other areas would initially further show the expansion of algal covered reefs into the SCS and the VR. Perhaps the SS and CS regions may have follow closely this decline. Aside from the effects of siltation that seems to be manifested in the benthic lifeform cover, the large ecological impacts that exacerbates other natural induced perturbations would be overfishing. The associated reef fish community assemblage would be better indicators of the condition of the reefs.

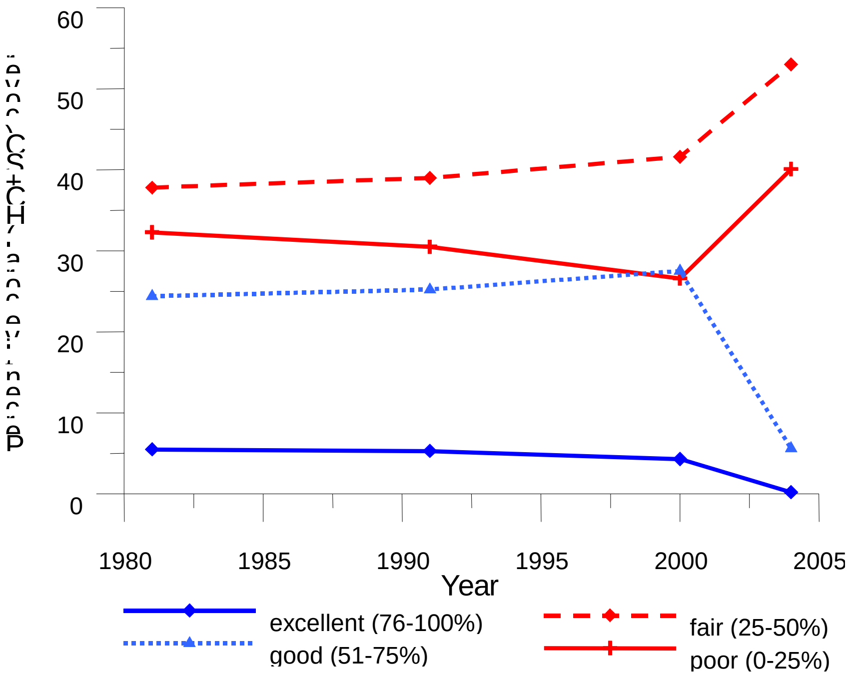

Figure 2. Trends in benthos cover from 1981 to 2004. Source: 1981 (Gomez and Alcala 1979, Gomez et al. 1981); 1991 (Gomez et al. 1994a, 1994b); 2000 (Licuanan and Gomez 2002).

Reef Fishes

The status of reef fishes can be best described through the derived estimated biomass (Nañola et al. 2002) in addition to species diversity, abundance and density estimates. Based from the current estimated biomasses at the national level, areas with biomass below 10 mt/km^2 are considered as overfished. These were divided further nominally as very low (< 5 mt/km^2) and low (5.1 to 10 mt/km^2) biomass estimates. More than 50% of the sites in CS, NPS, SPS and VR that were surveyed from April 1991 to April 2004 fall under very low and low categories. In contrast, only 20% in the SS region fall under these categories. Reef areas with 11-20 mt/km^2 biomass estimate (medium category) are considered as slightly or moderately fished areas. From 22 to 32% of the areas SCS, SS, and CS fall under this category. Lastly, reef areas with 21-40 mt/km^2 (high category) and >40 mt/km^2 (very high) biomass estimates are considered as areas having very minimal fishing and/or have been protected (i.e. MPA) at least for more than 5 years. High fish biomass category was common in VS and SS reef areas comprising 25.8% and 32.9%, respectively. The least were in NPS (7%) and SPS (3.5%). Very high fish biomass category was observed in the areas with high species diversity, SCS and SS regions comprising 14.6% and 14.5%, respectively. These regions have the presence of large marine protected areas such as the Tubbataha Reef National Marine Park in SS region and many island reef areas in the SCS (i.e. Spratly Islands). Although the latter were not officially declared as an MPA, these areas were “protected” by the military occupying the various reef islands (Table 3, Fig. 3).

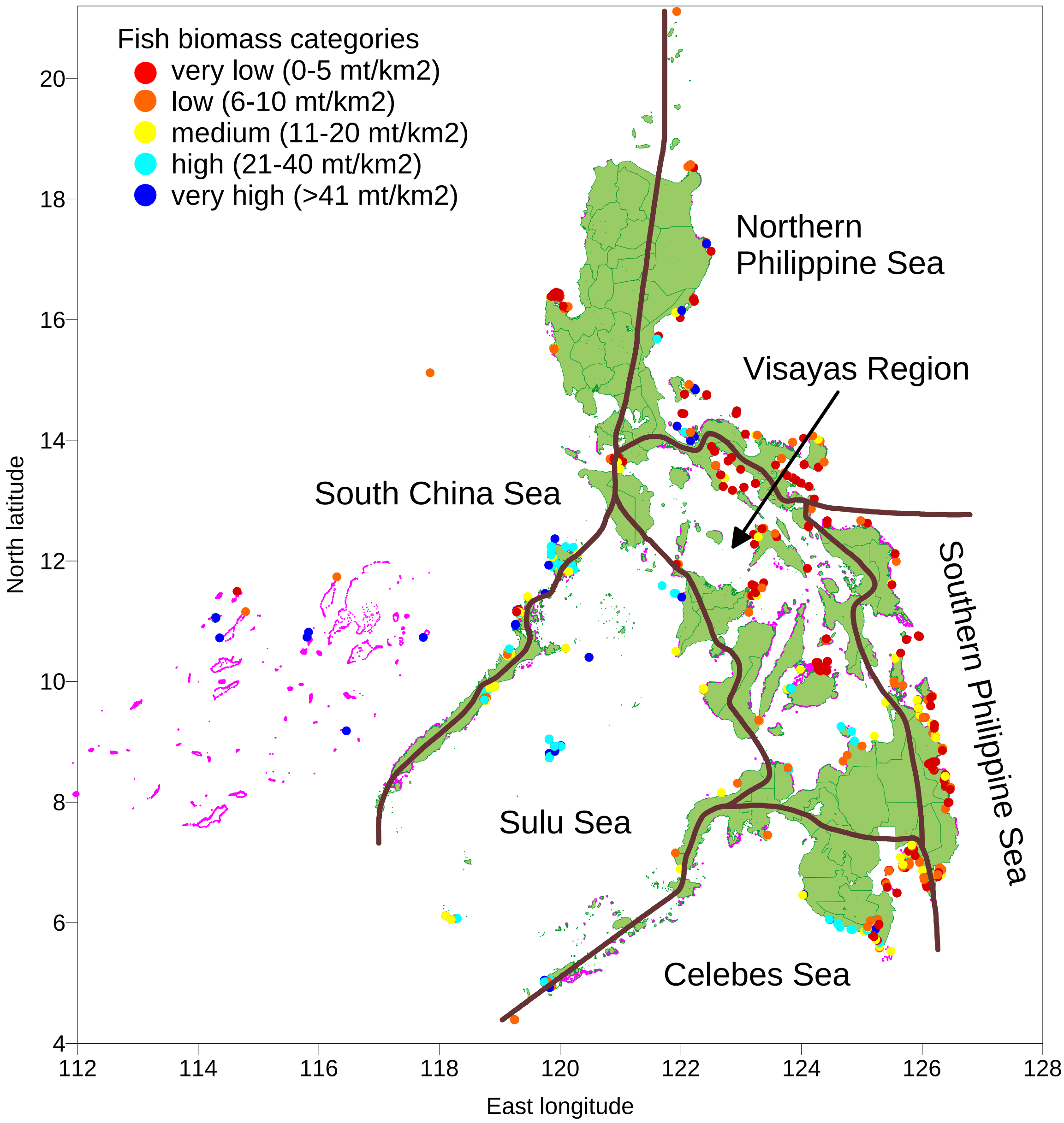

Figure 3. Philippine map and its biogeographic regions (Aliño and Gomez 1994) showing the color coded biomass classification covering the period from April 1991 to April 2004. For sites that were repeatedly surveyed, average data was used.

MANAGEMENT

Marine Protected Areas

Of over 600 MPAs that have been established in the Philippines, only around 10% of these MPAs are actually being managed effectively (Aliño et al. 2000). Ineffective enforcement is one of the primary reasons for failure in MPA management. There is usually confusion in designating who should be doing the enforcement, especially for MPAs under national programs (Arceo et al. 2002). The two national government agencies that have been given the mandate to establish MPAs or fishery refuges are the DENR and DA-BFAR, and there are often some jurisdictional issues between the two agencies. Despite the large numbers of MPAs in the country, only a small fraction of the country's coral reefs are actually being managed (Aliño et al. 2000). In recent years, many of the MPAs being established were initiated and managed by local community organizations such as people's organizations. Monitoring and evaluation activity is another major gap in the management of many existing MPAs in the Philippines.

Table 3. Updated classification of fish biomass (mt/km^2) derived from fish visual census (see Nañola et al. 2002). Percent composition per biogeographic region covers a total of 1,274 transects from April 1991 to April 2004. For sites that were repeatedly surveyed during this time, average data was used.

Biogeographic region	No. of transects	Classification of fish biomass									
		Very high (>40 mt/km^2)		High (21-40 mt/km^2)		Medium (11-20 mt/km^2)		Low (6-10 mt/km^2)		Very low (<5 mt/km^2)	
		No.	%	No.	%	No.	%	No.	%	No.	%
South China Sea	164	24	14.6	26	15.9	36	22.0	29	17.7	49	29.9
Northern Philippine Sea	100	6	6.0	7	7.0	19	19.0	24	24.0	44	44.0
Southern Philippine Sea	115	1	0.9	4	3.5	21	18.3	43	37.4	46	40.0
Visayas Region	164	15	9.1	26	25.8	27	16.4	41	24.8	56	33.9
Sulu Sea	76	11	14.5	25	32.9	25	32.9	13	17.1	2	2.6
Celebes Sea	143	8	5.6	28	19.6	33	23.1	40	28.0	34	23.8
Total	763	65	8.5	116	15.2	161	21.1	190	24.9	231	30.3

Coral reef management has strengthened in recent years due to additional legal support from the enactment of several national laws. Such as the Republic Act No. 7160 (Local Government Code of 1991), the National Integrated Protected Areas System (NIPAS) Act or Republic Act No. 7586 of 1992, and in 1994, the Philippines adopted a National Marine Policy in order to develop a comprehensive program to properly manage coastal and marine resources in compliance with the United Nations Convention on the Law of the Sea (UNCLOS). Most recently, under Section 81 of the 1998 Philippine Fisheries Code, at least 15% where applicable of the total coastal areas in each municipality shall be identified as fish sanctuaries. Other legal support were the Convention on Biological Diversity, the ASEAN Convention on the Conservation of Nature and Natural Resources, UN Convention on the Law of the Sea and MARPOL, and the World Heritage or UNESCO Man and Biosphere (Cheung et al. 2002). A National Coral Reef Strategy is currently being prepared to provide a clear and integrated management framework for the protection, conservation and rehabilitation of the coral reefs in the country.

GENERAL DISCUSSION AND RECOMMENDATIONS

In the past, the reefs in the Philippines are at highest risk from overexploitation, destructive fishing and other human-related impacts such as coastal development and sedimentation (Burke et al. 2002). Based from results presented by this study, the trends in benthic cover seems to decline continuously on a very gradual phase. But with the ongoing efforts now on MPAs, the overall trend can be put to hold and eventually will show positive results in the years to come. It has been suggested by Licuanan et al. (2004) that the use of reef fishery models can serve as a guide for coastal managers for better management of their resource for the sustainable use.

The following are some of the recommended measures for the sustainable use of coral reef resources in Philippines:

Recommendation

1. Establish more marine sanctuaries combined with enhancement or restoration efforts (i.e. Grow out of juveniles of high valued invertebrates and fish on overfished coral reefs).

2. Expand efforts in network of MPAs and corridors through integrated coastal resource management (i.e. Consolidate efforts into the priority marine corridors in the Calamianes, Batanes and Babuyan Islands, Surigao Straits, Davao Oriental and Sulu Archipelago).

3. Pursue large marine ecosystem based management and sustainable Philippine Archipelagic development (i.e. Pursue integration through establishment of LME Commission).

4. Institutionalize adaptive management efforts into various national coral reef strategies and global strategies (i.e. Establishment of a coral reef trust fund for Philippine Marine Sanctuary Strategy).

5. Improve linkage between sciences and management (i.e. Information, education and communication program and capability building for inter-stakeholder action groups).

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REFERENCES

Allen GR (2002) Reef and shore fishes of the Calamianes Islands, Palawan Province, Philippines. In: Werner TB, Allen GR (eds) A rapid marine biodiversity assessment of the Calamianes Islands, Palawan Province, Philippines. RAP Bulletin of Biological Asssessment 17. Washington, DC: Conservation International, pp 31-44

Aliño PM, Arceo HO, Palomar N, Uychiaoco AJ (2000) Challenges and opportunities for community participation for the management of marine protected areas (MPAs) in the Philippines (Abstract). Paper presented at the 9th ICRS, 23-27 October 2000, Bali, Indonesia

Aliño PM, Gomez ED (1994) Philippine coral reef conservation: Its significance to the South China Sea. In: Yamamoto K, Ishijima S, Sakihara S, Taira H, Shimabukuro Z, Teruya F, Nishihira F (eds). Development and Conservation in the Asia-Pacific Region, Proc. Regional Conf. EW Center Assoc, pp 222-229

Aliño PM, Nañola C, Campos W, Hilomen V, Uychiaoco AJ, Mamauag S (2004) Philippine Coral Reef Fisheries: Diversity in adversity. In: DA-BFAR (Department of Fisheries and Aquatic Resources). In turbulent seas: The status of Philippine marine fisheries. Coastal Resource Management Project of the Department of Environment and Natural Resources, Cebu City, Philippines, pp 65-69

Arceo HO, Aguinaldo MMS, Alino PM (2002). An orientation of marine protected areas: coastal resource management tools. In: Enhancing community participation in fishery resources management. Marine Science Institute, University of the Philippines, the Royol Netherlands Embassy and International Development Research Center, Canada 45 p

Barot NC, Santos MD, Garces LR (2004) Overview of Philippine Marine Fisheries. In: DA-BFAR (Department of Fisheries and Aquatic Resources). In turbulent seas: The status of Philippine marine fisheries. Coastal Resource Management Project of the Department of Environment and Natural Resources, Cebu City, Philippines, pp22-31

Bureau of Fisheries and Aquatic Resources (BFAR) (2001) Philippine fisheries profile. Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines

Burke L, Selig E, Spalding M (2002) Reefs at risk in Southeast Asia. World Resource Institute, Washington DC, USA. 72 p

Cheung CPS, Aliño PM, Uychiaoco AJ, Arceo HO (2002) Marine Protected Areas in Southeast Asia. ASEAN Regional Center for Biodiversity Conservation, Department of Environment and Natural

Resources, Los Baños, Philippines 142 p
Fortes MD, Santos KF (2004) Seagrass ecosystem of the Philippines:Status, problems and management directions. In: DA-BFAR (Department of Fisheries and Aquatic Resources). In turbulent seas: The status of Philippine marine fisheries. Coastal Resource Management Project of the Department of Environment and Natural Resources, Cebu City, Philippines, pp 90-95

Gomez ED and Alcala AC (1979) Philippine coral resources. In: The Philippine fisheries industry, Media Systems, Inc., Makati, Metro Manila. p. 105-111.

Gomez ED, Alcala AC, and San Diego AC (1981) Status of Philippine coral reefs. Proc. 4th Int Coral Reef Symp, Manila 1:275-282

Gomez ED, Aliño, PM, Yap HT, Licuanan WY (1994a) A review of the status of Philippine reefs. Mar Pollut Bull 29:62-68.

Gomez ED, Aliño PM, Licuanan WRY, Yap HT (1994b) Status report on coral reefs of the Philippines 1994. In Sudara S, Wilkinson CR, Chou LM (eds) Proc, 3rd ASEAN-Australia Symp on Living Coastal Resources. Volume 1: Status Reviews. Australian Institute of Marine Science, Townsville: 720 pp

Licuanan WY, Capili EB (2003) Range extensions of Japanese Scleractinia to the Philippines. Galaxea 5:63-67

Licuanan WY, Gomez ED (2002) Philippine coral reefs: status and the role of the academe to improve their management. Proc 9th Int Coral Reef Symp, Bali, Indonesia 2:835-840.

Licuanan WY, Castillo G. Campos W, Aliño P, Juinio-Meñez MA (2004) A model for the integration of biophysical and socio-economic considerations in the design and deployment of marine protected areas (Abstract). Paper presented at the 10th ICRS, June 28 to July 2, 2004, Okinawa, Japan

Manthachitra V (1994) Indices assessing the status of coral-reef assemblages: Formulated from benthic transect data. In: Sudara S, Wilkinson CR, Chou LM (eds) Proceedings, Third ASEAN-Australia Symposium on Living Coastal Resources 2:41-50
Nañola CLJr, Aliño PM, Dantis AL, Rañola MCG, Hilomen VV, Cabansag JPB (2002) Understanding Philippine Reef Fishes: A Key to Fisheries Management and Marine Biodiversity Conservation. In: Aliño PM, Miclat EFB, Nañola CLJr, Roa-Quiaoit HA, Campos RT (eds). Atlas of Philippine Coral Reefs. Philippine Coral Reef Information (PhilReefs). Goodwill Trading Co., Inc. (Goodwill Bookstore), Quezon City, Philippines, pp 22-26

National Statistics Coordination Board (NSCB) (2002) Philippine statistical yearbook. NSCB, Philippines

Trono GCJr (1999) Diversity of the seaweed flora of the Philippines and its utilization. Hydrobiologia 398/399:1-6

Veron JEN, Fenner D (2002) Corals (Zooxanthellate Scleractinia) of the Calamianes Islands, Palawan Province, Philippines. In: Werner TB, Allen GR (eds) A rapid marine biodiversity assessment of the Calamianes Islands, Palawan Province, Philippines. RAP Bulletin of Biological Asssessment 17. Washington, DC: Conservation International, pp 24-26

Wells FE (2002) Mollusks of the Calamianes Islands, Palawan Province, Philippines. In: Werner TB, Allen GR (eds) A rapid marine biodiversity assessment of the Calamianes Islands, Palawan Province, Philippines. RAP Bulletin of Biological Asssessment 17. Washington, DC: Conservation International, pp 27-30

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2.4. SINGAPORE

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ABSTRACT

Rapid changes have transformed Singapore’s coastal and marine environment, particularly since the 1960s. The demands on the coastal environment are high, driven largely by non-fisheries related economic interests of the small island state. With its limited land and sea space, the balance between development and conservation of natural areas remains a delicate issue. Almost the entire coastline of the main island, particularly the southern half is altered by land reclamation and many of the southern offshore islands merged by reclamation to form larger islands. Coral reefs, once abundant along the southwest coastline of the main island are lost to coastal reclamation and are now restricted to narrow fringing bands and patches among the southern offshore islands.

Ongoing land reclamation since the early 1970’s resulted in elevated sedimentation. Regular dredging of shipping lanes and dumping of dredged spoils further offshore contribute further to the sediment load. This chronic impact resulted in live coral cover decline at almost all twelve reef sites monitored since 1986 and reduced vertical growth zone of reef slopes. Those close to or in the path of sediment plumes suffered drastic coral cover loss. At the reef crest, two sites showed improvement, one remained unchanged while the rest declined. At the reef slope (3m depth), coral cover declined at all sites except one, which remained unchanged. The 1998 global bleaching event affected the reefs at an unprecedented level. Exceptionally elevated water temperature reaching 34^0C and coinciding with low tides resulted in 90% of hard corals bleached and eventual mortality of 25%. Despite these impacts, some reefs still support good coral cover and diversity. Overall, the degradation rate does not appear to be as high as expected and the rich biodiversity appears to confer some resilience.

To date, there are no marine protected areas covering coral reefs although proposals to protect identified reefs have been made. Currently, only two legislated nature areas have marine components but do not contain reefs. No national agency manages coral reefs but with the establishment of the Biodiversity Center within the National Parks Board in 2004, focus on the marine environment has increased. Artificial reefs and coral translocation have been investigated in the past. A recent reef restoration project started in 2001 using specially designed fiberglass modules and new projects targeting reef remediation are being initiated.

INTRODUCTION

The Republic of Singapore, located over one degree north of the equator, consists of one main island and over 50 smaller islands (Table 1). Coral reefs fringe most of the main island’s southwestern coast and many of the southern offshore islands. Development progressed quietly over the first half of the 20^{th} Century, but accelerated from the 1960s, fueled by demands of a growing nation and assisted by improving technology. More than half the country was built up by 1988 with forest cover reduced to 2.5 percent. Extensive land reclamation commencing from the early 1970’s increased the country’s size by 6% from $586km^2$ in 1967 to $697km^2$ in 2003 (Singapore Department of Statistics, 2003). The number of southern offshore islands decreased from sixty in the 1960’s to just over fifty in 2004, as adjacent islands were merged by reclamation to form larger ones suitable for industrial development. The territorial waters of Singapore (up to 12nm) cover an area of $744km^2$.

The marine environment contributes significantly to the country’s economic growth. Situated strategically at the crossroads of the shortest sea route between the Indian Ocean and the South China Sea, its natural harbour has allowed it to grow into one of the world's busiest container ports and the third largest oil refining centre. The trade-off in rapid development was loss of natural habitats. Just before the turn of the century, an estimated 60% of total coral reef areas were lost through coastal reclamation (Chou, 1995; Chou & Goh, 1998). Coral reefs estimated to cover an area of over $100km^2$ prior to the land reclamation programme decreased to $54km^2$ today (Burke *et al.*, 2002). The real reef extent is believed to be lower, and more accurate estimates are currently being made based on actual field mapping.

Commercial fisheries exploitation of the reefs has never been extensive given the small reef area. Extraction of food fish was largely sustenance-based, but declined through the decades with increasing urbanisation. Unauthorised collection of corals and reef invertebrates for the aquarium trade is illegal and the activity declined in the last ten years with a more informed public.

As urbanisation and industrialisation increased, pollution became a critical issue that was addressed early with the formation an Anti-Pollution Unit under the Prime Minister's Office in 1970 and the Ministry of the Environment in 1972. These merged in 1983 to form the Pollution Control Department, which manages all aspects of air and water pollution, hazardous materials, and toxic wastes, and has effective regulatory measures to prevent marine pollution. The strong pollution control measures were primarily aimed at protecting public health, and protection of natural habitats was never a high priority. Marine sedimentation is generated by land reclamation, regular dredging of rivers and shipping channels, and the dumping of these materials out at sea. The high sedimentation remains the greatest impact and threat to the coral reefs. All of Singapore's reefs are under very high threat from coastal development (Burke *et al.*, 2002).

Reef monitoring was initiated in the mid-1980's through the ASEAN-Australia Living Coastal Resources project. Twelve sites of six reefs are still being monitored presently. The Line Intercept Transect (LIT) method is used (English *et al.*, 1997). From 2003, several new sites were established and monitored by volunteers using the Reef Check method, working in collaboration with the Biodiversity Center of the National Parks Board.

Table 1. Country Statistics and Coral Reef Threats

General Country Statistics (Singapore Department of Statistics, 2004)	
- Coastline	268km
- Population	4.185million (2004)
- Population density	6004/km^2
- Land area	697km^2
- Continental shelf (up to 200m depth)	714 km^2
- Territorial sea (up to 12 nm)	744 km^2
- Claimed Exclusive Economic Zone (EEZ)	NA
- Estimated coral reef area	54 km^2
- Number of declared MPAs	2
- Number of proposed MPAs	4
- % of coral reefs within MPAs	0
Coral Reef Threats (see Figure 8 for more details)	
- Extractive - Fisheries	
o Small scale fisheries	Nil
o Medium to large scale fisheries	Nil
o Aquarium-trade related fisheries	Nil
o Aquaculture	818 metric tons (includes all marine fish)
- Extractive - Coral mining	Nil
- Semi-Extractive/Non-Extractive – Tourism	
o Resorts/Hotels	Nil
o Live-Aboard	Nil
o Dive Operators	Minimal local diving, restricted to few areas
- Semi-Extractive/Non-Extractive – Research	Minimal

Status of Coral Reefs

Distribution

Singapore's equatorial position and location at the edge of the Indo-Malayan triangle of marine biodiversity promotes the high diversity of its reefs. Quantitative studies prior to the 1960's are not known, but anecdotal accounts point to clearer waters and rich reef life then. An estimated 60% of reefs are already lost to land reclamation. All of the fringing reefs along the southwestern coast and a number in the southern islands have been buried. Existing reefs are confined to the southern islands (Fig 1). The total coral reef cover today is possibly below 30km^2.

Biodiversity

No comprehensive reef biodiversity assessments have been conducted, although many studies in the past three decades targeted various faunal groups (e.g. Goh & Chou, 1996; Lane & Vandenspiegel, 2003). Existing information indicate high diversity. Species richness of major groups is comparable to that of neighbouring countries with more extensive reefs. Close to 200 species of hard corals have been identified, accounting for almost 25% of the global species total. Species richness of other groups pooled from various studies indicates an appreciable diversity (Table 2).

Table 2. Species Number of Major Reef Associated Taxa

Estimated Coral Reef Area	Within Existing MPA's?	Coral		Fish	Mollusc	Crustacean	Echinoderm	Reptile	Sea Grass	Algae
		Hard Coral	Soft Coral							
54km^2	No	197	>20	>130	>250	>800	>60	<5	9	>30

Resource Uses

Coral reef resources are not massively exploited. The restricted reef area and their proximity to busy shipping lanes do not permit development of any economically viable reef-based activity. Although not exploited, they remain highly threatened and impacted by other human activities.

Reef Fish and Fisheries

Historically, direct dependence on coral reefs through subsistence harvesting was restricted to coastal and small island communities. The last offshore village community on Pulau Sakeng was relocated to the main island in early 1990's to enable construction of the Pulau Semakau offshore sanitary landfill. Fish exploitation is now mainly through recreational and subsistence fishing. Commercial fisheries are restricted to a declining number of fixed palisade traps. In the late 1990's, experimental deep-cage marine aquaculture was started in the southern islands, to determine its feasibility.

Tourism

Coastal tourism is largely focused on Sentosa, a recreational island south and close to the main island. Several other offshore islands (Kusu Island, St John's Island, Sister Islands and Pulau Hantu) are designated for leisure activities. The reefs are visited mostly by SCUBA trainees and the turbid conditions do not attract dive tourists.

Other Uses

There are no other economic uses except for its natural heritage value, genetic and research potential.

Monitoring Capacity

The reefs are monitored regularly by the National University of Singapore since the late 1980's and remain largely an institutional effort with little or no national level coordination until 2004, when the newly established Biodiversity Center (BC) of the National Parks Board initiated a national biodiversity database that included coral reef resources (Table 3).

Twelve permanent monitoring sites have been maintained since the initial surveys between 1986 and 1989 (Table 4). Initial assessments included coral reef benthos, reef fish, seagrass, sediment rate and physico-chemical parameter measurements. From 2000, only coral reef benthos surveys were conducted.

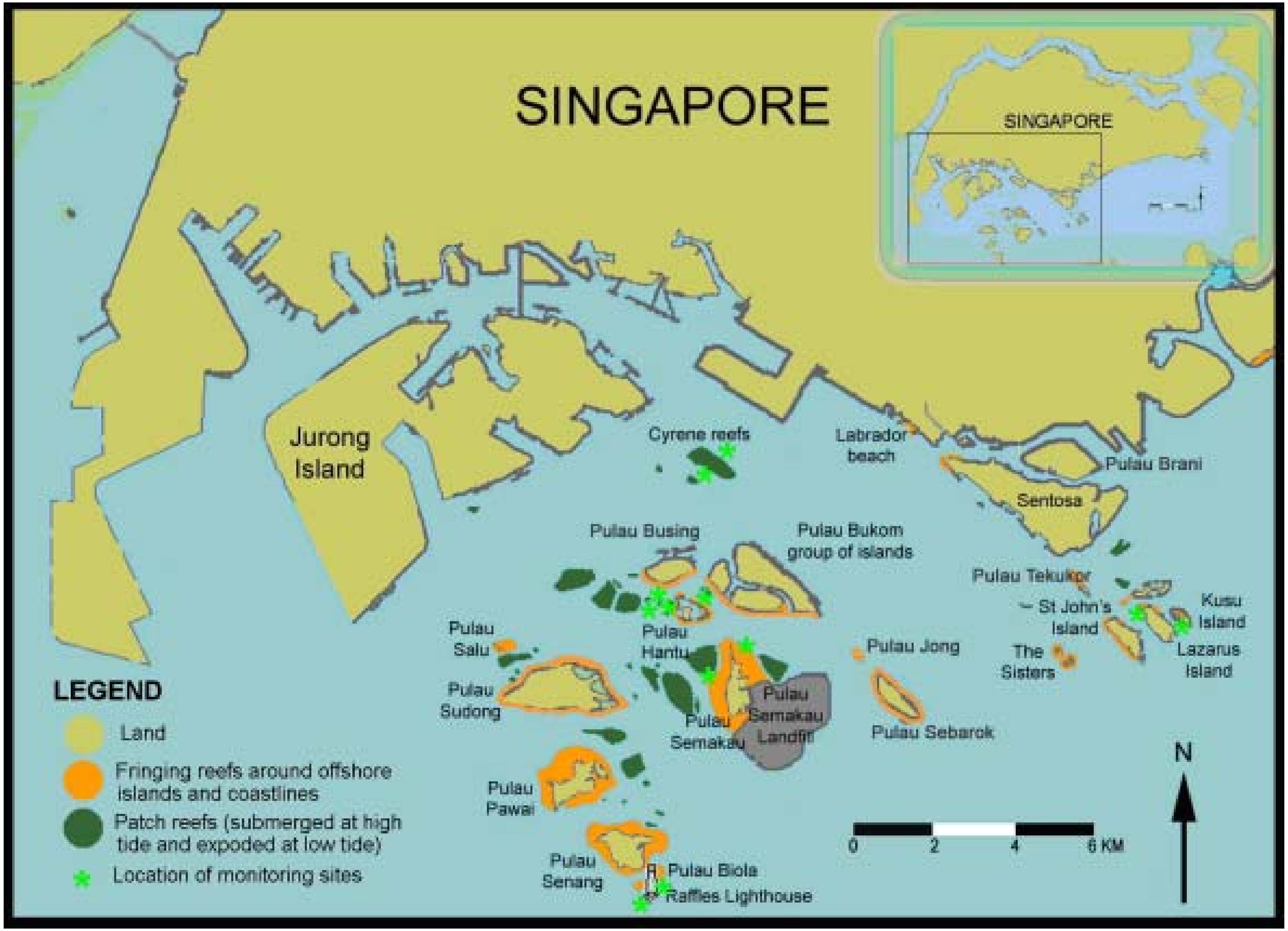

Figure 1. Location of existing coral reefs. Inset – map of Singapore.

Monitoring of the twelve sites from 1986 to 1994 was funded by the ASEAN-Australia Living Coastal Resources project, while assessments of additional sites were funded under the ASEAN-US Coastal Resources Management project in connection with artificial reef investigations. Between 1994 and 1998, monitoring was suspended due to a lack of funding. Monitoring is now conducted by the National University of Singapore biennially as components of other funded reef research projects. In 2004, the BC established 4 new monitoring sites in collaboration with a volunteer group using the Reef Check methodology.

Table 3. Reef Monitoring Capacity and Resources

Monitoring Status - Approximate year that coral reef monitoring began - Are there ongoing CR monitoring programmes? - Main source of funding for ongoing monitoring programmes - Main agency/ies or institution/s coordinating monitoring programmes - No. of monitoring sites in 2004 - No. of existing site to have continued monitoring in future	1986 Yes Various soft grants and *ad hoc* funding National University of Singapore, National Parks Board. Permanent Line Intercept Transect (LIT) sites – 12 sites in 6 locations Volunteer Reef Check/LIT – 6 Permanent LIT sites – 12 sites in 6 locations Volunteer Reef Check/LIT – 6 or more
General Status of Coral Reef Benthos - Overall status of coral reef benthos between 1986/88 and 2003, at 0m and 3m (proportion of 9 sites monitored with): o >75% Live Coral (LC) Cover o 50-75% LC Cover o 25-50% LC Cover o <25% LC Cover - Estimated changes inn reef condition at the 12 permanent monitored sites since the start of monitoring till 2003 that are: o Improving o Declining o Remained unchanged	**0m** **3m** **0m** **3m** 2/7 0/9 0/10 0/9 1/7 1/9 3/10 0/9 3/7 3/9 7/10 2/9 1/7 5/9 0/10 7/9 **0m** **3m** 2/12 (17%) 0/12 (0%) 9/12 (75%) 11/12 (92%) 1/12 (8%) 1/12 (8%)
Management Status - Marine Protected Area (MPA) status o Total number of MPAs – Declared o Total number of MPAs - Proposed o % of Reefs Within MPAs o % of MPAs that have good management rating - Governance structure o Overall Environmental Authority o Protection of Marine Resources - Legislation status o Number of current legislations related to coral reef conservation and management o	2 (Sungei Buloh Nature Reserve & Labrador Nature Park [coast]) 4 0 100 National Environment Agency National Parks Board 8

Status of Ongoing Coral Reef Initiatives and Projects	
- Local-funded CR projects	
o Local agency-funded monitoring programmes	1
o Local agency-funded research activities (all others)	3
o Local volunteer-funded activities/programmes	0
o Local NGO-funded activities/programmes	0
- International-funded CR projects	
o International agency-funded monitoring programmes	0
o International agency-funded research activities (all others)	1 (starting 2005)
o International volunteer-funded activities/programmes	0
o International NGO-funded activities/programmes	0
o	
Problems and Limitations	
- Personnel	Sufficient trained personnel in LIT and Reef Check methods; more training required for higher level reef fish identification and surveys
- Logistics	No logistical constraints
- Funding	Funding for long-term monitoring is a problem, although efforts to involve volunteers in basic Reef Check surveys are ongoing
Major Needs and Requirements	
- Monitoring sites	Sufficient sites being monitored
- Survey methods	Higher level fish surveys needed
- Expertise	More expertise needed in higher level fish identification
- Infrastructure	Sufficient infrastructure for monitoring
- Funding	More funding needed for long-term monitoring and reef restoration

Table 4 Reef Monitoring Status

Estimated Coral Reef Area	Within Existing MPA/s?	No of Permanent Monitoring Sites				Estimated Spread of Monitoring Sites	Monitoring Status	Parameters Surveyed	Survey Methods	Monitored By
		Prior to 1994	1994	2000	2004					
>100km^2 (1970's) to 54km^2 (2002)	No	12	12	12	12 (LIT) 4 (RC)	1	1	C-LC, C-DC, C-BL F-All A-RC, A-PP	LIT, RC	National University of Singapore; Blue Water Volunteers; National Parks Board

Notes:

Estimated Spread of Monitoring Sites:	Monitoring Status:	Parameters Surveyed:	Survey Methods:
1 = Sites spread over > 75% of region or more **2** = Sites spread over between 50-75% of region **3** = Sites spread over < 50% of region	**1** = Completed/Monitored in the past **2** = Ongoing monitoring **3** = One-off surveys	***Coral:*** **C-LC** = Live coral cover **C-DC** = Dead coral cover **C-BL** = Coral bleaching **C-DI** = Coral disease **C-CR** = Coral recruitment ***Other Benthos:*** **O-RC** = General invertebrates counts (Reef Check) **O-COT** = COT starfish surveys ***Fish:*** **F-ALL** = All species of fish **F-TG** = Target fish species ***Ambient:*** **A-RC** = Reef condition **A-PP** = Physical Parameters (Etc)	**LIT** = Line Intercept Transect (English *et al*) **PIT** = Point Intercept Transect **RC** = Reef Check **PQ** = Permanent Quadrat **BT** = Belt Transects **MT** = Manta Tow **NQ** = Non-Quantitative Assessment **TS** = Time Swiim **OT** = Others (specify)

STATUS OF REEFS

Reef Benthos

Singapore reefs are subjected to drastic changes over the past three decades. Quantitative data are available since the mid-1980's for twelve permanent sites at six locations (Refer to Figure 1 for monitoring site locations). Monitoring of some sites was, however, not regular. Surveys of the 6 and 10m slope were discontinued from 2000. Despite the data gaps, temporal change could be followed and general trends discerned.

Percent live hard coral cover at the twelve permanent monitoring sites at four depths between 1986 and 2003 (Table 5), and changes in coral cover between the first and last surveys at the 0m and 3m depths (Figures 2 - 7), together with visual observations indicate that:

1) For the shallow depths (0m and 3m), there was overall decline in coral cover between the first and last surveys at all sites, with the exception of the 0m depth at Cyrene Reefs (C1 & C2), which had improved cover;
2) At the 6m and 10m depth, coral cover declined at most sites with the exception of the 6m depth at Pulau Hantu (H1 & H2) and Raffles Lighthouse (R1 & R2), which improved;
3) There were distinct differences in the colouration, robustness and degree of attachment of coral colonies to the substratum:
    a. Colouration – hard corals became paler with depth; colonies beyond 6m appearing 5-10 times paler than shallower counterparts
    b. Robustness – corals such as *Pectinia*, *Echinopora* and *Echinophyllia* became less robust with depth, with visibly thinner skeletons
    c. Degree of attachment to substratum – corals were more easily detached from the reef with increasing depth; many loosely-attached colonies were easily displaced
4) Silt accumulation increased with depth – at some sites, substrata below 10m depth were completely smothered by silt.
5) Other reef benthos declined – occurrences of the more prominent and visible invertebrates like nudibranchs, giant clams and cowries decreased over the past 2 decades

Among the monitored locations, Cyrene Reef (a patch reef) is nearest to the main island. It is surrounded by major shipping lanes and in close proximity to the major Jurong island reclamation to its west since the late 1990's. It held a surprising diversity when first monitored but is now considered to be the most impacted. Fewer surveys were conducted with the last in 2000. The 0m depth at both C1 and C2 showed 106% and 28% relative increase in hard coral cover, although in absolute terms, the increases were only 11% and 5% respectively.

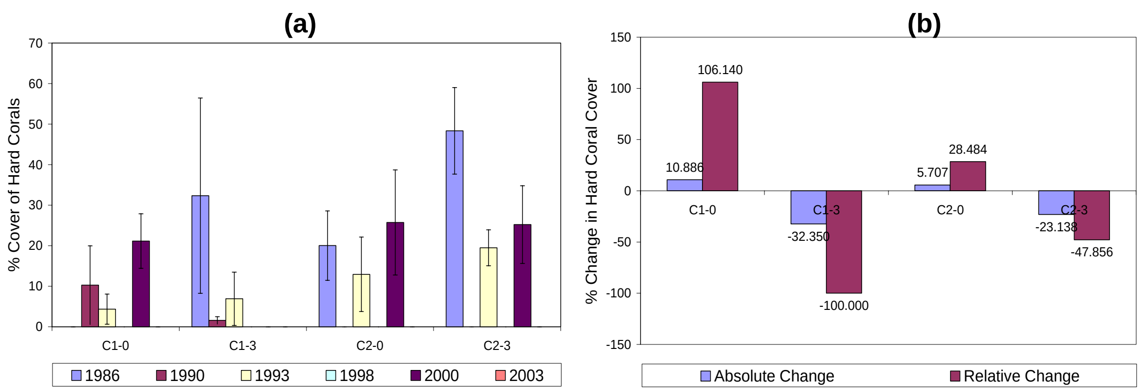

Figure 2. Cyrene Reef (C1 & C2). (a) Percent hard coral cover at 0m and 3m from 1986 to 2003. (b) Absolute and percent change of hard coral cover between the first and last surveys at 0m and 3m.

Table 5 Percent live coral cover at 12 sites in 6 locations of the southern islands between 1986 to 2003 ("-" indicates no survey conducted)

		1986-89	1990-92	1993	1998	2000	2003
Cyrene Reef	**C1-0**	-	10.26	4.34	-	21.14	-
	C1-3	32.35	1.59	6.91	-	-	-
	C1-6	0.00	0.61	0.00	-	-	-
	C1-10	4.81	0.00	0.00	-	-	-
	C2-0	20.04	-	12.94	-	25.74	-
	C2-3	48.35	0.00	19.50	-	25.21	-
	C2-6	1.29	12.49	5.25	-	-	-
	C2-10	0.00	0.00	0.41	-	-	-
Hantu West Patch Reef	**HW1-0**	41.45	37.29	41.61	19.78	-	38.78
	HW1-3	64.11	28.01	24.95	18.86	-	10.60
	HW1-6	7.78	16.43	19.67	7.26	-	-
	HW1-10	4.01	-	1.17	3.74	-	-
	HW2-0	70.38	63.88	61.95	33.77	-	13.56
	HW2-3	37.16	48.39	45.32	27.52	-	1.14
	HW2-6	22.50	36.42	36.22	-	15.90	-
	HW2-10	13.96	-	5.46	-	2.88	-
Lazarus Island	**L2-0**	-	60.79	21.62	21.62	25.87	-
	L2-3	-	19.64	16.45	7.03	13.17	-
	L2-6	-	0.91	6.43	0.92	-	-
	L2-10	-	0.54	0.00	0.00	-	-
	L4-0	-	4.37	8.91	0.60	1.99	4.13
	L4-3	-	1.05	0.76	2.88	2.49	1.93
	L4-6	-	0.00	0.15	0.25	-	-
	L4-10	-	0.05	0.13	0.00	-	-
Pulau Hantu	**H1-0**	31.40	8.39	10.18	16.61	5.69	8.57
	H1-3	27.66	6.85	15.96	12.87	-	5.49
	H1-6	3.89	-	9.19	17.77	-	-
	H1-10	0.35	-	0.00	2.55	-	-
	H2-0	49.11	48.70	41.10	26.55	9.38	46.78
	H2-3	52.10	29.98	32.93	26.00	23.39	26.22
	H2-6	3.75	-	17.32	24.92	-	-
	H2-10	5.49	-	2.44	5.85	-	-
Pulau Semakau	**S1-0**	-	26.05	11.09	9.89	12.22	23.37
	S1-3	43.83	-	16.91	7.93	13.29	14.34
	S1-6	5.97	-	6.98	6.67	-	-
	S1-10	2.48	-	0.92	0.00	-	-
	S2-0	-	51.80	56.27	40.63	15.37	21.38
	S2-3	61.04	30.71	32.59	22.73	17.93	11.59
	S2-6	1.69	-	1.15	5.76	-	-
	S2-10	*No 10m surveys as site-depth was lost due to sediment accumulation*					
Raffles Lighthouse	**R1-0**	76.634	78.318	73.395	48.420	38.070	56.675
	R1-3	30.633	41.603	25.827	40.500	27.360	27.813
	R1-6	7.537	11.620	13.650	8.840	-	-
	R1-10	6.713	1.855	4.020	1.750	-	-
	R2-0	76.109	67.025	75.170	50.090	51.680	48.840
	R2-3	45.500	40.180	55.766	36.567	44.530	18.921
	R2-6	7.464	6.350	33.861	18.620	-	-
	R2-10	1.718	2.766	1.850	3.300	-	-

Lazarus Island is easternmost of the six locations, and had one of the best (L2) and worst (L4) reef condition during the first survey from 1990-1992. L2 surveys were discontinued from 2002 when the site was lost to foreshore reclamation that joined Lazarus Island to neighbouring Kusu Island. The northeastern side of the island where L2 is located faces a more open sea. L4, at the southwestern side of the island, had low coral cover since the first survey, and the high relative increase of 83% at the 3m depth reflects less than a 1% absolute increase.

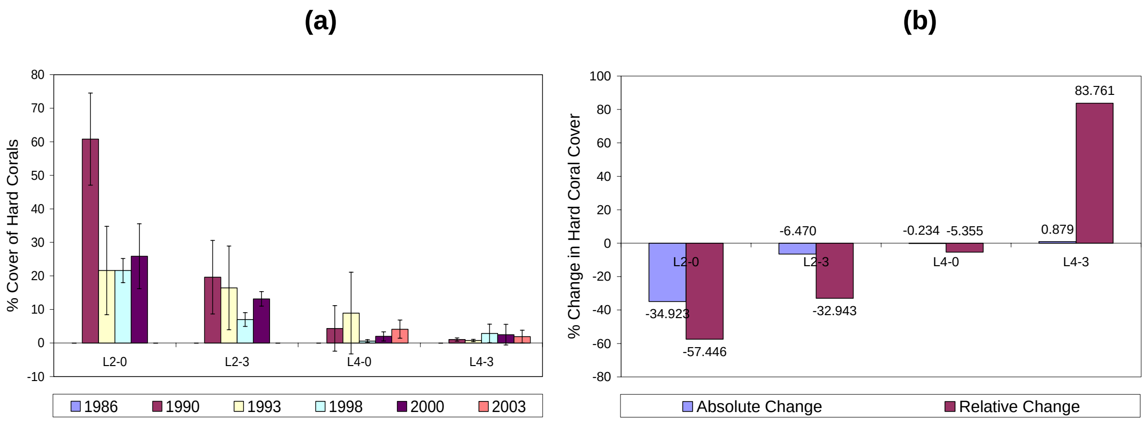

Figure 3. **Lazarus Island (L2 & L4). (a) Percent hard coral cover at 0m and 3m from 1986 to 2003. (b) Absolute and percent changes in coral cover between the first and last surveys at 0m and 3m.**

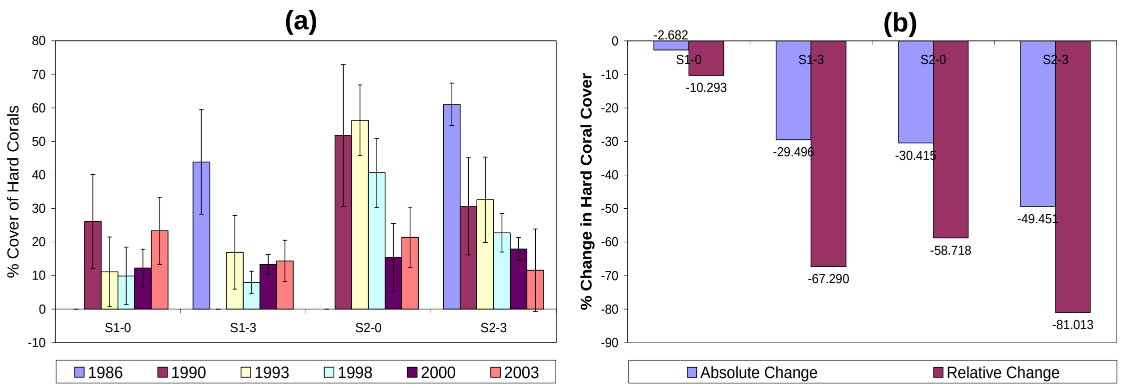

Figure 4 **Pulau Semakau (S1 & S2). (a) Percent hard coral cover at 0m and 3m from 1986 to 2003. (b) Absolute and percent changes in coral cover between the first and last surveys at 0m and 3m.**

Pulau Semakau is situated close to several other islands in the midst of the southern islands. It is one of the largest islands with extensive mangrove forests, reef flats and seagrass. The eastern flat was reclaimed and joined to an extensive retainer seawall structure demarcating the offshore landfill site from 1995 to 1998. Silt screens were placed to protect the island's western reef. There was an general decline in coral cover at S1 and S2 between 1986 and 2003. The decline from 1993 to 1998 during the construction of the dump site seawall was followed by a slight but steady improvement in coral cover since 1998.

Raffles Lighthouse (Pulau Satumu) is the southern-most island and least impacted. It supports the best reef life, in both diversity and abundance, in Singapore. It is off limits to divers and boaters and just outside the edge of a restricted military area that contains a number of large reefs and islands. There was an overall decline in hard coral cover and although the loss was large in both absolute and relative terms, coral cover at 0m still remains high at 57% and 49% at R1 and R2 respectively, compared to the other monitored sites.

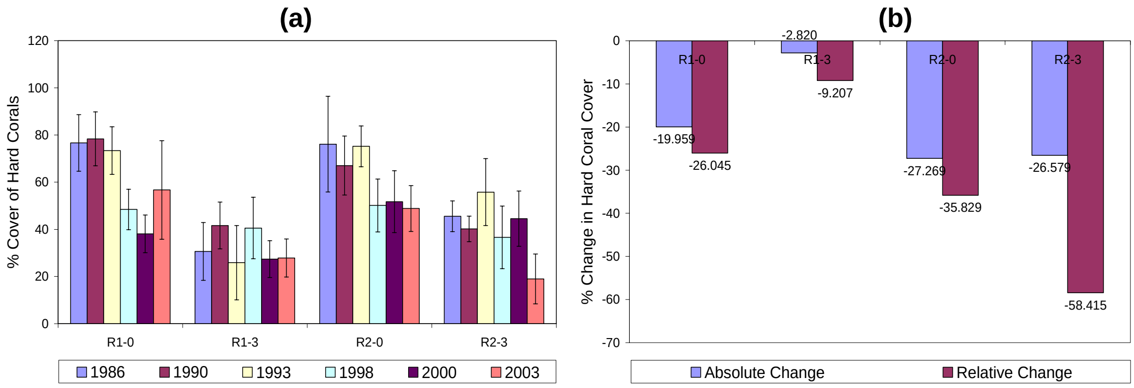

Figure 5 **Raffles Lighthouse (R1 & R2). (a) Percent hard coral cover at 0m and 3m from 1986 to 2003. (b) Absolute and percent changes in coral cover between the first and last surveys at 0m and 3m.**

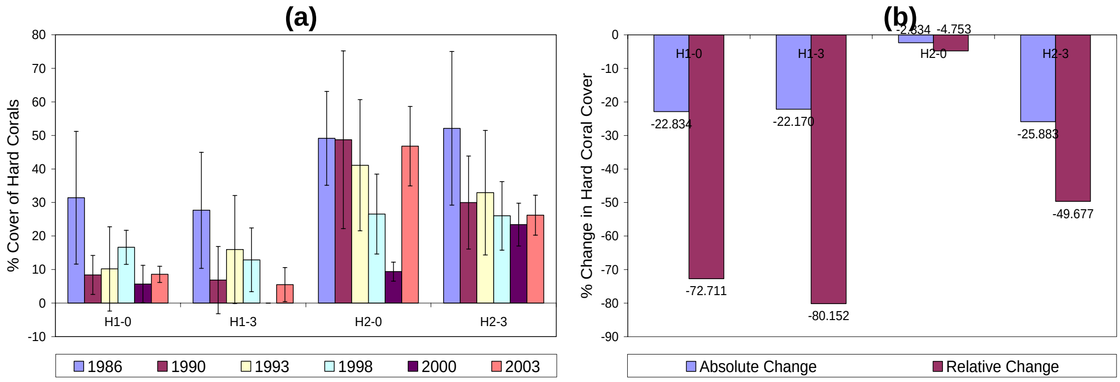

Figure 6 **Pulau Hantu (H1 & H2). (a) Percent hard coral cover at 0m and 3m from 1986 to 2003. (b) Absolute and percent changes in coral cover between the first and last surveys at 0m and 3m.**

Pulau Hantu is just northwest of Pulau Semakau, and is one of the few undeveloped islands with free access to the public. It comprises 2 small islands which were reclaimed in the mid-1970's to increase the islands' size from 2.4ha to 12.2ha. H1 lies along the northeastern side facing a group of oil refining islands, while H2 lies along the western side of the island facing several large patch reefs. The decline in hard coral cover at H1 was large, while the decline at H2 that was drastic in 2000 showed remarkable improvement in 2003.

Hantu West patch reef is situated west of Pulau Hantu. Since the late 1990's, the area around the patch reef was designated for barge anchorage. During the years from 1998 to 2000 when surveys were conducted here, several incidents of barges grazing the reef were observed. Sections of reefs appeared to be razed, leaving large areas of broken corals. HW1, situated close to Pulau Hantu and subjected to less vessel traffic than HW2, registered less decline in coral cover at the 0m depth.

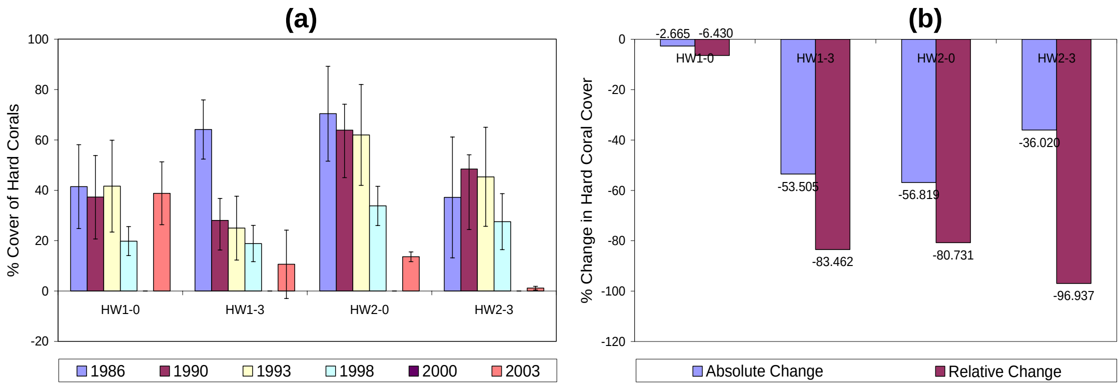

Figure 7 **Hantu West Patch Reef (HW1 & HW2). (a) Percent hard coral cover at 0m and 3m from 1986 to 2003. (b) Absolute and percent changes in coral cover between the first and last surveys at 0m and 3m.**

Reef Fish

Unlike reef benthos, there is limited work on reef fish. Fish visual censuses were conducted from the late 1980's to the mid-1990's but have not continued. The diversity of reef fishes is reported at 120 species (Lim & Low, 1998). Low, Leng & Chou (1997) showed that reef pomacentrids recruited twice a year, coinciding with the inter-monsoons.

STATUS OF RESOURCE USE

There is no livelihood dependence on coral reef resources in Singapore today. The estimated index scores for the current levels and trends in reef resource usage are non-existent to low for all categories (Table 6).

Table 6. Index Scores for Current Levels and Trends in Coral Reef Resource Usage (reef fish and fisheries, tourism, other uses, etc)

Extractive				Semi-Extractive / Non-Extractive			
Fisheries (Reef fish and others reef organisms)			Coral Mining	Tourism			Research
Small-Scale	Med to Large Scale	Aquaculture		Resorts/Hotels	Dive Operators	Live-Aboard	
1	1	1	1	1	2	1	2

Notes:

Index Score	Qualitative Description
1	***None:*** Activity/ies currently not present
2	***Low:*** Activity/ies currently present, but at very low intensity and not deemed to be a threat; sustainable but needs to be monitored and regulated.
3	***Medium:*** Activity/ies currently present with some resulting impacts but has not yet become a major threat; sustainable but needs to be strictly regulated.
4	***High:*** Activity/ies currently present and causing above acceptable impacts; becoming a major threat; not sustainable and needs to be reduced and strictly regulated.
5	***Excessive:*** Activity/ies currently present and is causing serious and possibly irreversible impacts; has become a major threat; not sustainable and needs to be stopped and strictly regulated.

STRESS AND DAMAGE TO CORAL REEFS

The limited and constantly shrinking reef area is under sustained threat from anthropogenic influences (Table 7). Protection of reefs has traditionally not been strong or well represented. Despite the lack of a legal framework for reef protection, Singapore reefs are still thriving in certain areas, and have shown some measure of resilience against chronic stress.

Sediments and Nutrients (land-based)
Sedimentation poses the highest threat. Reefs that are not lost directly to reclamation are exposed to chronically high and often sustained sediment levels associated with land reclamation and sea-bed dredging. These activities result in periods of excessive sediment loading alternating with periods of lower sediment input depending on the time and intensity of such activities. The morphology of some coral species appear to be affected by sedimentation (Todd *et al*., 2001, 2004).

Nutrient associated impacts like algal or other invasive blooms have not been reported, although one reef area (southeastern part of Raffles Lighthouse) is reportedly affected by non-seasonal macro-algal bloom that is possibly a result of point-source effluent discharge.

Damaging Fishing Methods
Fishing, and its associated damaging impact, is not a problem. Only limited recreational or subsistence hook-and line fishing occurs in a few areas, and are largely limited to non-reef areas.

Anchor and Trawler Damage, Others Kind of Damage (divers, trampling, etc)
Damage by anchors is not a problem, with few leisure boats anchoring near reefs. Shallow reefs have however, been occasionally sheared by barge grounding. An actual event was observed in 1999, when a barge being towed at night grazed over a fringing reef at low time. Other causes of physical reef damage, for example, by divers or reef gleaners, are not high or serious.

Development Damage to Coral Reefs (ports, airports, dredging, etc)
Coastal development and shoreline modification has contributed to the highest physical decline of coral reefs as large coastline areas are reclaimed (Hilton & Manning, 1995). All but about 0.2km of Singapore’s southern coastline remain, with many southern islands merged to create larger ones. Large scale development of Singapore’s coastline is necessary and unavoidable, and is estimated to continue over the next few decades.

Coral Bleaching
Reefs were affected by the 1998 global mass bleaching that coincided with the El Nino. Up to 90% of corals bleached when sea surface temperature reached 34^0C. Recovery from bleaching was however high compared to other countries and regions, with up to 75% of bleached corals recovering within one year. Since then, no further mass bleaching events have been reported.

Coral Diseases
Coral disease is not a threat and no disease outbreaks of any kind has been reported.

Outbreaking or Invasive Organisms
Crown-of-Thorns starfish has never occurred on Singapore reefs. The predatory coral-eating mollusc *Drupella* is present but outbreaks are highly localised and infrequent. The black-spined urchin, *Diadema* sp, is common but never in unusually high densities.

Coral Damage from Natural Events
Singapore reefs are largely sheltered from storms and other natural events by peninsular Malaysia to the north and Indonesia’s Riau islands to the south, southeast and southwest of Singapore. There are no existing records of coral damage from storms.

POTENTIAL THREATS TO CORAL REEFS
(Reef at risk (R@R) threat indicators)

Burke at al. (2002) categorised all of Singapore’s reefs under high threat, with most of the threat coming from coastal development. In 2004, new estimates were made by the authors to determine how the index may have changed (Fig. 8). The new estimates were not calculated using the R@R models but made based on local knowledge of the reefs.

Table 7. Index Scores for Current Stress and Damage to Singapore Reefs.

Sediments & Nutrients (land-based)	Damaging Fishing Methods	Anchor, Trawler & Others Kind of Damage (divers, trampling, etc)	Coastal Development Damage (ports, airports, dredging, etc)	Coral Bleaching	Coral Diseases	Outbreaking or Invasive Organisms (COTS, *Drupella*, *Diadema*, etc)	Coral Damage from Natural Events (storms, etc)
5	1	1	5	2	2	2	1

Notes:

Index Score	Qualitative Description
1	***None:*** Activity/ies currently not present
2	***Low:*** Activity/ies currently present, but at very low intensity and not deemed to be a threat; sustainable but needs to be monitored and regulated.
3	***Medium:*** Activity/ies currently present with some resulting impacts but has not yet become a major threat; sustainable but needs to be strictly regulated.
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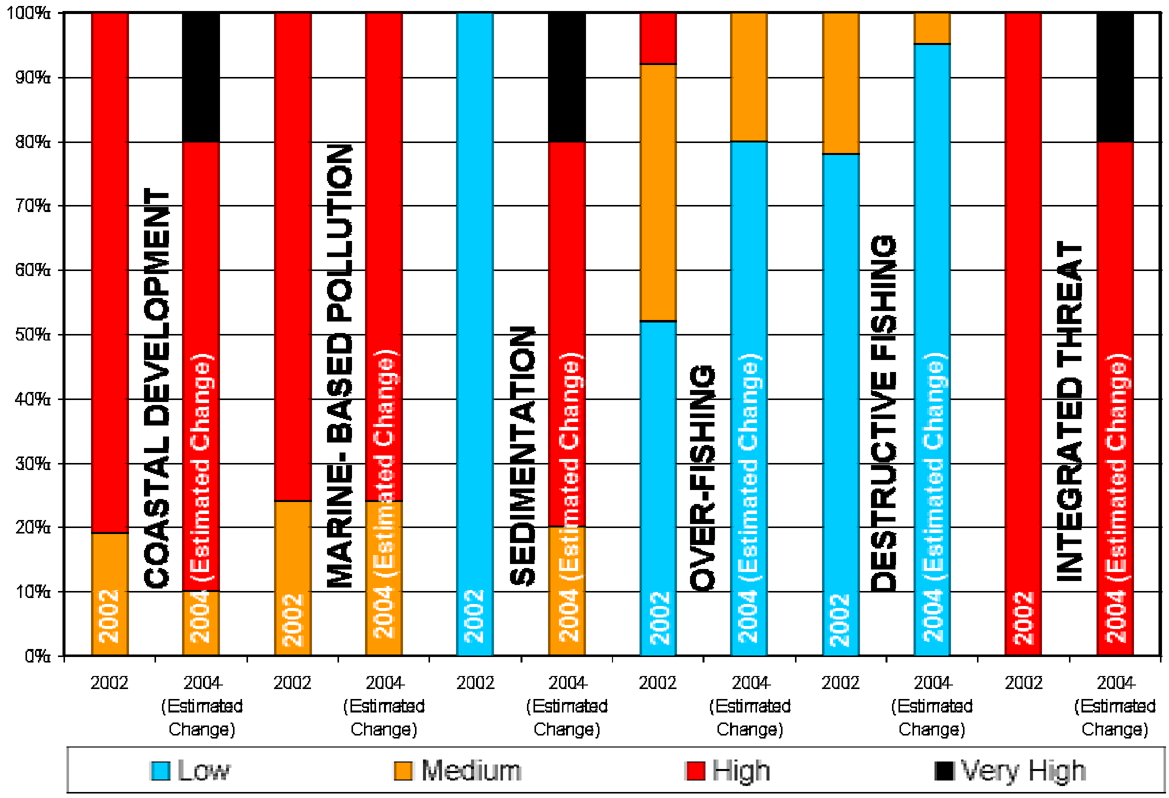

Figure 8. Reefs at Risk (R@R) threat estimates for 2002 (Burke *et al.*, 2002) and 2004 (Chou & Tun, 2004). (Note: the 2002 estimate for sedimentation by R@R analysis model is in the opinion of the authors, highly underestimated).

MANAGEMENT

Marine Protected Areas

Currently, two protected areas have associated marine components - the Sungei Buloh Wetlands Reserve and the Labrador Nature Area, both gazetted in 2001 (Table 8). The latter is essentially a terrestrial forest with an inter-tidal rocky shore flat containing a reef community, but not a true coral reef. It is limited in extent but remains the only beach along the southern coast that supports reef associated life.

Table 8. MPA Attributes and Management Effectiveness Scores for MPAs in Singapore

Total number of MPAs – Declared		2
Total number of MPAs – Proposed		Unknown
% of Declared MPAs with Coral Reefs Represented		0
Total % of Reefs Within Declared MPAs		0
% of Declared MPAs that have management effectiveness rating of:	Unknown	0
	Poor	0
	Moderate	0
	Good	50% (Burke *et al.*, 2002)
	Very Good	0
% of Declared MPAs with Areas that are:	<10, 000 ha	2
	Between 10,000 & 30,000 ha	0
	Between 30,000 & 50,000 ha	0
	Between 50,000 & 100,000 ha	0
	> 100,000 ha	0
% of Declared MPAs established:	Before 1994	0
	Between 1994 & 2000	0
	After 2000	2

Research

Coral reef research expanded in the early 1980's, conducted largely by or through collaborations with the Marine Biology Laboratory (formally the Reef Ecology Laboratory) of the Department of Biological Sciences, National University of Singapore. Research focus is diverse, ranging from biodiversity assessments to photo-physiological studies (Tun *et al.*, 1994, 1997), bioactivity (Ding *et al.*, 1999; Goh & Chou, 1998; Koh *et al.*, 2000, 2002; artificial reefs (Chua & Chou, 1994), restoration (Loh *et al.*, in press), reproduction (Guest *et* al., 2002, 2005).

Monitoring

Management of reef monitoring has traditionally been driven by key reef researchers in academic institutions, with no formal management protocol in place to archive monitoring information or coordinate monitoring efforts at the national level. With the recent establishment of the Biodiversity Center under the National Parks Board in 2004, efforts are made to coordinate national coral reef monitoring programmes between various groups and to establish a national biodiversity database, which will capture and incorporate existing monitoring information.

Legislation

There is currently no national policy directly related to coral reefs and no government agency with the distinct responsibility of managing reef resources. Direct exploitation of coral reef is largely restricted to research institutions, and the Land Office (Ministry of Law) issues licenses/approvals to control removal of corals and other reef resources for research purposes. There is no dedicated policing of coral reefs, but the Police Coast Guard will take action against unauthorised removal of corals.

Beneficial to the reefs is the effective management of marine pollution. Despite the constant threat of marine pollution, the coastal waters have remained largely pollution free due to strong pollution control measures. The Pollution Control Department (PCD) of the Ministry of the Environment is the central agency co-ordinating and implementing controls on pollution. Industries are required to include measures to reduce and control discharge of wastewater, cooling water and the disposal of wastes.
Industrial effluent and sewage are required to meet discharge standards set by PCD, which is backed by several Acts and Regulations, for example, the Trade Effluent Regulations, 1976 and the Poisons Act

(Hazardous Substances Rules 1986). The collection and disposal of toxic industrial waste is also controlled through licensing. Monitoring of the inland waterways and coastal waters is carried out regularly by the Strategic Planning and Research Department (SRPD) at over 80 points in and around the island. Some of the regulations could be related to coral reefs, either directly or indirectly (Table 9).

Table 9 Principle Acts and Regulations Affecting Coral Reefs in Singapore (Directly or Indirectly)

Principal Act / Legislation	Under Purview Of	Year Implemented	Year Revised (where applicable)	Last Amended
Environmental Pollution Control Act	National Environment Agency	1999	2002	
Fisheries Act	Agri-Food and Veterinary Authority	1966	2002	2002
Environmental Public Health Act	National Environment Agency	1987	2002	
Hazardous Waste (Control of Export, Import and Transit) Act	National Environment Agency	1997	1998	
Hydrogen Cyanide (Fumigation) Act	National Environment Agency	1947	1985	
Sewerage and Drainage Act	Public Utilities Board	1999	2001	
Foreshores Act	Urban Redevelopment Authority	1972	1985	1999
Endangered Species (Import and Export) Act	Agri-Food and Veterinary Authority	1989	2000	2005

REGIONAL AND INTERNATIONAL COOPERATION

Singapore is party to several regional and international conventions related to environmental protection, including:

1) Convention of Biological Diversity
2) Convention on International Trade of Endangered Species
3) Association of Southeast Asian Nations (ASEAN) Working Group on Nature Conservation
4) ASEAN Regional Centre for Biodiversity Conservation (ARCBC)
5) ASEANET (Southeast Asian Loop of BioNet)
6) United Nations Convention on the Law of the Sea (ratified 17 November 1994)
7) IMO conventions on maritime safety and prevention of marine pollution (SOLAS74, COLREG72, LOADLINES66, STCW95, SAR79, MARPOL73/78, CLC92 and FUND92)

CONCLUSIONS AND RECOMMENDATIONS

Singapore reefs have been subjected to decades of stress and change, but are still surprisingly diverse where they exist. One of the challenges is to manage and conserve its remaining coral reefs and preserve the biodiversity. Recommendations for managing and conserving Singapore's remaining coral reefs include:

1) Continued monitoring of coral reefs - for reliable assessment of changes in reef health;
2) Conduct thorough biodiversity assessment - present biodiversity inventory based on ad-hoc studies, leaving information gaps on various taxa;
3) Expand use of mitigation measures for high impact coastal activities - sediment containment measures effective when used in some reclamation projects;
4) Promote reef restoration activities - larval supply processes still intact, recruitment good and coral growth vigorous. Substratum modification and *in-situ* nurseries can enhance recruitment, growth and survival; and
5) Improve coral reef management - stronger coordination between agencies required; identification of a lead agency and formulation of a national policy.

REFERENCES

Burke, L., E. Selig & M. Spalding, 2002. Reefs at Risk in Southeast Asia. World Resources Institute, Washington. 72p.

Chou, L.M. 1995. Singapore reefs – protection needs and status. *In* K. Yamazato, S. Ishijima, S. Sakihara, H. Tatra, Z. Shimabukuro, F. Teruga & F. Nishihira (Eds.), Regional Conference on Development and Conservation in the Asia Pacific Region, East-West Center Association, Okinawa. p. 207-212.

Chou, L.M. & B.P.L. Goh, 1998. Singapore Coral Reefs- Balancing development and conservation. In: B. Morton (ed.) The Marine Biology of the South China Sea. Proceedings of the 3rd International Conference on the Marine Biology of the South China Sea, Hong Kong. p. 355-368.

Chou, L.M. & K.P.P. Tun, 2004. Coral reefs in one of the world's busiest ports. 10th International Coral Reef Symposium, Okinawa, Jun 28 to Jul 2.

Chua, C.Y.Y. & L.M. Chou, 1994. The use of artificial reefs in enhancing fish communities in Singapore. Hydrobiologia, 285: 177-187.

Ding, J.L., F.M.Y. Fung, G.W.S. Ng & L.M. Chou, 1999. Novel bioactivities from a coral, *Galaxea fascicularis*: DNase activity and apoptotic activity against a multiple drug resistant leukaemia cell line. Journal of Marine Biotechnology 1: 328-336.

Goh, N.K.C. & L.M. Chou, 1996. An annotated checklist of the gorgonians (Anthozoa, Octocorallia) of Singapore, with a discussion of gorgonian zoogeography in the Indo-West Pacific. Raffles Bulletin of Zoology, 44: 435-459.

Goh, N.K.C. & L.M. Chou, 1998. Bioactivity screening of Singapore gorgonians: antimicrobial activity, toxicity to *Artemia salina* and efficacy against *Plasmodium berghei*. Zoological Science. 15: 805-812.

Guest, J.R., A.H. Baird, B.P.L Goh & L.M Chou, 2002. Multi-specific, synchronous coral spawning in Singapore. Coral Reefs 21: 422-423.

Guest, J.R., A.H. Baird, B.P.L. Goh & L.M. Chou, 2005. Reproductive seasonality in an equatorial assemblage of scleractinian corals. Coral Reefs 24: 112-116.

English, S., C. Wilkinson & V. Baker (Eds.), 1997. Survey manual for tropical marine resources. 2nd Edition. Australian Institute of Marine Science, Townsville. 390p.

Hilton, M.J. & S.S. Manning, 1995. Conversion of coastal habitats in Singapore: indications of unsustainable development. Environmental Conservation, 22: 307-322.

Koh, L.L., N.K.C. Goh, L.M. Chou & Y.W. Tan, 2000. Chemical and physical defenses of Singapore gorgonians (Octocorallia: Gorgonacea). Journal of Experimental Marine Biology and Ecology, 251: 103-115.

Koh, L.L., T.K. Tan, L.M. Chou & N.K.C. Goh, 2002. Antifungal properties of Singapore gorgonians: a preliminary study. Journal of Experimental Marine Biology and Ecology, 273: 121-130.

Lane, D.J.W. & D. Vandenspiegel, 2003. A guide to seastars and other echinoderms of Singapore. Singapore Science Centre. 187p.

Lim, K.K.P. & J.K.Y. Low, 1998. A Guide to Common Marine Fishes of Singapore. Singapore Science Centre, 163p.

Loh, T.L., Tanzil, J.T.I., Chou L.M. (in press). Preliminary study of community development and scleractinian recruitment on fibreglass artificial reef units in the sedimented waters of Singapore.

Aquatic Conservation: Marine and Freshwater Ecosystems.

Low, J.K.Y, C.B. Leng & L.M. Chou, 1997. Pomacentrid population dynamics on Singapore coral reefs. Environmental Monitoring and Assessment, 44: 53-66.

Singapore Department of Statistics, 2003. Yearbook of Statistics Singapore, 2003.

Singapore Department of Statistics, 2004. Yearbook of Statistics Singapore, 2004.

Todd, P.A., P.G. Sanderson & L.M. Chou, 2001. Morphological variation in the polyps of the scleractinian coral *Favia speciosa* (Dana) around Singapore. Hydrobiologia, 444: 227-235.

Todd, P.A., R.J. Ladle, N.J.I. Lewin-Koh & L.M. Chou, 2004. Genotype x environment interactions in transplanted clones of the massive corals *Favia speciosa* and *Diploastrea heliopora*. Marine Ecology Progress Series, 271: 167-182.

Tun, K., A.C. Cheshire & L.M. Chou, 1994. Photosynthetic production of four scleractinian corals from Singapore. *In* S. Sudara, C. Wilkinson & L.M. Chou (eds.), Proceedings, 3rd ASEAN-Australia Symposium on Living Coastal Resources, Vol. 2: Research Papers. Chulalongkorn University, Bangkok, Thailand. p. 69-77.

Tun, K.P.P., A.C. Cheshire & L.M. Chou, 1997. Twenty-four hour in situ monitoring of oxygen production and respiration of the colonial zoanthid *Palythoa*. Environmental Monitoring and Assessment, 44: 33-43.

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2.5. THAILAND

Thamasak YEEMIN

ABSTRACT

The coral reefs in Thailand support a variety of human activities that can be categorized into three main groups: tourism and recreation; fisheries-related uses; and other uses. Coral reefs in Thailand are classified in 4 distinct groups with different oceanographic conditions, the inner part of the Gulf of Thailand, the east coast of the Gulf of Thailand, the west coast of the Gulf of Thailand and along the coastline of the Andaman Sea. The comprehensive reef survey program between 1995 and 1998 covering 251 sites in the Gulf of Thailand and 169 sites in the Andaman Sea was conducted by Department of Fisheries. In the Gulf of Thailand, 16.4% of the reefs were rated excellent, 29% good, 30.8% fair, and 23.8% poor. Reefs in the 'poor' category increased considerably after the severe 1998 bleaching event. In the Andaman Sea, 4.6% of reefs were excellent, 12% good, 33% fair, and 49.8% poor. Some reefs showed a declining trend in live coral cover, but other sites exhibited slight increases of live coral cover. Monitoring of reef fish was less extensive compared to benthic surveys. The surveys of coral reefs in certain provinces during 2002-2004 conducted by Department of Marine and Coastal Resources revealed that there were obvious changes in some reefs in the Gulf of Thailand. In general, coral reefs in the Andaman Sea were relatively unchanged during the last five years. The first tsunami disaster in history of Thailand occurred on December 26, 2004. The tsunami hit six provinces of Thailand along the coastline of the Andaman Sea. Department of Marine and Coastal Resources, Thai universities and volunteer diving groups conducted a rapid assessment program during December 30, 2004 to January 15, 2005 by using a survey method agreed by Thai researchers. A total of 175 study sites were completely carried out and the impacts of tsunami on coral reefs were categorized in to five groups. Only 13% of the study sites were in "high impact". No impact study sites were around 40%. Very low impact, low impact and moderate impact study sites were 21%, 17% and 9%, respectively.

Coral reef management in Thailand rests on laws and regulations that apply to all coral reefs and additional measures applicable only to marine protected areas. In recent years, central agencies, provincial governments and the private sectors have undertaken non-regulatory actions aimed at improving coral reef conditions through restoration, preventive measures and education. A National Coral Reef Strategy: Policies and Action Plan was adopted by the cabinet in 1992. However, there were no signs of reversing coral reef degradation because it was not functioned at the local level. There are only a few case studies of community-based management on coral communities in Thailand such as Had Chaolao in Chantaburi Province where local people manage coral communities for tourism. There are also several fisheries sanctuaries which are controlled by Department of Fisheries. Many islands, especially in Chonburi Province is managed by Thai Royal Navy. Certain islands, mostly in Chumporn Province, are assigned for bird nest concession that have been recognized as good condition reefs. All major coral reefs in Thailand are previously assigned to one of four management categories, i.e., general use zone, intensive tourism zone, ecotourism zone and ecosystem reserved zone. The majority of coral reefs are classified as ecotourism zone. There are many institutions involved in coral reef management and monitoring, especially Department of Marine and Coastal Resources and several universities.

Thailand has a lot of laws to be used for coral preservation and protection. Each law is issued and enforceable in different purposes. Institutions or organizations supervising and controlling each law are different. However, if the existing laws are fully and completely enforceable the coral preservation and protection will reasonably be carried out. The urgent management plans are; clear coral reef zoning and proper implementation; reduce the impacts of fishing and tourism; raise local and national awareness of the ecological and economic importance of coral reefs; restrict law enforcement in marine protected areas; develop appropriate methods and techniques for coral reef restoration.

INTRODUCTION

The coastal areas of Thailand, between latitudes 6o and 13o N, offer suitable environmental conditions for coral reef growth. There are approximately 153 km^2 of coral reefs along the total coastline of 2,614 km and over 300 relatively small islands. These are classified in 4 distinct groups with different oceanographic conditions; the inner part of the Gulf of Thailand (Chonburi Province); the east coast of the Gulf of Thailand (Rayong, Chanthaburi and Trat Provinces); the west coast of the 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, Pang-Nga, Krabi, Trang and Satun Provinces). Three reef types can be recognized: coral communities with no true reef structure; developing fringing reefs; and early formation of fringing reefs. The comprehensive reef survey program between 1995 and 1998 covering 251 sites in the Gulf of Thailand and 169 sites in the Andaman Sea was conducted by Department of Fisheries. In the Gulf of Thailand, 16.4% of the reefs were rated excellent, 29% good, 30.8% fair, and 23.8% poor. Reefs in the ‘poor’ category increased considerably after the severe 1998 bleaching event. For instance, certain areas of Rayong and Trat Provinces showed reduction in live coral cover of 80-90% from previous levels. In the Andaman Sea, 4.6% of reefs were excellent, 12% good, 33% fair, and 49.8% poor. The 1998 coral reef bleaching event affected coral reefs in the Andaman Sea to a much smaller extent than in the Gulf. Some reefs showed a declining trend in live coral cover, but other sites exhibited slight increases of live coral cover. In general, coral reefs in the Andaman Sea were relatively unchanged during the last five years. Monitoring of reef fish was less extensive compared to benthic surveys and it is difficult to provide a clear indication of reef fish status because of high temporal variations. However, fish populations were more abundant on reef slopes than on reef flats. Reef fish abundance gradients from nearshore to offshore be influenced by reef types and environmental factors. Most Thai coral reefs are used for fisheries but poor records are maintained of reef fish harvesting. Many reefs in rural areas are used by small-scale fishermen and for the collection of shells and ornamental fish in certain areas. The coral reefs provide fishery products as important sources of both food and income (Department of Fisheries 1999, Yeemin et. al., 1999, Yeemin et. al., 2001, Chou et. al., 2002).

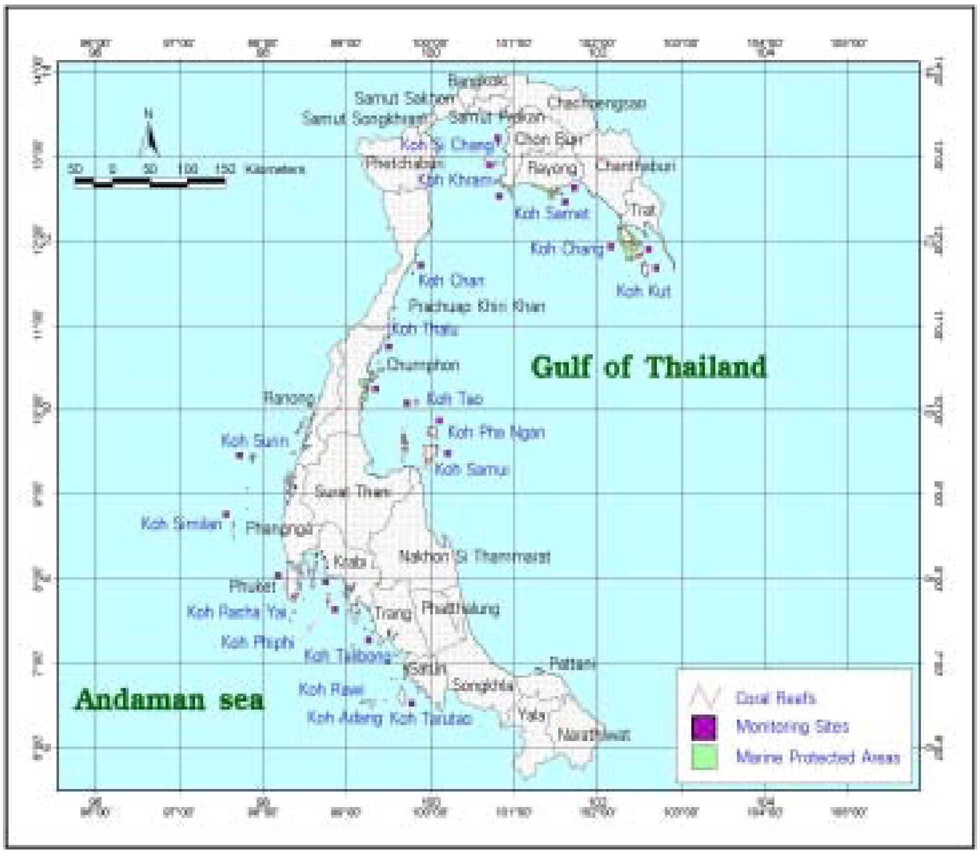


Figure 1. Map showing coral reef distribution, monitoring sites and marine protected areas in Thailand

Table 1. Important statistics

Marine area:	539,035 km^2
Coastline:	2,642 km
Land area:	513,119 km^2
Reef area:	1,787 km^2
	(Reef area as % of total in Southeast Asia: 0.972)
Population:	61 million
Coastal population:	4,258,537
No. of MPAs:	26
No. of monitoring sites:	250
Status of coral reef fisheries:	Increase (Coral reef organisms collection)
Biodiversity:	
Hard corals:	> 250 species
Soft corals:	> 30 species
Fish:	> 350 species
Molluscs:	> 300 species
Echinoderms:	> 200 species
Crustaceans:	> 1,000 species
Polychaete:	> 100 species
Seagrass:	12 species
Algae:	> 300 species

Status of Coral Reefs

The surveys of coral reefs in certain provinces during 2002-2004 conducted by Department of Marine and Coastal Resources revealed that there were obvious changes in some reefs in the Gulf of Thailand. In general, coral reefs in the Andaman Sea were relatively unchanged during the last five years (www.dmcr.go.th).

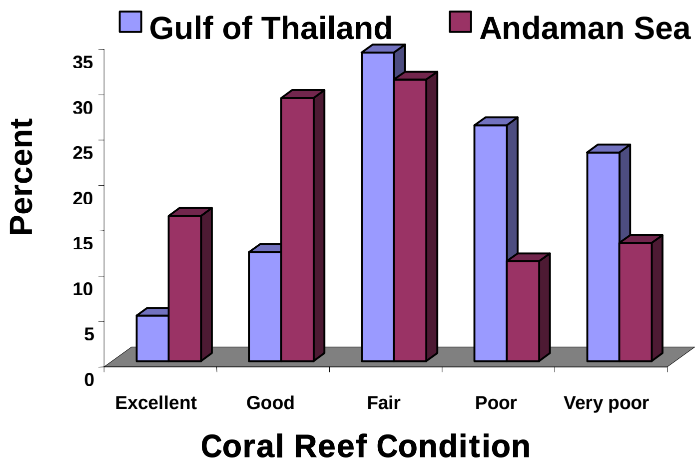


Figure 2. Percent coral cover and condition of coral reefs in the Gulf of Thailand and Andaman Sea.

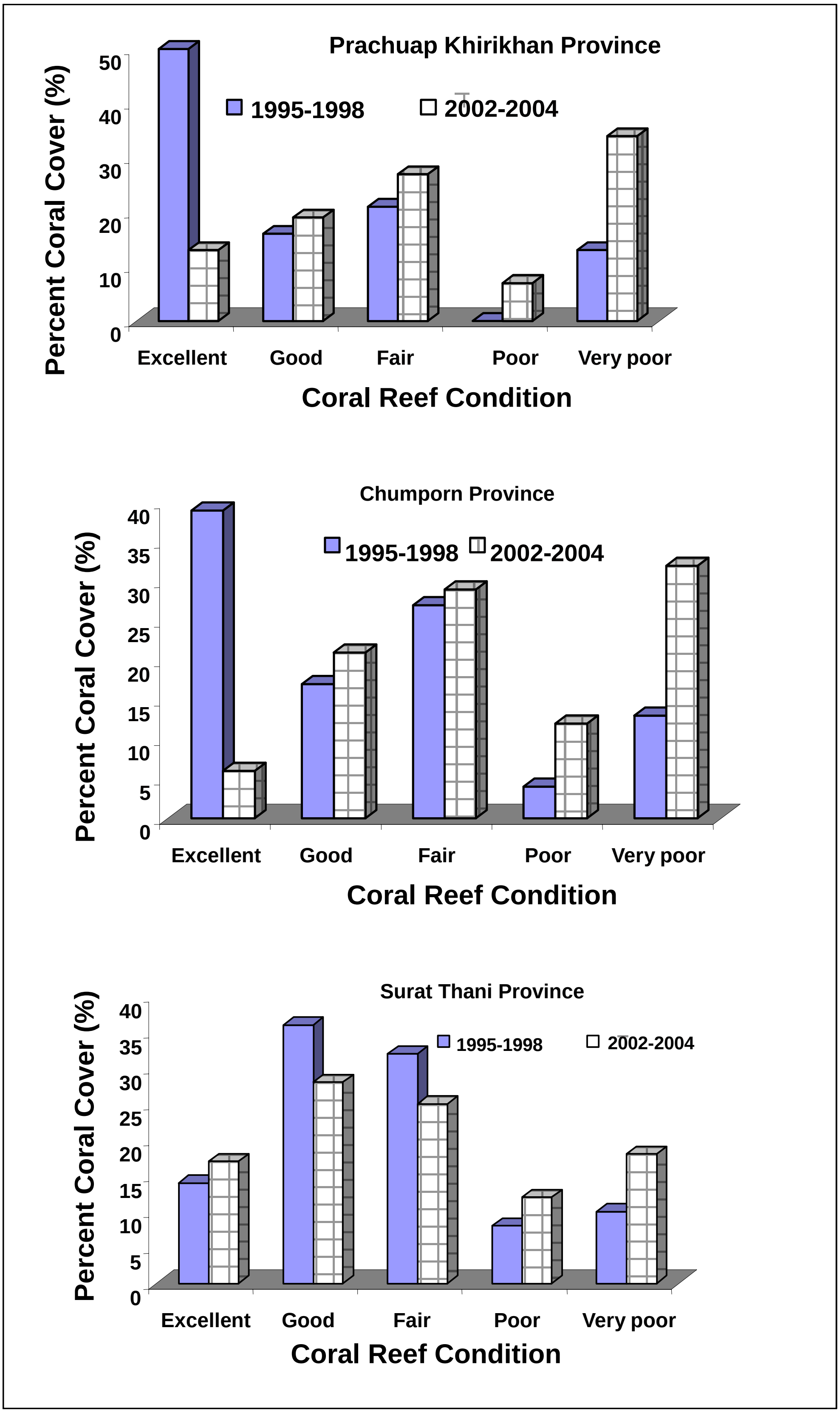


Figure 4. Percent coral cover and coral reef condition in the Gulf of Thailand from 1995 to 1998 and 2002 to 2004.

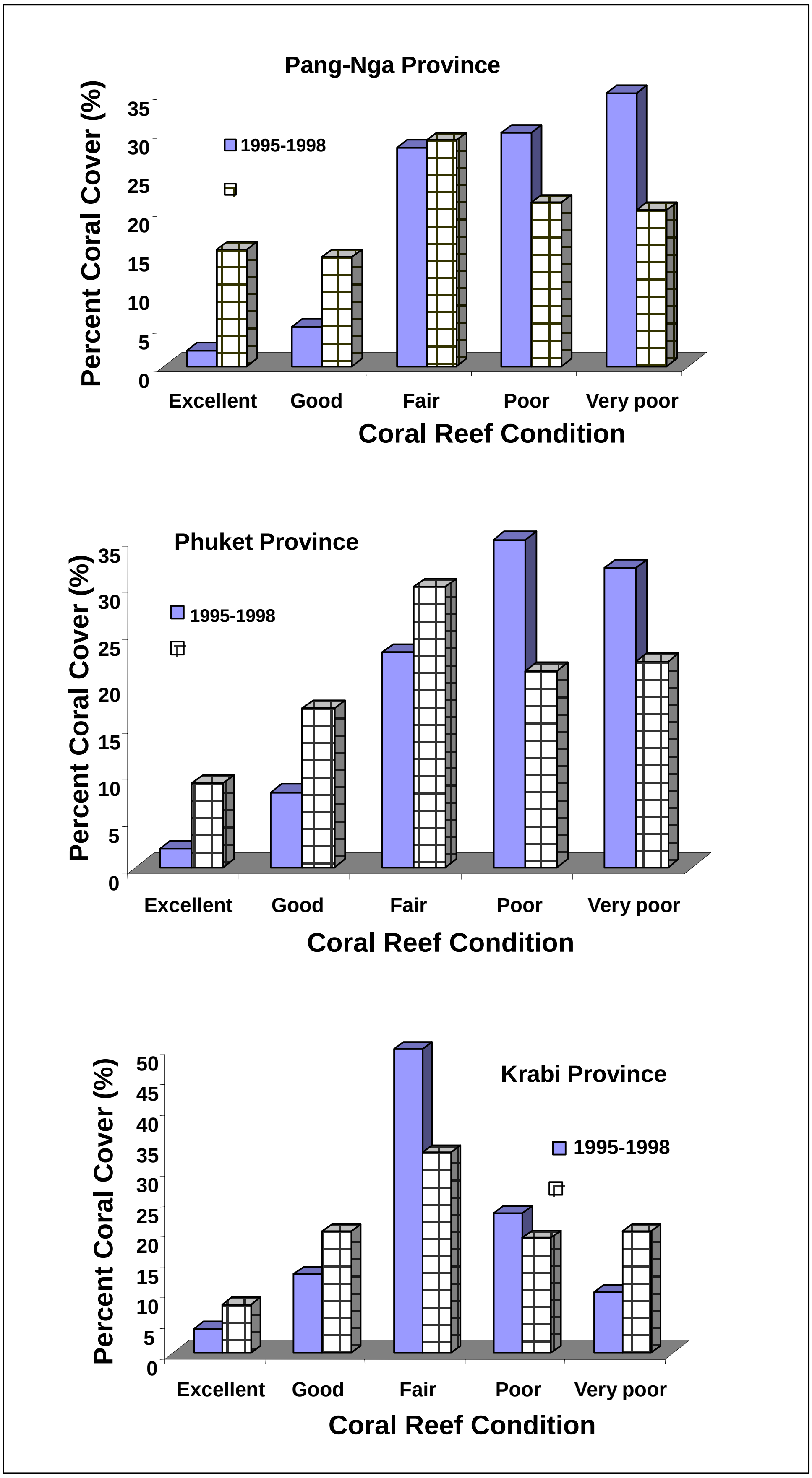


Figure 5. Percent coral cover and coral reef condition of the Andaman Sea in Thailand.

Prognosis of Coral Reef Condition

1954 No scientific research data; Based on qualitative information, reefs in good condition, live coral cover > 70% at 0-30 m depth.

1994 Decline in reef condition; live coral cover < 60% at 0-30 m depth.

2004 Further decline in reef condition, especially in shallow water; live coral cover < 30% at 0-10 m depth.

2014 Case I: Better management plan for reversing degradation trends and success implementation; live coral cover > 40% at 0-30 m depth.

Case II: More frequent bleaching and failure to manage fisheries and tourism property; live coral cover

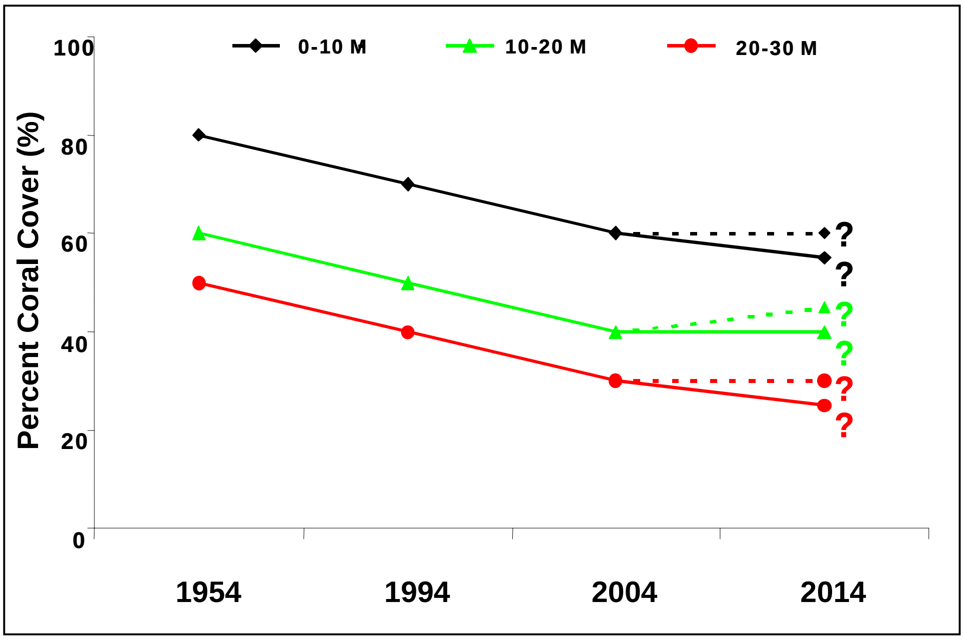


Figure 3. Prognosis of Coral Reef Condition in 1954, 1994, 2004 and 2014 in Thailand.

Reef Benthos

The coral reefs support a variety of human activities that can be categorized into three main groups: tourism and recreation; fisheries-related uses; and other uses. A clear pattern of change in coral reef use is evident, as small-scale or traditional fisheries are gradually being replaced by tourism activities. Local communities convert their fishing boats into tour boats or diving boats. This is seen in several provinces, such as Trat, Chumporn, Surat Thani, Pang-Nga, Trang and Satun. Tourism and recreational activities include diving, underwater photography, glass-bottom vessels, sea walkers, and sport fishing. Poorly managed tourism affects coral reefs through anchor damage, garbage accumulation, diver damage and wastewater discharge from coastal hotels and resorts. Live coral coverage on Tao Island in Surat Thani, one of the most popular snorkeling sites has declined 17% within a 5-year period. Coral reefs close to beach resorts are used intensively for tourism-related activities. Chanthaburi, Rayong, Surathani, Phuket, Trang, and Krabi are the major provinces for reef-related recreation. Coral reefs in several localities such as Pattaya, Koh Samet, Koh Tao, Koh Hae and Mu Koh Phi Phi group face the impact of conspicuously heavy tourism demand. Many localities are also facing a rapid and steady growth in tourism, with obvious increases in coral reef-related tourism activities. Several projects to establish mooring buoys at coral reef sites in the Andaman Sea have successfully reduced anchor damage. Shell and ornamental fish collection with the use of chemicals is among the serious problems causing coral reef degradation in the Gulf and the Andaman Sea. Dynamite fishing is rarely observed, even at remote islands. Sedimentation and wastewater pollution associated with rapid coastal development are recent and increasing severe problems in many provinces along the coastline. Jetty construction in several locations, especially in the west coast of the Gulf of Thailand, resulted in coral reef and seagrass degradation (Chou et. al., 2002, Yeemin et. al., 200).

Besides anthropogenic threats, the first extensive coral bleaching phenomenon in the Gulf of Thailand occurred in April-June 1998, and there were clear spatial variations in the extent of coral bleaching. Observed corals shown varied degrees of bleaching, and bleaching of coral recruits was observed at many study sites. Coral bleaching was widespread on shallow reefs, however, certain coral communities on deeper pinnacles, such as Hin Luk Bat in Trat Province, approximately 10-15 m in depth, showed no signs of bleaching. From long-term studies, Acropora and Pocillopora damicornis were severely affected. Several species of Acropora showed local extinction in certain locations, while Goniopora showed complete recovery after the bleaching event. Coral recovery in the inner Gulf of Thailand will require a longer period due to low coral recruitment. However, on the east and west coasts of the Gulf, large numbers of coral recruits, mainly Pocillopora, Acropora, Fungia and faviid are present (Chou et. al., 2002, Yeemin et. al., 1998).

Impacts of the Tsunami on Coral Reefs

The first tsunami disaster in history of Thailand occurred on December 26, 2004. The tsunami hit six provinces of Thailand along the coastline of the Andaman Sea, namely, Ranong, Phang Nga, Phuket, Krabi, Trang and Satun. Department of Marine and Coastal Resources, Thai universities and volunteer diving groups conducted a rapid assessment program during December 30, 2004 to January 15, 2005 by using a survey method agreed by Thai researchers. A total of 175 study sites were completely carried out and the impacts of tsunami on coral reefs were categorized in to five groups, i.e., no impact, very low impact (1-10% of corals were damaged.), low impact (11-30% of corals were damaged.), moderate impact (31-50% of corals were damaged.) and high impact (> 50% of corals were damaged.). Only 13% of the study sites were in “high impact”. No impact study sites were around 40%. Very low impact, low impact and moderate impact study sites were 21%, 17% and 9%, respectively (www.dmcr.go.th).

Table 2. Summary of the tsunami impacts on coral reefs along the coastline of the Andaman Sea. (% of total study sites)

Province	No impact (0% damaged coral)	Very low impact (1-10% damaged coral)	Low impact (11-30% damaged coral	Moderate impact (31-50% damaged coral)	High impact (>50% damaged coral)
Ranong	0.0	16.7	16.7	8.3	58.3
Pang Nga					
- Mu Koh Surin	0.0	23.8	33.3	23.8	19.0
- Mu Koh Similan	28.9	18.4	21.1	13.2	18.4
- Other areas	29.2	16.7	22.2	13.9	18.1
Phuket	57.1	23.8	14.3	4.8	0.0
Krabi					
- Mu Koh Phi Phi	33.3	26.7	13.3	20.0	6.7
- Other areas	40.0	26.7	13.3	13.3	6.7
Trang	25.0	50.0	25.0	0.0	0.0
Satun	71.0	16.1	9.7	0.0	3.2
In total (%)	**39.7**	**20.7**	**17.2**	**9.2**	**13.2**

Department of Marine and Coastal Resources and several universities have routine research on coral reefs in the Andaman Sea. In the case of Marine Biodiversity Research Group, Ramkhamhaeng University, we have conducted a research program on development of appropriate techniques and methods for coral reef rehabilitation for sustainable tourism in certain provinces since 2001. The research has mainly focused on condition of coral reef, status and change of coral fragment, coral reproduction, ecology of juvenile coral colony, coral recruitment (settlement plate experiment), status and change of partial mortality of coral colony and ecology of reef macroinvertebrates and fish. We will continue monitoring our 20 study sites in the Andaman Sea. Results from the studies in details at a monitoring site of Koh Phai, Mu Koh Phi Phi, Krabi Province showed that there were a number of coral species lost from the permanent belt transects. The tsunami also affected juvenile coral colonies. Coral fragment densities of Acropora and Montipora increased remarkably (Yeemin 2004).

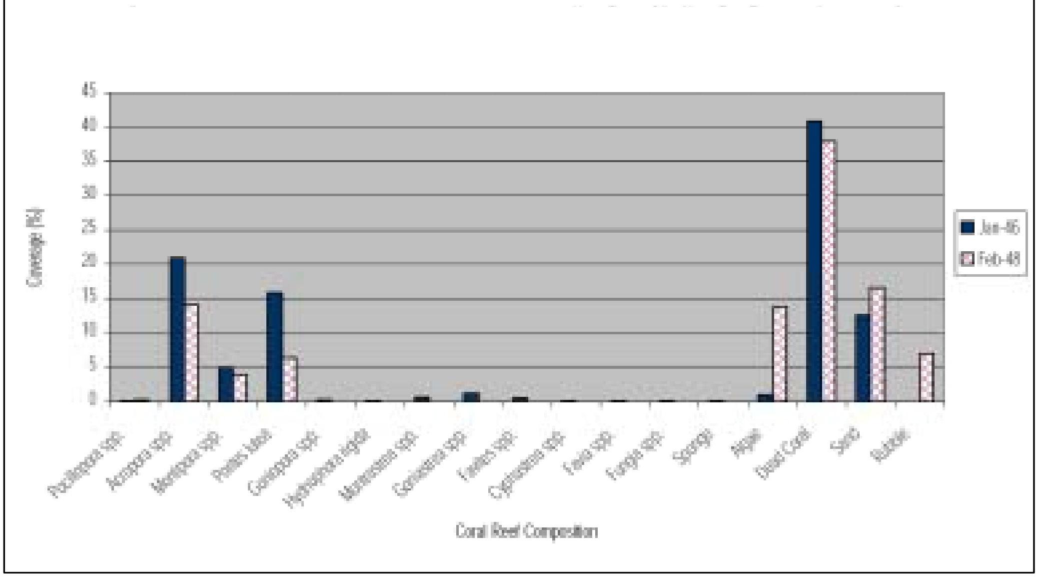


Figure 6. Change of coral cover after tsunami at a study site of Koh Phai, Mu Koh Phi Phi, the Andaman Sea.

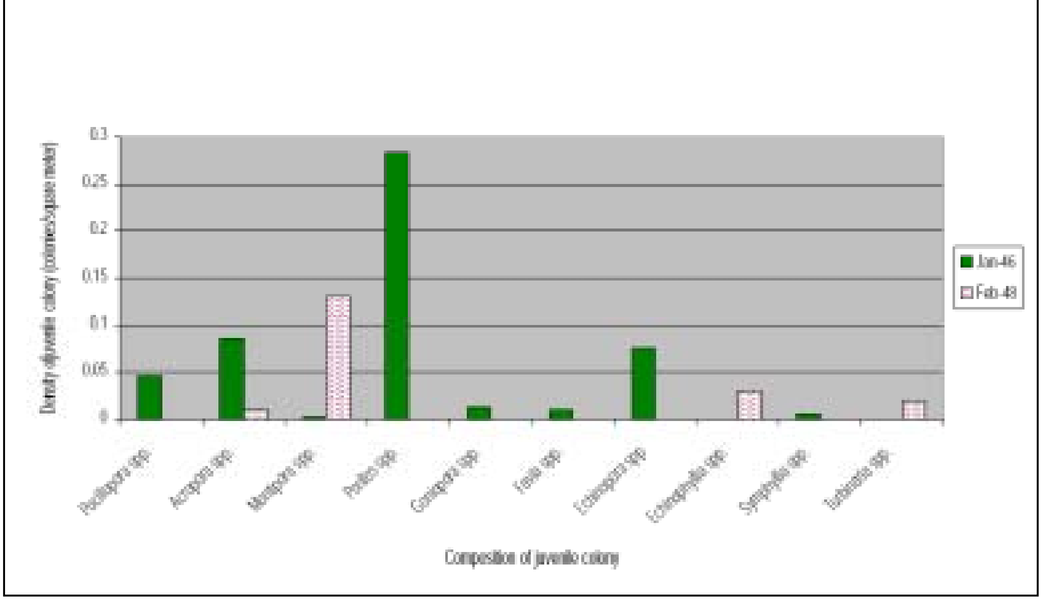


Figure 7. Change of Juvenile coral density after the tsunami at a study site of Koh Phai, Mu Koh Phi Phi, the Andaman Sea

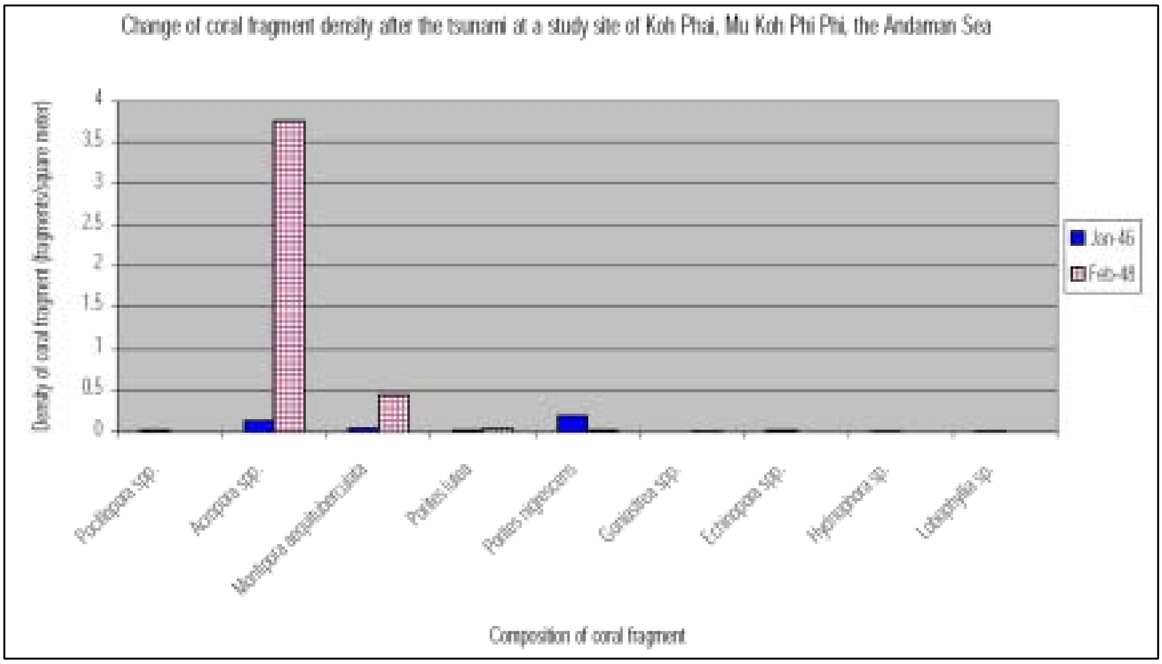


Figure 8. Change of coral fragment density after the tsunami at a study site of Koh Phai, Mu Koh Phi Phi, the Andaman Sea.

Strong wave and current, garbage, debris and bottom sediment movement mainly caused coral damages. Many coral colonies turned over, broke and buried in sand. Volunteer diving groups tried to fix the impacted coral colonies to suitable substrates and cleaned up the reefs. Marine National Parks temporarily closed around 18 study sites for naturally recovery. There are a lot of works to be planned and implemented after the tsunami disaster.

- Study in details in impacted sites to assess coral community changes.
- Implement a long-term coral reef monitoring program to cover a large number of study sites.
- Study on appropriate rehabilitation techniques in particular damaged areas.
- Study on coral reef management aspects, such as management of mooring buoy system, diving business and marine national park for tourism.
- Connection with international networks such as ICRI, GCRMN, etc.
- Academic exchange with foreign countries through meeting, seminar, training, site visit, study and research.
- Academic supports from foreign countries in the fields of coral reef restoration technology, artificial reef for tourism, marine biotechnology, GIS, remote sensing and coral reef management.

The Thai Government has established a few working groups concerning impacts of tsunami and recovery processes. Regarding to the aspect of a natural resources and environment, Department of Marine and Coastal Resources in collaboration with Thai universities are the main focal point.

Figure 9. The tsunami caused coral damage at Mu Koh Phi Phi, Krabi Province.

Figure 10. Coral reefs of Mu Koh Adang Rawi, Satun Province are healthy after the tsunami.

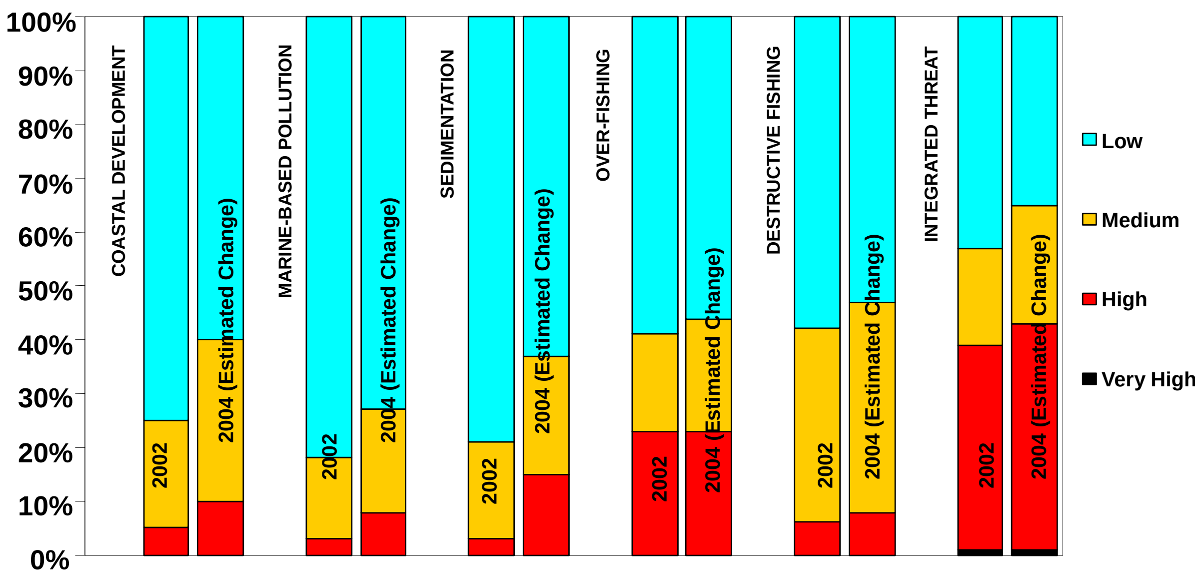


Figure 11. Potential Threats to Coral Reefs (Reef at Risk Threat Indicators)

Management

Coral reef management in Thailand rests on laws and regulations that apply to all coral reefs and additional measures applicable only to marine protected areas. In recent years, central agencies, provincial governments and the private sectors have undertaken non-regulatory actions aimed at improving coral reef conditions through restoration, preventive measures and education.

Several laws are used to protect coral reefs in Thailand, e.g. the Fisheries Law of 1947, the National Park Act of 1961, the Enhancement and Conservation of National Environmental Quality Act (NEQA) of 1975, etc. The Department of Fisheries (DOF) and Marine National Parks mainly enforce these regulations. There have been problems in enforcing coral reef protection regulations. For example, the language of the law and the subsequent regulations are often unclear or incomplete. Marine National Parks in Thailand include significant reef areas. Most of the parks containing reefs have been designated in the Andaman Sea, which only a few sites designated in the Gulf of Thailand. Together with the Fisheries Protected Areas, approximately 60% of Thailand's significant coral reefs are included a protected area.

Several institutional and operational constraints have, however, limited the effectiveness of Thailand's network of protected areas in preserving coral reef habitat. These include [9]; the size of the areas designated and the boundaries have been too broad or have not corresponded to resource protection priorities; there have been serious conflicts between park designation and traditional uses of marine resources, particularly fisheries; local economic and social priorities have been overlooked in the park management and development process; jurisdiction over marine resources is unclear and there have been apparent conflicts with fisheries regulations; and the emphasis of marine park management has been on accommodating visitor use rather than on resource protection, marine interpretation and enforcement.

Non-regulatory Measures

Public support for coral reef management increased dramatically the late 1980's. This support has come in part form the extensive media coverage of both the beauty and degradation of Kingdom's coral reefs. Commitment to coral reef conservation has also grown in response to direct action taken at both national and local levels to reverse trends in coral reef degradation. These actions have largely been voluntary. They depended on individuals, businesses and government agencies working together to solve problems. Such voluntary efforts are called "non-regulatory measures"

Non-regulatory measures can include education and scientific activities as well as direct management actions such as mooring buoy installation. Several organizations have led the effort to increase public awareness about importance of coral reefs, the human activities that are leading to their degradation and actions that can be taken to conservation this valuable habitat. This campaign has reached most of Thailand's mass media.

The Tourism Authority of Thailand and volunteer associations of divers and tour boat operators have cooperated to educate pilots and escort guides in coral reef ecology and ways to avoid damaging reefs. The results of such efforts have been impressive in terms of changed behavior and increased commitment to conservation. The National Park Division is beginning to include coral reef information in its park interpretive programs; and the Department of Fisheries, through its extension program, has offered conservation education to reef fishermen.

Cooperation among coral reef scientists in Thailand has been extensive and is essential to the national strategy formulation process. Researchers have worked together to document reef condition in Thailand through the ASEAN-Australian baseline study and the coral reefs project of Department of Fisheries.

Management Plans

A National Coral Reef Strategy: Policies and Action Plan was adopted by the cabinet in 1992. However, there were no signs of reversing coral reef degradation because it was not functioned at the local level. At present, the National Coral Reef Strategy: Policies and Action Plan is under revision. The revised national policies and measures for coral reef conservation for a period of 5 years, based on the national meeting on 30th January 2004, are showed as follows:

Policy 1: Manage coral reefs according to different ecological and economic values to maintain a balance of uses

Measure 1: Improve coral reef classification
- 3 projects

Measure 2: Determine criteria and measure for each management category
- 3 projects

Policy 2: Reduce reef degradation by increasing the effectiveness of existing laws, management plan and application of appropriate technology

Measure 1: Apply success methods to prevent coral reef degradation from the pilot study sites to other areas (6 projects)
Measure 2: Prevent impacts from new coastal development (7 projects)
Measure 3: Reef "code of conduct" (3 projects)
Measure 4: Expand local extension programs in fisheries habitat conservation (7 projects)
Measure 5: Enforce more effectively existing laws against illegal activities (4 projects)
Measure 6: Strengthen the capacity of local government in site planning and management (2 projects)

Policy 3: Build and maintain strong and broad public support
Measure 1: Launch national and local public information campaigns (7 projects)
Measure 2: Encourage volunteer groups, user and public participation in reef management. (11 projects)
Measure 3: Coral reef curriculum in schools and colleges (6 projects)

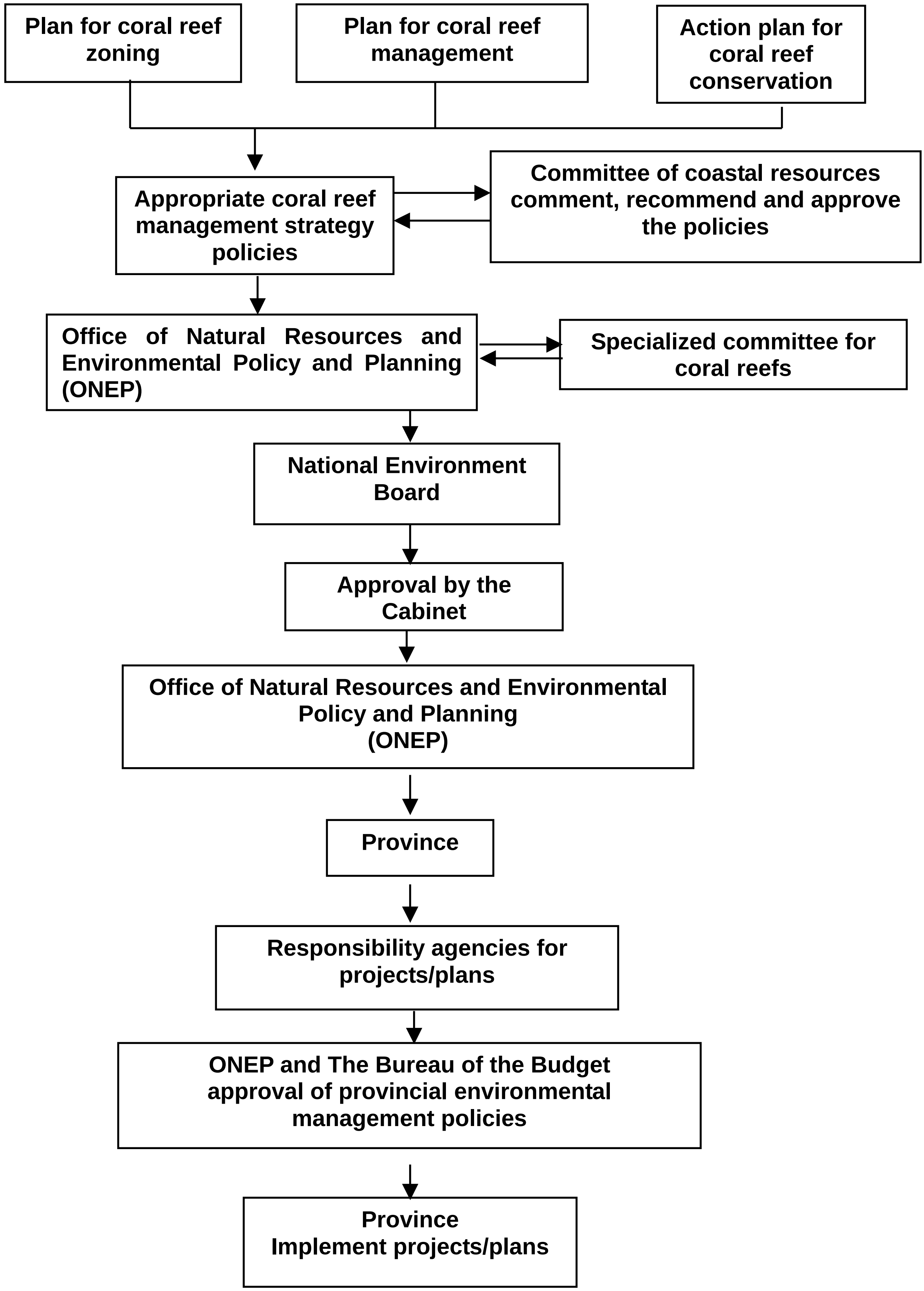
Policy 4: Revise Royal Thai Government legal, regulatory, and institutional framework
Measure1: Amend law and regulation concerning coral reef management (3 projects)
Measure 2: Improve coral reef management processes (2 projects)
Measure 3: Provide interagency leadership and coordination (6 projects)
Measure 4: Develop marine national park system plan (4 projects)

Policy 5: Monitor and evaluate progress
Measure 1: National monitoring program (7 projects)

Policy 6: Support management through scientific research and innovation
Measure 1: Basic coral reef research program (9 projects)
Measure 2: Applied coral reef research program (5 projects)
Measure 3: Promote and develop researchers in the fields of reef and marine ecology (3 project)

In total, there are 98 projects.

There are only a few case studies of community-based management on coral communities in Thailand such as Had Chaolao in Chantaburi Province where local people manage coral communities for tourism. There are currently 7 Marine National Parks in the Gulf of Thailand which play a major role on coral reef management in Thailand, harboring about 38% of the total area of coral reefs in the gulf. Based on the report by Department of Fisheries in 1999, conditions of coral reefs in the marine parks are classified mostly as fair to excellent. There are also several fisheries sanctuaries which are controlled by Department of Fisheries. Many islands, especially in Chonburi Province is managed by Thai Royal Navy. Certain islands, mostly in Chumporn Province, are assigned for bird nest concession that have been recognized as good condition reefs.


Plan for coral reef zoning
Plan for coral reef management
Action plan for coral reef conservation
Appropriate coral reef management strategy policies
Committee of coastal resources comment, recommend and approve the policies
Office of Natural Resources and Environmental Policy and Planning (ONEP)
Specialized committee for coral reefs
National Environment Board
Approval by the Cabinet
Office of Natural Resources and Environmental Policy and Planning (ONEP)
Province
Responsibility agencies for projects/plans
ONEP and The Bureau of the Budget approval of provincial environmental management policies
Province
Implement projects/plans

Coral reefs in Marine National Parks in the Gulf of Thailand

Province	*Coral reef* area (km^2)	Coral reef area in Marine National Parks (km^2)	(%)	Marine National Park in where coral found
Trat	15.89	4.84	30.46	Mu Koh Chang
Chantaburi	0.72	-	-	None
Rayong	3.50	2.71	77.4	Khao Laem Ya-Mu Koh Samet
Chonburi	7.59	-	-	None
Prachuap Khirikhan	2.04	0.22	10.80	Had Wanakorn, Khao Sam Roi Yod
Chumporn	6.50	6.14	94.50	Mu Koh Chumporn
Surat Thani	38.67	14.35	37.11	Mu Koh Angthong Tarnsadej
Total	**74.91**	**28.26**	**37.72**	7 Marine National Parks

*Source*s: Marine National Park Division, (excluding marine national parks at Had Khanom- Mu Koh Talay Tai and Au Manou)

Coral reef conditions in Marine National Parks in the Gulf of Thailand

Marine National Park	*Coral reef* area (km^2)	Coral reef conditions: Excellent (%)	Good (%)	Fair (%)	Poor (%)	Very poor (%)
Mu Koh Chang	4.84	23.50	31.21	25.67	9.75	9.87
Mu Koh Samet	2.71	12.57	36.73	29.66	2.30	18.74
Khao Sam Roi Yod	0.14	30.00	-	-	-	70.00
Had Wanakorn	0.08	60.00	40.00	-	-	-
Mu Koh Chumporn	6.14	41.17	22.38	29.30	3.09	4.06
Mu Koh Angthong	3.31	31.66	36.43	20.69	5.33	5.89
Tarnsadej	11.04	5.20	56.10	33.70	2.5	2.50

Source: Department of Fisheries, 1999

Coral reefs in Marine National Parks in the Andaman Sea

Province	*Coral reef* area (km^2)	Coral reef area in Marine National Parks (km^2)	(%)	Marine National Park in where coral found
Ranong	2.57	2.51	97.70	Laem Son, Payam
Pang-Nga	25.60	16.86	65.90	Laem Son, Surin, Similan, Pang-Nga Bay
Phuket	16.63	1.82	10.94	Sirinath
Krabi	13.53	11.30	83.50	Phi-Phi, Tarn Bok, Lanta
Trang	4.47	2.09	46.80	Chao Mai, Petra
Satun	15.80	14.30	90.50	Petra, Tarutao
Total	**78.60**	**48.88**	**62.19**	12 Marine National Parks

*Source*s: Marine National Park Division, (excluding marine national parks at Had Khanom- Mu Koh Talay Tai and Au Manou)

Coral reef conditions in Marine National Parks in the Andaman Sea

Marine National Park	*Coral reef* area (km^2)	Coral reef conditions				
		Excellent (%)	Good (%)	Fair (%)	Poor (%)	Very poor (%)
Mu Koh Payam	0.80	-	1.90	40.70	40.70	16.70
Laem Son	0.90	5.65	26.05	29.18	27.43	11.80
Mu Koh Surin	7.53	14.45	13.45	43.20	25.83	4.08
Mu Koh Similan	4.53	1.98	11.56	34.07	17.03	35.36
Pang-Nga Bay	4.70	-	0.05	14.04	69.10	16.81
Sirinath	1.82	-	-	18.60	32.60	48.80
Mu Koh Phi-Phi	7.79	2.85	19.29	60.49	12.35	5.02
Tarn Bok Khorani	0.39	-	3.37	61.93	27.60	7.10
Mu Koh Lanta	3.15	7.84	26.96	39.36	9.88	15.98
Haad Chao Mai	1.69	8.70	35.10	38.70	11.27	6.27
Mu Koh Petra	2.01	0.42	26.35	36.92	20.14	16.18
Mu Koh Tarutao	13.49	17.37	15.98	42.91	10.72	13.03

Source: Department of Fisheries, 1999

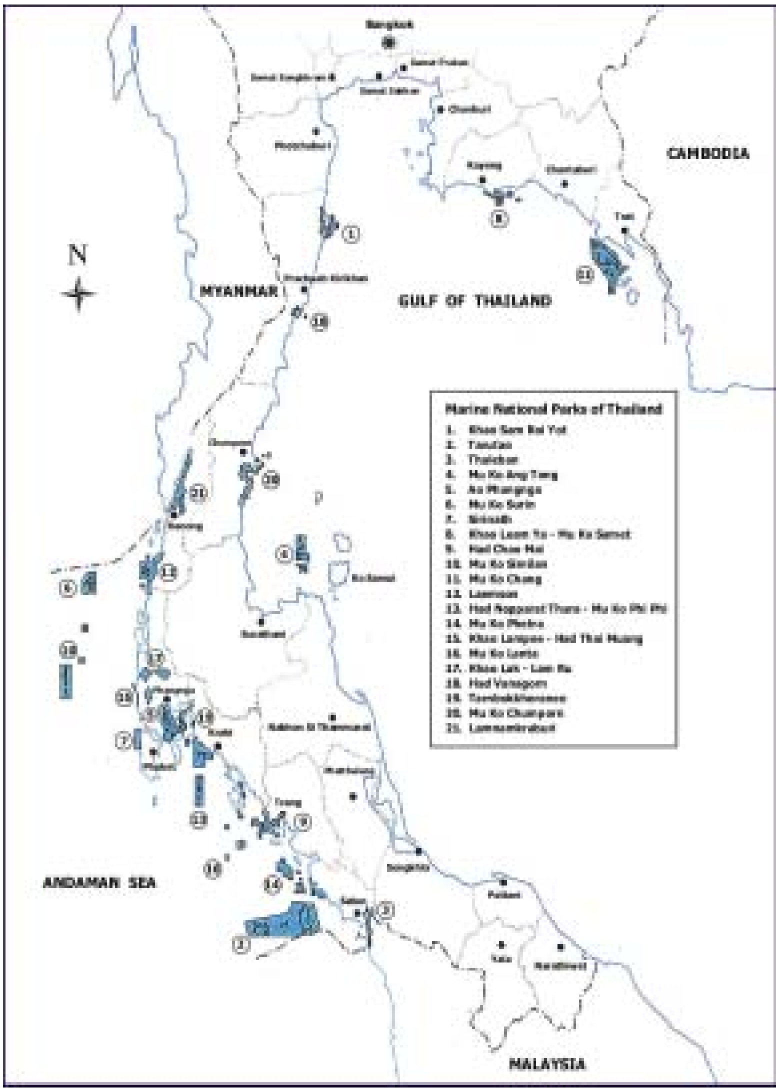


Figure 10. Map of Marine National Parks in Thailand

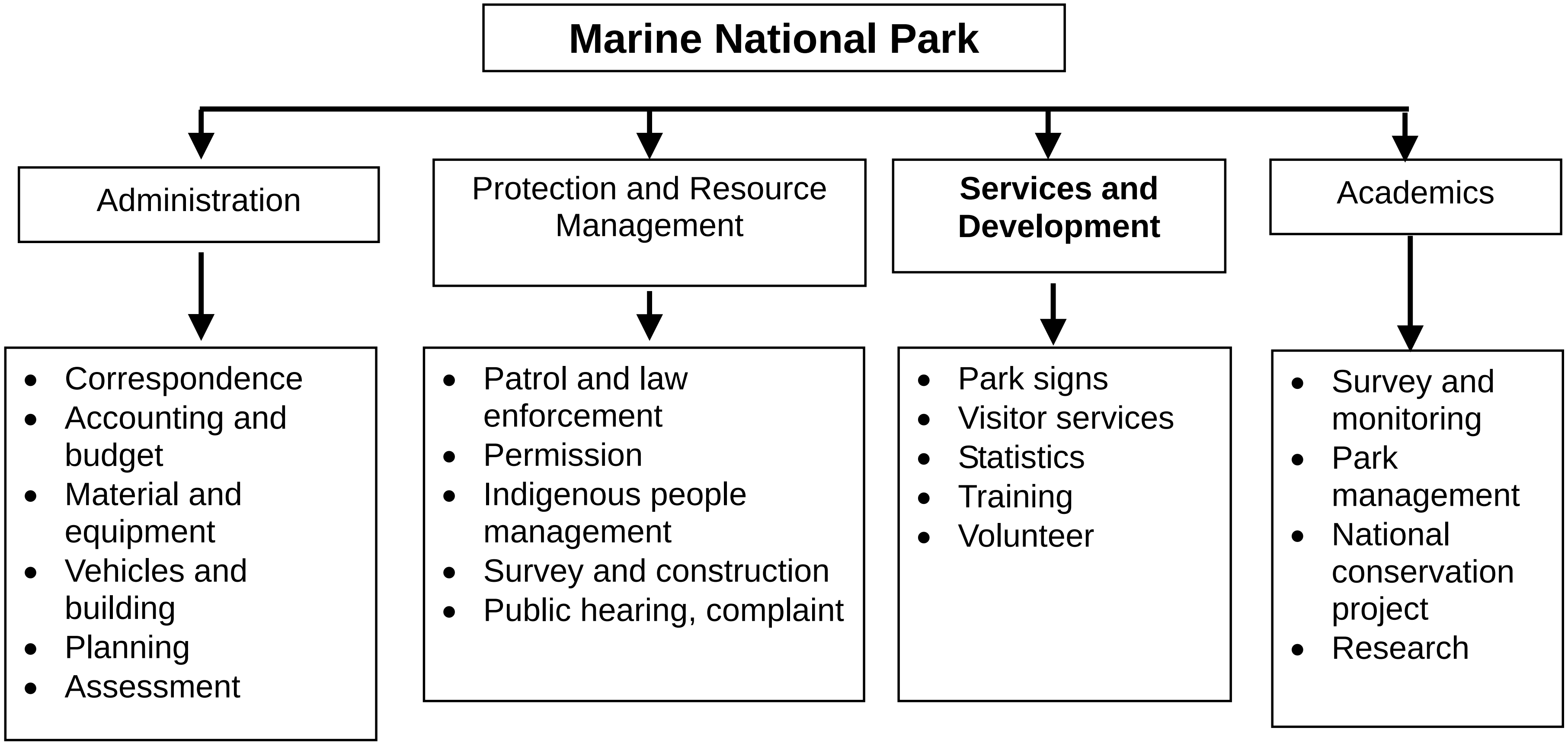


Figure 11. General organization chart of marine national park in Thailand

Coral Reef Zoning

All major coral reefs in the Gulf of Thailand are previously assigned to one of four management categories as follows:

- General Use Zone
- Intensive Tourism Zone
- Ecotourism Zone
- Ecosystem Reserved Zone

A total of 290 coral reef sites is classified by using the above criteria. The majority of coral reefs in the Gulf of Thailand are classified as ecotourism zone.

Coral reef zoning in the Gulf of Thailand

Province	Coral Reef Zoning (Number of island/site)				***Total***
	General Use Zone	**Intensive Tourism Zone**	**Ecotourism Zone**	**Ecosystem Reserved Zone**	
Chonburi	6	2	33	5	46
Rayong	2	4	12	0	18
Chantaburi	0	0	1	3	4
Trat	3	0	34	5	42
Prachuap Khirikhan	9	0	6	4	19
Chumporn	18	0	44	2	64
Surat Thani	10	4	71	2	87
Nakhon Sithamamarat	0	0	1	0	1
Songkhla	4	0	2	0	6
Pattani	2	0	0	0	2
Naratiwat	0	0	1	0	1
Total	54	10	205	21	290

Innovative Incentive Mechanisms for Coral Reefs Management:
Payment for Environmental Services (PES)

Present status of marine national parks concerning revenue

- ***Sources of revenue***

  Marine national parks in Thailand have applied the rules to collect revenue of certain activities. The important fees are:

  - **Entrance fees**

    All marine national parks collect the entrance fee from tourists. The rates are as follows:
    - Thai-Adult 20 Baht
    - Thai-Child 10 Baht
    - Foreigner-Adult 200 Baht
    - Foreigner-Child 100 Baht
  - **Diving fees**

    At the present Mu Koh Surin and Mu Koh Similan marine national parks collect SCUBA diving fee at the rate 200 Baht/individual/day applied for both Thai and foreign divers.
  - **Accommodation fees**

    All marine national parks have their own accommodation for tourists. There are various types of house with different accommodation rates as summarized below:
  - **Miscellaneous incomes**

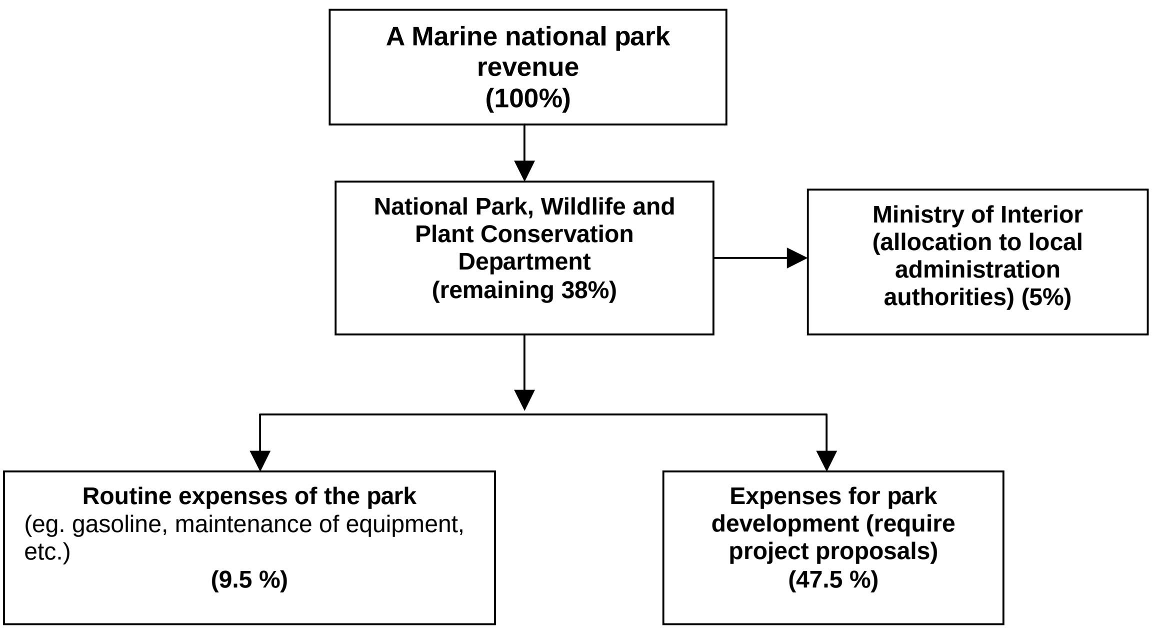
Marine national parks can earn various types of income such as souvenir shops, restaurants, diving equipment rent, boat rent, etc**.**

Table 3. Accommodation fee for Marine Naitonal Parks in Thailand.

Marine National Park	Accommodation fee (Baht)	
	Tent or house/night	Using facilities/ ind./night
Mu Koh Chang, Trat Province	100-300	20
Khao Laem Ya-Mu Koh Samet, Rayong Province	100-1,000	20
Khao Sam Roi Yod, Prachuap Khirikhun Province	100-2,000	20
Hadd Wanakorn, Prachuap Khirikhun Province	100-800	20
Mu Koh Angthong, Surat Thani Province	100-1,000	20
Sirinath, Phuket Province	100-1,200	20
Mu Koh Phi-Phi. Krabi Province	100-1,200	20
Mu Koh Lanta, Krabi Province	200-2,000	40
Tan Bok Khorani, Krabi Province	200	20
Laem Son, Ranong Province	100-2,400	20
Lamnamkraburi, Ranong Province	800-1,200	20
Pang-Nga Bay, Pang-Nga Province	100-900	20
Mu Koh Surin, Pang-Nga Province	200-2,000	40
Mu Koh Simlan, Pang-Nga Province	200-1,000	40
Khao Lampee-Hadd Taimuang	100-1,000	20
Khao Lak-Lamroo, Pang-Nga	100-1,000	20
Hadd Chao Mai, Trang Province	100-800	20
Mu Koh Tarutao, Satun Province	100-4,000	20
Talayban, Satun Province	100-1,200	20
Mu Koh Petra, Satun Province	100-2,400	20

- ***Revenue collection***
  Marine national parks collect the fees directly from visitors and/or tourism operators. Other miscellaneous incomes are available depending on location and management plan of the parks.

- ***Revenue allocation***
  All revenue and income collected by a marine national park have to be sent to National Park, Wildlife and Plant Conservation Department in Bangkok. Five percent will be sent to Ministry of Interior and then allocated to relevant local administration authorities. The park can spend 9.5 percent for Routine expenses such as gasoline, maintenance of equipment, etc. The park is able to request 47.5 percent for other park development projects but it must submit proposals to explain details of expenses. The executive board of National Park, Wildlife and Plant Conservation Department will consider and approve the project proposal before budget allocation to the park. The remaining 38 percent will be deposited at the National Park, Wildlife and Plant Conservation Department and can be spent for any activities depending on the department policies. A summary chart is shown below.



- National Park, Wildlife and Plant Conservation Department is newly established therefore it needs a period of time to rearrange rules, regulation and management structures.
- The processes for request of budget are complicated and required a long period of time.
- The SCUBA diving fee seems to be relatively high for some diver groups.
- Revenue collection mechanisms should be improved.
- Revenue collection system is still being new for Thailand so public relation is required.

- ***Challenge and recommendation***

  The parks have identifiable stakeholders that are interested in various aspects of park tourism and activities. All of these stakeholders are interested in participating in the various planning and management functions associated with park tourism, especially for innovative incentive mechanisms. Examples of stakeholders include:

  - Park managers
  - Park volunteers
  - Park visitors
  - Governments
  - Allied and competing government
  - Agencies
  - Profit-making private sector
  - Non-governmental organizations (NGO's)
  - Local community
  - Native community
  - Educational institutions
  - Research bodies
  - Media
  - Park employees
  - Tourism operators
  - Concessionaires, licensees and permit holders
  - Residents with private in holdings (private land parcels within the park)
  - Resource extraction interests
  - Diving clubs.

It is very important to design appropriate networking among those stakeholders in order to achieve the final goal of sustainable tourism in marine national parks.

Management Capacity and Monitoring for Coral Reefs

There are many institutions involved in coral reef management and monitoring in Thailand:

- Office of Natural Resources and Environmental Policy and Planning
- Department of Marine and Coastal Resources
  - Institute of Marine and Coastal Resources Research (Phuket Marine Biological Center)
  - Eastern Marine and Coastal Resources Research Center
  - Central Marine and Coastal Resources Research Center
- National Park, Wildlife and Plant Conservation Department
  - Marine National Park Division (26 Marine National Parks)
- Ministry of Tourism and Sport
- Tourism Authority of Thailand
- Royal Thai Navy
- Chulabhorn Research Institute
- Pollution Control Department
- Chulalongkorn University
  - Department of Marine Science
  - Aquatic Resources Research Institute
- Ramkhamhaeng University
  - Marine Biodiversity Research Group
- Kasetsart University
  - Faculty of Fisheries

- ❑ Burapa University
  - Department of Aquatic Science
  - Marine Science Institute
- ❑ Prince of Songkla University
  - Department of Biology
- ❑ Maejo University – Chumporn Campus
- ❑ Rajamangala Institute of Technology
- ❑ Rajabhat Institute Rambhaibarni
- ❑ Department of Fisheries
- ❑ Reef Check Thailand
- ❑ NGOs

Legislation

- ***Law Related to Preservation and Protection of Coral Reef*** (SEA-Coral Reefs-Thailand 2003(a))

  Coral is one of the important and beneficial natural resources for human beings and any other lives. It causes tourism attraction, works employment, job and revenue creation to the local people and nation in amount of many ten thousand bahts each year. However, presently the problems of declination incurred to the coral has been more and more severe arising out of many causes, both from nature and human being action. Therefore, the state and private sectors including any other organizations have realized the importance of coral and helped together to preserve and protect it, such as, install mooring buoy, not sell or buy the coral, collect solid waste on beaches and coral reefs, etc. and especially use of legal measures to preserve and protect corals.

  1. Constitution of the Kingdom of Thailand B.E. 2540
  2. Travel Agency Business and Guide Act B.E. 2535
  3. Wildlife Preservation and Protection Act B.E. 2535
  4. Fisheries Act B.E. 2490
  5. National Park Act B.E. 2504
  6. Enhancement and Conservation of National Environmental Quality Act B.E 2535
  7. Navigation in Thai Waterways Act B.E. 2456
  8. Import and Export of Commodity Act B.E. 2522
  9. Empowering Royal Thai Navy to Suppress Some Offences On the Seas Act B.E. 2490

  From the laws as mentioned above, it is appeared that Thailand has a lot of laws to be used for coral preservation and protection. Each law is issued and enforceable in different purposes. Institutions or organizations supervising and controlling each law are different. However, if the existing laws are fully and completely enforceable the coral preservation and protection will reasonably be carried out.

  In order to have more effectiveness in control and inspection system and to generate more benefits to the concerned persons, including having more productiveness in preservation and protection of coral and environment, it is expedient to amend the following laws:

  1. It is reasonable to divide the categories of travel agency business into each activity, such as, scuba diving, skin diving or snorkeling, semi-submarine, submarine, sea walking, canoe or kayak, etc., because the said activities cause direct impacts to coral reef environment. The applicant must comply with all rules and procedures of the said activity before obtaining permission from the Travel Agency Business and Guide Committee. However, the Ministerial Regulation (B.E. 2536) under Section 14 of the Travel Agency Business and Guide Act B.E. 2535 will be amended.

  2. It is reasonable for the subcommittee considering sea walking and diving in each province adjacent to seashore to determine the criteria's to grant permission for skin diving or snorkeling, semi submarine, submarine, canoe or kayak, as same as scuba diving or sea walking travel agency business.

  3. It is reasonable to enact the Royal Decree determining the coral resources to be the Wildlife Sanctuary" under Section 33 of the Wildlife Preservation and Protection Act. B.E. 2535 and

present to Cabinet for approval and promulgate in the Government Gazette.

4. It is reasonable for the Minister of Natural Resources and Environment to present to the National Wildlife Preservation and Protection Committee for approval in determining the coral resources to be the “Non – hunting Wildlife Area” under Section 42 of the said Act.

5. It is reasonable for the Provincial Council which has coral resources to issue the provincial notification with approval of the Minister of Agriculture and cooperatives determining the said coral resources to be the “Preservation Fisheries” under Section 7 of the Fisheries Act. B.E. 2490

6. It is reasonable for the Minister of Natural Resources and Environment with suggestion of the National Environment Board to issue the ministerial regulation determining the area of coral resources to be the “Environmental Protection Area” under Sections 43 and 44 of the National Enhancement and Conservation of Environment Quality Act. B.E. 2535.

7. It is reasonable to have law enforcement fully and completely with the government clearest policy and financial and man – power support, including with public participation and assistance.

Conclusions and Recommendations

The following suggestions, adapted from (Eagles et. al., 2001), may be useful as a framework for planning of management and conservation of coral reefs in Thailand (SEA-Coral Reefs-Thailand 2003(b), SEA-Coral Reefs-Thailand 2003(c), Thamrongnawasawat 2004)

1. Strong links between private tourism businesses and protected area systems are necessary. Representatives from all sectors need to work together to develop sustainable forms of tourism for protected areas.

2. Integrate environmental concerns into national and regional tourism policies and projects in Thailand. Sustainable nature-based tourism needs to be made a fundamental part of government policies relating to tourism.

3. All park systems require a public use and tourism policy, as well as a legal structure that enables the policy to be implemented. Review existing legislation to make sure it is compatible with sustainability goals, and make adjustments as necessary. Ensure that written instruments that provide a legally enforceable framework are in place (e.g., laws, governmental policies, and property rights).

4. A sustainable tourism action plan should be created for each protected area. This should be done in consultation with the tourism sector and the local communities. This tourism plan should be part of the overall park management plan that all protected areas must have for successful long-term planning and management to occur. Conservation and tourism objectives for each protected area need to be identified.

5. All parks and protected areas should use visitor management methods such as zoning, visitor channeling, education, interpretation and policy enforcement to ensure that tourism levels and impacts remain within acceptable limits established for the area. A monitoring program should be established to evaluate the success of these management tools. Indicate how often evaluations will occur and how revisions will be incorporated when necessary.

6. Develop incentive measures that will influence the decision-making process. Create inducements that are specifically intended to motivate government, local people, and international organizations to conserve biological and cultural diversity. Review existing legislation and economic policies to identify and promote incentives for the conservation and sustainable use of the resources, stressing removal or mitigation on incentives that

threaten biological diversity.

7. Invest and assign some tourism revenue to local communities, so that local people see direct financial benefits from park tourism.

8. Allocate sufficient funds for effective planning and management of protected areas, including the management of tourism. A professional management team should be in place, with funding, before the area is opened to tourism.

9. Ensure every protected area has a realistic budget.

10. Encourage creative and innovative methods for raising revenue for protected areas.

11. Urgent management plans are:
    - Clear coral reef zoning and proper implementation.
    - Reduce the impacts of fishing and tourism.
    - Raise local and national awareness of the ecological and economic importance of coral reefs.
    - Restrict law enforcement in marine protected areas.
    - Develop appropriate methods and techniques for coral reef restoration.

References

Department of Fisheries 1999. Coral Reef Maps in Thai Waters. Vol.1-2. pp. 284 +198 (in Thai).

Yeemin T, Ruengsawang N, Sudara S. 1999. Coral reef ecosystem in Thailand. In: C. Koh, editor. Proceedings of the 1st Korea-Thailand Joint Workshop on Comparison of Coastal Environment: Korea-Thailand, Seoul, Korea,. Seoul: Seoul National University. p. 30-41.

Yeemin T, Sudara S, Kraiphanont N, Silsoonthorn C, Ruengsawang N, 2001. Asa S. In the International Coral Reef Initiative Country Report: Thailand. Regional ICRI Workshop for East Asia, Cebu, Philippines.

Chou LM, Tuan VS, Philreefs, Yeemin T, Cabanban A, Suharsono, Kessna I. 2002. Status of Southeast Asia Coral Reefs. In: Wilkinson C., editor. Status of Coral Reefs of the World: 2002. Australian Institute of Marine Science, Townsville, Queenlands, Autralia. p. 123-153.

www.dmcr.go.th

Yeemin T, Ruengsawang N , Buaruang J. 2001. Coral reef management strategy policies in Thailand : lessons learnt for a decade. Paper presented at The 5th International Conference on the Environmental management of Enclosed Coastal Seas, Kobe, Japan.

Yeemin T, Ruengsawang N, Buaruang J, Nopchinwong P, Asa S, Panthewee W. 1998. Coral bleaching in the Gulf of Thailand: a significant natural disturbance. Paper presented at 24th Congress on Science and Technology of Thailand, October 1998: Bangkok, Thailand.

Yeemin, T. 2004. Progress report of the project on development of appropriate techniques and methodologies in coral reef rehabilitation for sustainable tourism in Krabi, Trang and Satun Provinces, Ramkhamhaeng University.

Office of the National Environmental Board (ONEB) 1991. A National Coral Reef Strategy for Thailand, Volume 1. Statement of Need. Office of the National Environmental Board, University of Rhode Island, and U.S. Agency for International Development.

SEA-Coral Reefs-Thailand 2003(a). Review of National Legislation for Coral reefs, Thailand. UNEP/GEF Project on Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand.

Eagles PF, Bowman J, Margaret E and Tao TC-H. 2001. Guidelines for Tourism in Parks and Protected Areas of East Asia. IUCN, Gland, Switzerland and Cambridge, UK.

SEA-Coral Reefs-Thailand 2003(b). Review of National Data and Information: Coral reefs, Thailand. UNEP/GEF Project on Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand.

SEA-Coral Reefs-Thailand 2003(c). Demonstration Site Proposal: Mu Koh Chumporn, Thailand. UNEP/GEF Project on Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand.

Thamrongnawasawat T, 2004. Recommendations for Mu Koh Surin National Park Management. Report on ICRAN Project: Mu Koh Surin, Thailand.

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2.6. VIETNAM

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Abstract

The surveys during 2002 – 2003 provided more information to confirm high biodiversity of coral reefs in Vietnam with the records from 300 to 350 reef building coral species in some areas in the south coastal waters. The results of coral reef monitoring at 10 sites, however, showed a negative figure of coral reef status. Data obtained by Reef Check and AIMS techniques presented the dominance of reefs with poor and fair conditions of coral cover (18% and 30% respectively at 50 monitored reefs). Abundance of invertebrate and fish indicators also showed reduce of reef economical organisms. Positive figure was only recorded at some reefs in Ninh Thuan, Phu Quoc. As presenting in previous status report, main threats to coral reefs included over-catching and destructive fishing... Moreover, there were some abnormal phenomena happening during 2002 – 2003. Meanwhile coral bleaching did not occur extensively as in 1998, there was the serious outbreak of Crown of thorn starfish in Van Phong and Nha Trang bays. Environmental risk caused by algae bloom killed almost coral reefs in Ca Na bay (Binh Thuan province) and the recovery is occurring slowly after the event. Sedimentation is continuously considered as a strong impact in Ha Long – Cat Ba islands with extensive threats to coral reefs. Recently, Vietnam government and oversea agencies have supported to develop a network of marine protected areas. Preliminary results of Hon Mun and Cu Lao Cham projects and initial activities of some new National Parks (Phu Quoc, Nui Chua) are creating perspective to manage MPAs with coral reefs as a target ecosystem. Local governments at number of sites are encouraging to build different models suitable to their practices in coral reef management and wise use. National action plan for coral reef management is also developing in the framework of UNEP GEF / SCS project and will be approved by authorization of Vietnam government.

Table 1: Summary Status of Coral Reefs Monitored in South Vietnam During 2002 - 2003

Areas	Number of sites	Total coral cover categories (%)			
		0 - 15	16 - 30	31 - 50	51 - 75
Cu Lao Cham	***5***		2	3	
Van Phong bay	***4***		3	1	
Nha Trang bay	***9***	2	4	2	1
Ninh Thuan	***6***		2	2	2
Ca Na bay	***4***	1	1	1	1
Con Dao	***8***	3	1	3	1
Phu Quoc	***6***		1	5	
Nam Du	***4***			3	1
Tho Chu	***4***	3	1		
Total	***50***	9	15	20	6
Ratio (%)	***100***	18	30	40	12

Introduction

Vietnam has coastline more than 3200 km stretching through more than 15 degrees of latitudes from 8o30' N to 23oN with a big variation in climate and biodiversity along this broad N – S cline. In term of socio – economic, Vietnam has been implementing "Doi Moi" policy which creates strong development during recent years. Twenty nine coastal provinces per 64 in the total contribute a very important role during the country's development.

Table 2: Summary Country Statistics and Coral Reef Resources

Land area	332,200 km^2 (MacKinnon, 1997)
Population	78 million
Population density	217 / km^2
Coastline length	3260 km
No. coastal provinces	29
Shelf to 200m in depth	3,279,000km^2
EEZ	1,000,000km^2
No. of islands	More than 3000
Est. Coral Reef area	1,300km^2 (Spaldling, 2000)

Coral reef distribution

Geographic location and natural conditions of Vietnam coastal waters in general is suitable for development of reef-building species except some areas affected strongly by river inputs with low salinity and high turbidity. Coral reefs normally distribute at shallow coastline waters, around the islands with hard bottom, and create series of atoll in offshore islands including Paracel and Spratly archipelagoes (Figure 1). However, distribution and morphology of coral reefs relatively differ amongst geographic locations.

In term of reef-building coral ecology, natural conditions of coastal areas in western Tonkin Gulf are less favorable for reef development. Unfavorable factors are low temperature in the winter and big influences of river inputs from the mainland. Corals mainly distribute in the outwards of Ha Long Bay, Bai Tu Long, Co To archipelagos, Long Chau islands which are mostly surrounded by shallow and muddy bottoms. Coral reefs in the western Gulf of Tonkin are, therefore, narrow and just expand until the depth only of 5-7 meter. Coral reefs just spread to the depth of 10 meter in some further areas, eg. Bach Long Vi island.

Coral reefs grow better in the coastal central waters and islands of Southeastern areas. The temperature of these areas is normally higher than 20 0C and has offshore influences. Substratum morphology constitutes many bays and islands, which partly create diversity in habitats. Thus, coral reefs popularly distribute surrounding most islands from Cu Lao Cham to Con Dao and along the coastline from Danang to Binh Thuan province. Fringing coral reefs are very diverse in morphology and may be large from 50 to 800 meter. Besides, many reefs are observed on submersed banks which are common in the continental shelf.

Nearshore areas of Southwestern waters are unfavorable for coral growth because of muddy bottom and low transparence. Coral reefs there distribute surrounding offshore islands such as Phu Quoc, Nam Du, Tho Chu are relatively similar in morphology because of low fluctuation in hydrological regime and hydro-dynamics The differentiations are mainly created by bottom structures. The coral reefs here are normally from 50 to 100 meter large and spread to 10 – 13 meter deep.

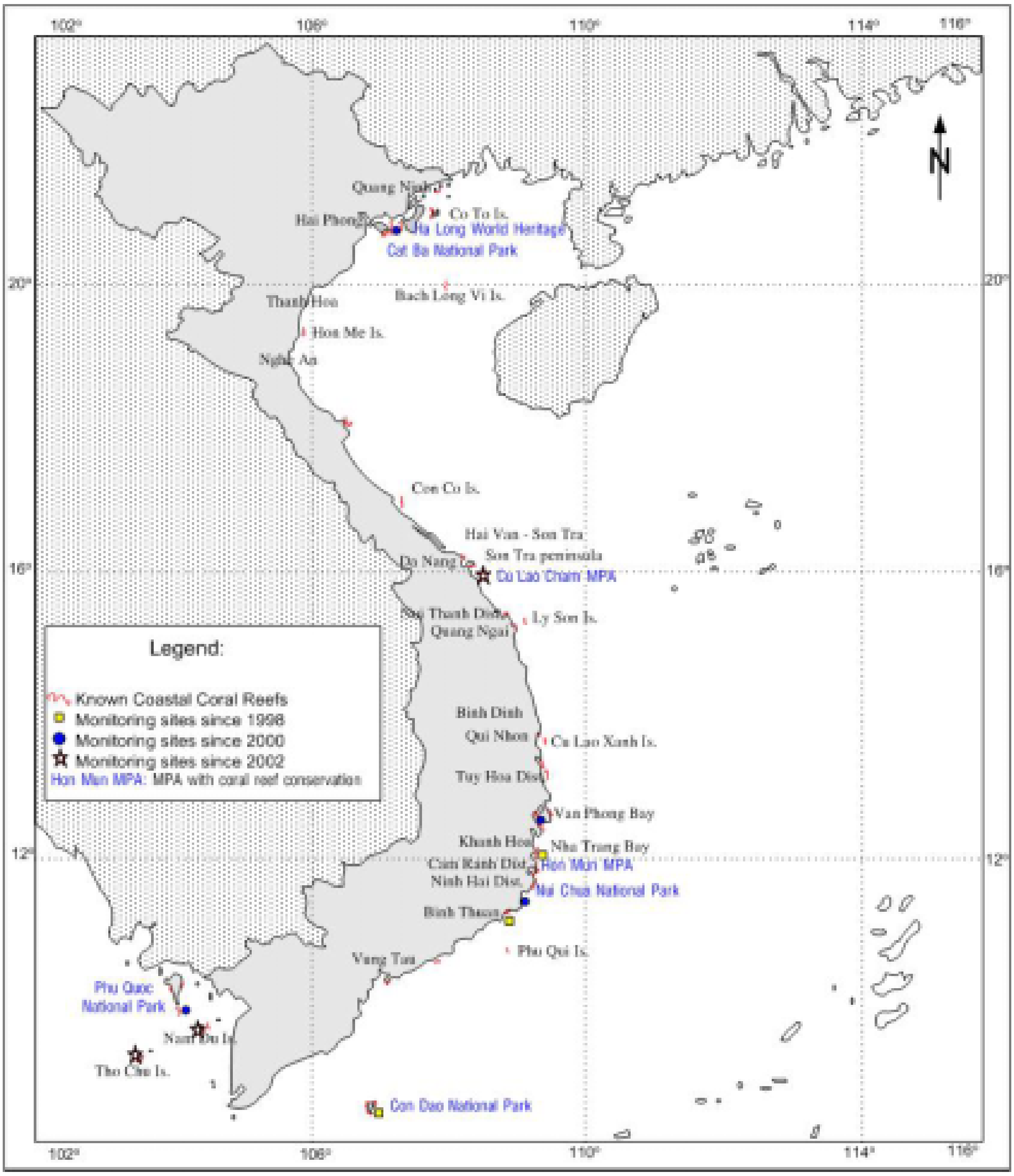

Figure 1: Reef Distribution in the coastal waters of Vietnam (also monitoring sites and MPAs)

Biodiversity

Based on the taxonomic system of Veron & Stafford-Smith (2000) and after amending results of Vietnam coral taxonomy of many authors up to date, a list more than 400 hard coral species belonging to 81 genera, 18 families was established. From more than 400 known species, there are some 380 species belonging to 74 genera of the hermatypic corals (Table 3).

Table 3. List of hard coral genera with their distribution in the coastal waters of Vietnam (* Ahermatypic corals)

No	Genera	West Tonkin Gulf	Midle central	South central	South-eastern	South-western
1	*Stylocoeniella*	+	-	+	+	-
2	*Pocillopora*	+	+	+	+	+
3	*Seriatopora*	-	+	+	+	+
4	*Stylophora*	+	+	+	+	+
5	*Palauastrea*	-	-	-	-	-
6	*Madracis*	+	+	+	+	+
7	*Montipora*	+	+	+	+	+
8	*Anacropora*	-	+	+	+	-
9	*Acropora*	+	+	+	+	+
10	*Astreopora*	+	+	+	+	+
11	*Porites*	+	+	+	+	+
12	*Goniopora*	+	+	+	+	+
13	*Alveopora*	+	+	+	+	+
14	*Pseudosiderastrea*	+	+	+	+	+
15	*Psammocora*	+	+	+	+	+
16	*Coscinarea*	+	+	+	+	+
17	*Pavona*	+	+	+	+	+
18	*Leptoceris*	+	+	+	+	+
19	*Gardineroseris*	-	+	+	+	+
20	*Coeloseris*	-	+	+	-	+
21	*Pachyseris*	+	+	+	+	+
22	*Cycloseris*	-	+	+	+	+
23	*Diaseris*	-	+	+	+	+
24	*Cantharellus*	-	-	+	+	+
25	*Heliofungia*	-	-	+	-	-
26	*Fungia*	+	+	+	+	+
27	*Ctenactis*	-	+	+	+	+
28	*Herpolitha*	+	+	+	+	+
29	*Polyphyllia*	+	+	+	+	+
30	*Halomitra*	+	-	+	+	-
31	*Sandalolitha*	+	+	+	+	+
32	*Lithophyllon*	+	+	+	+	+
33	*Podobacia*	+	+	+	+	+
34	*Galaxea*	+	+	+	+	+
35	*Echinophyllia*	+	+	+	+	+
36	*Oxypora*	+	+	+	+	-
37	*Mycedium*	+	+	+	+	+
38	*Pectinia*	+	+	+	+	+
39	*Blastomussa*	-	-	+	-	-
40	*Micromussa*			+		
41	*Cynarina*	+	+	+	-	-
42	*Scolymia*	-	+	+	+	+
43	*Australomussa*	-	-	+	-	-
44	*Acanthastrea*	-	+	+	+	+
45	*Lobophyllia*	+	+	+	+	+
46	*Symphyllia*	+	+	+	+	+
47	*Hydnophora*	+	+	+	+	+

No	Genera	West Tonkin Gulf	Midle central	South central	South-eastern	South-western
48	*Merulina*	+	+	+	+	+
49	*Caulastrea*	-	+	+	+	+
50	*Favia*	+	+	+	+	+
51	*Barabatoia*	+	+	+	+	+
52	*Favites*	+	+	+	+	+
53	*Goniastrea*	+	+	+	+	+
54	*Platygyra*	+	+	+	+	+
55	*Australogyra*	+	+	+	-	+
56	*Leptoria*	+	+	+	+	+
57	*Oulophyllia*	+	+	+	+	+
58	*Oulastrea*	+	+	+	+	+
59	*Montastrea*	+	+	+	+	+
60	*Plesiastrea*	+	+	+	+	+
61	*Diploastrea*	-	+	+	+	+
62	*Leptastrea*	+	+	+	+	+
63	*Cyphastrea*	+	+	+	+	+
64	*Echinopora*	+	+	+	+	+
65	*Moseleya*	-	-	-	-	+
66	Trachyphyllia	+	+	+	+	+
67	Wellsophyllia	-	+	-	-	-
68	Euphyllia	+	+	+	+	+
69	Catalaphyllia	-	-	+	-	-
70	Plerogyra	+	+	+	+	+
71	Physogyra	+	-	+	+	-
72	Heterocyathus *	-	+	+	-	+
73	*Turbinaria*	+	+	+	+	+
74	*Duncanopsammia*	-	-	+	-	+
75	*Heteropsammia*	+	-	+	+	+
76	*Dendrophyllia* *	+	+	+	+	+
77	*Tubastrea* *	+	+	+	+	+
78	*Balanophyllia* *	+	-	+	-	+
79	*Culicia* *	-	-	+	-	-
80	*Flabellum* *	-	-	+	-	-

In total, the record of 74 hermatypic genera proved that the coastal waters of Vitenam have high generic richness of coral fauna of the world. The basic advantage is geographic location of the waters closed to the coral dispersal center including Philippine – Indonesia. However, levels of coral diversity should not be identical for whole coastal waters due to length over 3000 km of coastline crossing many latitudes. The reason is that coral distribution crossing the latitudes related to gradient of physical environment and ecological change. These are main factors affecting biodiversity of corals (Veron, 1998).

The surveys on coral fauna characteristic (Vo Si Tuan, 1998) showed a clear differentiation in generic richness of the hermatypic corals in the coastal waters of Vietnam under influences of natural conditions (temperature, dispersal level with coral diversity center, coastline change in the history and sedimentation regime. Supplementary analysis improved this hypothesis with some change. South central waters might be assumed as the most diverse area in the number of recorded genera (71) and also species number with nearly 350 in Nha Trang bay (Vo Si Tuan et al., in press), more than 300 in Ninh Hai reefs (DeVantier, unpublished). The number of recorded genera at southeastern and middle central waters are relatively diverse (61 genera). Detailed surveys at Con Dao islands showed species richness of hermatypic corals with more than 300 species recorded (DeVantier, unpublished). Records of 60 hermatypic genera in southwestern waters recommended that coral fauna there is more diverse than that in Tonkin Gulf (53 hermatypic genera recorded).

The supplementary surveys during 2002 – 2004 allow to assume that there are 4 zones of reef-building coral distribution and to adjust the isopangeneric contours of reef-building corals established by Veron (1993) for South China Sea (Figure 2). The boundaries between zones are based on the differences among water masses of western part of South China Sea (Vo Si Tuan, 1998). The isopangeneric contour of 60 genera originates from Con Co island (appr. 17th latitude). Tonkin Gulf should belong to area less than 60 genera of hermatypic corals. Middle central waters are located in the southern side of this line and the number of genera ranged from 60 - 70. Isopangeneric contour of 70 genera originates from Varella cape (approximately 13th latitude) and then covers Paracel and Spratly archipelagos. The survey on population inter-dependence in the South China Sea using genetic structure of the fish Dascillus trimaculatus (Ablan et al., 2002) supported the establishment of a boundary in Varella cape. The areas with more than 70 genera compose of South central waters, Paracel and Spratly. Isopangeneric contour of 70 genera in the South originates from northern limitation of influence of Mekong River. Although only 61 genera of hermatypic corals recorded up to present, Con Dao islands are proposed being encompassed in this area because of favorable natural conditions and its species diversity in limited reef area. Besides, southeastern submersed banks without surveys yet have also potential to add the list of hard corals.

Table 4: Estimated number of species for major groups of coral reef organisms in the coastal waters of Vietnam

Taxon	*No. Family*	*No. Genera*	*No. Species*
Echinoderm	30	63	96
Crustacean	44	144	251
Polychaeta	38	110	176
Molluscs	78	177	446
Fish	44	139	411

The surveys from 1993 to present on coral reef communities provided a list nearly 1000 species of invertebrates (Table 4). Moluscs were the most diverse with nearly 500 species recorded and than Crustacean – more than 250 species, Polychaeta – appr. 170 species and Echinoderm – nearly 100. Reef littoral fauna occupied more than 200 species, the rest belonged to sub-littoral organisms. The areas of Con Dao islands and coastal waters of Khanh Hoa province received more surveys with more than 400 and 300 species respectively.

In total, some 411 species of coral reef fish, from 139 genera in 44 families were recorded in some major locations in coastal waters of Vietnam. Of these, the families Pomacentridae (66 species) and Labridae (61 species) were both well represented, as was the Chaetodontidae (32 species). The locations in the south-central Vietnam, including Nha Trang Bay and Ca Na Bay had more diverse in species of coral reef fish, having number of 222 and 211 species respectively, than other locations in coastal waters of Vietnam.

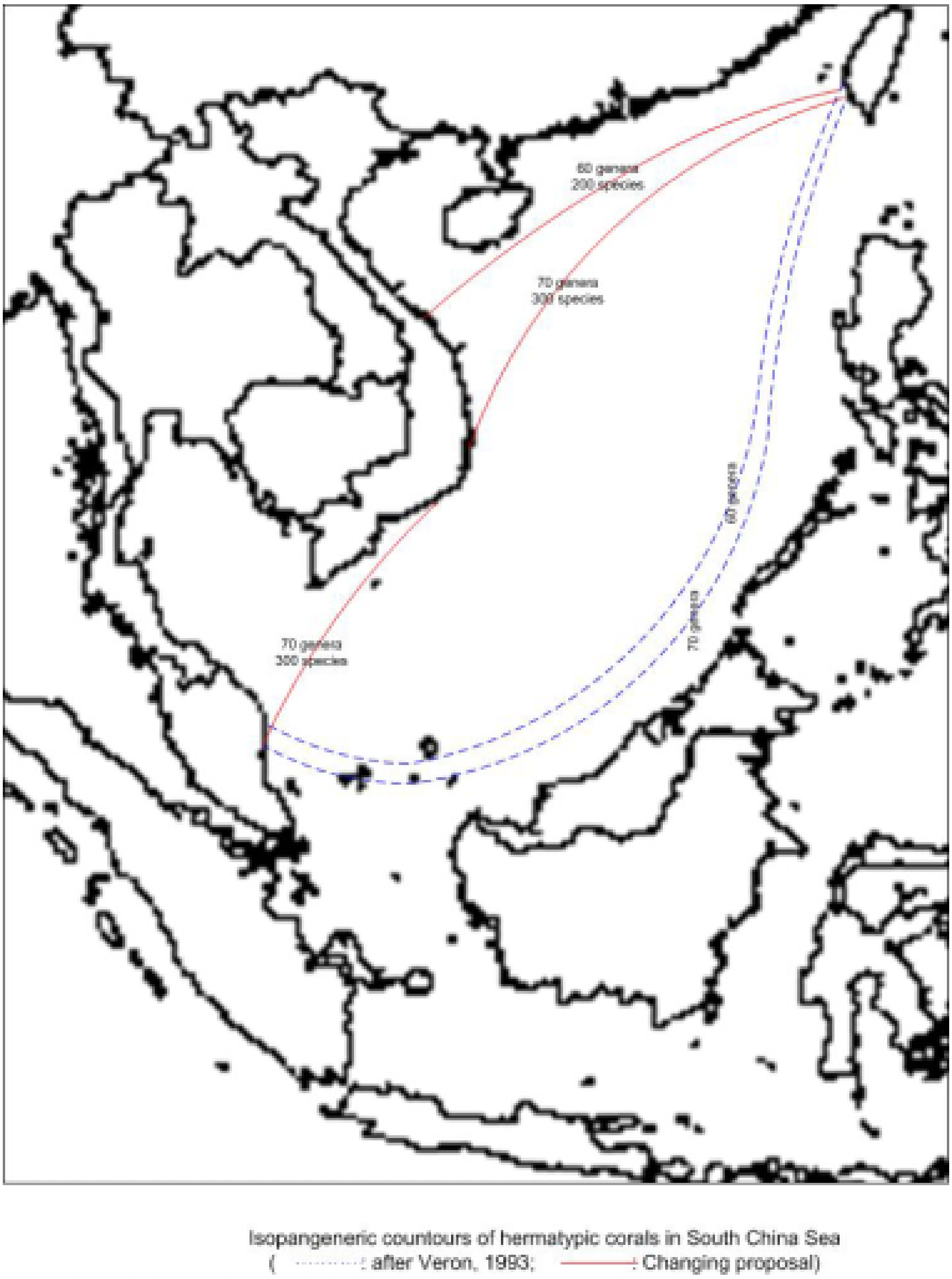

Figure 2. Vietnamese waters belonging to high diversity of hermatypic corals

Resource Use

i) Fisheries

Although no data on current harvest of reef fishes and invertebrates are available in the most of coastal provinces, but fisheries from reefs have been considered as a major economic benefits to different coastal communities in Vietnam. Many commercial species of fish, molluscs, crustaceans and echinoderms live and shelter in coral reefs and these are the important resources.

Table 5: Main fishing activities and marine resources collected on coral reefs in Vietnam.

Fishing activity	Main marine organisms fished
Hookah air diving with or without dynamites and poisons	Groupers, sweetlips, top shells, triton shells, giant clams, lobsters, ornamental fish and live corals
Net (gill net, purse seine, drift net)	Sweetlips, snappers, cardinalfish, coral breams, anchovies
Light fishing	Anchovies and cuttlefish
Long line	Cuttlefish and fish
Fixed net	Mackerel, tuna, snapper, jacks
Trap net	Cuttlefish and fish
Gleaning on tidal flat	Seaweeds, gastropods, bivalves and fish

Coral reef fisheries are typically multi-species fisheries with typically multi-gear fisheries being used. Different fishing activities including hookah air diving, purse seine and gill net, light fishing, drift nets, long line, most trawls and gleaning on tidal flat are commonly found in the coastal provinces in Vietnam where coral reefs involved, with a variety of marine organisms being harvested (Table 5).

Many commercial reef fish such as groupers, snappers, sweetlips, emperors, parrotfish and triggerfish are being caught. Live groupers Epinephelus spp., Plectropomus spp. and Cephalopholis spp. have become the favoured targets and being harvested on the reefs because of their high prices. Lobster is also bring high benefit not only by catching but also by cage culture with juveniles from the nature. During the last some years, ornamental fish such as butterflyfish, angelfish, wrasse, scorpions,… were being caught for local and international aquarium trade.

It can be said that coral reef species trade has developed rapidly in Vietnam as the demand for live reef species, especially the one for food, is growing due to consumers demand and the economic development of many Asia countries, especially China. In addition, Vietnam is located near to the two biggest markets such as Hong Kong and China - a nation importing upto 90% of food fish in the world. Most of live reef species is exported legally from the southern provinces, through Tan Son Nhat Airport of Ho Chi Minh City. In the north, a small amount of live reef species is transported over land crossing the border provinces with China. Some others go through the Noi Bai Airport of Hanoi. Illegal exports to China and Hongkong is mainly conducted by ships. This export means are popular in the northeastern Vietnam.

ii) Tourism

Nha Trang City is considered as a major center of marine tourism development in Vietnam where coral reefs surrounding nearby islands are very diverse and abundant. Number of visitors to Nha Trang has recently increased, with an approximate value in excess of more than 300 billions VND (equivalent 20 millions US$) being recorded in 2003. Annual visitation to the islands in Nha Trang Bay was estimated at 30,000 people in 1995 to more than 400,000 people in 2003. About ten percent of them joined diving and snorkling on the reefs of Hon Mun MPA. These services brought benefit about 400,000 US$ occupying approximate 2% of total income of tourist sector in Khanh Hoa province. There was a further dramatic increase in numbers and diversification of operations. A tourism survey conducted by IUCN in 2000 revealed that many tourists would be willing to pay round US$ 1-2 each to visit Hon Mun Marine Protected Area.

Tourism can be expected to play an increasingly important role in the development strategies of Phu Quoc district, Kien Giang province for the next ten years. Number of tourists (mostly domestic tourists) visited the islands has been increased dramatically during the last 7 years, from 4,543 people in 1995 to 74,997 people in 2001. The total international tourists visit Phu Quoc in 1995 were 1,106 peoople, increasing to 42,748 people in 2001. The duration of international visitors spent at the islands avearged 3 - 4 days per person while this increased to 3 - 5 days to domestic tourists. The total benefits of the district collected from tourism have also increased from 1.5 billions in 1995 to 11 billions VND in 2001. At present, tourism in Phu Quoc has been mainly focused on land while marine environment was not well attractive to visitors. Plans for marine tourist development have been designed by many coastal provinces. Some coral reef locations shall play an important role such as Con Dao, Phu Qui, Cu Lao Cham islands, Ha Long bay...

iii) Other use
Dead coral exploitation for lime material and making dykes of aquaculture ponds has been popularly happened at some places of south central provinces. Some living hard corals, horny corals and soft corals are currently exploiting and trading at the big scale without control in species, exploitation yield, and transparency in the coral trade.

Cage aquaculture is developing now in some coastal waters with main species including lobsters, groupers. Their juveniles are collected from coral and rocky reefs. Recently, there are some 15 thousands of cages rearing more than a million lobsters in south central Khanh Hoa province (mainly at Nha Trang and Van Phong bays).

Uses of coral reefs as a resource for education and aesthetic have been considered in Nha Trang bay and Con Dao National Park. There were number of students from different universities coming for enhancing awareness and knowledge on marine ecology and conservation. The photos contest on natural beauty was organized last year with number of photos of coral reefs of Nha Trang and Van Phong bays.

Status of Coral Reefs

During 2002 – 2003, coral reef monitoring in Vietnam were practiced following ReefCheck and AIMS techniques with some modification to meet Vietnamese capacity. There were two new sites established in the gulf of Thailand and the areas monitored in the north were not continued in this period. As the discussion during International Workshop on Coral Reef Monitoring Data, Penang, Malaysia, 2 –4 December, 2003, a simplification to a 5 point scale was recommended for presentation of monitoring variables. The meeting designed criteria for categorizing and scoring all indicators to calculate Reef Condition Index (Cover/Abundance Index, Pest Index and Stress/Damage index), Human threat Index, and Reef Management Index.   These indexes were used in the paper for assessment of reef status. Based on score range of each variable and index, it is possible to understand the status of whole the reef and also of single parameters (Table 6).

Table 6. Categories of score range for assessment of reef status (Designed by International Workshop on Coral Reef Monitoring Data, Penang, Malaysia, 2 –4 December, 2003)

Score range				
1 - 1.8	1.81 - 2.6	2.61 - 3.4	3.41 - 4.2	4.21 - 5
Poor	Fair	Good	Very Good	Excellent

Status of Reef Benthos

The data collected at 9 monitored areas show low cover of hard corals (Table 4). The reefs at coastal Ninh Thuan and around Nam Du islands reached the best cover   (average value more than 40%). The lowest covers belong to the reefs around Tho Chu islands and in Ca Na bay. In overall, Acropora corals occupied low cover, except at Ninh Thuan reefs. The reasons would be their sensitivity to storms and coral bleaching, example at Con Dao during 1997 - 1998 (Vo Si Tuan, 2000). Soft corals were more common at the reefs of Cu Lao Cham islands (middle central coastal waters). Fleshy macroalgae was recorded abundantly around Tho Chu islands and also in Van Phong bay.

Table 7: Site Summaries for Benthos Cover (%) of Monitored Reefs of Vietnam

Areas	*Values*	*Acropora*	*Non-Acropora*	*Hard corals*	*Soft corals*	*Fleshy Macroalgae*	*Other benthos*	*Dead corals*
Cu Lao Cham	**Mean**	**0.38**	**18.37**	**18.75**	**16.25**	**4.62**	**2.94**	**0.75**
	Stdev	0.50	7.29	7.17	9.34	3.03	2.28	0.73
Van Phong bay	**Mean**	**5.86**	**21.02**	**26.88**	**1.17**	**6.095**	**4.77**	**10.08**
	Stdev	6.67	7.37	4.63	1.56	7.26	5.09	13.72
Nha Trang bay	**Mean**	**3.45**	**20.16**	**23.61**	**3.23**	**4.13**	**3.72**	**5.00**
	Stdev	4.29	10.31	13.26	3.17	5.47	2.56	4.85
Ninh Thuan	**Mean**	**15.11**	**24.98**	**40.08**	**0.63**	**2.03**	**2.87**	**1.88**
	Stdev	11.65	12.75	15.04	0.77	2.37	4.57	4.44
Ca Na bay	**Mean**	**2.81**	**14.81**	**17.63**	**9.25**	**3.25**	**4.06**	**33.63**
	Stdev	2.62	14.59	16.00	14.02	4.23	4.11	42.61
Con Dao	**Mean**	**6.60**	**16.48**	**23.08**	**0.23**	**7.77**	**0.74**	**0.00**
	Stdev	8.65	16.07	18.05	0.43	7.33	0.85	0.00
Phu Quoc	**Mean**	**5.67**	**30.84**	**36.51**	**0.00**	**0.00**	**3.34**	**0.05**
	Stdev	3.51	9.10	9.79	0.00	0.00	1.35	0.12
Nam Du	**Mean**	**2.73**	**44.62**	**47.35**	**0.00**	**0.79**	**5.71**	**0.71**
	Stdev	0.82	11.85	11.69	0.00	0.79	1.41	0.39
Tho Chu	**Mean**	**7.19**	**4.14**	**11.32**	**0.00**	**19.76**	**0.86**	**0.08**
	Stdev	4.99	1.51	4.73	0.00	11.46	0.97	0.16

Reef monitoring activities during 2002 – 2003 mainly considered the abundance of Crown of Thorn Starfish (COTS) and Diadema sea urchin for benthos (Table 8). The records of high density of COTS on the reefs of central coastal waters (Cu Lao Cham islands with the average density of 50 ind./ha), Van Phong - > 150 ind/ha and Nha Trang bays - > 60 ind./ha) suggested further surveys to explain the reasons. The outbreak of COTS in Nha Trang bay started in 2001 (Vo Si Tuan, 2002) and continues a problem for reef conservation (Vo Si Tuan et al., 2002). Sea urchin Deadema reach rather high abundance around the coastal islands of the gulf of Thailand (Phu Quoc and Nam Du). The comparison of Diadema density in 2000 – 2001 (Vo Si Tuan, 2002) with that during 2002 – 2003 recognize the increasing trend at almost areas, except at Ninh Thuan coastal waters (Table 9).

The score estimation for cover of benthic groups was done based on classifying cover categories of Englich et al. (1997). The data did not permit to estimate score of coral covers based on comparison with previous data to have good assessment of trend of change because of lack of data of some new sites. The detailed index scores once again reflect the condition of the reefs and make easier to compare among the areas (Table 10). Almost reefs are in fair and good conditions in term of hard coral cover. COST indexes showed the problem for the areas not only with high average density (Van Phong, Nha Trang, Cu Lao Cham) but also common observation as in Tho Chu islands. Fleshy Macroalgae indexes presented good condition for almost reefs.

Table 8: Area Summaries for Benthos Abundance (ind./500m^2)

Areas	*Values*	*Crown Of Thorn Starfish*	*Diadema*
Cu Lao Cham	**Mean**	**2.50**	**26.61**
	Stdev	3.50	32.65
Van Phong bay	**Mean**	**7.74**	**43.92**
	Stdev	12.52	48.16
Nha Trang bay	**Mean**	**3.34**	**63.13**
	Stdev	3.45	85.05
Ninh Thuan	**Mean**	**0.00**	**4.17**
	Stdev	0.00	3.24
Ca Na bay	**Mean**	**0.24**	**125.76**
	Stdev	0.34	163.71
Con Dao	**Mean**	0.13	20.38
	Stdev	0.35	56.03
Phu Quoc	**Mean**	**0.08**	**434.09**
	Stdev	0.20	173.20
Nam Du	**Mean**	0.00	460.88
	Stdev	0.00	189.11
Tho Chu	**Mean**	1.13	89.77
	Stdev	1.34	132.55

Table 9. Increasing trend of *Diadema* density (ind./500m^2) on the reefs of south Vietnam

Areas	**2000 - 2001**	**2002 - 2003**
Van Phong	28.5	43.9
Nha Trang	4.6	63.1
Ninh Thuan	7.1	4.1
Con Dao	4.9	20.4
Phu Quoc	124.3	434.1

Table 10: Area Summaries: Index Scores for Major Benthic Groups (COTS - Crown of Thorn Starfish and DIAD - *Diadema*)

Area	Hard Corals	Soft Corals	Other sessile Benthos	Fleshy Macroalgae	COTS	DIAD
Cu Lao Cham	2.00	2.00	1.00	5.00	3.60	4.20
Van Phong	2.25	1.00	1.00	4.75	2.75	4.25
Nha Trang	2.11	1.11	1.00	4.89	3.00	4.00
Ninh Thuan	3.00	1.00	1.17	5.00	5.00	4.67
Ca Na	2.20	1.60	1.00	5.00	4.80	4.20
Con Dao	2.13	1.00	1.00	4.75	4.75	4.88
Phu Quoc	2.67	1.00	1.00	5.00	4.83	3.33
Nam Du	3.50	1.00	1.00	5.00	5.00	3.50
Tho Chu	1.75	1.00	1.00	3.75	3.50	4.00
Average	**2.40**	**1.19**	**1.02**	**1.21**	**4.46**	**4.26**
Stdev	**0.55**	**0.36**	**0.06**	**0.41**	**0.85**	**0.56**

Status of Reef Fish

The data analysis of fish main groups showed the density of target fish group (the surveys did not separate size of fish). Predatory reef fish was poor in almost coastal reefs. Only the reefs in the Gulf of Thailand (Phu Quoc, Nam Du and Tho Chu) remained good density of predatory fish. Pomacentrids were the same figure with huge density in the gulf. Meanwhile, grazer fish group was not very different among the areas (Table 11).

Table 11. Area Summaries: Abundance for Fish Groups (PFSH – Large Predatory Reef Fish; GFSH – Large Grazers, POM – Pomacentrids)

Areas	Value	Density (ind./500 m^2)		
		PFSH	GFSH	POM
Cu Lao Cham	**Mean**	**7.40**	**22.60**	**341.60**
	Stdev	4.92	16.85	133.62
Van Phong bay	**Mean**	**2.00**	**62.63**	**297.00**
	Stdev	1.47	59.88	190.18
Nha Trang bay	**Mean**	**5.06**	**61.11**	**463.39**
	Stdev	2.90	22.70	314.01
Ninh Thuan	**Mean**	**2.33**	**23.25**	**163.83**
	Stdev	1.97	12.16	53.26
Ca Na bay	**Mean**	**0.80**	**40.20**	**228.20**
	Stdev	1.25	20.08	100.52
Con Dao	**Mean**	**13.76**	**35.16**	**302.80**
	Stdev	6.73	26.84	243.82
Phu Quoc	**Mean**	**22.92**	**76.00**	**2383.50**
	Stdev	8.18	25.63	2159.36
Nam Du	**Mean**	**36.00**	**20.25**	**4621.38**
	Stdev	20.95	28.32	2428.46
Tho Chu	**Mean**	**36.38**	**23.25**	**6329.88**
	Stdev	15.53	9.13	3086.28

Table 12: Area Summaries: Index Scores for Major Fish Groups

Area	Major Fish Group			Index Score
	PFSH	GFSH	POM	
Cu Lao Cham	7.40	22.60	341.60	3.60
Van Phong	2.00	62.63	297.00	3.50
Nha Trang	5.06	61.11	463.39	3.96
Ninh Thuan	2.33	23.25	163.83	3.33
Ca Na	0.80	40.20	228.20	3.47
Con Dao	13.76	35.16	302.80	4.08
Phu Quoc	22.92	76.00	2383.50	4.50
Nam Du	36.00	20.25	4621.38	3.92
Tho Chu	36.38	23.25	6329.88	4.92
Average	**14.07**	**40.49**	**1681.29**	**3.92**
Stdev	**14.33**	**21.00**	**2298.24**	**0.52**

The logarithmic 4 abundance categories used by Russ (1985; see: English et al., 1997) was applied for scoring fish indexes (Table 12). It is clear that predatory fish had low index in the range of fair condition at a lot of areas. Overall index was better thanks to high score of pomacentrids.

Stress and Damage to Coral Reefs

Sediments and Nutrients

Ha Long – Cat Ba coastal areas are examples for a strong impact of sedimentation on coral reefs. The previous studies showed that the suspended sediment concentration in the water at those areas is rather high. Coral reefs of the Cat Ba National Park were damaged by high sediment concentration discharged from mining activities of Quang Ninh province. The coastal areas in central Vietnam have been known as less impact of river run-off. However, studies also showed that the coral reefs in some nearshore areas are influenced by sedimentation from the rivers in the rainy season. It is highly concerned that high water turbidity has not only locally occurred, but also expanded to a large area, where corals are currently distributing.

Nutrient richness is another threat to number of coastal reefs. Previous surveys recorded over growth of seaweed at some areas in the north paert of Nha Trang Bay and south part of Van Phong Bay... (Pham Van Thom & Vo Si Tuan, 1996). Aquaculture is dramatically developing at shallow areas created negative influence on nearby coral reefs. Data collected from recent studies showed algae blooms at aquaculture areas which will be a potential threat to coral reefs nearby (Pham Van Thom, unpublished).

There was a environmental risk caused by algae bloom occurring in July 2002 which was considered as a natural phenomena. The event killed almost coral reefs along 15 km of the nearshore band of Ca Na bay (Binh Thuan province). The comparison with data collected by coral reef monitoring indicated the strong impact to nearshore communities with coral covers decreasing seriously, even to zero value. The surveys on recovery of hard corals during 2003 - 2004 conducted by quadrate method showed the low recovery with appearance of few colonies (ca. 50 colonies per 100 m^2) of 10 genera, mainly Montipora, Acropora, Pocillopora, Galaxea and Favia (Vo Si Tuan et al., unpublished data).

Overfishing and Damaging Fishing Methods

Overfishing is considered as a common problem of coastal waters of Vietnam. The interview conducted in Cu Lao Cham islands, Hon Mun Protected Area, Ninh Thuan province showed the awareness of local communities on reduction of reef living resources. The data obtained during 2002 – 2003 by coral reef monitoring reflect the poorness of ReefCheck indicators. The commercially valuable groups of large groupers Serranidae (e.g. Plectropomus, Epinephelus, Cephalopholis spp.) and Lutjanidae (Lutjanus spp.) were both highly depauperate and low relative abundance and sizes, reflecting the intense fishing pressure. Only few of them were recorded at few sites in Cu Lao Cham, Con Dao islands, Nha Trang bay. Other notable absentees from almost areas included the labrid Hump head maori wrasse Chelinus undulatus and serranid barramundi cod Cromileptes altivelis, once common components of many Indo-west Pacific reef fish assemblages. These species are among the most favoured of all target fishes for the Asian live fish food trade, and are now locally extinct in many areas of East Asia, almost certainly including Hon Mun MPA. They were observed at only one site of Con Dao islands.

Benthic indicators being commercial species were not recorded at number of sites. The Giant Clam Tridacna squamosa was observed commonly only in Cu Lao Cham. Similarly, the Giant Triton Charonia tritonis was not seen in any of sites monitored. This spectacular shell has been extensively collected from most of its Indo-west Pacific distribution range over the past century, and is still for sale in local marine curio shops of Nha Trang, and a feature of many home ornament collections. Sources of the commercial shells are unknown but may include the Spratley Islands and other remote reef areas. Notable absentees in almost areas were the commercially important sea cucumber species, except in Cu Lao Cham with common observation of low value species Holothuria edulis. The same situation occurred for lobsters which were recorded at few sites of Cu Lao Cham, Nha Trang and Ca Na bays. the focus of a commercial fishery prior to the collapse of its local population. The top shell Trochus nilotichus presented only in Con Dao islands with low density.

Dead coral exploitation using for construction material and making dykes of aquaculture ponds has been popularly happened at some places in south central provinces..coral exploitation at littoral areas decreased distribution areas of corals, created hydraulic unbalance of coral reefs as well as increased sedimentation caused by erosion, aggradations and exploitation. Hard corals, horny corals and soft corals are currently exploited and traded at the big scale for domestic end export demands but without statistic data.

Table 13. Area Summaries: Index for Stress/Damage (DC – Recently killed dead coral, ANC – Anchor damage, BMB – Blast fishing damage, BRK - Coral breakage by other causes, BL - Bleaching, RUP – non-fishing related rubbish, RFB – fishing related rubbish)

Areas	DC	ANC	BMB	BRK	BL	RUP	RFB
Cu Lao Cham	5.00	5.00	5.00	5.00	5.00	1.00	2.80
Van Phong	5.00	5.00	5.00	3.50	5.00	4.00	5.00
Nha Trang	5.00	5.00	5.00	4.44	5.00	4.56	4.44
Ninh Thuan	4.83	5.00	5.00	5.00	5.00	4.83	4.83
Ca Na	3.40	5.00	5.00	5.00	5.00	1.80	5.00
Con Dao	5.00	5.00	5.00	4.75	5.00	1.50	3.88
Phu Quoc	5.00	5.00	5.00	3.00	5.00	1.17	1.00
Nam Du	5.00	5.00	5.00	5.00	5.00	1.00	2.00
Tho Chu	5.00	5.00	5.00	3.00	3.00	1.00	2.25
Average	**4.80**	**5.00**	**5.00**	**4.30**	**4.78**	**2.32**	**3.47**
Stdev	**0.53**	**0.00**	**0.00**	**0.88**	**0.67**	**1.64**	**1.49**

There are few statistic data concerning with destructive fishing. Some interviews with local fishermen showed existence of dynamite fishing in some reef areas. The survey in Nha Trang bay (Vo Si Tuan et al, 2002) showed that ca. 10 % of manta-tows had evidence of blast fishing in the form of 'craters' and/or other obvious physical damage to reef areas - a significant figure when it is remembered that extensive sandy areas and rocky shores also formed a substantial part of the survey and in the latter areas blast evidence is not well preserved. The data collected by monitoring pratices did not record any traces on the transects and the index values were maximum (Table 13). In overall, dynamite fishing has been decreased, but cyanide fishing has been become more popular for increased demand of living fish trade. Hookah diving using poison has brought to high benefit for a lot of coastal fishermen in Cu Lao Cham, Nha Trang and Ca Na bays, Phu Quoc islands... According to above-mentioned survey, evidence of poison fishing was found at a lot of reefs in Nha Trang bay. Abandoned poison fishing 'squirt bottles' were also observed on one reef . Overall ca. 5 % of manta-tow sites were affected, with at least some of the surface-supply 'hookah' divers using poisons to capture fish, both for food and to supply the lucrative aquarium trade. However, cyanide is thought to be used regularly, and evidence is not always obvious.

Anchor and Others Kind of Damage

The damage caused by anchoring was recorded mainly in tourist sites such as Nha Trang bay. As showing in the habitat survey (Vo Si Tuan et al, 2002), anchor damage was apparent in < 10 % of survey sites overall, where almost half the sites were affected to greater or lesser degree, and focused in areas with the most intensive tourism activities. Other sites with noticable damage were in the vicinity of the villages and where fishing boats anchor. Overall data of the monotoring sites did not presented anchor damages on the transects and showed maximun values of the index (Table 13). Meanwhile, some kinds of other damages causing coral breakage, rubbishes (non-fing and fishing related) were recorded in almost areas and presented via low values of the indexes (Table 13). This means that rubishes were dischared a lot directly to the sea by local communities and fishermen.

Development Damage to Coral Reefs

During recent years a number of fishing ports were constructed at a lot of the islands with coral reefs such as Cu Lao Cham, Bach Long Vi, Phu Qui, Con Dao. Port building and dredging nearby Ha Long bay were considered a reason of sediment loading to coral reefs. There has directly or/and indirectly damaged coral reefs but without the detailed surveys on the impacts.

Coral Bleaching

Extensive bleaching has not observed in Vietnam since 1999 with no record in the monitoring during 2002 – 2003 and bleaching index almost being 5, except some records in offshore Tho Chu islands (Table 13). The impacts of the event in 1998 have been recognized via evidences of dead corals with unbroken colonies in Cu Lao Cham, Phu Quoc islands ect. by the surveys during 2002 – 2003. Repeated monitoring in Con Dao islands has been continued to examine the succession of the reefs after detailed surveys in 1998.

Outbreaking or Invasive Organisms

COTs have been a considered problem causing degradation of the reefs in some coastal central areas. Actually, its outbreak occurring for some recent years would be a serious damage to a lot of reefs. The increase of Diadema density in number of areas is also a considered phenomenon. Be aware that the population of this species was decreased during 1999 – 2001 because of catching for lobster culture in Nha Trang and Van Phong bay (Vo Si Tuan, 2002).

Table 14. Integrated Threat index calculated for 4 indicators (CDEV – Coastal development, MPOL – Marine based pollution, OFSH – Over-fishing, DFSH – Destructive fishing)

Areas	***CDEV***	***MPOL***	***OFSH***	***DFSH***
Cu Lao Cham	4.00	4.00	4.00	4.00
Van Phong	2.25	3.00	1.50	2.75
Nha Trang	3.33	3.89	3.89	3.89
Ninh Thuan	4.50	4.50	3.83	3.83
Ca Na	4.20	4.40	3.20	2.20
Con Dao	3.50	4.38	4.75	5.00
Phu Quoc	4.83	5.00	4.00	4.00
Nam Du	5.00	5.00	3.50	4.00
Tho Chu	5.00	5.00	3.25	3.50
Average	**4.07**	**4.35**	**3.55**	**3.69**
Stdev	**0.92**	**0.66**	**0.90**	**0.81**

Potential Threats to Coral Reefs

Burke et al. (2002) with Reef at Risk assessment indicated that most coral reefs in the coastal waters of Vietnam were under threats with 50% of the reefs ranked at high level and 17% at very high level. Destructive fishing was assessed as popular and serious with 85% coral reefs at medium and high levels. This situation would be continued with reduction of blast fishing, but popularity of poisoning because of increased demands of living fish trade. Over fishing was indicated a serious threat to a half of coral reefs and would occur in forthcoming period to meet requirement of local communities with crowded population. The other threats were been concerned by Burke et al. (2002) as lesser like potential sedimentation (47% coral reefs), coastal development (40% coral reefs) and pollutions (7%). These treat could be increased in parallel with rapid economic development of the country. Sedimentation impacts observed in western Gulf of Tonkin and eastern Gulf of Thailand will continue to be a serious concern in near future. Rapid developments of new roads, factories, settlement bases, ports in the coastal zone will cause more physical impacts, sedimentation and nutrient inputs. Marine based pollution would be also increased due to more oil and gas exploitation and marine transportation including an oil - transferring base at Van Phong bay. The estimation of potential threat levels to the monitored reef areas was presented in table 14.

Management

Marine Protected Areas

With the sponsor of GEF, DANIDA and Vietnamese Government, some new MPAs such as Hon Mun, Cu Lao Cham have been established in the network managed by Ministry of Fisheries. A number of protected areas designed before for terrestrial conservation such as Con Dao, Nui Chua, Phu Quoc, Cat Ba National Parks and Ha Long World Heritage have implemented some activities for conservation of coral reefs and related ecosystems (See figure 1 for distribution of protected areas with coral reef conservation). The effectiveness of MPA management has, however, been limited because of low capacity for marine component. Up to present, only Hon Mun and Cu Lao Cham MPAs, and Con Dao National Park have implemented surveys on biodiversity and resource use for zoning and management plan of marine component.

At local levels, some provinces and cities also started to prepare protection plan and managing their coral reefs. The model of coral reef management with various objectives is applied to coral reefs in Ninh Hai district (Ninh Thuan) province in order to resolve the conflicts between economic stakeholders in using and conserving the local reefs. The plan to establish "no-take" zones or sanctuaries with small-scales is being made in Ninh Hai and in Van Phong Bay. However, they are only first-step pilot models in order to seek out effective measures in reaching integrated managing of coral reefs in particular and of marine protected areas in general in a sustainable way.

Monitoring

Coral reef monitoring in Vietnam was officially carried out since 1998 with supports from UNEP, Total Foundation, WWF, DANIDA, ReefCheck and NOAA. Up to present, there have been total 10 monitoring areas using ReefCheck and LIT technique with additional indicators. Besides the monitoring meaning, this way should help with raising awareness of communities on conserving of marine natural resources with the participation from the local people. The data collected have been sent to ReefCheck International and ReefBase. Some results also used for management. For example, management plan of Con Dao National Park is adjusted to increase the effectiveness, and Hon Mun Protected Area and the province authorities organized a propaganda for COT cleanup in Nha Trang bay.

Legislation

Since 1st July 2004, the Law of Fisheries is applied formally in Vietnam. It is very important legal document for marine conservation in general and coral reef conservation in particular. The Chapter on MPA builds a comprehensive base for marine resource management. Under the law, Ministry of Fisheries has developed MPA network with the mechanism to involve related sectors for marine conservation. The network includes existing protected areas designed before for terrestrial conservation located on the coast and islands.

In the framework of UNEP GEF / SCS project "Reversing environmental degradation trend of the South China Sea and Gulf of Thailand, a database of Vietnam coral reefs was established and national report will be published. The National Action Plan for sustainable management is waiting for approval of authorization. Vietnam has blended the region in activities for coral reef conservation.

Conclusions and Recommendations

The data obtained by monitoring during 2002 – 2003 and calculated indexes gave a figure on the status of coral reefs and their management in Vietnam, mainly in the south (table 15). Although lack of considering physical limitation to reef condition, it is possible to notice that the reefs in the coastal waters of Vietnam are not in very good conditions. The monitored reefs had hard coral cover belonging mainly to fair and good categories, and low density of predator and grazer fishes. The Cover/abundance index of all areas had values of average category (good score range). The outbreak of COT occurring in some areas and increasing trend of Diadema sea urchin were phenomena to be considered. Otherwise, some reef areas suffer significant impacts of stress/damage such as coral breakage, rubbish... Human potential and existing activities continue causing impacts to the reefs. There is no reef with intact condition and a number of areas have suffered seriously increased impacts. Existing mechanism for coral reef management is considered in poor and fair condition in a lot of areas with very low values of Reef Management Index.

Table 15. Area summaries: General Score showing Cover /Abundance Index (CAI), Reef Pest Index (RPI), Strees/damage Index (SDI), Reef Condition Index (RCI), Human Threat Index (HTI), Reef Management Index (RMI). (Calculated by method agreed in Penang workshop of GCRMN)

Area	CAI	RPI	SDI	RCI	HTI	RMI
Cu Lao Cham	2.97	3.90	4.11	3.66	4.00	2.80
Van Phong	2.79	3.50	4.64	3.64	2.38	1.25
Nha Trang	3.00	3.50	4.78	3.76	3.75	2.78
Ninh Thuan	2.88	4.84	4.93	4.21	4.17	3.00
Ca Na	2.89	4.50	4.31	3.90	3.50	1.40
Con Dao	2.95	4.82	4.30	4.02	4.41	3.25
Nam Du	3.18	4.25	4.00	3.81	4.38	1.00
Tho Chu	3.18	3.75	3.46	3.46	4.19	1.00
Phu Quoc	3.31	4.08	3.60	3.66	4.46	2.67
Average	**3.02**	**4.13**	**4.24**	**3.79**	**3.91**	**2.13**
Stdev	**0.17**	**0.51**	**0.50**	**0.50**	**0.66**	**0.88**

Recently, management and sustainable use of coral reefs Vietnam have received more consideration from authorization and local communities. The Law of Fisheries, National Action Plan for Coral Reefs and other legal documents reflect interests to coral reef conservation. The implemented activities belonging to different issues (MPA, monitoring, legislation, community involvement) during recent years have indicated perspectives of coral reef management with higher effectiveness. Practically, a number of reefs have received more effective management such as in Con Dao, Ninh Thuan. The newly established MPAs (Hon Mun, Cu Lao Cham) have implemented solutions to improve coral reef management. With the willingness of the Government and oversea support, coral reefs in Vietnam should be conserved for biodiversity conservation and for better life of coastal communities.

References

ABLAN M.C.A., McManus J.W., Chen C.A., Shao K.T., Bell J., Tuan V.S. & Arthana I.W., 2002. Meso-scale Transboundary Units for the Management of Coral Reefs in the South China Sea. Naga, WorldFish Center Quarterly (Vol. 25, No. 3 & 4) July – December: 4-9

BURKE L., SELIG E., SPALDING M., 2002. Reef at Risk in Southeast Asia. World Resource Institute. 72pp.

PHAM VAN THOM, VO SI TUAN, 1997. Characteristics of chemistry environment and possible relation to coral reef degradation in Nha Trang bay. Proceeding of First Conference on Marine Biology, Nha Trang, 1997:54-61 (in Vietnamese)

VERON J. E. N., 1993. Coral of Australia and the Indo-Pacific. University of Hawaii Press. Honolulu.

VERON J. E. N., 1998. Corals in space and time. The biogeography and Evolution of the Scleractinia. VNSW press. 321 pp.

VERON J.E.N. & Stafford-Smith M., 2000. Corals of the World. AIMS Publisher. Three volumes.

VO SI TUAN, 1998. The Hermatypic Scleractinia of South Vietnam. Hong Kong University, The Marine Biology of the South China Sea III: 11- 21.

VO SI TUAN, 2000. Report of status of coral reefs in Vietnam: 2000. Proceeding 9th International Coral Reef Symposium, Bali, Indonesia 23-27 October 2000, vol. 2: 891-894.

VO SI TUAN, 2000. The corals at Con Dao Archipelago (South Vietnam): Before, during and after the bleaching event in 1998. Proceeding 9th International Coral Reef Symposium, Bali, Indonesia 23-27 October 2000, vol. 2: 895-899.

VO SI TUAN, HUA THAI TUYEN, NGUYEN XUAN HOA, LYNDON DEVANTIER, 2002. Shallow water habitats of Hon Mun Marine Protected Area, Nha Trang bay, Vietnam: distribution, extent and status 2002. Collection of Marine Research Works. Volume XII. Institute of Oceanography, Nha Trang, Vietnam.

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3. STATUS OF CORAL REEFS IN NORTHEAST ASIAN COUNTRIES

3.1. CHINA

HUANG Hui

Abstract
Coral reefs play an important role in providing marine biodiversity and marine resources in China. The total area of coral reefs in China, including fringing reefs and atolls, is about 30,000 km^2. The corals in China can be divided into 3 types: Oceanic type: Xisha (Paracel) Islands and Nansha (Spratly) Islands; Transitional type: Hanan Island; Marginal type: Southern China's coastal area.

The degradation trends of coral reefs in China are continuing. The economic and population growths, particularly in coastal areas, are contributing to the degradation of coral reefs. The rich biodiversity is threatened by human activities, such as over exploitation, pollution, coral mining for construction, destructive fishing, and unsustainable tourism. In the past ten years, state and municipal governments have passed legislation to preserve the coral reefs. Coral transplantation experiments have been carried out to rehabilitate the reefs. Extensive survey, long-term monitoring, increasing public awareness, management enforcement, and financial support are the main needs for China.

Introduction
China has an extensive coastline that stretches from its border with Vietnam along the northern South China Sea to the Korean peninsula. However, unlike Taiwan and Japan, The mainland China does not benefit from the Kuroshio warm-water currents. The lack of warm water along much of China's coast has inhibited coral reef growth. This report does not include Taiwan and Hong Kong regions, because their own separated reports will be made by others.

Few coral reef surveys have been carried out in China, with more information available about the reefs in the Sanya Reserve than anywhere else. Reefs in the Ya Long Bay area of the reserve have high live coral cover at 80 -- 90 percent, and they were in good condition. However, a large area of coral bleaching, mainly the Acroporo species, were found this year (2004). Coral cover in the Qionghai Coral Reserve on the eastern Hainan Islands averages between 60 and 70 percent. Reefs outside of reserves are not clear.

Table 1. Summary Country Statistics and Coral Reef Resources

Reef type	Distribution	Area (km^2)	Reference
Oceanic type	Xisha Islands, Zhongsha Islands and Nansha Islands	26060	Summed from Zhao(1999)
Transitional type	Hainan Island	500	Chen G.
Marginal type	Southern China's coastal area mainly in: Xuwen (Leizhou peninsula, southwest Guangdong province); Weizhou Island and Xie Yang Island (Guangxi autonomous region); Nan Ao island and Daya Bay (southeast Guangdong province); Dongshan Bay (Fujian province)	30	Estimated for the listed area individually
Total		26590	26590

Coral Reefs
Coral reefs in China include fringing reefs along the southern China's coastal waters of continent and offshore islands and atolls of South China Sea Islands (see Fig.1). Typical fringing reefs occur mainly on part of coasts of Hainan Island and Taiwan Island. Because high latitude and low winter temperature, only limited and scattered subtidal coral communities and very locally fringing reefs occur along the coasts of

southern China's continent from Dongshan Bay (23 45 N), the westernmost bay of Fujian Province, to western coast of Leizhou Peninsula, and offshore islands from Diaoyudao Islands (25 45 N) to the north of Taiwan to Weizhou Island in Guangxi. There are about 128 atolls of South China Sea Islands including Dongsha Islands, Xisha Islands, Zhongsha Islands and Nansha Islands, of which about half emerged atolls and another half drowned atolls. The emerged atolls and the drowned atolls are about 1/6 and 5/6 of the total area which is about 30,000 km^2 (Zhang, 2000, 2001a). The total area of all about 53 sandy cays or islets on atolls of South China Sea Islands only 11.41km^2 (Zhao, 1999). Up to 2004, there are 3 Marine Coral Reefs Reserves in China. More MPAs are in the planning process.

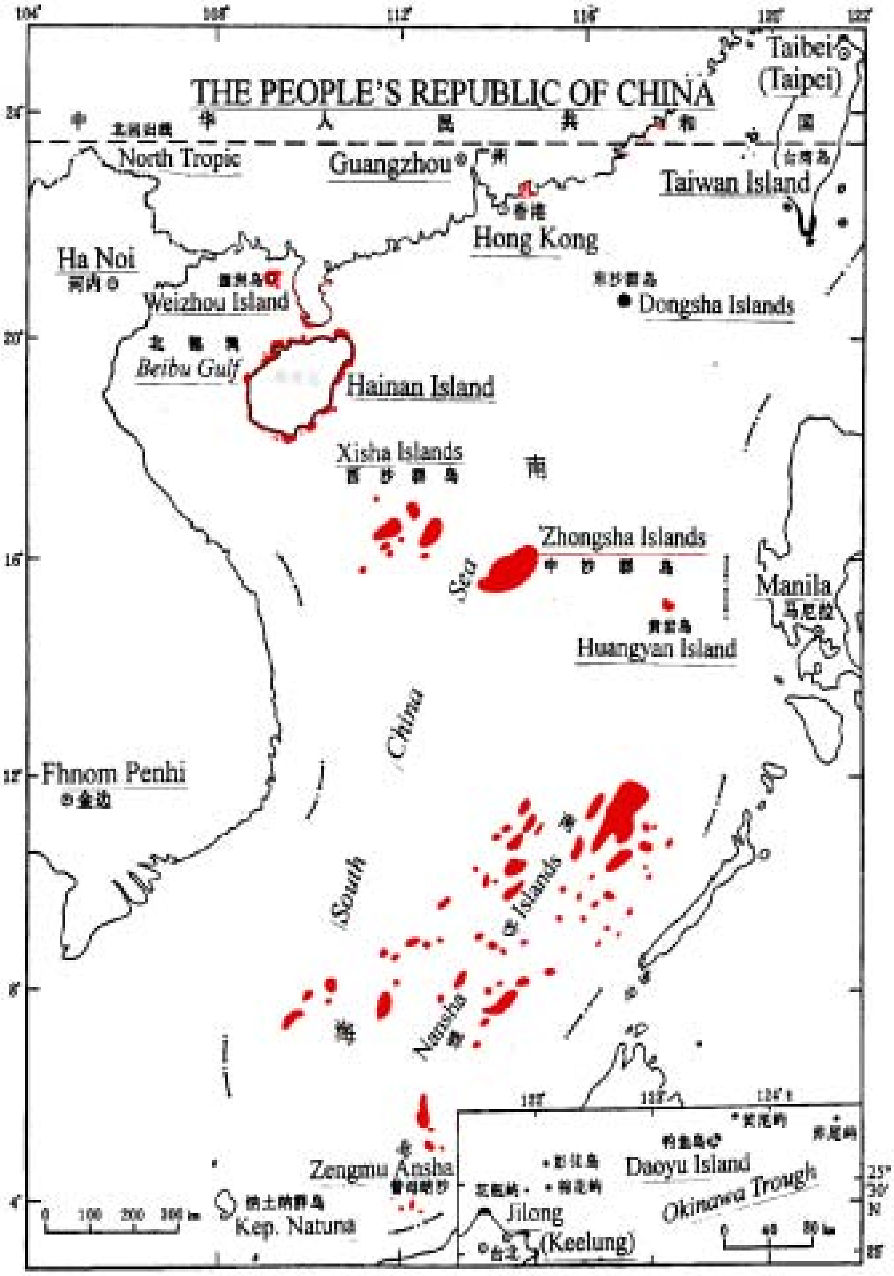

Figure 1. Reef Distribution in China

Biodiversity

Coral reef communities are generally thought to be extremely diverse. Among marine communities, the highest species diversity undoubtedly occurs in certain reef communities. Zou (2001) estimated that at least 54 genera and 174 hermatypic coral species occur in mainland China. 21 genera and 45 species of shallow water reef-building corals 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.

Although stony corals generally comprise the most important component of coral reefs, there are plenty of other organisms living in association with the reefs. South China sea waters hosted at least 12 species of seagrass. The seagrass bed is home for plenty of other organisms, from invertebrates, fish, turtle and dugong.

A great diversity of algae is also living in the coral reefs. Mollusks, crustaceans, echinoderms, polychaete, fishes are other important component of the reef which play their intricate roles in the ecosystems of the coral reef.

Table 2. Estimated Number of Species for Major Groups

	Hard corals	Soft corals	Fish	Molluscs	Echinoderms	Crustaceans	Polychaete	Seagrass	*Algae*
Xisha Islands	127	>9	>500	>500	>127	>350	>93	12	>182
Nansha Islands	>100	>17	>700	>900	>159	>1300	>59	>10	>100
Sanya	60	15	100	367	25	122	NA	5	60

* Note: The figures in the table for corals are based on Zou (2001); The other biota for Xisha Islands are based on books and monographs (South China Sea Institute of Oceanology 1978, Institute of Oceanology 1975, 1978,1980,1983,1985), for Nansha Islands are calculated from Chen (2003), and for Sanya are based on Institute of Marine Planning and Design (2002).

Resource Use

China's reefs have been particularly targeted for economically important fish and mollusc species. Coastal communities have utilized fishery resources, seaweed, and other biological resources for their subsistence for centuries.

i) 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. Spearfishing 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.

ii) Tourism

Reef-related tourism is rapidly developing in Sanya city. In the last decade the natural beauty and uniqueness of coral reefs have attracted millions tourists both domestic and international to travel to Sanya city. Places like Yalong Bay, Xipai Island, West Island, Dadonghai, Xiaodonghai have become major tourist destinations in the country.

iii) Other Uses

Coral reefs can provide raw materials for building construction. The use of stony coral for limestone has been known for several decades in Xuwen, Guangdong province. It will threat the sustainability of the resources, which may have far-reaching environmental impact.

Coral reefs are open laboratories for education and research. South China Sea Institute of Occeanology, Chinese Academy of Sciences (SCSIO), was founded on January 1959. It is one of the largest and most comprehensive multidisciplinary marine research institutions in China. Since its establishment, the SCSIO has done pioneering and foundation-laying research in the fields of coral reefs of South China Sea.

Status of Coral Reefs

Coral reefs in China have faced many negative anthropogenic impacts for decades. Reduced degradation rate and possible improvement will occur if necessary management actions are adopted especially in coral reef reserve. Take Sanya National Coral Reef Nature Reserve for example, the local marine administration in Sanya has been entrusted by the State Ocean Agency to manage the area, and taken some effective protective measures. As a result, coral reefs in Sanya National Coral Reef Nature Reserve keep in good condition.

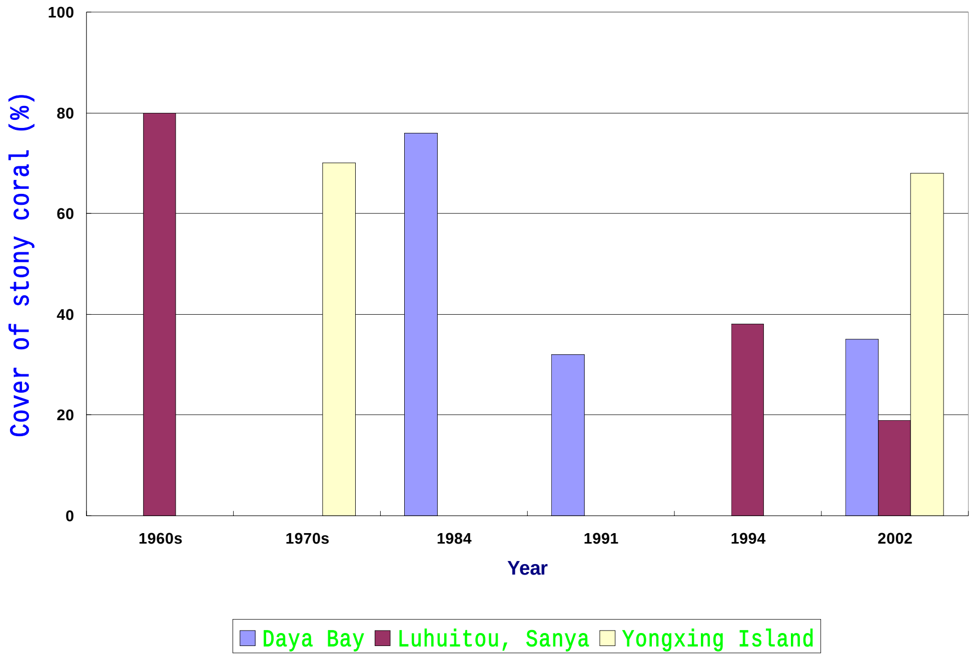

Figure 2. Coral Cover in Daya Bay, Luhuitou and Yongxing Island from 1960's to 2002.

Status of Reef Benthos (especially corals)

Before 1984, coral reefs in China was in good condition, coral cover was >70%. Coral percent cover was 76% in Daya Bay, Guangdong province in 1984. Coral percent cover was >70% in Luhuitou, Sanya, Hainan province in 1960s. Coral percent cover was >70% in Yongxing Island, Xisha Island in 1970s. In the 1990s, coral reef conditions declined occurred in great pace due to the fast social-economic growth. Coral percent cover was 32% in Daya Bay in 1991. Coral percent cover was 38% in Luhuitou, Sanya, in 1994. During the recent surveys in 2002 in China, Coral percent cover was 35% in Daya Bay and 19% in Luhuitou. However, the coral percent cover was 68% in Yongxing Island, Xisha Island.

Status of Reef Fish

Quantitative data by which changes in fish abundance at a species level could be examined over recent decades are virtually non-existent. However, interviews of fishers and divers, and the recent surveys suggest that many taxa have suffered serious declines on local reefs in recent decades. In marine natural reserves the commercially important reef fish species shows greater diversity, abundance and size than on fished reefs.

Stress and Damage to Coral Reefs

China's reefs have been particularly targeted for valuable edible fish and mollusc species. Overfishing and destructive fishing practices have badly damaged coral communities around Hong Kong and Xisha islands, causing most high-value fish species to become locally extinct. Around Hainan Island, illegal fishing activities and the sale of living corals for the aquarium trade are also problems. Sedimentation, freshwater incursion, and sewage outflows have adversely impacted China's reefs, particularly near the mainland.

Sediments and Nutrients (land-based)

Human activities on land are causing sediments and nutrients to flow onto coral reefs. Failure in proper managing the land resources have caused problems of siltation.

Damaging Fishing Methods

Irrational fishery practices such as blasting, and use of cyanides are very destructive to the coral reefs. Blasting has been widely practiced in Hainan island or even in remote islands such as Nansha. Islands. On regular bomed reefs coral mortality may be 50-80%. Cyanide-fishing is carried out by large-scale commercial operators who take fish from remote areas such as Xisha island and Nansha island. Cyanides are also used for collecting aquarium fishes.

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

Developments in the country, especially in costal areas, have direct impacts on coral reefs. For example, local governments has bombed out Mabian Zhou, Daya Bay for 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.

Coral Diseases

During the former surveys, mass coral diseases in Yongxing Island (Xisha Islands) in 2002 and in Zhubi Reef(Nansha Islands) in 2004 has been founded.

Potential Threats to Coral Reefs (Reef at Risk Threat Indicators)

The RRSEA analysis finds that 92 percent of China's reefs are under significant threat. Overfishing is the most pervasive threatening over three-quarters of China's reefs. Sedimentation from upland sources is estimated to impact 40 percent of all reefs, and coastal development endangers over 28 percent.

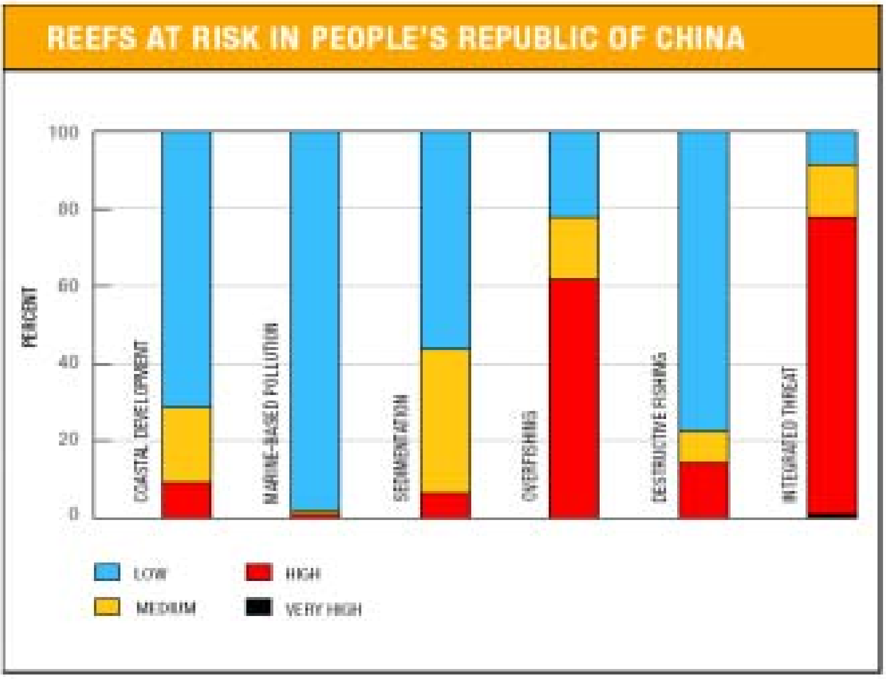

Figure 3. Reef At Risk Index in People's Republic of China.

Management

A small number of academic institutions, notably South China Sea Institute of Oceanology Chinese Academy of Sciences, in addition to government, conduct a variety of smallscale monitoring program of corals, fishes and basic environmental parameters.

Marine Protected Areas

Up to 2004, there are 3 Marine Coral Reefs Reserves in China(mainland). More MPAs are in the planning process. Marine coral reefs reserves are “no-take” areas with only approved scientific research allowed within their boundaries. A brief description of the 3 MPAs are as follows:

Sanya National Coral Reefs Nature Reserve (5,568ha) in Sanya City, Hainan Province was established in 1990. This is the only national coral reef reserve. The annual mean biomass in the tidal zone of the area is 518.2/m^2, with an annual average habitating density of 205.7 ind/m^2. Among the nektons, fish species consist the majority which making up 60%. The average fish biomass in a year is more than 15 kg/ha, with a density of 49 fish/ha. Coral-dependant benthos species in the area is rich, which together form a typical tropical marine ecosystem. In a recent biological comprehensive survey in 1997, large number of specimens of benthos and intertidal species were taken. More than 600 species were got in spring, in which there were 71 Crustacea species, 10 Echinodernata species, 223 Mollusca species, and 301 Pisces species; and more than species obtained in fall, in which there were 41 coral species, 51 Crustacea ones, 15 Echinodermata ones, 144 Mollusca ones and 134 Pisces ones. In addition, in the area there are over 60 large benthic algae with the largest quantity in spring and the smallest in winter.

Dongshan Bay Provincial Coral Reefs Nature Reserve (11,070ha) in Dongshan Bay, Fujian Province was setup in 1998. A total of six species of scleractinian corals and 12 species of hexacorals/octocorals have been recorded in Dongshan Bay. In the stereoscopic habitat formed by corals, 154 associated species have been found (Huang, 1999).

Dengloujiao Provincial Coral Reefs Nature Reserve in Guangdong Province was setup in 2002 to protect a population of coral reefs.

Monitoring

The program ‘Restoration of Coral Reef Ecosystem and Protection and Management of Its Biodiversity in South China Sea of China’ was put in priority programs of 21 Century Ocean Agenda of China.

Legislation

There are a series laws or regulations involved 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 demand that all coastal development programs need accord with the Division of Marine Functional Zonation made by government.

Conclusions and Recommendations

In the last twenty years, coral reefs in China faced above mentioned many pressures and problems. So, it needed special coordinating efforts from government, local community and scientists. 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 take 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 reef in China should be better in the near future. However, It is a changing perspective, depending on how much efforts we strive.

References

Andy Cornish Ph.D., Status of reefs in Hong Kong 2003, Unpublished submission to ReefBase, July 2003

Chen G.., Sustainable development and ecological utilization of coral reef resources. Research and Development of South China Sea, 1997, (4): 53-55 (In Chinese)

Dai C F. Reef environment and coral fauna of southern Taiwan. Atoll Res. Bull., 354: 1-28

Hodgson G and Yau E P M. Physical and biological controls of coral communities in Hong Kong. In: Lessios H A, Macintyre I G (EDS). Proceedings of the 8th International Coral Reef Symposium. Panama: Smithsonian Tropical Research Institute, 1997, 1: 459-464

Institute of Marine Planning and Design (Hainan province), 2002. The ten-year lookback survey on management and protection of the Sanya National Coral Reef Reserve. 93pp.

Institute of Oceanology (Chinese Academy of Sciences), 1975. Studia Marina Sinica 10: monograph on marine biota of Xisha Islands 1. China Science Press. 230pp. (in Chinese with english abstract)

Institute of Oceanology (Chinese Academy of Sciences), 1978. Studia Marina Sinica 12: monograph on marine biota of Xisha Islands 2. China Science Press. 266pp+33plates. (in Chinese with english abstract)

Institute of Oceanology (Chinese Academy of Sciences), 1979. Studia Marina Sinica 15: monograph on marine biota of Xisha Islands 3. China Science Press. 232pp+27plates. (in Chinese with english abstract)

Institute of Oceanology (Chinese Academy of Sciences), 1980. Studia Marina Sinica 17: monograph on marine biota of Xisha Islands 4. China Science Press. 197pp. (in Chinese with english abstract)

Institute of Oceanology (Chinese Academy of Sciences), 1983. Studia Marina Sinica 20: monograph on marine biota of Xisha Islands 5. China Science Press. 277pp+1plates. (in Chinese with english abstract)

Institute of Oceanology (Chinese Academy of Sciences), 1985. Studia Marina Sinica 24: monograph on marine biota of Xisha Islands 6. China Science Press. 194pp. (in Chinese with english abstract)

Lin Xingqing et al (eds). The Division of Marine Functional Zonation of Guangdong Province. Beijing: Science Press, 1991,1-134 (in Chinese)

Liu Ruiyu. The effects of human activities on benthos diversity. In: Center for Coastal Ocean Sciences and Technology, Zhongshan University (ed.). Symposium on Coastal Ocean Resources and Environment '97, Proceedings of SCORE '97, Hong Kong, 1997. Hong Kong: Center for Coastal and Atmospheric Research, The Hong Kong University of Science and Technology, 1998, 39-46 (in Chinese with an English abstract)
Oceanic Bureau of Hainan Province. The Division of Marine Functional Zonation of Hainan Province. Beijing: Ocean Press, 1992,1-134 (in Chinese)

South China Sea Institute of Oceanology (Chinese Academy of Sciences), 1978. Collected works on marine biota of Xisha and Zhongsha Islands. China Science Press. 328pp. (in Chinese with English abstract)

State Oceanic Administration. 21 Century Ocean Agenda of China. Beijing: Ocean Press, 1996 (In Chinese)

State Technical Control Bureau. Technical Directives for the Division of Marine Functional Zonation, National Standard (GB17108-1997). Beijing: China Standard Press, 1998, 1-20 (in Chinese)

Wang Lu et al. Distribution of submarine landscape in Yalong Bay. Research and Development of South China Sea. 1997, (2): 45-52 (In Chinese)

WWF Hong Kong. Environment Education Survey at Yalong Bay, Sanya, Hainan Island, China. WWF Project Final Report (Contract REFERENCE: CN0073.05/China), 1999, 1-39

Yu Dengpan, Zou Renlin. Study on the species diversity of the scleractinian coral community on Luhuitou fringing reef. Acta Ecologica Sinica, 1996, 16(5): 469-475 (In Chinese with an English abstract)

Zhang Qiaomin. Coral reefs conservation and management in china In: International Consultative

Workshop on Economic Valuation and Policy Priorities for Sustainable Management of Coral Reefs, 10 - 12 December 2001, ICLARM, Batu Maung, Penang, Malaysia

Zhang Qiaomin. Mangrove and Coral Reef Coastal Resources of China and Its Development. In: Chen Bang-Fuh, Wu Chaoyu, Chen Jaychung (eds.). Symposium on Coastal Ocean Resources and Environment '99, Proceedings of SCORE '99, Guangzhou, 1999. Hong Kong: Center for Coastal and Atmospheric Research, The Hong Kong University of Science and Technology, 2000, 228-234. (In Chinese with an English abstract)

Zhao Huanting, Zhang Qiaomin, Song Chaojing et al. Geomorphology and Environment of the South China Coasts and South China Sea Islands. Beijing: Science Press, 1999, 370-453 (In Chinese)

Zhao Huanting. Development of organic reef study in China. Quaternary Sciences, 1996, (3): 253-262 (In Chinese with an English abstract)

Zou Renlin, Ma Jianghu, Song Shanwen. Hermatypic Scleractinia in Shallow Waters of Hainan Island. Beijing: Science Press, 1975,1-66 (In Chinese)

Zou Renlin. Status and protection initiatives of coral reefs in China. In: Biodiversity Committee of the Chinese Academy of Sciences and Department of Protection for Wild Animals and Forest Plants, Forest ministry of China (eds). Research Progress of Biodiversity, Proceedings of First Meeting on Biodiversity and sustainable development. Beijing: Chinese Scientific and Technologic Press, 1995, 281-290 (In Chinese with an English abstract)

Zou, R.L., 2001. Fauna Sinica: Coelenterata Anthozoa, Scleratinia Hermatypic Coral. Beijing: China Science Press. Pp.1～289pp, plates 1～55

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3.2. HONG KONG

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Abstract

Coral communities are mainly found in the eastern and northeastern coasts of Hong Kong. They are good sources of fish and other invertebrates for both artisanal and recreational fishers. They are also becoming important as recreational destinations for the public. There are currently four marine parks and one marine reserve in Hong Kong, with two, Tung Ping Chau and Hoi Ha Wan Marine Parks primarily designated for the protection of coral communities. There is an increasing number of scientific studies being undertaken within these marine protected areas (MPAs). All the MPAs are now being monitored for various physical parameters and biodiversity and abundance of corals, fish, other invertebrates and algae. In some, visitors' impact is also being monitored. These monitoring programmes are likely to remain in place in the near future. Although coral communities in Hong Kong are subject to increasing threat from rapid development both within Hong Kong as well as across the border from Shenzhen, mainland China, the corals within the marine parks in the northeast are so far, generally healthy. Some increase in coral cover has been registered over the last four years. Occasional bleaching, predation, human or storm disturbances have been observed. There are 84 species of hard corals reported from Hong Kong and at least 61 of these are found within the marine parks. The fish community within the marine parks, however, may be in a more difficult situation than the corals, as fish populations are not free from exploitation even within the marine parks so the recovery is slow. Outside the protected areas, both coral and fish populations are subjected to even greater threats. Protection of many of these coral communities is urgently needed.

MPAs are playing very important roles in the conservation of Hong Kong marine environment. However, the total area currently under protection is only <2% of the total marine area. The Marine Parks Ordinance provides the legal basis for further designation of more areas as MPAs and enforcement of marine conservation strategies within the MPAs. More areas should be designated as marine parks or reserves but greater efforts and more resources are needed in order to fulfill these goals. Establishment of MPAs is probably the best way to protect Hong Kong marine environment at the moment. But how long these MPAs can remain healthy is a very serious question to consider as developments around Hong Kong may not spare them eventually. There is a need for a broader, more strategic planning on future development and environmental protection and conservation not just for Hong Kong, but for the whole Pearl River Delta region in south China as well.

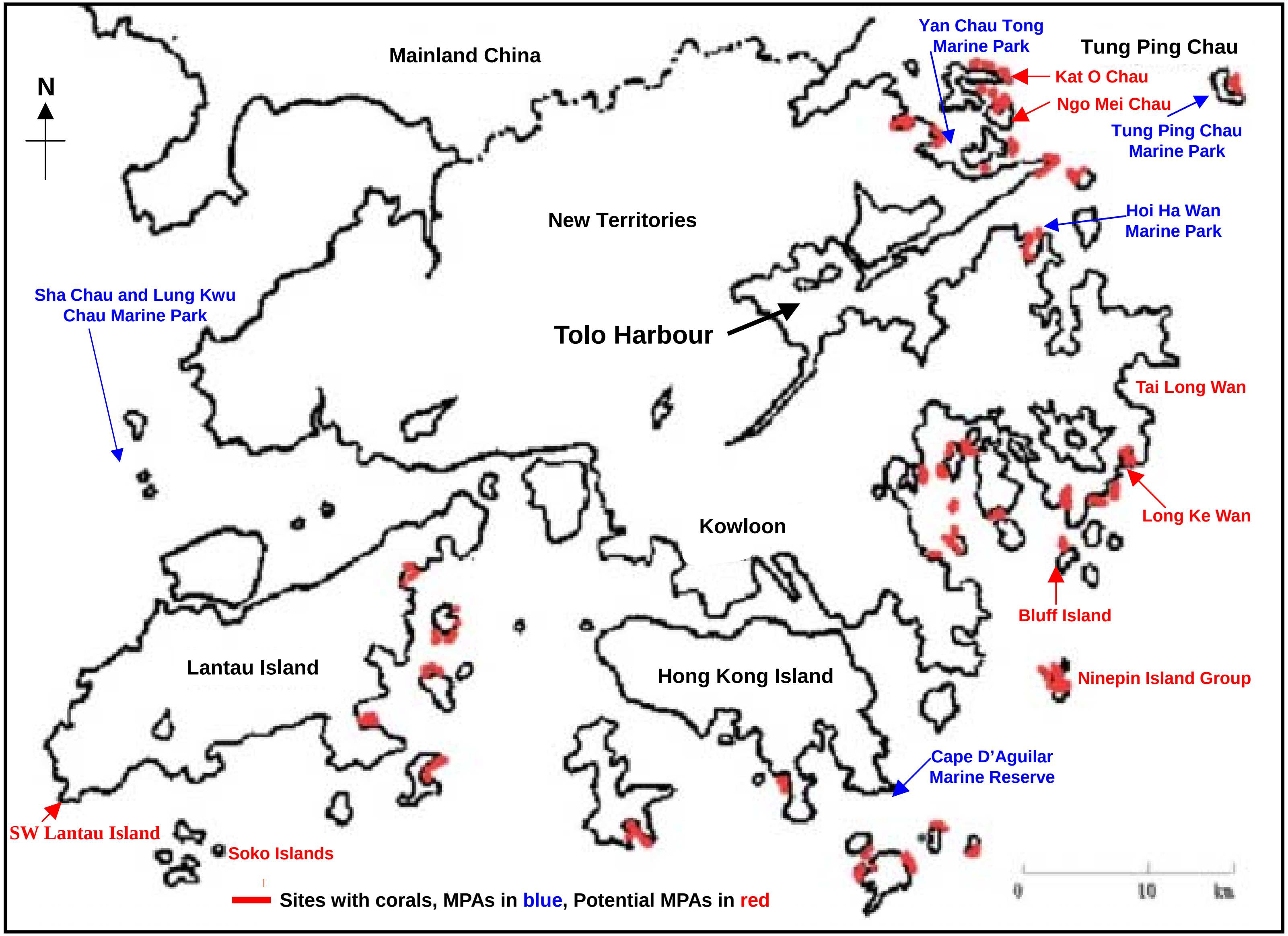

Figure 1. **Coral distribution, Marine Protected Areas (MPAs) and potential MPAs in Hong Kong. Corals are mainly distributed along the northeast and eastern coasts of Hong Kong.**

Table 1. Summary of Coral Reef Status in Hong Kong

Coral Reef Areas	No true mature coral reefs, only fringing coral communities, no detailed estimate on total coral areas, but in some marine parks, e.g. Tung Ping Chau Marine Park, the coral area covers about 32,000 m^2
Marine Protected Areas (for coral communities)	Tung Ping Chau, Hoi Ha Wan, Yan Chau Tong Marine Parks
MPAs with Monitoring Programmes	All MPAs have monitoring programmes for water quality, diversity of corals, fish, algae and other invertebrates
Threats to Coral Communities:	
Natural Disturbance	Occasional destruction of corals by storms, some bleaching and predation by corallivorous gastropods but not on a large scale
Coastal development	Population growth, tourism, infrastructure development and associated environmental impact, most serious threats are dredging and reclamation for port and land development
Marine-based pollution	Increased container and boat traffic, potential oil spills and leakage, ballast discharge, organic waste from fish cages
Land-based pollution	Domestic sewage discharge, sedimentation and organic waste, e.g. fertilizers, from Pearl River and local streams, pollutants from land fill leakage, solid waste
Disease	Coral tumour, probably some other diseases
Over-fishing	Probably the most serious threat, all coral communities are over-exploited
Destructive fishing	Use of explosive less frequent now than 10 years ago, but still a potential threat, use of gill net often resulting in entangle of nets with corals – forming ghost nets, trawling a potential threat though no concrete evidence of its destruction to HK coral communities

Introduction

Hong Kong's marine environment (Table 2) is largely influenced by the discharge of freshwater from the Pearl River in the west, particularly in the summer. Most coral communities are concentrated in the eastern and northeastern shores (Figure 1) where rocky hard bottoms are more extensive and the general water conditions more oceanic (Watts, 1971; Morton and Wu, 1975; Morton, 1980; Morton and Morton, 1983; Hodgson and Yau, 1997). High sedimentation rate and low salinity make it difficult for corals to survive in the west. Most studies on Hong Kong coral and coral communities are therefore confined within the eastern shore.

Early records of corals collected from Hong Kong were reported by Verrill (1869, 1902 in Morton, 1991). This is followed by a report on some octocorals from Hong Kong (Shen, 1940). Trott (1972) first described the presence of coral communities within Tolo Harbour, a narrow embayment in the northeastern New Territories. Fossil corals have also been reported in Hong Kong geological formation (Yim et al., 1981). Scientific interest in the diversity of coral communities in the northeastern shore of Mirs Bay, including Hoi Ha Wan, Chek Chau, Tolo Harbour and Tolo Channel, started in the late 1970's and throughout the 1980's, when a number of studies were conducted (Cope, 1982a; 1982b; 1984; 1986; Cope and Morton, 1988; Morton, 1988a; Scott, 1984; Scott and Cope, 1982; 1989; Thompson and Cope, 1982; Veron, 1982; Wang and Zou, 1992; Zou, 1982; Zou and Scott, 1982; Zou et al. 1983). Other studies focused on soft corals (Li, 1986), coral associated invertebrates, including polychaetes (Mak, 1982), molluscs (Scott, 1980; Dudgeon and Morton, 1982), echinoderms (Thompson, 1982) and species associated with coral-gallery communities (Morton et al., 1991). This series of works provides baseline information for Hong Kong coral studies.

Table 2. Summary statistics about Hong Kong coral communities and resources.

Marine area	1,651 km^2
Coastline	1,181 km^2
Land area	1,102 km^2
Reef area	32,000 m^2 (Tung Ping Chau Marine Park)
Population	6.8 million
Coastal population	100%
No. of MPAs	4 marine parks and 1 marine reserve
No. of monitoring sites	Coral communities, invertebrate and flora abundance: monitored in 3 marine parks, fish communities in 4 marine parks and 1 marine reserve
Status of coral reef fisheries	Over-exploited

Rapid economic growth in the 1980's and 1990's prompted large-scale reclamation of coastal areas for development. Marine sand was one of main sources of filling materials for these reclamation projects. Extensive dredging for marine sand in eastern waters as well as dumping of contaminated sludge from dredging of Victoria Harbour posed significant threats to the coastal environment, including the coral communities. The Civil Engineering Department (CED) of Hong Kong Government contracted consultant companies, mainly Binnie Consultants Limited (BCL), to undertake the first extensive ecological subtidal surveys. A large amount of general information on coral species distribution and abundance around different parts of Hong Kong was generated from a series of reports submitted to the CED. This series of reports contributed to a general knowledge on coral distribution in different parts of Hong Kong territorial water (Binnie Consultant Limited, 1998). Most recently, an underwater survey on the distribution of corals in Hong Kong was completed (Oceanway, 2002a) and the identity of coral species found in Hong Kong water was verified with the establishment of reference collections housed at the Chinese University of Hong Kong Simon S.F. Li Marine Science Laboratory (CUHK MSL) and at the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government (Ang et al., 2003).

Two sites, Hoi Ha Wan and Yan Chau Tong, were designated as marine parks and one other site, Cape d'Aguilar, was designated as a marine reserve in 1996 (Figure 1). A general description of the marine reserve at Cape d'Aguilar is given in Morton and Harper (1995). Additional studies, aimed at different aspects of coral biology were carried out in these sites. This included distribution of hermatypic (Clark, 1998a) and ahermatypic corals (Clark, 1997a) in Cape d'Aguilar, transplant studies between Hoi Ha Wan and Cape d'Aguilar (Clarke, 1997b; 1998b), reproductive studies of selected coral species in Hoi Ha Wan (Collinson, 1997; Clarke 1998b), and coral distribution in Yan Chau Tong and vicinity (McCorry, 2000). Artificial reef projects, initiated by The University of Hong Kong and later by the AFCD provided some opportunities to look at early growth of coral recruits, particularly *Oulastrea crispata*, on artificial substrata (Lam, 1998; 2000a; 2000b; Leung, 2000), as well as recruitment of fish on these man-made structures (Cook et al., 1997; Wilson, 2003).

Between 1996 to 1999, AFCD followed up studies on the feasibility of four sites to be designated as marine parks or marine reserves. These works were contracted out to three tertiary institutions in Hong Kong (Ni and Qian, 1999; Tsang and Milicich, 1999a, 1999b; Ang et al., 2000). Tung Ping Chau was subsequently designated as the fourth Hong Kong marine park in Nov. 2001 (Figure 1). Between the late 1990's and early 2000's, many more studies were initiated to study the coral community in Tung Ping Chau, as well as to compare the corals of Tung Ping Chau with those in Hoi Ha Wan, Yan Chau Tong and other sites around Hong Kong. This series of studies included topics on dynamics of coral community (Tam, 1998), coral reproduction and recruitment (Liu and Ang, 2002; McCorry, 2002; Lin, 2003), population dynamics of corals (Ma, 2005), siltation and burial effects on corals (Yeung, 2000; Wong, 2001), bleaching and predation on corals (Cumming and McCorry, 1998; Choi, 2002; McCorry, 2002), coral algal interactions (Choi, 2003; Ma, 2005), coral diversity (Wong, 1998a; 1998b; McCorry, 2002; Lun, 2003), coral responses to injuries (Woo, 2005), as well as the genetic structure of coral associated zooxanthellae (Chen et al. 2003) and of common Hong Kong coral species (Ng and Morton, 2003; Lam and Morton 2003). Studies on reef fish in Hong Kong were also carried out in different sites around Hong Kong, both within and outside the marine parks and reserve (Cornish, 2000; Ang et al., 2004b; Tam, 2005).

Other than the three marine parks and one marine reserve mentioned above, another marine park, the Sha Chau Lung Kwu Chau Marine Park, was established in 1996 for the protection of Indo-Pacific Hump-Backed Dolphin (*Sounsa chinensis*, locally better known as the Chinese White Dolphin). This marine park is located in the western waters of Hong Kong and no hard corals have been recorded from there. A few other sites, notably Fan Lau (southwestern Lantau Island), Soko Islands, Southern Lamma Island, Kat O and Ngo Mei Chau, Tai Long Wan, Long Ke Wan, Bluff Island and Nine Pine Island Group have all been surveyed for the possible establishment of marine parks (Figure 1). Except for the first two sites where the main focus of protection will be the dolphin and porpoises, all the other sites are known to have good cover of corals. The protection of coral communities in these sites will certainly be one of the main focuses if these sites are established as marine parks in the future.

Coral Reefs

There is no true coral reef in Hong Kong. Corals communities are patchily distributed along rocky shores and over sand, generally at < 10 m depth. These communities are mainly found in the northeast and eastern coasts although isolated patches of corals can also be found in the southern and western waters (Figure 2). Eighty four species of reef building corals have now been reported from Hong Kong waters (Ang et al., 2003). Many of the Hong Kong coral communities are dominated by a few species. In northeast waters, these are notably *Platygyra acuta, Favia speciosa, Leptastrea purpurea, Porites lutea, Porites lobata,* and *Lithophyllon undulatum,* among others. These corals are mainly of the massive or encrusting / laminae growth forms. In eastern waters, branching form like *Acropora* spp. or plate-like form like *Montipora* spp. can be important. The highest diversity of corals is found in northeastern waters and this area is coined as the coral triangle by Ang (2002) and is considered to be of highest conservation value with respect to corals and coral communities. Other coral communities or patches of corals are found in the eastern, south and southeastern shores, with a lot less found in the western waters (Figure 2).

The marine parks are the main monitoring sites for corals and fish. The number of coral species and coral cover found in different sites within the marine parks are given in Table 3. Monitoring of these marine parks has been undertaken by a research team from the Simon S. F. Li Marine Science Laboratory of the Chinese University of Hong Kong in recent years. Using permanent transects and quadrats, the team has monitored coral cover, coral diversity, fish and algal abundance and diversity in Tung Ping Chau before and after the establishment of this island as a marine park in 2001 (Ang et al., 2004b). The team has also been engaged in the monitoring of marine flora and coral community in Hoi Ha Wan and Yan Chau Tong Marine Parks in 2003 (Ang et al., 2004a; 2004c). Monitoring data were compared with data collected earlier (Oceanway, 2002b; McCorry, 2002).

The global volunteer coral reef monitoring programme, Reef Check, was initiated in Hong Kong in 1997 (Hodgson, 1997; 1999) and has been managed by the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government since 2000. It is now an annual event. The number of participating teams has increased from 16 in 2000 to 33 in 2004 (AFCD, 2001; 2002; 2003; 2004). The sites surveyed also increased from 16 to 33. It has been well received and teams participating in Reef Check come from the academe, NGOs, recreational diving groups and government departments. Figure 3 shows the sites covered by Reef Check in 2003 while coral cover reported in Reef Check for these different sites are given in Figure 4.

Biodiversity

Although Hong Kong is located in a subtropical region, its biodiversity is quite high. Its flora and fauna are characterized with species from both the tropical and temperate regions with some species appearing only seasonally, e.g. the algae. The estimated number of major groups of organisms associated with coral communities is given in Table 4. To date, only a reference collection of hard corals has been established (see Introduction). A reference collection on other invertebrates, fish and marine plants is currently being established at the Simon S.F. Li Marine Science Laboratory of the Chinese University of Hong Kong. Some specimens collected within Hong Kong waters are also kept at the AFCD and the Swire Institute of Marine Science (The University of Hong Kong) at Cape d’Aguilar.

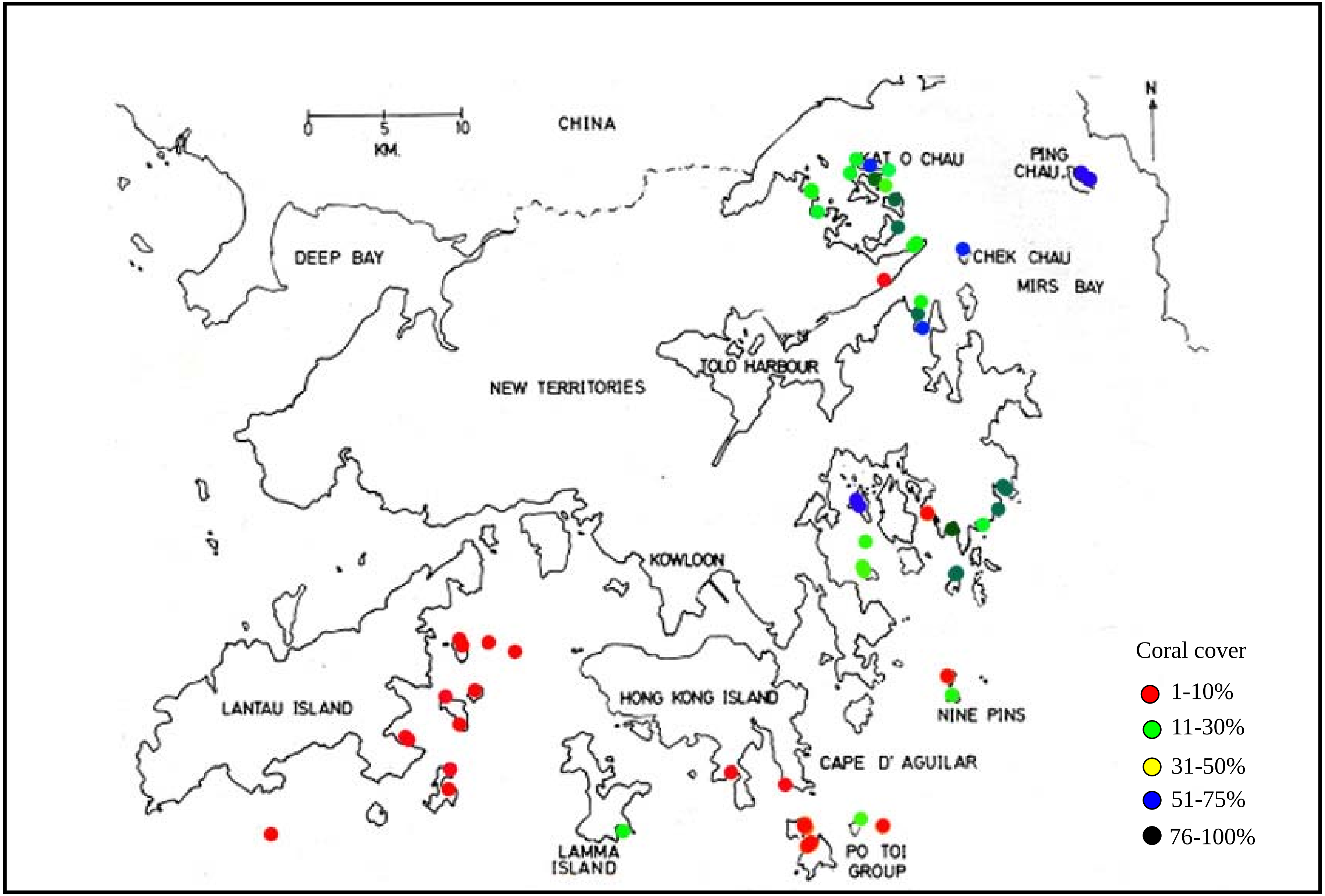

Figure 2. Coral abundance in Hong Kong (Based on Oceanway 2002a)

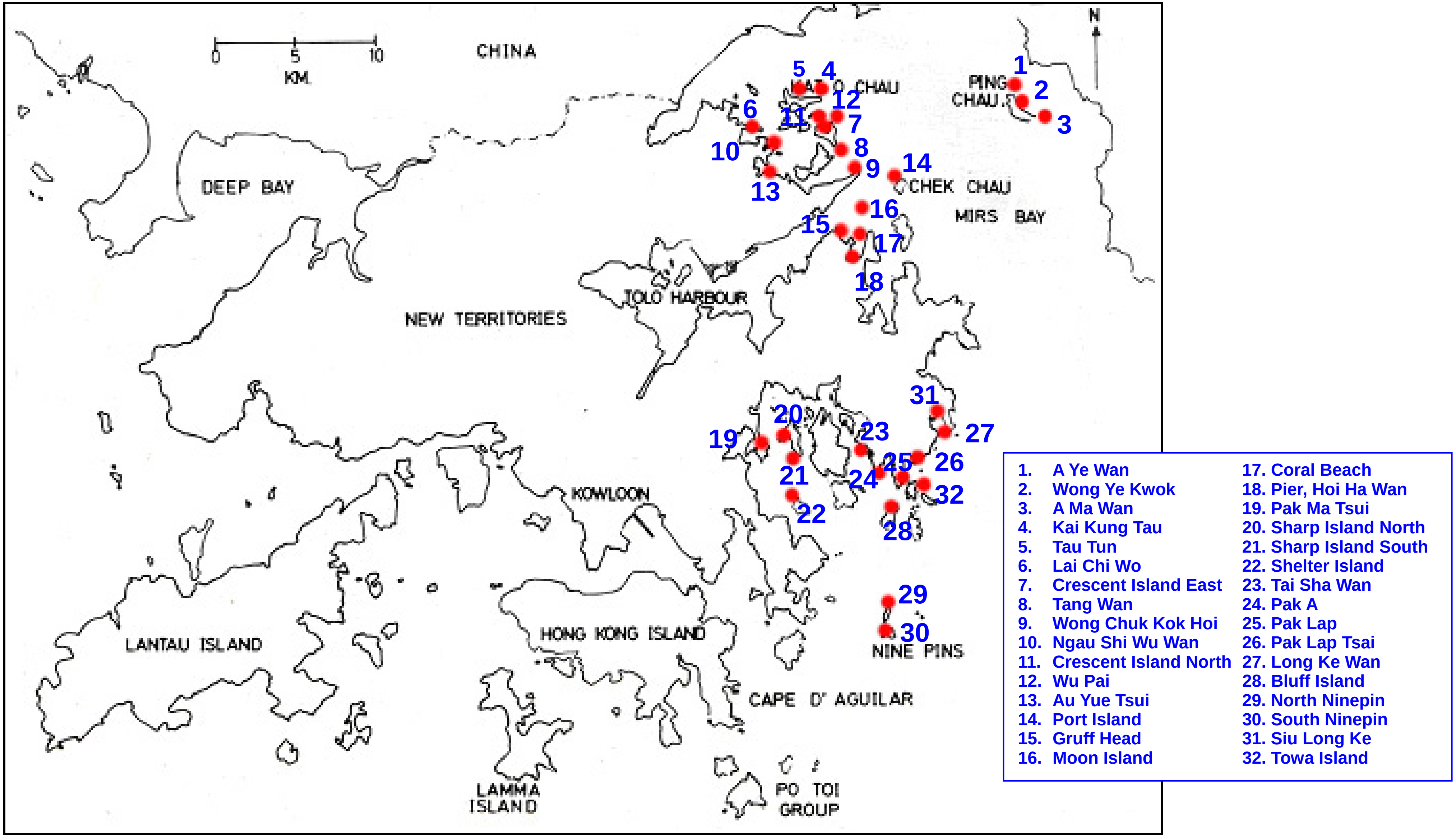

Figure 3. The 32 sites covered by Hong Kong Reef Check in 2003 (http://www.afcd.gov.hk/conservation/con_e.htm).

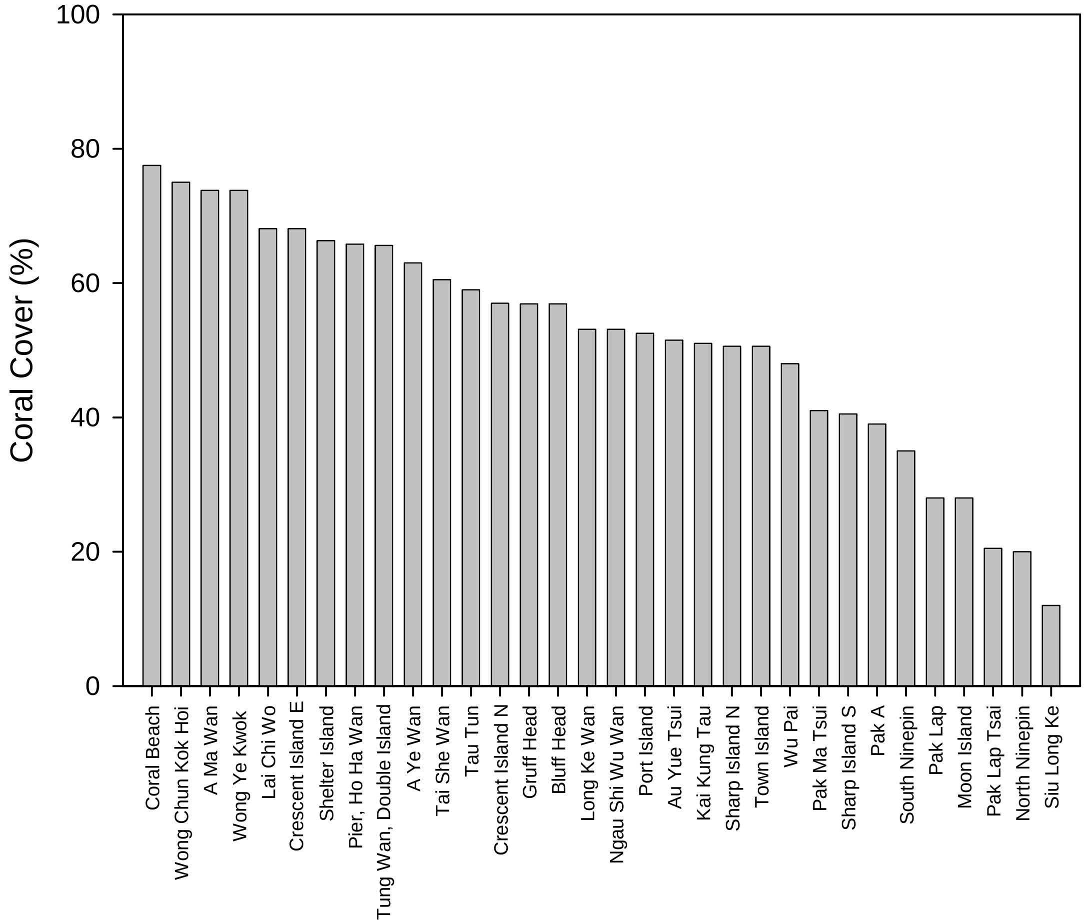

Figure 4. Coral cover (%) in 32 survey sites from Reef Check Hong Kong in 2003 (http://www.afcd.gov.hk/conservation/con_e.htm).

Table 3. Summary of coral richness and percentage cover in coral monitoring sites in Hong Kong marine parks from 2002-2004. Please refer to Figure 1 for the location of the marine parks.

Marine Park	Site	No. of Coral Species	Coral Cover (%)*
Tung Ping Chau	A Ye Wan	26	17.2
Tung Ping Chau	A Ma Wan	39	46.2
Hoi Ha Wan	Coral Beach	43	72.5
Hoi Ha Wan	Gruff Head	52	42.4
Hoi Ha Wan	Moon Island	50	41.5
Hoi Ha Wan	Pier	51	55.5
Yan Chau Tong	Au Yue Tsui	32	21.7
Yan Chau Tong	Lai Chi Wo	40	71.3

* Coral cover data for Tung Ping Chau Marine Park were taken in 2002-2003 survey based on permanent transects (Ang et al., 2004b), data for Hoi Ha Wan and Yan Chau Tong Marine Parks were taken in summer 2003 using line intercept method (Ang et al., 2004a).

Resource Use

i) Reef Fish and Fisheries

The Hong Kong fishing fleet landed an estimated 169,790 tonnes of fisheries produce valued at US $1,600 million in 2002. Most of the total catch however, (about 90%) are from waters outside Hong Kong. The industry consists of some 4,770 fishing vessels and 10,860 fishers. There is also a large auxiliary sector servicing the fishing industry, including fish wholesale and retail marketing, fuel and fishing gear supply, and ice manufacturing which employ a large number of people.

Fishing activities involving bigger fishing vessels (> one ton) are mainly conducted in the waters of the South and East China Seas. These vessels are mainly manned by family members with the assistance of hired crew. Main fishing methods include trawling (pair trawling, stern trawling, shrimp trawling and hang trawling), long lining, gill netting, purse-seining, hand lining and cage trapping, with the majority of the total catch obtained through trawling. Fish groups caught include grouper, snapper, seabream, rabbitfish, eel, wrass, and grunt.

Table 4. Estimated number of species of major groups of marine organisms in Hong Kong coral communities.

Groups	No. of Species
Hard corals	84
Soft corals	26
Polychaetes	218
Crustaceans	77
Molluscs	55
Echinoderms	95
Fish	500
Seagrass	4
Algae	299

Commercial fishing of near shore rocky reefs and associated coral communities is primarily conducted by several thousand small fiberglass or wooden boats powered by outboards or inboard diesel engines. This mechanization, the small size of Hong Kong waters and the scattered distribution of fishing villages and government typhoon shelters around the local coastline mean that all reefs are within an hour traveling time of the nearest fishing port. As such, all reefs except for those under protection are regularly fished. Those in more exposed areas to the east probably receive less fishing pressure than those in sheltered bays due to the difficulty of fishing the exposed sites in rough weather. The primary fishing ports for small vessels targeting reef fishes, including those from coral communities, are Aberdeen to the south, and Sai Kung and Tai Po to the east.

Commercial reef fishing is primarily conducted using hand-line, small cages made from “chicken-wire” and monofilament nets (single and multi-layer). All non-toxic reef fishes are targeted and even small damselfishes and cardinalfishes will be kept, although groupers, snappers, parrotfishes, sea-breams etc. are the most desired. Long-lining is less frequent. There is also the collection of *Diadema* and *Anthocidaris* sea-urchins for their roe by hookah divers operating from mainland China. There is little specific targeting of marine ornamentals. All marine fishes caught in Hong Kong waters are consumed locally although the smallest may be used for mariculture feed.

Recreational fishing with hook and line is a popular pastime, and becoming increasingly so despite the often small size of fish caught. Spearfishing with SCUBA (and re-breather) is also practiced by a small number of enthusiasts, estimated at around 800 in the late 1990s. The latter are surprisingly adept at taking groupers, snappers, sweetlips, sea-breams and wrasses at sizes larger than those generally caught by the commercial fishery.

Local village people still dig for clams during low tide. Other gastropods, crustaceans or sea urchins are also being collected from rocky shores. Use of traps and gill net is a common practice for trapping fishes, crabs or other invertebrates. Collection of lobsters or abalones by divers could also happen but this is becoming very rare simply because of the lack of these animals in the water. All these organisms are collected mainly for food. However, there are no statistics on the amount of biomass harvested.

Hong Kong has a mariculture industry which is in decline, primarily due to poor water quality. There are designated aquaculture zones within Hong Kong waters. Cages were used to grow commercially important fish like groupers and sea breams from imported and locally caught fry but a lot of these cages are now used simply as holding tanks for imported fish, before they are delivered to the end users like restaurants. There is some oyster farming in the west, Deep Bay area. More recently, the Hong Kong government has allowed the conversion of some of these caged farming sites as recreational area for people to fish from these cages using hook and line.

ii) Tourism

Hong Kong is a popular tourist destination but foreign tourists do not generally venture into Hong Kong waters except at some swimming beaches. Hong Kong water is usually turbid and hence is not attractive for these foreign visitors. However, with the recent establishment of marine parks and the promotion of local government departments on the attractiveness of the undersea world of these parks, the number of local visitors to these areas is on the increase. The SARS near-epidemic in 2003 discouraged many Hong Kong local people from visiting foreign destinations and a lot of them turned to visit the local country and marine parks instead. For Tung Ping Chau Marine Park, for example, the number of visitors sky rocketed from one to two thousand visitors a year some six or seven years ago to a few thousands over a single weekend during peak summer season.

There is no major infrastructure, like resorts, that caters specifically to marine related activities in Hong Kong. Many old village homes in surrounding islands and coastal villages, however, have been converted into weekend vacation houses for local visitors. In recent years, diving activities have become so popular that diving clubs, offering SCUBA diving lessons and rentals of snorkeling and SCUBA diving equipment, have been established in Tung Ping Chau Marine Park. One other popular destination, the Hoi Ha Wan Marine Park, is easily accessible by land. It attracts many visitors making one-day trip to the park even on weekdays.

Many environmentally oriented groups have sprung out during the last few years. Together with some local travel agencies, they rode on the bandwagon of local interests in eco-tourism by offering one-day tour to different destinations, including some coastal areas. Some also provide “floating tour” into coral communities inside the marine parks or in other coastal sites with reasonably high coral cover. In such a floating tour, visitors will be equipped with life vest, mask and snorkel (sometimes also fins) and will be guided over a coral area, floating but without really diving into it. This is possible as most coral areas in Hong Kong are very shallow (< 2 m deep) and are fringing along the coast. Many dive shops also offer diving courses and very often, check-out dives are conducted inside the marine parks or in shallow areas where coral communities are found. There is currently no data on the number of eco-tour groups, nor the number of people who have joined the floating tour, or have dived in the coral areas as part of their SCUBA diving training. Nonetheless, recreational diving activity is certainly on the increase and there must be more than 20,000 divers in Hong Kong today. A lot of them, of course, go out of Hong Kong to dive in many different places around the world.

iii) Other Uses

The major tertiary institutions in Hong Kong have all conducted research related to corals or coral communities. The Chinese University of Hong Kong has its Simon S.F. Li Marine Science Laboratory located in Tolo Harbour, just next to the main campus. Major coral and reef-related research works are conducted in Tung Ping Chau, Hoi Ha Wan and Yan Chau Tong Marine Parks. The University of Hong Kong has its Swire Institute of Marine Science located inside the Cape d’Aguilar Marine Reserve. The City University of Hong Kong has a laboratory in the Marine Life Centre located inside the Hoi Ha Wan Marine Park. This Marine Life Centre is built and operated by WWF Hong Kong for education purposes. The Marine

Life Centre operates a glass bottom boat inside the park. The University of Science and Technology operates a Coastal Laboratory located on campus in Sai Kung, New Territories.

The idea of a glass bottom boat from the Marine Life Centre has caught the imaginations of some local entrepreneurs and fishers. Long before the glass bottom boat of WWF Marine Life Centre had even been delivered to Hong Kong by its builder in Australia, some local entrepreneurs had already constructed their own glass bottom boats. Among these are small fiber-glass or wooden boats with home-made glass bottom viewer and a large 200 person capacity boat with a glass bottom bow area. This large glass bottom boat has created some problems for the management of the marine parks as it poses the danger of damaging the corals in very shallow region of the coastal areas. In fact some damages to corals, including overturn of coral colonies, have been documented within Hoi Ha Wan Marine Park and these have been attributed to impact from the large glass bottom boat. Currently there is no provision within the Marine Park Ordinance that restricts the operation of any form of glass bottom boats. Amendments to the Ordinance are now being sought in order to address this problem. In the mean time, the large glass bottom boat is currently grounded by the Marine Department of the Hong Kong SAR Government on the ground of safety consideration.

The Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government also organizes educational tours and training for high school teachers and students. These tours may include field trips to the marine parks. Other high schools may also organize trips of this nature.

Status of Coral Reefs

Status of Reef Benthos (especially corals)

Monitoring works on Hong Kong marine parks are primarily carried out by the research team from the Chinese University of Hong Kong, Simon S. F. Li Marine Science Laboratory. Tung Ping Chau and Hoi Ha Wan Marine Parks have the highest diversity and cover of corals.

Way back in 1996, before Tung Ping Chau was designated as a marine park, permanent transects and quadrats were established and annual monitoring carried out. Subsequent to the establishment of Tung Ping Chau as a marine park in 2001, monitoring was carried out to compare the status of the coral communities before and after the marine park designation. Permanent transects and quadrats were set up in two sites, A Ye Wan (AYW) and A Ma Wan (AMW), which were designated as core areas with a greater degree of protection (e.g. no fishing and collection of marine organisms) than the rest of the marine park.

Generally, there was no significant change in the coral community structure in AYW and AMW between 1999 and 2002/2003 (Ang et al., 2004b). Percentage cover of corals, however, increased faster in AMW, at 9% from 37.5% in 1999 to 46.15% in 2003 than in AYW, at 2% from 15.5 % in 1999 to 17.14% in 2003. There were some changes in the ranking in dominance of some coral species from 1999 to 2003 but the dominant species remained the same. These are *Platygyra acuta, Pavona decussata, Porites lutea, Leptastrea purpurea* and *Goniopora lobata* in AMW and *Platygyra acuta, Platygyra carnosus, Leptastrea purpurea* and *Favites flexuosa* in AYW. A total of 61 coral species have been reported from Tung Ping Chau Marine Park and 44 of these are located within the permanent transects. No major environmental disturbances (e.g. typhoon, high water temperature) appear to have seriously affected the overall coral community structure in Tung Ping Chau in the last four years so the coral communities are stable and healthy.

Changes in seaweed cover and invertebrate abundance were also monitored and were found to be highly seasonal. No obvious change in algal assemblage and its associated invertebrate abundance was observed between 1999 and 2002/2003. The number of species reported from Tung Ping Chau Marine Park, as well as from Hoi Ha Wan Marine Parks is given in Table 5.

Hoi Ha Wan and Yan Chau Tong Marine Parks are two of the first marine parks designated in Hong Kong in 1996. First coral survey after the marine park designation in Hoi Ha Wan was conducted by Wong (1998a). Further monitoring study, for both Hoi Ha Wan and Yan Chau Tong Marine Parks, was undertaken in the late 90s (McCorry, 2002), 2001 (Oceanway, 2002b), and again in 2003-2004 (Ang et al., 2004a). Data prior to 1996 were more scattered, and the methods used to gather these data were not standardized. It is thus difficult to compare changes occurring in these marine parks before and after their designation.

The present monitoring programme focused only on the hard (Scleractinian) corals. While corals form dominant community in Hoi Ha Wan Marine Park, they are not the major benthic forms in Yan Chau Tong Marine Park. In Hoi Ha Wan Marine Park, using the random point video transect method, the percentage of coral cover was found not to vary significantly between 2001 and 2003/2004, although the number of coral species recorded has slightly increased from 59 to 64. This may simply be a consequence of recent work to verify the Hong Kong coral species (Ang et al., 2003), resulting in the confirmation and clarification of previously confusing coral identification, than to an actual increase in recruitment of previously unrecorded coral species. In Yan Chau Tong Marine Park, the situation was similar. The number of species recorded is 47. A line intercept method was also employed in 2003-2004 as part of an effort to evaluate the best monitoring method that could be used in Hong Kong turbid waters. In general, the coral cover is very high (70%) in selected sites within both marine parks but most of these sites are not extensive. High coral covers are also recorded mainly in shallow water (< -3m CD).

Table 5. Number of algal species found in different sites within Tung Ping Chau and Hoi Ha Wan Marine Parks. (Data based on Ang et al., 2004a; 2004c).

Marine Parks	Site	No of species
Tung Ping Chau	A Ye Wan	26
	A Ma Wan	24
	Lung Lok Shui	25
	Lan Kwo Shui	25
	Chau Mei Kok	25
Hoi Ha Wan	Heung Lo Kok	5
	Beach	13
	Flat Island	7
	Mo Chau	16
	Coral Beach	3
	Mangrove site	3
	Pier	3
	Lan Lo Au	2

Monitoring of these three marine parks is on-going. Selected sites within the marine parks have been designated for long term monitoring. Monitoring work will also cover fish abundance and diversity, as well as the presence of other invertebrates and algae.

Reef Check has become an annual activity in Hong Kong. It is currently being led and organized by the AFCD. In 2003, 32 teams participated in Reef Check, and in 2004, one more team joined in. As the sites monitored by Reef Check are selected *a priori*, they are among the sites with the best coral cover. The sites and results of Reef Check from 2001 to 2004 can be found in AFCD website (http://www.afcd.gov.hk/conservation/con_e.htm).

Status of Reef Fish

Quantitative data by which changes in fish abundance at a species level could be examined over time are, until recently, virtually non-existent. The AFCD, which manages the local capture fishery, does not compile regular landings records or conduct fishing surveys by which trends over time could be evaluated. However, some family level data are available from port surveys which are carried out infrequently. For instance, in 1991 production figures for demersal fishes caught by all vessels under 15 m in length were shown to comprise a small portion of the total catch (Wilson and Wong, 1996). Production figures for the top 10 reef-related families (by weight) were: rabbitfishes, Siganidae (863 t); mullets, Mugilidae (444 t); sea breams, Sparidae (397 t); scorpionfishes, Scorpaenidae (397 t); cardinalfishes, Apogonidae (231 t); moray eels Muraenidae (59 t); groupers, Serranidae (56 t); snappers, Lutjanidae (55 t); grunts, Haemulidae (14 t) and filefishes, Monacanthidae (13 t). The port survey was repeated in 2001-2 but comparable data are not currently available.

In general, the reef fishery is considered to be overfished, a view supported by higher production values for rabbitfishes, mullets and cardinalfishes, than groupers or snappers (Wilson and Wong, 1996). Interviews of fishers and divers, anecdotal accounts, the grey literature and recent surveys suggest that the following taxa have suffered serious declines on local reefs in recent decades: requiem sharks, large groupers, parrotfishes, and the only large local wrasse, the Black-spot tuskfish (*Choerodon schoenleinii*) (Sadovy and Cornish, 2000; Cheung, 2001).

The creation of areas where fishing is not permitted shows promise for improving the health of local reef fish stocks. In recent years there have been reports from protected natural and artificial reefs of assemblages of commercially important reef species showing greater diversity, abundance and size than on fished reefs (Wilson, 2003; Cornish, pers. obs.).

Conservation of reef fish abundance and diversity is one of the objectives of marine protected areas in Hong Kong. However, except for marine reserve where fishing is not allowed, fishing is allowed in marine parks under a licensing system. Only the original inhabitants of the park area are given the permit to fish, and for using only non-destructive fishing gear (e.g. no trawling), but several hundred fishers are licensed to fish in the marine parks in eastern waters. Marine parks are therefore, not completely no-take zones in Hong Kong. Tung Ping Chau was a popular destination for recreational fishers. These people lobbied hard to be allowed to fish around this island after its designation as a marine park. Consequently, a compromise was reached wherein two areas are designated as the recreational fishing zones within the marine park, but only hook and line, and one person one line is allowed.

The first study on the fishes inhabiting coral communities in Hong Kong in 1997/98 recorded 195 species from three sites (Cornish, 2000). Adults of commercially important species were extremely scarce and biomass was dominated by a species of sweeper (Pempheridae). Fish diversity, abundance and biomass were consistently greater in summer than winter and it appears that many fishes retreat within the coral framework in winter when the water temperature is often 16 ^{o}C or lower.

Monitoring in Tung Ping Chau Marine Park was carried out in 2003-2004 to assess for changes in fish diversity and abundance (Ang et al., 2004b). A comparison was also made between the fish data collected in 1999, before the island was designated as a marine park, with the current status, two years after its designation. Comparison was also made between recreational fishing sites and core areas within the park where fishing is not allowed even by the local inhabitants. A hundred species belonging to 36 families of fish were reported from Tung Ping Chau Marine Park during this study (Table 6). Some of these are considered to be rare. Generally, the number of fish observed in summer was higher than that in winter. The highest species richness was found in A Ma Wan (AMW) with 42 species belonging to 19 families recorded in spring 2003.

In summer 2002, the mean fish abundance was higher in the core areas (i.e. AMW and AYW) than in the recreational fishing areas (i.e. Chau Mei and Lan Kwo Shui) but the species diversity was slightly higher in the fishing areas than in the core areas. In winter 2003, both fish abundance and species diversity were not significantly different among the four sites.

There was a significant 75% increase in the mean fish abundance found in AMW between summer 1999 and summer 2002. There was also an increase in fish abundance in AYW within this same period but the increase was not statistically significant. However, there was a significant drop in species diversity, especially in AYW but not in AMW, suggesting that there were significant changes in the number of individuals in some species but not in the others. The situation was different for winter. Both mean fish abundance and species diversity did not change significantly in both sites between winter 1999 and winter 2003. No comparison could be made for changes in fish abundance and diversity between times in the recreational fishing areas as there was no baseline data for these two sites prior to 2002.

Status of Resource Use

Extraction of corals as building materials is not a common practice in Hong Kong, hence is not a serious problem. Occasionally though, coral heads washed up on shore may be utilized by coastal inhabitants. There were historical records of corals being used in kiln. There was also a claim that most corals in Hong Kong were harvested for kiln firing about 100 years ago, resulting in a complete destruction of all Hong Kong coral communities. There is, however, no way to substantiate this claim. Collection of corals for sale as decorative materials, or for use in aquarium has been reported. There is again, no detailed data on this.

Table 6 Number of species per family of reef fish in Tung Ping Chau Marine Park (based on Ang et al., 2004b).

Family	Number of Species	Family	Number of Species
Acanthuridae	1	Monacanthidae	1
Apogonidae	7	Mugilidae	1
Aulostomidae	1	Mullidae	5
Blenniidae	6	Muraenidae	2
Bothidae	1	Nemipteridae	1
Callionymidae	1	Pempheridae	1
Carangidae	2	Pinguipedidae	1
Chaetodontidae	9	Pomacanthidae	1
Echeneidae	1	Pomacentridae	10
Fistularidae	1	Scaridae	1
Gerreidae	2	Scorpaenidae	5
Gobiidae	11	Serranidae	6
Haemulidae	1	Siganidae	1
Holocentridae	1	Sparidae	1
Kyphosidae	2	Syngnathidae	1
Labridae	8	Synodontidae	1
Lutjanidae	2	Tetraodontidae	2
Microdesmidae	1	Zanclidae	1

Fishing remains the main activity associated with resource use of Hong Kong coastal coral communities. Fishing activities include subsistence fishing from family based fishers using nets, lines and traps and recreational fishing using hook and line or spear fishing by divers. Fishing activities of these sorts are likely to continue for some time to come.

Interests in eco-tourism are on the increase and the whole coral community is increasingly being appreciated as a resource in itself for tourist related activities. This trend is likely to increase in the coming years with more and more people learning how to SCUBA dive. There is also an increasing trend for schools to organize activities related to the marine environment. Glass bottom boat viewing is also becoming more popular and different types of glass bottom boats are becoming more available to tourists and weekend vacationers.

Physical Environment

Hong Kong has a subtropical environment. The summer water temperature can be close to 30^{o}C and the winter temperature can be as low as 13^{o}C. Hong Kong has a distinct wet season that starts around March and lasts till September. Autumn and winter are usually dry. On average, five to six storms (typhoon) visited Hong Kong per year in the last 18 years. About one of these would be more severe, registering a gusty wind speed of up to 130 km/hr. In general, most storms are not too severe to cause extensive destruction of coral communities, although they have been documented to topple individual coral heads (Woo, 2005). Increase in the number of beached corals at Cape d'Aguilar Marine Reserve was reported to be associated with typhoons (Clark and Morton, 1999; Morton, 2002).

The physical environments of the marine parks are being monitored by the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong Government on a monthly basis from 1999 to 2003, but on a seasonal basis starting 2004. Parameters monitored include temperature, DO, salinity, turbidity, pH and nutrients among others (http://parks.afcd.gov.hk/newmarine/eng/water_report/index.htm). There is a large variation in these parameters on an annual basis (Figures 5 to 7).

The research team from the Chinese University of Hong Kong Marine Science Laboratory is monitoring closely the physical conditions of Tung Ping Chau Marine Park. Temperature probes have been placed in two sites within the park at two depths and temperature is being recorded at every half an hour interval. Monitoring for temperature change has been going on for the last five years. Also monitored are physico-chemical parameters like DO, salinity, pH, and nutrients (NH_4, NO_3, NO_2 and PO_4) on a biweekly basis. Detailed analysis of these data is still being prepared.

Stress and Damage to Coral Reefs

Sediments and Nutrients (land-based)

High sedimentation due to dredging and land reclamation, high nutrients due to effluence of untreated sewage and high heavy metal contents due to industrial effluence are some of the main marine pollution problems in Hong Kong (Wu, 1988; Morton, 1994). Various issues concerning the conservation of Hong Kong marine environment, especially Hong Kong corals have been raised (Morton, 1979; 1980; 1988b; 1989; 1990; 1992b; 1994; 1995; 1996; 1997; 1998; 2000). Only very few works have so far been done in Hong Kong to evaluate the effect of pollution on corals. Scott (1990) suggested a significant decline in coral species diversity and abundance in Tolo Harbour and Tolo Channel due to chronic pollution. Colonies of *Platygyra sinensis* collected from Bush Reef, Chek Chau and Hoi Ha Wan were examined for their growth rates and heavy metal contents in their skeleton. Bush Reef was the most polluted of the three sites, Hoi Ha Wan was a disturbed site and Chek Chau was the cleanest. Growth rate was found to be significantly less (7.1 mm yr^{-1}) in corals from Bush Reef than in those from Chek Chau (9.1 mm yr^{-1}). There was also a decline in growth rate over the period from 1979 to 1985 when pollution inside Tolo Habour became more serious. The skeletal contents of seven metal elements, namely Al, Cd, Cu, Pb, U, V and Y, were examined (Scott, 1990). The concentrations were very high when compared with published records in coral skeleton from other places. The concentration of Cd was 0.055-2.62 $\mu g.g^{-1}$, that of Cu was 7.87-8.57 $\mu g.g^{-1}$, Pb was 0.206-0.793 $\mu g.g^{-1}$, U was 1.44-5.71$\mu g.g^{-1}$, and that of Y was 0.044-0.155 $\mu g.g^{-1}$. No As, Hg, Cr and Gd were detected. Interestingly, the highest concentrations of these metals were found in corals from the disturbed site Hoi Ha Wan, rather than from Bush Reef. Scott (1990) suggested that enhanced uptake was affected by disturbance.

McCorry and Blackmore (2000) followed up the study on the concentration of metal in coral skeleton. They also examined the concentration of metals in coral tissue. Core samples of *Platygyra sinensis* were collected from Fong Wong Fat, Gruff Head, and Chek Chau along a putative pollution gradient from inner Tolo Harbour to Outer Tolo Harbour (Tolo Channel) (Figure 1). Concentrations of several metal elements were examined, including Cu, Zn, Fe, Mn, Pb and Cd. Except for Cu and Zn, all other metals were highest in coral tissues and skeleton from samples collected from Fong Wong Fat. The concentration of Cu and Zn was highest in coral tissue from Gruff Head. Their results indicated a general lowering of the skeletal metal concentrations from those reported by Scott (1990), although direct comparison must be taken with caution as different methods were used (McCorry and Blackmore, 2000). Besides, except for Chek Chau, samples used in Scott (1990) and in McCorry and Blackmore (2000) did not come from the same sites. The exact effect of heavy metals on coral mortality and growth is still not clear.

Scott (1990), Scott and Cope (1990), Morton (1990) and McCorry and Blackmore (2000) have all alluded to eutrophication as a cause for the decline of coral diversity and abundance in Tolo Harbour and Tolo Channel. Excessive nutrients may affect coral growth or recruitment success indirectly by reducing light penetration (because of plankton bloom), inducing benthic algal blooms, or encourage growth of filter feeders like mussels, ascidians or barnacles that compete with corals for space or even suffocate corals. It has also been suggested that the hypoxia event of 1994 that killed a lot of corals around Mirs Bay may have been made worse by the presence of excessive organic nutrients (BCL, 1995a). Increased organic nutrients have also been suggested to cause an increase in the number of coral borers (Dudgeon and Morton, 1982) such that bioerosion is potentially a very important destructive force against corals (Clark and Morton, 1999). More coral borers are found under more “stressful” conditions. Increase in the number of coral predators, like gastropods (Cumming and McCorry, 1998; Choi, 2002), may also be an indirect effect of organic pollution.

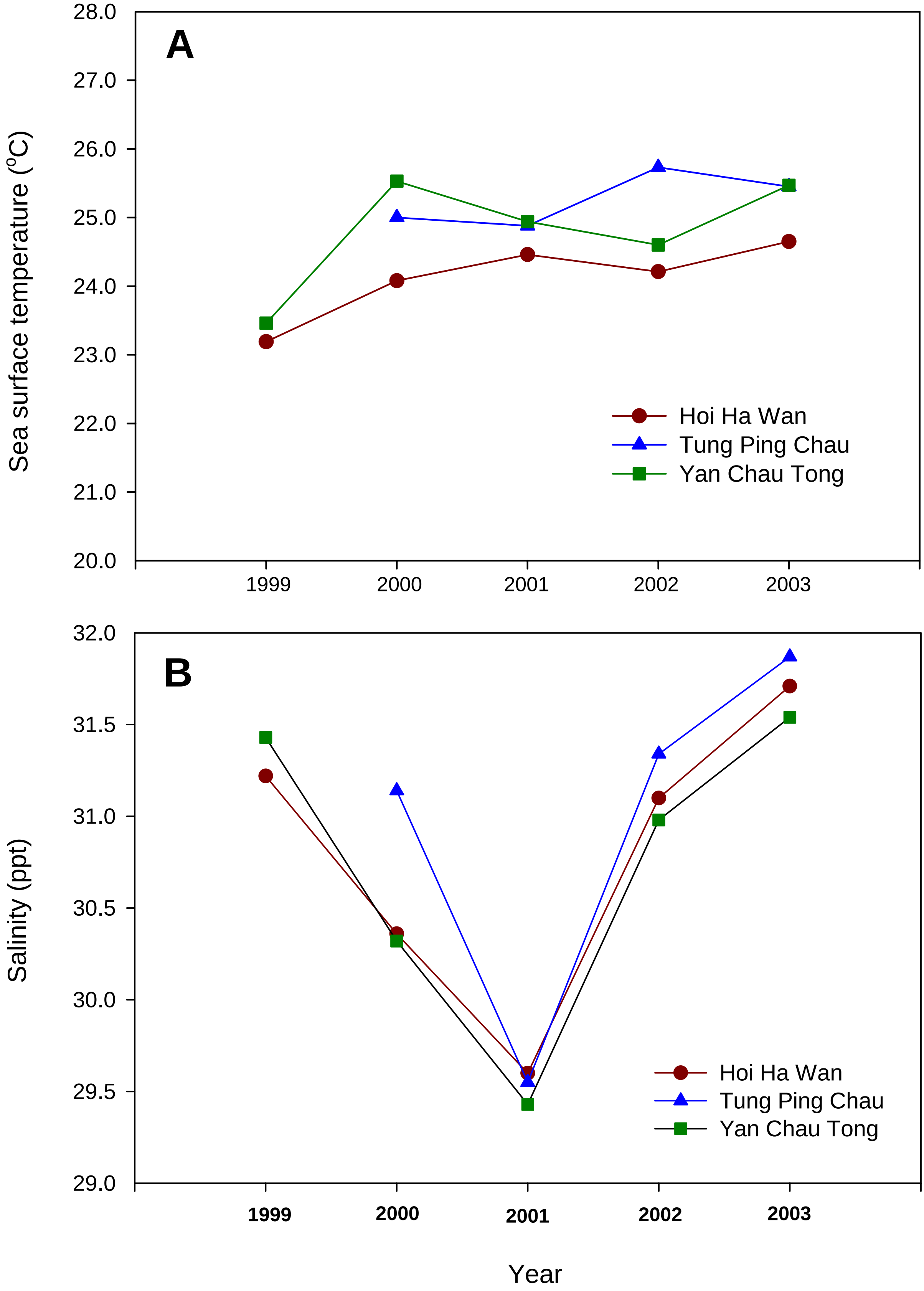

Figure 5. **The annual trend of A. Temperature, B. Salinity, in three Hong Kong Marine Parks, Hoi Ha Wan, Tung Ping Chau and. Yan Chau Tung, from 1999 to 2003. (http://parks.afcd.gov.hk/newmarine/eng/water_report/index.htm)**

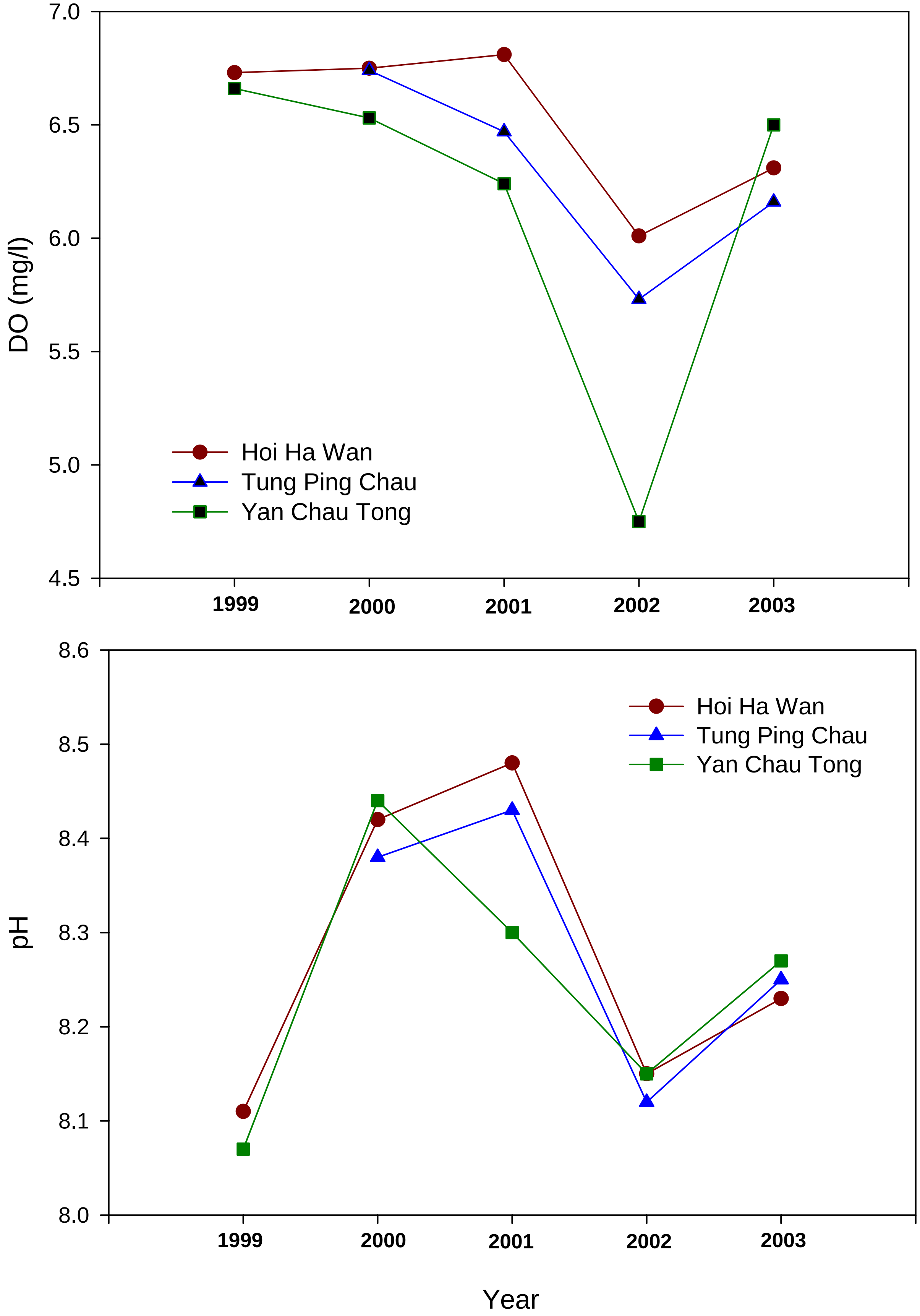

Figure 6. **The annual trend of A. Dissolved Oxygen (DO), B. pH, in three Hong Kong Marine Parks, Hoi Ha Wan, Tung Ping Chau and. Yan Chau Tung, from 1999 to 2003. (http://parks.afcd.gov.hk/newmarine/eng/water_report/index.htm)**

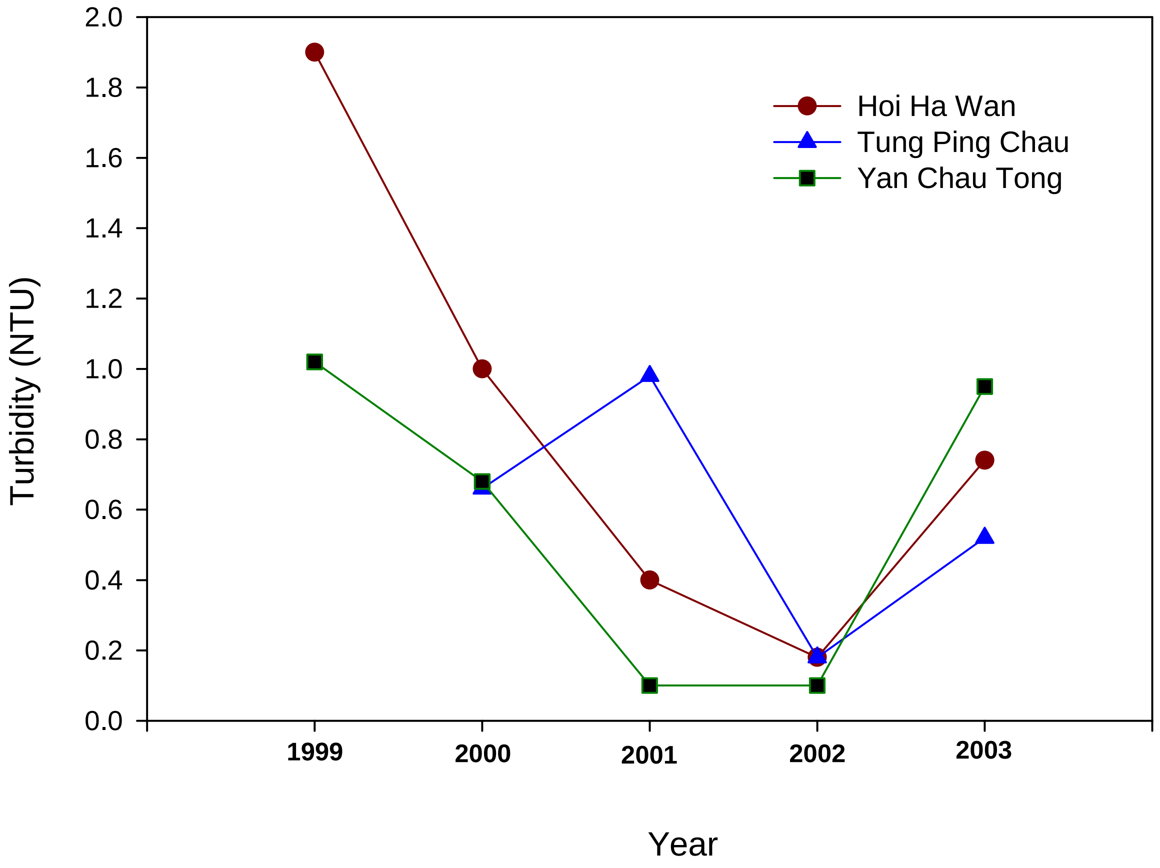

Figure 7. **The annual trend of turbidity in three Hong Kong Marine Parks, Hoi Ha Wan, Tung Ping Chau and. Yan Chau Tung, from 1999 to 2003. (http://parks.afcd.gov.hk/newmarine/eng/water_report/index.htm)**

Dredging from marine borrow to satisfy the need for large reclamation projects like the Hong Kong International Airport at Chek Lap Kok generated excessive siltation around the dredged areas. Hodgson (1994) reported extensive mortality of corals in South Ninepin attributable to heavy siltation brought about by dredging in Tung Long Wan Borrow area. Siltation effects on corals in Po Toi, Sung Kong and Cape d'Aguilar are currently being monitored. There are some reports of siltation being built up on acroporid corals found in these places due to offshore dredging (Wong, C.C., personal communication).

Wong (2001) examined the tolerance of two coral species in Tung Ping Chau, *Platygyra sinensis* (=*Platygyra acuta*) and *Goniopora columna*, to sediment burial. *Platygyra sinensis* appeared to be more efficient in clearing sediments. Ninety percent of the 1000 mg.cm^{-2}.day^{-1} of sediments applied on colonies of *Platygyra sinensis* could be cleared by the corals within 24 hrs. Only 50% of the sediments were cleared by *Goniopora columna* within the same time period. Both corals experienced significant reduction (> 50%) in their zooxanthellae and chlorophyll a concentration when subject to sediment burial. This may be due to tissue loss, rather than the actual loss of zooxanthellae. Both species could survive complete burial for a short time, but tissue necrosis started to appear under 48 hrs burial. Similar experiments were conducted on *Porites lobata* (Yeung, 2000). The responses of this species were very different. Colonies of *Porites lobata* survived 48 hrs complete burial. Coral tissue appeared bleached with the loss of zooxanthellae. However, the corals recovered readily after removal of the sediments and regained their colours. The ability of *Porites lobata* to better survive sedimentation may explain their abundance in highly turbid areas like Yan Chau Tong.

Damaging Fishing Methods

Baseline information are not sufficiently available to allow assessment of fish diversity, abundance and stock biomass of Hong Kong waters in the past. But Hong Kong waters are generally considered as being overfished. A lack of legal restrictions on both the size of gears employed (e.g. hook size, mesh size) and of the size of fishes and invertebrates landed has led to a decrease in the size of the animals being targeted in recent decades. For instance, over 60% of the fish species occurring on coral communities are vulnerable to direct removal by fishing, and many when they are under 10 cm in length (Cornish, 2000). As a result, many commercially important species are taken before they have reached size of sexual maturation.

Although a significant proportion of fishing activities from Hong Kong fishers is carried out in adjacent waters around Hong Kong, e.g. in the East China or South China Seas, trawling, gill-netting, purse-seining and traping using different types of cages are still practiced within Hong Kong territorial waters especially by family based, subsistence fishers. Data are scarce but there have also been a small number of surveys showing low Catch Per Unit Effort and/or biomass. For example, biomass of all fishes on three shallow coral communities in 1997 and 98 derived by visual census and collection was estimated at 20-29 $g.m^{-2}$, one of the lowest yet recorded anywhere from a coral habitat (Cornish, 2000). Biomass at one of the sites, Sharp Island (where fishing is not regulated) declined by 80% from 1997 to 2003. The two remaining sites are within marine parks where recreational fishing and trawling are prohibited but where licensed commercial fishing using hook and line, trap and gill net still take place in most areas. Fish biomass at Tung Ping Chau Marine Park (designated in 2001) remained stable from 1997-2003 but decreased by 54% in the Hoi Ha Wan Marine Park (designated in 1996) over the same period (Cornish, 2000; Cornish, unpublished data). The legal commercial fishing is the most likely cause. Illegal fishing may also contribute to this decline.

In recognition of the poor health of fish stocks in Hong Kong waters, the Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government has proposed three measures to reduce fishing effort. These are intended to be put in place in the next few years following a public consultation period in early 2005, but progress is slow, partly as legislative approval is needed for some aspects. The measures are:

1. To initiate a fishing license scheme whereby all commercial fishing vessels must be licensed with the government. This will allow control of the number of vessels in the local fishery for the first time.

2. To create two large Fisheries Protection Areas (FPAs) in Port Shelter and Tolo Harbour and Channel in eastern and northeastern waters. It is proposed that trawling and spearfishing be banned in the FPAs, and no-take zones created where artificial reefs have been deployed.

3. To extend the fishing ban carried out in waters surrounding Hong Kong by mainland Chinese authorities in June and July to Hong Kong. The ban is intended to allow many species to grow and reproduce without disturbance, although indications are that it may not be applied to all vessels in Hong Kong waters.

These three measures have the potential to greatly reduce fishing pressure in Hong Kong waters and address the overfishing problem, but only if suitable regulations are enacted and enforced, particularly under the fishing license scheme and within the FPAs.

Other efforts have been put forward by the Hong Kong SAR Government to increase fish yields. These include the deployment of artificial reefs and restocking of commercially important fishery species like fish and prawn in marine parks (http://www.afcd.gov.hk/index_e.htm; http://www.hk-fish.net). The first phase of the artificial reef project deployed a total of 372 units (29 350 m^3) of artificial reefs in Hoi Ha Wan and Yan Chau Tong Marine Parks in 1999. In the second phase completed in 2003, 143 (128 950 m^3) artificial reefs were deployed in Outer Port Shelter and Long Harbour, both outside the marine parks. More than 40,000 fish and 1 million prawn fry have been released in trial runs in the past few years in selected places, including Hoi Ha Wan and Yan Chau Tong Marine Parks. There have been reports of promising results from these efforts, but data are scarce and their long term effect in restoring Hong Kong fishery resources may yet to be realized.

Instances of fishing with poisons are rare in local waters but destructive fishing using explosives has taken place in Hong Kong for more than 100 years. The first legislation prohibiting fish bombing was passed in 1903 and has been periodically updated since then but the practice has never been eliminated and still causes sporadic destruction to remote coral communities (Cornish and McKellar, 1998). However, the combined efforts of the Marine Police and AFCD have kept the use of explosives low, and it probably has less impact on coral communities than other anthropogenic activities in most areas.

Anchor and Trawler Damage, Other Kinds of Damage (divers, trampling, etc)

There are no actual/measured data on anchor and trawler damage to Hong Kong coral communities. There are, however, anecdotal evidences to indicate that anchor damage could be quite significant at popular destinations for yacht and pleasure crafts, e.g. in Un Kong Wan in eastern Hong Kong waters and in Chek Chau in northeastern waters. The AFCD has now put up signs in these two sites advising yatch owners not to drop their anchors in coral areas. Although anchoring is restricted within the marine parks, illegal anchorage may occur. The frequency of such occurrence, however, is not known. More recently, there are claims of corals being overturned due to glass bottom boat activity. Other damage by eco-tourists and swimmers standing on the coral heads may also be substantial. The extent of this type of damage has yet to be assessed.

Shrimp trawlers have the potential to cause significant damage to deeper coral communities as there are many such vessels in Hong Kong. There are no restrictions on how shallow they can trawl. As such, trawlers often approach within 100 m of the coast of shallow bays trying to fish in fishing grounds missed by others. However, no specific instances of damage to coral communities by trawlers are known from recent years.

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

Reclamation of coastal areas has been on going in Hong Kong for the last 20 years as a major undertaking by the Hong Kong Government to create new land. Out of a total land area of about 1100 km^2 in Hong Kong, more than 60 km^2 of which were reclaimed land. Most of these reclaimed lands are concentrated around Victoria Harbour, western waters and Tolo Harbour in the northeast. It is not difficult to imagine how much of the Hong Kong coastline has been changed over the last 20 years. As far as major coral communities in Hong Kong are concerned, the impact of reclamation may not be so extreme as most coral communities are found in the eastern and northeastern shore. However, reclamation, and the loss of coastal marine habitat due to it, is only part of the picture. The extraction of materials for use in reclamation is the other part. Materials used in reclamation include construction wastes, earth and rocks dug out from mountain borrows and marine sand. The reclamation that went with the construction of Hong Kong new airport in Chek Lap Kok in the mid 90’s was one of the largest coastal reclamation projects undertaken in the world. One of the main sources of materials for this project was marine sand from Hong Kong’s eastern waters. Dredging for marine sand caused extensive sedimentation on the coral communities along the eastern shores (BCL, 1994; 1995b).

In recent years, the development of a container terminal in Yim Tin, Shenzhen, north of Hong Kong, also involved extensive reclamation of the coastal areas. Although no detailed monitoring of the resulting sedimentation effect was carried out on the Hong Kong side, anecdotal evidence indicates an increase in sedimentation on coral communities in the northeast. To what extent this huge reclamation project will affect the coral communities in Hong Kong, including those in marine parks, remain to be seen.

There are other developmental projects being planned or are already being implemented in Shenzhen or along the northeastern shore of Hong Kong. Examples of these include the building of a gas pipeline from Shenzhen to Tolo Harbour, with part of the pipeline traversing close to Tung Ping Chau Marine Park. Although EIAs have been undertaken and mitigation measures have been proposed, the potential threat of these developmental projects to Hong Kong marine parks and coastal coral communities has not diminished.

Coral Bleaching

No extensive coral bleaching has been observed in Hong Kong, not even during the El Niño year of 1998. More localized bleaching events, however, have been reported (McCorry, 2002; Choi, 2003; Woo, 2005). Bleaching of select coral species, like *Goniopora* spp, *Hydnophora excesa* and *Montipora* spp, has been observed but was usually associated with isolated colonies. Bleaching of these corals was more readily noticeable in summer, but paling of colour in other massive corals like *Porites lobata* or *P. lutea*, may happen in the summer or in the winter as well. This appears to be occurring regularly (Choi, 2003; Woo, 2005). Loss of colour is therefore not only associated with increased temperature in summer, but may also be associated with decreased temperature in the winter, which can reach as low as 13^{o}C. Other factors like lowering of seawater salinity due to heavy rainfall, were also likely to cause coral bleaching (McCorry, 2002; Woo, 2005). Most of the bleached or discoloured corals recover so no massive mortality of corals can be attributed to bleaching alone.

Coral Diseases

No detailed monitoring on coral disease has been undertaken although Oceanway (2001) reported the prevalence of tumours in some dominant coral species like *Platygyra sinensis* (=*Platygyra acuta* ?). No black band nor white band diseases have been observed within the marine park areas. The failure to observe such disease may simply be a result of lack of expertise in this area.

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

The crown of thorn starfish *Acanthaster planci* is not found in Hong Kong waters. In its place as coral predators are the gastropods *Drupella rugosa* and *Cronia margariticola*. Some aggregations of these snails could be observed. Some outbreaks have been reported (e.g. Cumming and McCorry 1998) but these were mainly large aggregation of these snails on isolated coral heads. Other than this, their numbers are generally small and their distribution quite restricted.

In a close monitoring of these corallivorous gastroprods in Tung Ping Chau Marine Park, Choi (2002) found their number to reach a peak in spring, followed by a decline in summer and fall. Their number reached a minimum in winter. There appeared to be significant positive correlation between water temperature and gastropod activities.

Corallivorous gastropods were observed in most of the sites monitored in Hoi Ha Wan and Yan Chau Tong Marine Parks (Ang et al., 2004a) on *Platygyra carnosus* and other faviids like *Favites flexuosa* and *Favia rotumana*. However, the scale of predation was not extensive enough to suggest any population explosion of these predators.

Coral Damage from Natural Events (storms, etc)

On average, five to six typhoons (tropical storms) of various intensities visited Hong Kong annually in the last 18 years (http://www.weather.gov.hk/informtc/historical_tc/fttcwc.htm). Of these, about one would have the intensity of maximum gust wind ranging from 63 to 135 Km/hr (Signal No. 8). 1999 was one of the busiest years with five typhoons registering at signal no. 8. In general, however, apart from some overturn of coral colonies, the damage to the coral communities is not very serious. Nonetheless, plate-like corals, e.g. *Monitopora* spp., and some massive forms like *Cyphastrea serailia*, were observed to be more seriously damaged than other species in Tung Ping Chau Marine Park (Tam, 2005). Bleaching of massive coral heads has also been reported to be a result of typhoons (Clark and Morton, 1999; Morton, 2002).

Several suspected hypoxia events were reported in Hoi Ha Wan and Yan Chau Tong Marine Parks in the last 10 years. A particularly serious one occurred in 1994 when a layer of water with low temperature and low dissolved oxygen stayed at –2 m CD for nearly 2 months in Mirs Bay. This seriously affected the corals of Hoi Ha Wan and extensive mortality (up to 83%) of corals in deeper water was observed (Wilson, 1994; BCL, 1995a). Subsequent surveys (BCL, 1997; Wong, 1998a) found some signs of recovery. Some coral recruits, especially those of *Lithophyllon undulatum* were observed.

A suspected hypoxia event was again observed during the early months of 2004 in some sites in north-western part of Yan Chau Tong Marine Park. In these sites, most corals were found to be covered by a thin sheath of what appeared to be fungal growth. Large scale partial mortality of corals was observed, leading to a large decrease in the coral cover (Ang et al., 2004a). Morality of marine vertebrate (fish) and invertebrate was also recorded in both Hoi Ha Wan and Yan Chou Tong Marine Parks over this same period.

Potential Threats to Coral Reefs (Reef at Risk Threat Indicators)

Hong Kong coral communities are very small, with sizes usually ranging from a few meters to only tens of meters wide from the shore, up to a depth of 5 meter or less. They are therefore very vulnerable to human disturbances. Coastal development and reclamation, pollution from sewage, eutrophication, heavy metal and other industrial wastes and sedimentation, over-fishing and destructive fishing all contribute to their demise. Based on very general surveys, the degradation of Hong Kong coral communities is widely perceived by the recreational divers (Haddock, 1995; Wan, 2003).

Hong Kong coral communities are under serious threat but no reef at risk indicators have ever been calculated for these communities before. Based on data from various sources, the reef at risk indicators for Hong Kong coral communities are now presented in Figure 8 and can be summarized as follow: About 15% of Hong Kong coral communities are subject to a very high degree, and another 80% to high degree of potential threat from coastal development. About 10% of these are subject to very high degree, and another 80% to high degree of marine based pollution impact. Sedimentation is a serious threat as well, with 5% of the communities subject to very high degree, and 60% to high degree of siltation effects. All of the coral communities are overfished, and 80 to 90% of them are exposed to damaging fishing practices.

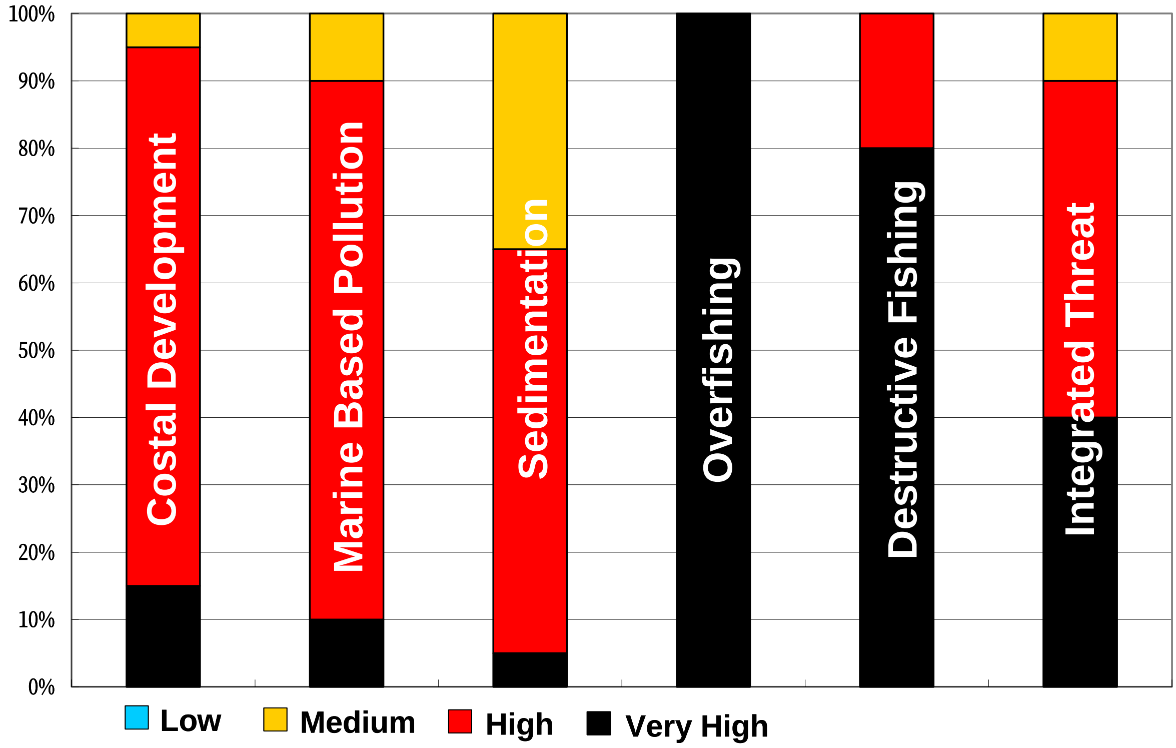

Figure 8: Estimation of relative Reef at Risk in Hong Kong.

Management

Marine Protected Areas

There are currently four Marine Parks (Tung Ping Chau, Hoi Ha Wan, Yan Chau Tong, and Sha Chau and Lung Kwo Chau) and one Marine Reserve in Hong Kong (Table 7). Coral communities are the main target of protection in Tung Ping Chau and Hoi Ha Wan Marine Parks. Several other sites have been surveyed and are targeted for protection in the future. These include Fan Lau (Southwest Lantau), Soko Island Group, Southern Lamma Island (all in southwest and south of Hong Kong), Kat O Chau and Ngo Mei Chau, Tai Long Wan, Long Ke Wan, Bluff Island and Nine Pine Island Group (Figure 1).

Table 7. Marine Protected Areas in Hong Kong (not including wetland parks)

Name	Size (hectares)	Location	Established	Main Target for Protection
Hoi Ha Wan	260	NE	1996	Coral Communities
Yan Chau Tong	680	NE	1996	Mangrove and Seagrass
Cape d’Aguilar	20	SE	1996	Corals, fish and others
Sha Chau and Lung Kwu Chau	1,200	SW	1996	Chinese White Dolphin
Tung Ping Chau	260	NE	2001	Coral Communities and Seaweeds

Monitoring

Monitoring for the health and conditions of Hong Kong marine parks, with focus on their coral communities, is an on-going project. The Agriculture, Fisheries and Conservation Department (AFCD) of the Hong Kong SAR Government is the lead government agency overseeing the protection of Hong Kong marine parks.

AFCD provides the funding for research teams from tertiary institutions to monitor the parks. Currently (2004 – 2005), monitoring of the three marine parks in the northeast, Tung Ping Chau, Hoi Ha Wan, and Yan Chau Tong, is being undertaken by the Marine Science Laboratory of the Chinese University of Hong Kong. Permanent photoquadrats, line intercept and random point methods are employed in these monitoring programmes for benthic communities and visual census method for fish assemblages. In addition, a long-term monitoring programme to monitor coral fish assemblages at two of the marine parks and an additional site has been carried out since 1997 from the Swire Institute of Marine Science (Cornish, 2000; unpub. data.). Monitoring of Cape d'Aguilar Marine Reserve, especially its fish abundance and diversity, is undertaken by AFCD itself. Other research scientists from tertiary institutions in Hong Kong regularly conduct scientific studies within the marine parks and marine reserve. WWF Hong Kong also has an ongoing coral monitoring programme within Hoi Ha Wan Marine Park to assess possible impacts that may arise from educational activities in connection with its Marine Life Centre located inside the Marine Park.

Reef Check has been in place in Hong Kong since its founding. Since 2000, AFCD has taken the lead in organizing annual Reef Check activities in Hong Kong. Reef Check has received very good exposure and in 2004, 33 teams of volunteers have participated, surveying 33 sites around Hong Kong including many sites outside the marine protected areas. Starting Reef Check 2003, the same team is asked to survey the same site. This strategy is likely to be maintained over the years. Other than Reef Check, there are no other monitoring programmes to monitor Hong Kong coral communities outside the marine protected areas.

Legislation

Hong Kong is a signatory of CITES. Several legislatures in Hong Kong have in one way or another provided protection for Hong Kong coral communities or coral community-related organisms. These legislatures are listed in Table 8. The Wild Animal Protection Ordinance and the Animals and Plants (Protection of Endangered Species) Ordinance both cover the terrestrial and aquatic organisms, including marine organisms. They cover the collection, possession and trade of endangered and rare species, especially those restricted under CITES. The Environmental Impact Assessment (EIA) Ordinance, especially its Technical Memorandum Annexes 8, 9, 16 and 17, cover aspects of the fisheries and ecological impacts. Coral communities are always considered as a sensitive receiver in any place where corals are found. EIA reports have become a good source of information on coral communities in places where major project development may be taking place. There have been some surprises at times to find corals in some of the more remote, least expected areas, especially in the west coast. But by far the most important legislature that has a direct bearing on the protection of coral communities is the Marine Parks Ordinance enacted in 1995 to take effect in July 1996. This Ordinance provides for the designation, control and management of marine parks and marine reserves under the Country and Marine Parks Authority of the Agriculture and Fisheries Department (now the Agriculture, Fisheries and Conservation Department). The Authority is advised by the Country and Marine Parks Board that is made up of representatives from different government departments, the academia, NGOs and the public. Coral communities are very often the main focus or target of protection in the designation of marine park and marine reserve.

Table 8. Principle acts and regulations in Hong Kong affecting coral reefs.

Wild Animals Protection Ordinance (Cap. 170)
Animals and Plants (Protection of Endangered Species) Ordinance (Cap. 187)
Marine Parks Ordinance (Cap. 476)
Environmental Impact Assessment Ordinance (Cap. 499), Technical Memorandum Annexes 8, 9, 16, 17

Conclusions and Recommendations

Hong Kong coral communities certainly receive better attention and protection today than 10 years ago. The government, the NGOs and the academe have all done their shares in promoting public awareness on the importance of coral protection in Hong Kong as well as in the region as Hong Kong is the largest importer and consumer of live reef fish in the world. There are, however, still a lot of works to be done. Hong Kong coral communities continue to be faced with enormous threat from development and ignorance. It is hoped that greater long-term conservation of Hong Kong coral communities can be achieved with the following recommendations:

1. Long Term Monitoring of Coral Communities: Continuous evaluation of the health and conditions of coral communities should be carried out focusing on existing and potential marine parks/reserve. Monitoring should be led by experienced scientific personnel and training programme should be put in place to develop more qualified personnel. Setting up of monitoring stations and permanent transects and quadrats to evaluate coral growth and impacts on corals is urgently needed, especially within the marine protected areas.

2. More Comprehensive Monitoring Programme: Monitoring programmes should not be confined to corals or fish alone but should include other organisms, e.g. algae as well as other dominant benthic invertebrates. Indicator species should be identified and other monitoring approaches may be needed.

3. Better Management of Tourist Activities: The number of visitors to marine parks is certainly on the increase. Visitors' impact to coral communities in the marine park, as well as in other places outside the marine park, should be assessed. The activities of divers within the park should be regulated and monitored and a greater consensus with the tourism and diving operators should be attained on how best to control divers activities and eco-tourism operation.

4. Better Management of Marine Parks/Reserve: For historical reason, fishing by the local inhabitants is still allowed within the marine park, although with some regulations. Reducing fishing effort in the marine parks is vital in order to allow fish stocks to recover and the designation of no-take (core) areas within marine parks is an essential part of this. There is a promising example in Tung Ping Chau Marine Park with this type of management strategy.

5. Better Enforcement of Marine Parks Ordinance Against Poachers and Illegal Fishers: More resources should be made available for better enforcement of the Marine Parks Ordinance. Poaching and illegal fishing within the marine parks are quite rampant and for various reasons, successful prosecution of the offenders has not been easy. Many of these poachers are playing mouse and cat with the law enforcers so setting up of permanent outposts in the marine parks could be an effective solution to this problem.

6. Reduced Fishing Efforts in and out of Marine Park, Provision of Alternative Livelihood for Fishers: This is particularly important for the local inhabitants whose livelihood or way of life may be affected by the setting up of marine parks. Some fishers are critical about the marine park conservation efforts. Provision of alternative livelihood could be the key to address their concerns.

7. Better and Effective Public Education Campaign and Involvement of Citizens in Management of Marine Parks/Reserve: Many education campaign has been launched by the government, NGO's, schools and other concerned organizations and individuals over the years but old habits and attitudes are difficult to change. It will take sustained efforts on public education to change these. On the other hand, it is important to make the public realize that their interests are at stake with the deterioration of the environment. This is especially so with respect to diving tour operators, owners of vacation houses and the like. Ultimately, their business interests are closely tied up with a healthy marine environment. Local interest groups may serve as watchdog to help the enforcement of marine park regulation.

8. Designation of More Areas as Marine Parks/Reserves: In Hong Kong, 40% of the land area have already been designated as country park. Marine conservation effort is far behind in this regard with less than 2% of the marine area currently under protection. Existing marine protected areas are small, highly fragmented and far apart. No doubt for the system of marine protected areas to be more effective in achieving its conservation objectives, more areas need to be placed under protection. Currently no clear goal has been set by the government in terms of percentage of marine area to be set aside as protected areas. There is a need to have a comprehensive plan on marine conservation strategy as part of the sustainable development plan of the whole territory. For this plan to succeed, it should take into consideration the strategic development of the whole Pearl River Delta region of southern China.

References

AFCD, 2001. 2001 Hong Kong Reef Check Report. Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

AFCD, 2002. 2002 Hong Kong Reef Check Report. Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

AFCD, 2003. 2003 Hong Kong Reef Check Report. Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

AFCD, 2004. 2004 Hong Kong Reef Check Report. Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., 2002. Conservation of corals in Hong Kong. In: Proceedings of IUCN/WCPA-EA-4 Taipei Conference. March 18-23, 2002, Taipei, Taiwan. (Tsai, H.M. ed.). Taiwan Organizing Committee for the Fourth Conference of the Protected Areas in East Asia, Taipei, Taiwan. pp. 277-295.

Ang, P.O., L.M. Chu, K.H. Chu, C.K. Wong and N.Y.S. Woo, 2000. Study on the Suitability of Ping Chau to be Established as Marine Park or Marine Reserve. Submitted to Marine Parks Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., L.M. Chu, K.H. Chu, C.K. Wong and N.Y.S. Woo, 2002. Study on the Suitability of Kat O and Crescent Island to be Established as Marine Park or Marine Reserve. Final Report submitted to Marine Parks Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., D. McCorry and L.S. Choi, 2003. Establishing a Reference Collection and Field Guides for Hong Kong Scleractinian Coral. Final Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., L.S. Choi and M.W. Lee, 2004a. Monitoring on Coral Communities in Hoi Ha Wan and Yan Chau Tong Marine Parks 2003-2004. Final Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., M.M. Choi, L.S. Choi, K.Y. So and M.C. Tam, 2004b. Biological Monitoring in Tung Ping Chau Marine Park. Final Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., C.W. Fong, M.M. Choi, and S.Y. Wong, 2004c Marine Flora Studies in Hoi Ha Wan Marine Park. Final Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Ang, P.O., T.P. Lin, W.C. Ma, and M.C. Tam, 2004d. Biological Monitoring in Sha Chau and Lung Kwo Chau Marine Park. Second Quarterly Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Binnie Consultants Limited (BCL), 1994. South of Ninepins Borrow Area Environmental Impact Assessment. Draft Report. For Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Binnie Consultants Limited (BCL), 1995a. 1994 Hypoxia and Mass Mortality Event in Mirs Bay. Final Report. For Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Binnie Consultants Limited (BCL), 1995b. Underwater Ecological Survey of North Ninepin Island with a Focus on Coral Recruitment. For Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Binnie Consultants Limited (BCL), 1997. Hoi Ha Wan Quantitative Survey Final Report. For Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Binnie Consultants Limited (BCL), 1998. Marine Ecology Studies. Summary Data Report. For Geotechnical Engineering Office, Civil Engineering Department, Hong Kong Government.

Chen, C.A., K.K. Lam, Y. Nakano, W.S. Tsai, 2003. A stable association of the stress-tolerant zooxanthellae, *Symbiodinum* Clade D, with the low-temperature-tolerant coral, *Oulastrea crispata* (Scleractinia, Faviidae) in subtropical non-reefal coral communities. Zoological Studies 42: 540-550.

Cheung, W.L., 2001. Changes in Hong Kong's capture fisheries during the 20th century and reconstruction of the marine ecosystem of local inshore waters in the 1950s. Department of Ecology and Biodiversity, The University of Hong Kong. pp. 186.

Choi, L.S., 2003. Algal-Coral Interactions in Tung Ping Chau, Hong Kong. M.Phil. Thesis, The Chinese University of Hong Kong.

Choi, M.M., 2002. Coral Bleaching in *Porites lobata* and Predation on *Acropora tumida* by Corallivorous Gastropods in Tung Ping Chau, Hong Kong. M. Phil. Thesis. The Chinese University of Hong Kong.

Clark, T.H., 1997a. The distribution of ahermatypic corals at Cape d'Aguilar, Hong Kong. In The Marine Flora and Fauna of Hong Kong and Southern China IV. Proceedings of 8th International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 2-20 April 1995, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 221-233.

Clark, T.H., 1997b. Tissue regeneration rate of coral transplants in a wave exposed environment, Cape D'Aguilar, Hong Kong. Proceedings of 8th International Coral Reef Symposium, Panama. 2: 2069-2074.

Clark, T.H., 1998a. The distribution of hermatypic Scleractinian corals at Cape d'Aguilar, Hong Kong. In The Marine Biology of the South China Sea. Proceedings of the Third International Conference on the Marine Biology of the South China Sea, Hong Kong, 28 October – 1 November 1996. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 151-164.

Clark, T.H., 1998b. The Ecology of Indigenous and Transplanted Corals in the Cape d'Aguilar Marine Reserve, Hong Kong. Ph.D. Thesis, University of Hong Kong, Hong Kong.

Clark, T.H., 2000. A re-survey of the coral communities in the Cape d'Aguilar Marine Reserve, Hong Kong. In The Marine Flora and Fauna of Hong Kong and Southern China V. Proceedings of the Tenth International Marine Biology Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong, 6-26 April 1998. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 341-350.

Clark, T.H. and B. Morton, 1999. Relative roles of bioerosion and typhoon-induced disturbance on the dynamics of a high latitude scleractinian coral community. Journal of the Marine Biological Association of U.K. 79: 803-820.

Collinson P.R.J., 1997. The Ecology of a Peripheral, Subtropical Coral Community in Hong Kong. Ph.D. Thesis, University of Hong Kong, Hong Kong.

Cook, D.C., A.L.K. Chan, K.C.C. Fok, and K.D.P. Wilson, 1997. A fisheries research profile prior to artificial reef deployment in Hong Kong. In Proceedings of the PACON 97 Symposium on Resource Development – Environmental Issues and Sustainable Development of Coastal Waters, Hong Kong 1997. PACON International. pp. 444-455.

Cope, M., 1982a. A *Lithophyllon* dominated coral community at Hoi Ha Wan, Hong Kong. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 587-593.

Cope, M., 1982b. Interspecific coral interactions in Hong Kong. Proceedings of the Fourth International Coral Reef Symposium 2: 357-362.

Cope, M., 1984. An Ecological Survey of the Scleractinian Coral Community in Hoi Ha Wan, Hong Kong. M.Phil. Thesis, University of Hong Kong, Hong Kong.

Cope, M., 1986. Seasonal, diel and tidal hydrographic patterns, with particular reference to dissolved oxygen, above a coral community at Hoi Ha Wan, Hong Kong. Asian Marine Biology 3: 59-74.

Cope, M. and B. Morton, 1988. The scleractinian coral community at Hoi Ha Wan, Hong Kong. Asian

Marine Biology 5: 41-52.

Cornish A.S., 2000. Fish Assemblages Associated with Shallow, Fringing Coral Communities in Sub-tropical Hong Kong: Species Composition, Spatial and Temporal Patterns. Ph.D. Thesis, Department of Ecology and Biodiversity, The University of Hong Kong.

Cornish A.S. and D. McKellar, 1998. A history of fishing with explosives and poisons in Hong Kong waters. Naga, The ICLARM quarterly 21: 4-9

Cumming, R.L. and D. McCorry, 1998. Corallivorous gastropods in Hong Kong. Coral Reefs 17: 178.

Dudgeon, D. and B. Morton, 1982. The coral associated Mollusca of Tolo Harbour and Channel, Hong Kong. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press. Hong Kong, pp. 627-650.

Haddock, J.E. 1995. Marine Life Degradation in Hong Kong: An Evaluation of Possible Causes and Mitigating Strategies. M.Sc. Thesis, The University of Hong Kong.

Hodgson, G., 1994. The environmental impact of marine dredging in Hong Kong. Coastal Management in Tropical Asia 2: 1-8.

Hodgson, G., 1997. Opportunities for marine conservation in Hong Kong and Southern China. In Proceedings of the First International Symposium on Marine Conservation Hong Kong, 26-27 October 1996, Hong Kong. The Hong Kong Marine Conservation Society. pp. 5-15.

Hodgson, G., 1999. A global assessment of human effects on coral reefs. Marine Pollution Bulletin 38: 345-355.

Hodgson, G. and E. P. M. Yau, 1997. Physical and biological controls of coral communities in Hong Kong. In Proceeding of 8th International Coral Reef Symposium, Panama City, 24-29 June 1996, Panama. Smithsonian Tropical Research Institute, Panama. 1: 459-464.

Lam, K.K.Y., 1998. The Colonization of an Experimental Artificial Reef at Hoi Ha Wan Marine Park, Hong Kong. Ph. D. Thesis. The University of Hong Kong.

Lam, K.K.Y., 2000a. Sexual reproduction of a low-temperature tolerant coral *Oulastrea crispata* (Scleractinia, Faviidae) in Hong Kong, China. Marine Ecology Progress Series 205: 101-111.

Lam, K.K.Y., 2000b. Early growth of a pioneer recruited coral *Oulastrea crispata* (Scleractinia, Faviidae) on PFA-concrete blocks in a marine park in Hong Kong, China. Marine Ecology Progress Series 205: 113-121.

Lam, K.K.Y. and B. Morton, 2003. Morphological and ITS1, 5.8S and partial ITS2 ribosomal DNA sequence distinctions between two species of *Platygyra* (Cnidaria: Scleractinia) from Hong Kong. Marine Biotechnology 5: 555-567.

Leung, K.F., 2000. The Use of Stabilized Coal Combustion Solid Residues for Artificial Reef Construction in Hong Kong: An Examination of Environmental Impacts. Ph. D. Thesis. The University of Hong Kong.

Li, C.P., 1986. The Alcyonacea in Hong Kong waters. Tropic Oceanology 5(4): 19-25.

Lin, T.P., 2003. Reproduction Patterns of Scleractinian Corals from Tung Ping Chau, Hong Kong and the Effect of Physical Factors on These Patterns. M.Phil. Thesis, The Chinese University of Hong Kong.

Liu, S.H., and P.O. Ang, 2002. Fecundity and gametogenesis of the dominant coral *Platygyra sinensis* in Tung Ping Chau, Hong Kong. Asian Conference on Marine Science and Technology, Kuala Lumpur, Malaysia, 2002.

Lun J., 2003. Hong Kong Reef-Building Corals. Marine Conservation Series. Comos Books Ltd.

Ma, W.C. 2005. The Growth and Population Dynamics of the Scleractinian Coral *Oulastrea crispata* in Tung Ping Chau, Hong Kong. M.Phil. Thesis, The Chinese University of Hong Kong.

Mak, P.M.S. 1982. The coral associated polychaetes of Hong Kong, with special reference to the Serpulids. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 595-617.

Marine Parks and Reserves Working Group, 1989. Feasibility Study of Marine Parks and Marine Reserves in Hong Kong. Marine Parks and Reserves Working Group, Agriculture and Fisheries Department, Hong Kong Government, Hong Kong.

McCorry, D., 2000. Shallow scleractinian coral communities of Yan Chau Tong/Lai Chi Wo Marine Park and outer Double Heaven, Hong Kong. In The Marine Flora and Fauna of Hong Kong and Southern China V. Proceedings of the Tenth International Marine Biology Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong, 6-26 April 1998. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 351-368.

McCorry, D., 2002. Scleractinian Coral Communities of Hong Kong: Status, Threats and Proposal for Management. Ph.D. Thesis, The University of Hong Kong.

McCorry, D. and G. Blackmore, 2000. Tolo revisited: A resurvey of the corals and their metal burdens in Tolo Harbour and Channel twelve years and one million people later. In The Marine Flora and Fauna of Hong Kong and Southern China V. Proceedings of the Tenth International Marine Biology Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong, 6-26 April 1998. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 455-484.

McCorry, D. and R. L. Cumming, 1999. Hong Kong's corals communities: surviving adversity? Coral Reefs 18: 408.

Morton, B., 1979. The ecology of the Hong Kong seashore. In The future of the Hong Kong Seashore. B. Morton. (ed.). Oxford University Press, Hong Kong. pp 99-123.

Morton, B., 1980. An introduction to Hong Kong's marine environment with special reference to the north-eastern New Territories. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 25-53.

Morton, B., 1988a. Hong Kong. In Coral Reefs of the World. Volume 3: Central and Western Pacific. S.M. Wells and M.D. Jenkins (eds.). United Nations Environment Programme and International Union for Conservation of Nature and Natural Resources. pp. 171-174.

Morton, B. 1988b. Hong Kong’s first marine ecological disaster. Marine Pollution Bulletin 19: 299.

Morton, B. 1989. Pollution of coastal waters of Hong Kong. Marine Pollution Bulletin 20: 310-318.

Morton, B., 1990. Pollution and the sub-tropical inshore hydrographic environment of Hong Kong. In The Marine Flora and Fauna of Hong Kong and Southern China II. Proceedings of the Second International Marine Biological Workshop: the Marine Flora and Fauna of Hong Kong and Southern China. Hong Kong 1986. B. Morton (ed.). Hong Kong: Hong Kong University Press. pp. 3-30.

Morton, B., 1991. A Bibliography of Hong Kong Marine Science 1842-1990. Hong Kong University Press, Hong Kong.

Morton, B., 1992a. An introduction to Hoi Ha Wan. In The Marine Flora and Fauna of Hong Kong and Southern China III. Proceedings of Fourth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1989, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 781-787.

Morton, B., 1992b. A case for marine conservation: Hong Kong’s scleractinian coral communities. In The Marine Flora and Fauna of Hong Kong and Southern China III. Proceedings of Fourth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1989, Hong Kong. B. Morton (eds.). Hong Kong University Press, Hong Kong. pp. 3-16.

Morton, B., 1994. Hong Kong's coral communities: Status, threats and management plans. Marine Pollution Bulletin 29: 74-83.

Morton, B., 1995. Hong Kong’s corals. Marine Pollution Bulletin 30: 230-231.

Morton, B., 1996. Protecting Hong Kong’s marine biodiversity: present proposal, future challenges. Environmental Conservation 23: 55-65.

Morton, B., 1997. Hong Kong’s first Marine Parks and Reserve. Marine Pollution Bulletin 34: 68-69.

Morton, B., 1998. Hong Kong's Marine Parks Ordinance and designation of the first marine parks and reserve: Where next? In The Marine Flora and Fauna of Hong Kong and Southern China IV. Proceedings of 8th International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 2-20 April 1995, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 541-561.

Morton, B., 2000. Coastal zone management for marine conservation in Hong Kong: The need for regional co-operation in southern China. In The Marine Flora and Fauna of Hong Kong and Southern China V. Proceedings of Tenth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 6-26 April, 1998. Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 3-33.

Morton, B., 2002. Effects of extreme rainfall, typhoons and declaration of marine reserve status on corals beached at Cape d’Aguilar (1998 and 1999). Journal of the Marine Biological Association of U.K. 82: 729-743.

Morton, B. and G. Blackmore, 2000. The Impacts of an Outbreak of Corallivorous Gastropods, *Drupella rugosa* and *Cronia margariticola* (Muricidae), on Hong Kong’s Scleractinian Corals. Final Report submitted to the Government of the Hong Kong Special Administration Region, China.

Morton, B. and E. Harper, 1995. An Introduction to the Cape d’Aguilar Marine Reserve, Hong Kong. Hong Kong University Press, Hong Kong.

Morton, B. and J. Morton, 1983. The Sea Shore Ecology of Hong Kong. Hong Kong University Press, Hong Kong.

Morton, B. and J. Ruxton, 1997. Hoi Ha Wan. World Wide Fund for Nature Hong Kong, Hong Kong.

Morton, B. and S.S. Wu, 1975. The hydrology of the coastal waters of Hong Kong. Environmental Research 10: 319-347.

Morton, B., D. Dudgeon, S.Y. Lee, J. Bacon-Shone, and T.C. Leung, 1991. Hong Kong’s scleractinian coral-gallery communities. Asian Marine Biology 8: 103-115.

Ng. W.C. and B. Morton, 2003. Genetic structure of the scleractinian coral *Platygyra sinensis* in Hong Kong. Marine Biology 143: 963-968.

Ni, I. and P. Qian, 1999. Study on the Suitability of Shelter Island Area to be Established as Marine Park or Marine Reserve. Final Report. A consultancy service submitted to Agriculture and Fisheries Department by Hong Kong University of Science and Technology.

Oceanway Corporation Ltd., 2001. Preliminary Findings on the Incidence of Coral Tumours at Hoi Ha Wan Marine Park. Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Oceanway Corporation Ltd., 2002a. Corals and Coral Communities of Hong Kong: Ecological Values and Status 2001-02. Underwater Survey in Coastal Waters of Hong Kong. Final Report submitted to Marine Conservation Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Oceanway Corporation Ltd., 2002b. Coral Monitoring Marine Parks Programme. Hoi Ha Wan and Yan Chau Tong/Lai Chi Wo Marine Parks: 2001-2002. Report submitted to Marine Parks Division, Agriculture, Fisheries and Conservation Department, Hong Kong SAR Government.

Sadovy Y. and A.S. Cornish, 2000. Reef Fishes of Hong Kong. Hong Kong University Press, Hong Kong.

Scott, P.J.B., 1980. Associations between scleractinians and coral-boring molluscs in Hong Kong. In Proceedings of the First International Workshop on the Malacofauna of Hong Kong and Southern China, 1977, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 121-138.

Scott, P.J.B., 1984. The Corals of Hong Kong. Hong Kong University Press, Hong Kong.

Scott, P.J.B., 1990. Chronic pollution recorded in coral skeletons in Hong Kong. Journal of Experimental Marine Biology and Ecology 139: 51-64.

Scott, P.J.B. and M. Cope, 1982. The distribution of scleractinian corals at six sites within Tolo Harbour and Channel. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 575-586.

Scott, P.J.B. and M. Cope, 1989. Tolo revisited: a survey of the corals in Tolo Harbour and Channel six years and half a million people later. In Proceedings of the Second International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1986, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 1203-1220.

Shen, C.J., 1940. The spicular corals of Hong Kong. Journal of the Hong Kong Fisheries Research Station 1(2): 272-277.

Tam, M.C., 2005. Fish Assemblages in Fished and Protected Areas of the Tung Ping Chau Marine Park. M. Phil. Thesis, The Chinese University of Hong Kong.

Tam, T.W., 1998. The Object-oriented Simulation on the Community Structure of a Coral Community in Ping Chau, Hong Kong. M. Phil. Thesis, The Chinese University of Hong Kong.

Tam, T.W., 2005. Ecological Monitoring and Objected-Oriented Simulation Studies on Stability and Alternative Stable States of Coral Reef Communities. Ph.D. Thesis, The Chinese University of Hong Kong..

Thompson, G.B., 1982. Some echinoderms collected from coral habitats in Tolo Harbour, Hong Kong. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 651-654.

Thompson, G.B. and M. Cope, 1982. Estimation of coral abundance by underwater photography. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 557-573.

Trott, L.B., 1972. Marine ecology in Tolo Harbour, Hong Kong. Chung Chi Journal 11: 26-32.

Tsang, E. and M. Malicich, 1999a. Study on the Suitability of South Lamma to be Established as Marine Park or Marine Reserve. Submitted to Marine Parks Division, Agriculture and Fisheries Department, Government of Hong Kong SAR.

Tsang, E. and M. Malicich, 1999b. Study on the Suitability of South West Lantau to be Established as Marine Park or Marine Reserve. Submitted to Marine Parks Division, Agriculture and Fisheries Department, Government of Hong Kong SAR.

Veron, J.E.N., 1982. Hermatypic Scleractinia of Hong Kong – an annotated list of species. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 111-125.

Verrill, A.E., 1869. Synopsis of the polyps and corals of the North Pacific Exploring Expedition, under Commodore C. Ringwold and Captain John Rodgers, USN, from 1853-1856. Collected by Dr. W. Stimpson, Naturalist to the Expedition, Part 4. Proceedings of the Essex Institute 6: 1-104.

Verrill, A.E., 1902. Notes on corals of the genus Acropora (Madrepora Lam.) with new descriptions and figures of types and of several new species. Transactions of the Connecticut Academy od Arts and Science 11: 207-266, pls. 36-36F.

Wan, M., 2003. The status of scleractinian corals in Hong Kong, with a survey of diver's opinion. In Perspectives on Marine Environmental Changes in Hong Kong and Southern China, 1977-2001. Proceedings of an International Workshop Reunion Conference. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 757-781.

Wang, Z.H. and R. L. Zou, 1992. A fuzzy clustering analysis of the Genus *Favia* (Anthozoa: Scleractinia) at Hoi Ha Wan. In The Marine Flora and Fauna of Hong Kong and Southern China III. Proceedings of Fourth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1989, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 883-889.

Watts, J.C.D., 1971. A general review of the oceanography of the northern sector of the South China Sea. Hong Kong Fisheries Bulletin 2: 41-50.

Wilson, K.D.P., 1994. Coral catastrophe at Mirs Bay. About Life. Autumn: 8-10.

Wilson, K.D.P., 2003. Artificial Reefs and Reef Fish in Hong Kong. Friends of the Country Parks and Cosmo Books Ltd., Hong Kong pp 176

Wilson, K.D.P. and E.C.K. Wong, 1996. Fisheries, mariculture and marine protected areas in Hong Kong. Coastal Infrastructure Development in Hong Kong, a review. Civil Engineering Office, Civil Engineering Department, Hong Kong Government: 215-231

Wong, C.C., 1998a. A Survey of the Coral Communities at Hoi Ha Wan after Establishment of Marine Park. Summer Student Project Report, Agriculture and Fisheries Department, Hong Kong SAR Government.

Wong, C.C., 1998b. Comparison of Scleractinian Coral Communities Between Hoi Ha Wan and Tung Ping Chau. Directed Research Report, Environmental Science Programme, The Chinese University of Hong Kong.

Wong, C.C., 2001. The Responses of Two Scleractinian Corals, *Platygyra sinensis* and *Goniopora columna*, to Sedimentation and Burial. M. Phil Thesis, The Chinese University of Hong Kong.

Woo, C.K., 2005. The Recovery of Scleractinian Corals from Injuries in Tung Ping Chau, Hong Kong. M. Phil Thesis, The Chinese University of Hong Kong.

Wu, R.S.S., 1988. Marine pollution in Hong Kong: a review. Asian Marine Biology 5: 1-23.

Yeung, K.P., 2000. Changes in Zooxanthellae Density and Chlorophyll-a Concentration in Corals *Porites lobata* after short-term sediment burial. Directed Research Report, Environmental Science Programme, The Chinese University of Hong Kong.

Yim, W.W.S., P. S. Nau and B. R. Rosen, 1981. Permian corals in the Tolo Harbour formation, Ma Shi Chau, Hong Kong. Journal of Paleontology 55: 1298-1300.

Zou, R.L., 1982. A numerical taxonomic study of *Turbinaria* (Scleractina) from Hong Kong. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 127-134.

Zou, R.L. and P. J. B. Scott, 1982. The Gorgonacea of Hong Kong. In Proceedings of the First International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1980, Hong Kong. B. Morton and C.K. Tseng (eds.). Hong Kong University Press, Hong Kong. pp. 135-159.

Zou, R.L., Z. Meng and X. Guan, 1983. Ecological analyses of ahermatypic corals from the northern shelf of South China Sea. Tropic Oceanology 2(3): 1-6.

Zou, R.L., Z. H. Wang and C. P. S. Cheung, 1992. A resurvey of the corals at Hoi Ha Wan, after eight years and the Tai Leng Tun borrow area. In The Marine Flora and Fauna of Hong Kong and Southern China III.

Proceedings of Fourth International Marine Biological Workshop: The Marine Flora and Fauna of Hong Kong and Southern China, 1989, Hong Kong. B. Morton (ed.). Hong Kong University Press, Hong Kong. pp. 837-849.

Zou, R.L. and J. M. Zou, 1984. Antipatharians from Hong Kong waters with a description of a new species. Asian Marine Biology 1: 101-106.

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3.3 STATUS OF CORAL REEFS OF TAIWAN

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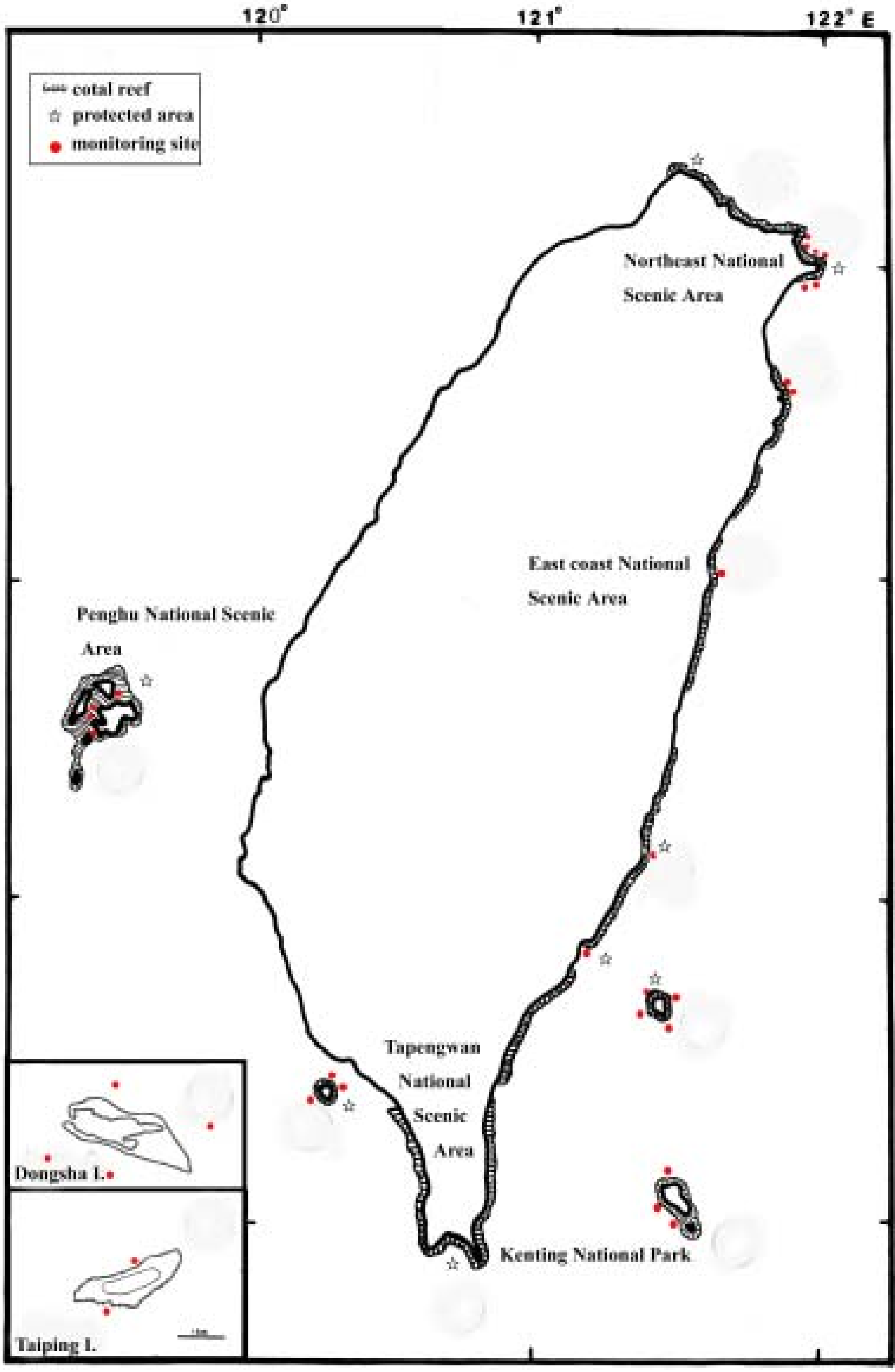
Abstract
Coral reefs are found in all the waters around Taiwan except in the sandy area on the west coast. Coral reefs are the most important marine ecosystems in Taiwan since they support local fishery resources, tourism industry, and coastline protection. A total of 32 sites in 8 major reef regions around Taiwan were monitored yearly using the Reef Check protocol from 1997 to 2004. In addition, 4 sites at Dongsha Island were surveyed every two to four years. The percentage of hard coral cover showed a wide range of variation among the 32 sites. Both increasing and decreasing trends in coral cover were observed during the survey years, resulting in no significant changes among years. However, more increasing trends at reef slope and more decreasing trends at reef flat were found, suggesting that the reef flat biota was more frequently influenced by anthropogenic disturbances than that of the reef slope. Among sites showing decreasing trends of coral cover, 88% of the cases were coupled with increasing in the proportion of other substrates such as dead coral and algae. The abundances of fish and invertebrate indicators at most sites were at low levels suggesting that most reefs were under the heavy stress of overfishing. In general, only coral reefs at Lutao (Green Island) and the inner bay of Penghu Islands, both with high coral cover, were in favorable conditions. The reefs of Kenting National Park in southern Taiwan showed a trend of stable or increasing in coral cover but under stressed indicating that the reef management practices were needed to be improved. Most coral reefs in Taiwan are within national parks, national scenic areas or coastal conservation zones and these areas are protected by the National Park Law and the Coastal Environmental Protection Plan. However, the current laws are inadequate to protect coral reefs. The revision of laws and the planning of MPAs with effective management are currently processing by governmental administrations. The enforcement of laws and pollution control, particularly sedimentation from terrestrial runoff, are major needs for protection of coral reefs in Taiwan. Besides, effective management of marine recreation activities and raising public awareness are also needed.

Table 1: Summary of coral reef status in Taiwan

Area	Reef type	Management	Long-term monitoring sites	status
Southern Taiwan	Fringing reef	Kenting National Park	6	Stressed
Eastern Taiwan	Patch reefs	East Coast National Scenic Area	3	Fair
Ilan County	Patch reefs	None	4	Poor
Northeastern Coast	Patch reefs or coral community	Northeastern Coast National Scenic Area	4	Poor
Hsiaoliuchiu	Fringing reef	Tapengwan National Scenic Area	4	Poor
Penghu Islands	Fringing reefs or patch reefs	Penghu National Scenic Area	4	Poor
Lutao (Green Island)	Fringing reefs	Eastern Coast National Scenic Area	4	Fair
Lanyu (Orchid I.)	Fringing reefs	None	3	Fair
Dongsha (Pratas) I.	Atoll	Dongsha National Park	None	Poor
Taiping (Itu Aba) I.	Atoll	Coast guard	None	Fair

Introduction

Coral Reefs
Coral reefs are found in all the waters around Taiwan except in the sandy area on the west coast. The main reef area is around the southern tip of the island, the Hengchun Peninsula where well-developed fringing reefs are found. These reefs are characterized by diverse and abundant scleractinians and alcyonaceans with living coral cover ranged from 30 to 60% (Dai, 1991). The northern, northeastern and eastern rocky coasts have flourishing or patchy coral communities with scattered reef development. These coral communities are dominated by scleractinians with living coral cover ranged from 15 to 40%.



Map 1. Distribution of coral reefs, monitoring sites, and MPAs in Taiwan.

Coral reefs are also found on the shallow waters surrounding offshore islands including Lutao (Green Island), Lanyu (Orchid Island), Hsiaoliuchiu and Penghu Islands (the Pescadores). The coral reefs at Lutao and Lanyu, located off southeastern Taiwan, are densely covered with abundant scleractinians and alcyonaceans and living coral cover 40 to 70% of the bottom. Hsiaoliuchiu, off the southwestern Taiwan, is an uplifted reef island. The coral fauna of this island is dominated by scleractinians with living coral cover ranged from 20 to 50% (Yang et al. 1975). Penghu Archipelago is composed of 64 islands located about 50 km west off Taiwan in the Taiwan Strait. Corals are widely distributed in the shallow subtidal areas of these islands and coral communities in these islands are dominated by scleractinians with living coral cover ranged from 20 to 60%. Dongsha (Pratas) Island and Taiping (Itu Aba) Island are atolls in the South China Sea (Dai et al. 1995; Dai and Fan 1996). These reefs are formerly inhabited by rich scleractinians and alcyonaceans. However, coral cover at Dongsha Island declined to a very low level (<10%) following intensive overfishing, destructive fishing, and the coral bleaching event in 1998 (Soong et al. 2002, Dai 2005).

Most coral reefs in Taiwan are within National Parks or National Scenic Areas. These include the Kenting National Park in South Taiwan, the Northeast Coast National Scenic Area, the East Coast National Scenic Area, Tapengwan National Scenic Area, Penghu National Scenic Area, and Dongsha National Park. The status of coral reefs in eight regions including NE coast, Ilan County, East Taiwan, South Taiwan, Lutao, Lanyu, Hsiaoliuchiu and Penghu Islands, have been monitored by the Reef Check surveys from 1997 to the present.

Biodiversity

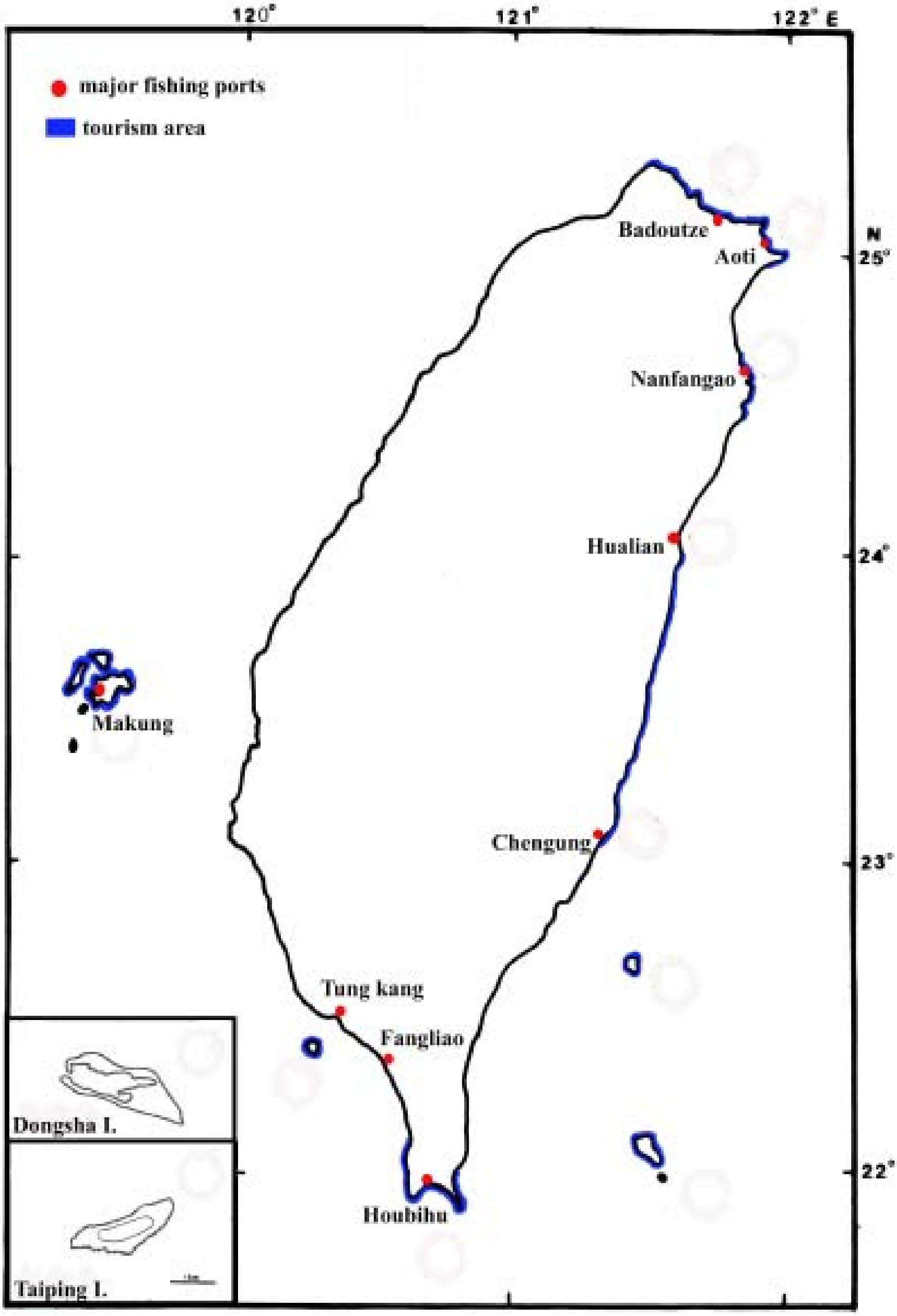
Species diversity of reef organisms on the coral reefs around Taiwan area is relatively high. Approximately 300 species of scleractinian corals, 50 species of alcyonaceans, 20 species of gorgonians, 130 species of decapod crustaceans, 90 species of echinoderms, 1200 species of reef fishes and 150 species 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 north and northeast coast of Taiwan. A total of 101 species of scleractinians in 34 genera, 28 species of alcyonaceans in four genera, three species of gorgonaceans and three species of hydrocorals have been recorded from Dongsha Island (Dai et al. 1995). A total of 163 species of scleractinians, 15 species of alcyonaceans, 6 species of gorgonaceans and 421 species of reef fishes have been recorded from Taiping Island in the Spratlys of the South China Sea (Dai and Fan, 1996; Chen et al. 1997). Since only few surveys have been conducted on most reefs, far more species have not been reported and the estimated species diversity is possibly much higher than the number currently known.

Table 2: Estimated number of species of reef biota in Taiwan

Area	Scleractinians	Octocorals	Fish	Molluscs	Crustaceans	Macroalgae
Southern Taiwan	300	100	1200	600	300	200
Eastern Taiwan	200	50	800	500	300	250
Ilan County	120	50	800	500	200	200
Northeastern Coast	100	50	800	400	250	300
Hsiaoliuchiu	200	50	1000	400	250	200
Penghu Islands	200	50	1000	500	300	250
Lutao	300	100	1200	600	300	200
Lanyu	300	100	1200	600	300	200
Dongsha I.	300	100	1200	600	300	200
Taiping I.	300	100	1200	600	300	150

Resource Use

Coral reefs in Taiwan are important for both fisheries and tourism. Fish and invertebrates collected from waters adjacent to coral reefs comprise considerable portion of the total catch of near shore 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 the Kenting National Park in south tip of Taiwan, 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 upon coral reefs. Approximately 150,000 people rely on coral reefs, at least in part, for livelihood.



Map 2: Major Fishing Ports and tourism use areas in Taiwan.

i. Reef Fish and Fisheries

Reef fish, mollusks (abalones, squids and octopus), crustaceans (spiny lobsters and crabs), fleshy algae are the target of near shore fishery in Taiwan. Fishing ports are distributed around the coast of Taiwan and offshore islands. Principal fishing ports includes Badoutze on the northern coast, Aoti on the northeastern coast, Nanfanao in Ilan county, Chengung on the eastern coast, Houbihu on the southern coast, Fangliao and Tungkang on the southwestern coast, and Makung in Penghu Islands. Reef fish are caught by a variety of gears including long line, purse seines, gill nets, and spearing. Aquarium fish collection are common on most reef areas. Abalones are mainly harvested on the eastern and northeastern coastal areas. Squids and octopus are mainly harvested on the northern and southwestern coasts and Penghu Islands. Spiny lobsters are collected on most reefs and fleshy macroalgae are harvested by local fisherman on the northeastern coast and Penghu Islands. Reef fisheries in Taiwan have a long history for more than 300 years. However, most of the fishery resources have been depleted during the past two or three decades.

ii. Tourism

Reef tourism in Taiwan started to flourish in 1990. Scuba diving, snorkeling, and glass-bottom boats are the major recreation activities on most reefs. Main resorts and diving centers are located at Kenting in southern Taiwan, Longdong on northeastern coast and Lutao. Since most reefs are readily accessible from the shore, cruise and boat diving are not as common in Taiwan.

iii. Other Uses

Research and education facilities using coral reef resources include National Aquarium and Museum of Marine Biology in southern Taiwan, several research stations of Taiwan Fisheries Research Institute in northern, eastern, southwestern Taiwan and Penghu Islands. Besides, many institutes collect soft corals, reef sponges and macroalgae for pharmacological studies.

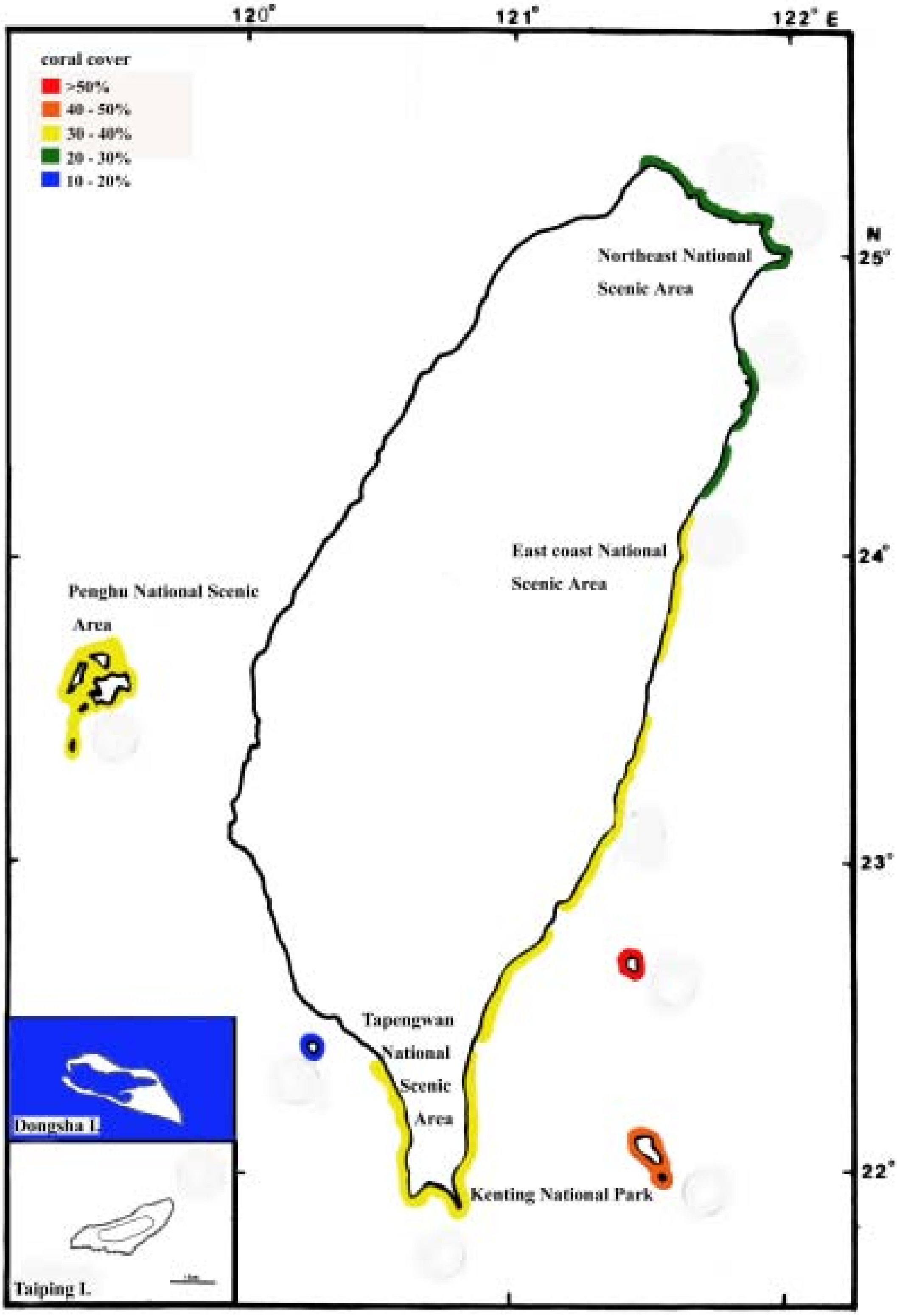
Status of Coral Reefs

a. Status of Reef Benthos (especially corals)

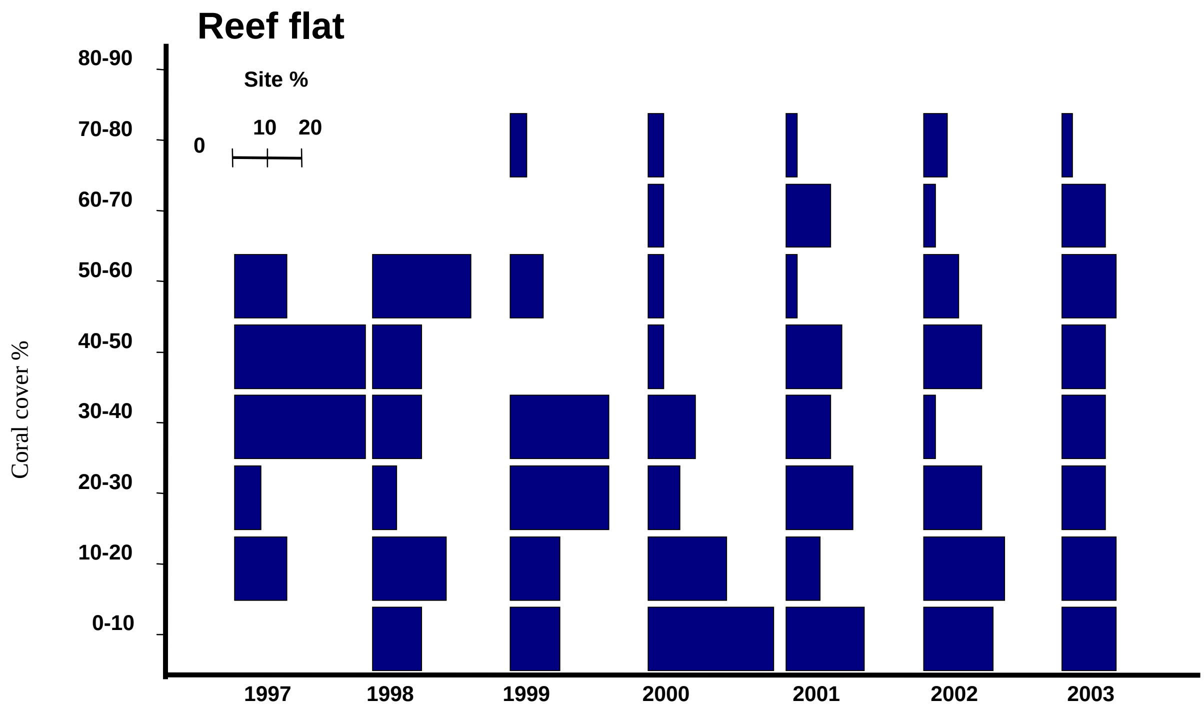
Coral reefs at 32 sites in 8 regions have been monitored using Reef Check surveys from 1997 to 2004. These monitoring are conducted by members of the Taiwanese Coral Reef Society and volunteers of local diving clubs.

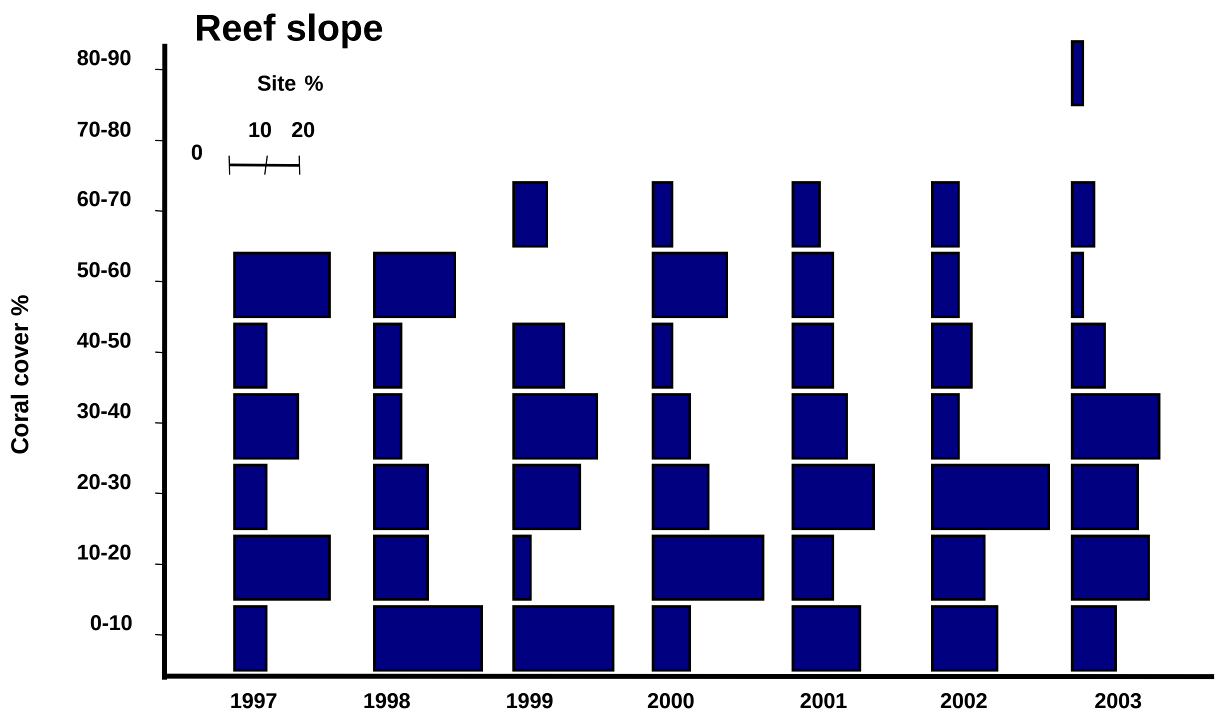
The percentage of hard coral cover on 32 sites showed a wide range of variation. The highest coral cover was found at the Inner Bay of Chinwan (65%), Penghu Is., Hsiangjiaowan (65%) in southern Taiwan, and Kunguan (59%) at Lutao, representing sites with reefs in “good conditions”. Living coral cover at more than half (18/32) of the sites was lower than 30%. Coral cover at reef sites on the northeastern coast and Ilan County was generally below 30%, indicating the marginal environment for coral growth. In tropical environment of southern Taiwan, living cover of hard corals at five in six sites was higher than 30%. Results also show a general trend of stable or increasing in coral cover on Taiwanese coral reefs especially after 2001, but some of these reefs were still under stress. Since both increasing and decreasing trends were observed at different sites, overall, no significant changes in coral cover among years from 1997 to 2004 were detectable using trend analysis.

Hard corals were the dominant benthic organisms at most sites, although soft corals were relatively abundant at four sites. The percentage of dead corals and coral skeletons covered by macroalgae were very high at Dongsha Island reflecting severe reef damage caused by destructive fishing and rising sea temperatures in recent years. Similar phenomenon also occurred at several sites in eastern Taiwan. Bare rocks occupy a large percent of the substrate at many sites, especially in southern Taiwan, Hsiaoliuchiu, northeastern coast and Ilan County, suggesting that reef destruction in these areas occurred several years ago. Approximately 30% of the sites showed a higher cover of fleshy and coralline algae, mostly in northeastern coast and Lanyu suggesting a phase-shift from coral-dominated to algal-dominated reefs. Low density of herbivores and nutrient enrichment are the possible factors responsible for the increasing of macroalgae on reefs.



Map 3: Average coral cover on reefs in Taiwan.





Graph 1: Trends in coral cover at 32 monitoring sites in eight areas around Taiwan from 1997 to 2003.

Table 3: Area summaries for percent cover of major benthic groups on reefs in Taiwan in 2004

Area	Hard coral	Soft coral	Macroalgae	Dead coral	Bare rock	Sand & mud	Others
South Taiwan	41.76	6.30	6.55	0.22	36.40	7.27	1.55
East Taiwan	33.30	9.90	34.40	0.35	13.45	5.35	3.25
Ilan County	21.30	7.80	25.23	0.15	40.40	5.15	0
NE Coast	22.55	1.63	39.88	1.88	22.28	10.93	0.85
Hsiaoliuchiu	14.60	0	24.87	11.07	20.93	27.87	0.66
Penghu Islands	32.30	0.45	25.90	27.55	0.25	12.45	1.10
Lutao	52.75	13.80	3.90	3.95	17.00	6.60	2.00
Lanyu	41.13	15.93	5.60	3.87	24.80	7.33	1.34
Dongsha I.	11.50	7.62	31.30	38.20	6.27	3.46	1.65

b. Status of Reef Fish

The abundance of fish indicators remained very low at most sites from 1997 to 2004. Humphead wrasse, bumphead parrotfish, and reef barracuda were absent at all of the 32 reef sites monitored. None grouper was recorded at 78% of the reef sites. Grouper were relatively common in Penghu islands where they were recorded at five among seven sites, although the population density was very low and their body sizes were small. Grouper are heavily fished by a variety of methods in the waters around Taiwan due to their high commercial values. The abundance of snappers was also very low, none was recorded at 63% of the sites and only one or two individuals were found in a belt transect of 500 m^2 at 26% of the sites. The extremely low densities of grouper, sweetlips 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 predominantly fall in the >2-4 fish per 100 m^2 class. This is much lower than most Indo-Pacific reef sites where the majority were in the >6-8 fish per 100 m^2 class. The low density of butterfly fish indicates that the reefs are under the stress of aquarium fish collection.

c. Status of Resource Use

All of reef areas in Taiwan have been overfished and fishery resources have been depleted at least ten years ago. As apparently seen in the results of Reef Check surveys from 1997 to 2004, the abundance of all fish indicators were very low and very few commercially valuable fishes existed on the reefs in Taiwan. Most reefs also suffered from intensive aquarium fish collections. Marine recreation activities, mainly scuba diving and snorkeling, were flourishing during the past ten years. Reefs on the northeastern coast, southern Taiwan, Lutao, Lanyu, and Penghu Islands have been frequently visited by tremendous amount of tourists every year. The trend for tourism development is accelerating due to the growing demand for marine recreations, putting even more pressure on these reef sites.

d. 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. SST has been constantly monitored at major port areas but the trend of variation during the past 20 years is still obscured. Salinity and turbidity have only been measured occasionally, although the increase in turbidity, which could be detected by satellites images, has been brought up recurrently. The existing data of our physical environment are not sufficient to unveil the long-term trend of environmental changes.

Stress and Damage to Coral Reefs

a. 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 coastal areas, especially after storms. These runoffs have carried large amounts of sediment and nutrients to the reef areas. In addition, sewage from most human-inhabited coastal areas is often discharged into the ocean without proper wastewater treatment. This induces serious nutrient enrichment to reef ecosystems especially in northeastern and southern Taiwan, and Hsiaoliuchiu.

b. ***Destructive Fishing Methods***

Although blast and poison fishing methods have been officially banned, there are still sporadic reports on these illegal fishing methods. These fishing practices mainly occur in southern Taiwan and several offshore islands including Hsiaoliuchiu, Lutao, Lanyu, Penghu Islands and Dongsha Island. Gill nets have been commonly used for fishing in most reef areas and discarded fishing gears are often found entangled on the reefs. Preventive measures to reduce illegal fishing practices include intensive inspections and patrols by coast guards, although the effective strength of law enforcement varies in different areas.

c. Anchor and Trawler Damage, Other Kinds of Damage (divers, trampling, etc)

Damages caused by anchoring were found every once in a while on most reefs. Bottom-trawlers, with their heavy gears sweeping across reef surface, have caused severe damage to coral reefs in Penghu Islands. Trampling and mechanical breakage of coral skeleton by divers and tourists have always been a serious problem at diving hotspots in Lutao, Penghu and southern Taiwan.

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

The construction of the Fourth Nuclear Power Plant in Yenliao, northeastern Taiwan, could be responsible for the deterioration of coral reefs in that area. Thus, the reefs are being monitored regularly in recent years. In other areas of northeastern and eastern Taiwan, damages on coral reefs occurred as a consequence of the construction of fishing ports and coastal highway.

e. Coral Bleaching

Extensive coral bleaching was observed in Penghu Is., and Hsiaoliuchiu reefs following heavy rainfalls associated with typhoons in June and July, 2004. Apparently these bleaching events were related to the significant reduction of light intensity in the water column due to high turbidity.

f. Coral Diseases

No coral disease outbreak was observed or reported in the past in Taiwan. However, coral diseases including various kinds of tissue or skeleton abnormality were noticed in northeastern, eastern, and southern Taiwan, also offshore islands such as Hsiaoliuchiu and Penghu Is. It has been noticed that the incidences of coral diseases are rapidly increasing. There is an urgent need for studies on coral diseases in Taiwan.

g. Outbreaking or Invasive Organisms (COTS, Drupella, Diadema, etc)

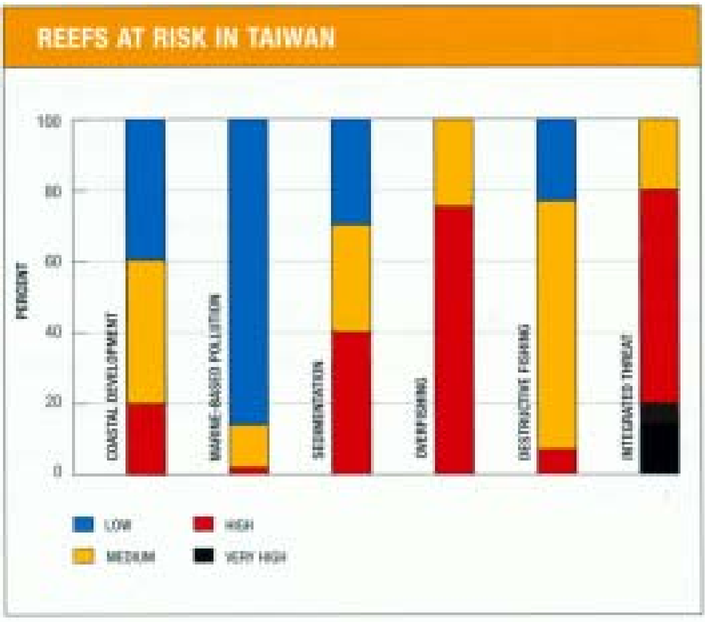
COTs have rarely been observed on the reefs around Taiwan. They can only be found sporadically and occasionally. High densities of *Drupella* were discovered at one site in Penghu Islands. However, it is not an outbreak since this snail is rare on other reefs. Outbreak of a sea anemone, *Condylactis nanwanensis*, was noticed in Nanwan Bay, southern Taiwan. This species has been suggested as an invasive species possibly from the Caribbean through the aquarium trade (Tsai et al. 2002). The outbreak of this sea anemone, which destroyed coral tissue and weakened coral skeleton, resulted in severe damage to coral reefs (Chen and Dai, 2004). However, the abundance of the sea anemone decreased and that of hard corals recovered from 2003 to 2005 (Fan et al. unpubl. data).

h. Coral Damage from Natural Events

Coral damages, mainly mechanical breakage and sediment burial, caused by typhoons have been occasionally observed at monitoring sites. These damages caused by typhoon disturbances vary greatly 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 Is. suffered seriously from Typhoon Chibi in September 2001, with coral mortality up to 90%, and have not recovered since then.

Potential Threats to Coral Reefs (Reef at Risk Threat Indicators)

A revision of the five indicators of RRSEA analysis demonstrates that all of Taiwan's reefs are threatened. Overfishing and destructive fishing together threatened 75% of the reefs; sedimentation and coastal development both threatened 50% of the reefs.



Graph 2: Reef at Risk Threat Indicators for reefs in Taiwan in 2004.

~~6.~~Management

a. Marine Protected Areas

Most of the reef areas are within national parks or national scenic areas. The management is entrusted in the following Authorities: Kenting National Park in south Taiwan; the Northeastern Coast National Scenic Area; the East Coast National Scenic Area; Tapengwan National Scenic Area; and Penghu National Scenic Area. Unfortunately, the effectiveness of this management is poor, because the lack of adequate laws restricts the power of these authorities to enforce 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.

b. Monitoring

Monitoring of coral reefs has been conducted by Taiwanese Coral Reef Society using Reef Check surveys from 1997 to the present. This long-term monitoring is sponsored by the Administration of Fisheries of the Taiwanese government. Another long-term ecological research program was launched in 2001 to study and 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 the Research Center for Biodiversity, Academia Sinica (http://140.117.92.194/lter).

c. Legislation

Coastal resources are protected under the National Park Law and the Coastal Environmental Protection Plan which are administered by the National Park Department, Ministry of Interior. Despite this, these laws are not competent to protect coastal areas. The Coastal Area Protection Act, which is focused on conservation and sustainable management, is under revision by legislators. This law may strengthen the legal basis for the management of coastal areas in Taiwan.

~~7.~~Conclusions and Recommendations

Data from our past surveys indicates that coral reefs of Taiwan are under concomitant, intense pressure of overfishing and destructive fishing, pollution and nutrient enrichment from terrestrial sedimentation, marine recreational activities, and global climate change. Our results show that only one-fifth of the reef sites in Taiwan are in "good conditions", with coral coverage higher than 50%. About half of the reef sites are in "stressed conditions", with coral coverage between 30 to 50%. The rest of the sites are in "degraded conditions", with coral coverage lower than 30%. The assessments of fish and invertebrate indicators revealed that all kinds of marine organisms with commercial values are very rare, further illustrating that coral reefs of Taiwan are in a highly disturbed, overfished situation.

Consequently, when considering strategies for coral reefs conservation, ways to eliminate or alleviate anthropogenic threats to coral reefs are of primary concern. In order to protect coral reef resources, the following measures are recommended: the establishment of MPAs, marine pollution control, development of coral nurseries, changeover to a sustainable exploitation of marine resources, cultivation of endangered species, raise public awareness, and initiate related researches regarding coral reefs and marine ecological conservations. We proposed the MPAs should include reef sites that have had stable, high coral coverage during the past surveys and high biodiversity. These areas include Longdong Bay, Maoao Bay, Tofuchia, Shitiping, Sansientai, Lutao, Lanyu, west of Shiaoliuchiu, and Chinwan, Jiangjunao, Dongyuping, and Xiyuping of Penghu Islands.

8.References

Chen CA, Dai CF (2004) Local phase shift from *Acropora*-dominant to *Condylastis*-dominant community in the Tiao-shi reef, Kenting National Park, southern Taiwan. Coral Reefs 23: 508.

Chen JP, Jan RQ, Shao KT (1997) Checklist of reef fishes from Taiping Island (Itu Aba Island), Spratlys Islands, South China Sea. Pacif. Sci. 51(2): 143-166.

Chen JP, Shao KT, Ho LT, Chen LS, Kao PH, Wu YY (1992) Fish fauna and their geographical distribution in the coastal waters around the Hsiao-Liuchiu, southwestern Taiwan. Acta Zool. Taiwanica 3(2): 105-134.

Dai CF (1991) Reef environment and coral fauna of southern Taiwan. Atoll Res. Bull. 354: 1-28.

Dai CF (2005) Coral reefs in Dongsha Island: past, present and future. Proc. 10th Coral Reef Symp. Okinawa (in press).

Dai CF, Fan TY, Wu CS (1995) Coral fauna of Tungsha Tao (Pratas Islands). Acta Oceanogr. Taiwanica 34(3): 1-16.

Dai CF, Fan TY (1996) Coral fauna of Taiping Island (Itu Aba Island) in the Spratlys of the South China Sea. Atoll Res. Bull. 436:1-21

Dai CF, K. Soong, J.S. Huang, C.A. Chen, T.Y. Fan, H.Y. Hsieh, J.S. Chang (2002) The status of coral reefs in Taiwan and the conservation problems. Proceedings of IUCN/WCPA-EA4 Taipei Conference, p. 265-276, Taipei.

Shao KT (1994) Biodiversity and conservation of marine fishes in Taiwan with emphasis on the coral reef fishes. Institute of Botany, Academia Sinica, Monograph Series 14: 307-318.

Shao KT, Chen CP, Ho LT, Lin CP, Kao PH, Lin PL, Chen LS (1994) Checklist and distribution patterns of the fishes of the Pescadores Islands. Proc. 4th Indo-Pacific Fish Conference, Kasetart University, Bangkok, Thailand, p. 267-280.

Tsai WH, Dai CF, Fan TY (2002) Population structure and reproduction of the sea anemone *Condylactis* sp. In Nanwan Bay, southern Taiwan. Proceedings of IUCN/WCPA-EA4 Taipei Conference, p. 743-751, Taipei.

Soong, K., C.F. Dai, C.P. Lee (2002) Status of Pratas Atoll in the South China Sea. Proceedings of IUCN/WCPA-EA4 Taipei Conference, p. 739-741, Taipei.

Yang RT, Chi KS, Hu SC, Chen HT (1975) Corals, fishes, and benthic biota of Hsiao-Liuchiu. Institute of Oceanography, National Taiwan University, Special publication No. 7, 53 p.

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3.4. JAPAN

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Abstract

Coral diversity of Japan is quite high at the northern latitude with approximately 475 species recorded. Corals widely distribute from Ryukyu Islands to northern islands including Kyushu, Shikoku and Honshu. Main disturbances on corals are crown-of-thorns starfish (COT) and bleaching. Outbreak of COTs occurred around the Ryukyu Islands from the late 1960's to 1990's. Although most of the coral had been recovered gradually by 10 to 20 years after the outbreak, the number of COTs started increasing again in 2000's. A catastrophic bleaching event occurred in Japan, especially devastating around Ryukyu Islands, in summer of 1998. Relatively small scale bleaching occurred in 2001, 2002 and 2003. On the other hand, coral coverage is increasing in the northern islands, Kyushu, Shikoku and Honshu, because of elevated water temperature in winter relaxing the limits for coral growth in the area. Soil runoff by the coastal development is also one of the major threats to the reefs. Large numbers of corals were killed by sedimentation after heavy rain in Ishigaki and Shikoku in 2001. Drupella, a corallivorous gastropod, is a major predator of corals in northern islands. Drupella outbreaks occurred in Shikoku and Kyushu from the late 1970's to 1990's. Some of the areas still have a large number of Drupella. However, these threats and disturbances drew people's attention toward the marine environment and coral conservation. There are several management practices conducted in the local communities to control the disturbances. The government has also started considering integrated coastal management involving different types of stakeholders for coral conservation.

Introduction

In 2004, the Ministry of the Environment and Japanese Coral Reef Society published "Coral Reefs of Japan", which is a comprehensive status book on Japanese coral reefs. This is a first output of coorperative work between government and academic community. More than forty coral reef scientists and managers contributed to the publication. Most of the informations of this chapter are cited from the "Coral Reefs of Japan.

Coral Reefs

The seas that surround Japan range from sub-tropical to subarctic regions. Hermatypic corals are distributed from Southern Ryukyus to northward of the Tokyo Bay along the Pacific coast of mainland of Japan and to Sado Island along the Sea of Japan. The major coral reefs develop along the Ryukyu Archipelago (including the Tokara Archipelago, the Okinawa and Amami islands, the Miyako and Yaeyama islands), and around Ogasawara Islands.

Along the Pacific coast, Northern Ryukyus are on the boundary of coral reefs and rocky reefs. Coral reefs do not occur though coral communities are distributed from Kagoshima Prefecture to Chiba Prefecture along the coast of the mainland of Japan. Manazuru in the Sagami Bay and Tateyama in the Tokyo Bay have highest latitude coral communities at 35°North along the Pacific coast. In the Sea of Japan, highest latitude of uroshima corals are observed in Sado Island (38°North) in Niigata Prefecture (Environment Agency 1994). Highest latitude coral reef (33°North) was reported in Iki Island in Nagasaki Prefecture in 2001 (Yamano et al. 2001).

Coral reef area in Japan is estimated as 2,600 km^2 calculated by World Resource Institute based on 1km resolution gridded data set assembled under the "Reefs at Risk Southeast Asia" project, rounded to two significant digits (Burke et al., 2002).

In the national survey on coral reefs conducted from 1990 to 1992, coral distributions were recorded in 16 prefectures, which are Okinawa, Kagoshima, Miyazaki, Ohita, Kumamoto and Nagasaki in Kyushu Region, Kochi, Ehime and Tokushima in Shikoku Region, Shimane, Wakayama, Mie, Shizuoka, Kanagawa, Tokyo and Chiba in Honshu Region (Environment Agency 1994). Total length of coastline of these prefectures was estimated as 18,705 km (Environment Agency 1998). Total population of local municipalities along the coast of these prefectures was also estimated as 4,628,709 people calculated from the national census in 2000 (Ministry of the Environment and Japanese Coral Reef Society 2004).

Figure 1. A map of coral distribution of Japan

Table 1: Summary Country Statistics and Coral Reef Resources

	reef area (km^2)	coastline length (km)	population	predicted coral diversity
Japan	2600	18,705	4,628,709	475
	Burke et al., 2002	Environment Agency 1998	Ministry of the Environment and Japanese Coral Reef Society 2004)	Ministry of the Environment and Japanese Coral Reef Society 2004

Biodiversity

A total number of hermatypic coral species in Japan is estimated as 475species of 80 genera. Species richness of corals is the highest in southern Ryukyus and decreases northward to mainland Japan. Three hundred and seventy one species are estimated to occur in the Yaeyama Archipelago in Southern Ryukyus and 24 species were found at Tateyama, the northern end of coral distribution along the Pacific Coast. Kuroshio Current from the south is considered to be the most important factor producing the high species richness of Japanese coral fauna (Ministry of the Environment and Japanese Coral Reef Society 2004).

The total number of species of other taxonomic groups in coral reef regions has not been estimated fully yet. However, the total number of species of fish in Japan is #,863 (Nakabou 2002), the total number of genera of Octocorals in Japan is estimated as more than 86 genera (Nishimura 1992) and the total number of species of macro algae is approximately 1,400 in Japanese waters (Yoshida 1998), and more than 2,000 species of Molluscs have been reported in the Ryukyu Archipelago (Marine Parks Center of Japan 1988)

Table 2: Summary of Biodiversity for major groups of marine organisms in Japan

	uroshima corals in Japan	Molluscus in Ryukyus	macro algae in Japan	Octocorals in Japan	fishes in Japan
total number of spesies	475	2,000	1,400		3,863
total number of genera	80			86<	
data source	Ministry of the Environment and Japanese Coral Reef Society 2004	Marine Parks Center 1988	Yoshida 1998	Nishimura 1992	Nakabou 2002

Resource Use

e- ***Reef Fish and Fisheries***

Fishing has been an important part of Japanese culture. However, the fish catch has been decreasing in coral reefs area (fig.2) and overfishing is expected as one of the causes (Kakuma 2004). Coral reef fishery includes hook-and-line, bottom long lines, gill nets, fixed nets, drive-in nets, and SCUBA fishery, shellfish gathering. Coral reefs are also used for aquaculture of " urosh", edible brown algae (Cladosiphon okamuranus or Nemacystus decipens), green algae (Caulerpa lentillifera) and prawn (Penaeus japonicus). Spangled emperor (Lethrinus nebulosus), sea snail (Trochus niloticus), crab (Portunus pelagicus), sea urchin (Tripneustes gratilla) and giant clam (Tridacna crocea) are cultured in the coral reef area from their hatcheries. Besides the commercial fishery, subsistence fishing is common for local residents in the coastal area in Okinawa.

ii) Tourism

Scuba diving is one of the major activities in marine tourism. Most of the areas, where corals distributed, are popular diving sites, because of the coral communities and their diverce fish fauna. Diving centers are located along the coasts from Okinawa to Chiba Prefecture, and even along the Sado Island where the highest latitude corals are observed. Snorkeling and grass-bottom boat tours are also the popular activities in coral reef regions. Owners of small local inns operate grass-bottom boats and provide snorkel tours in some parts of Okinawa. Sea kayak tour is the new activity in coral reefs and mangrove areas. Recreational fishing is another majour activity of the marine tourism. Local fishers provide fishing tours of line and trolling to visitors.

iii) Other Uses

Coral reefs have always been closely linked with the lives of local people in Ryukyu Archipelago, where beaches are used in every life not only for fishery but also for recreational purposes. School and public education and awareness activities are also conducted at the shallow reefs and the beaches. Many scientists conduct research work in the coral reef region.

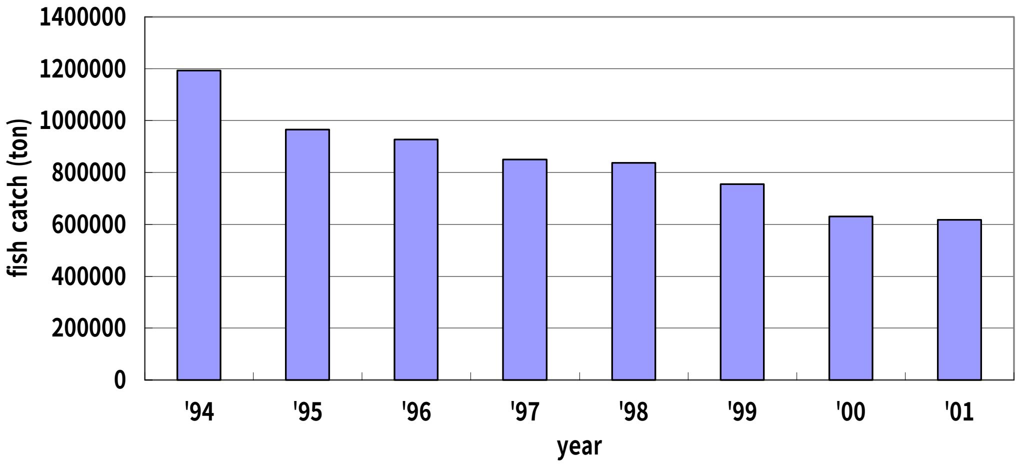

Figure 2. Total fish catch of coastal fisheries in coral retlated areas.

(All the data were compiled from the Statistical Information Center of Ministry of Agriculture, Forestry and Fisheries, and the statistical data of local uroshima es from 1994 to 2001)

Status of Coral Reefs

After the mass bleaching in 1998, corals have been recovered gradually from the damage in Ryukyu Archipelago. However, the number of crown-of-thorns starfish (COTs) is increasing and coral bleaching caused by high water temperature is occurring again, repeatedly. On the other hand, coral communities have been observed with their live coral cover increasing, in further north in mainland Japan.

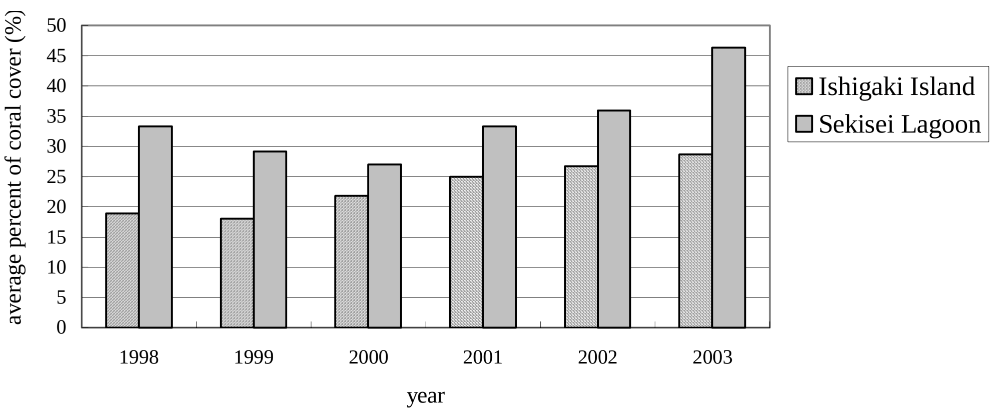

Figure 3. Average coral cover (%) during annual mointoring around Ishigaki Island and Sekisei Lagoon from 1998 to 2003.

Table 3: Summary of coral monitoring in 2003.

Area	Average coral Cover (%)	average of bleaching rate in the uroshima (%)	% of sites bleached (%)	bleached coral coverage(%)	average mortality of *Acropora* (%)	no. of sites surveyed
Sekisei Lagoon	46.3	28.3	76	35.188	2.7	123
Ishigaki Island	28.7	13.6	100	28.7	2.6	75
Kerama Islands	30.9	1	0.1	0.0309	-	10
Okinawa Island	8.5	0	0	0	0	17
Amakusa	30.8	0	0	0	0	12
Ashizuri	28.2	0.5	0.1	0.0282	0	11
Kushimoto	48.9	0	0	0	0	14
Ogasawara	30.3	2.6	100	30.3	26.9	9

Status of Reef Benthos (especially corals)

Ministry of the Environment has conducted survey at total 198 stations in Sekisei Lagoon in Yaeyama Islands and in the sea area around Ishigaki Island every year. The average coral cover in Sekisei lagoon showed 46.3% and increase of 10.4 points from 2002. The average coral cover around Ishigaki Island was 28.7% and 2.0 points higher than that in 2002 (fig. 3). Both results indicate a trend of increasing in coral cover in Southern Ryukyus, which is the process of recovery from the bleaching in 1998.

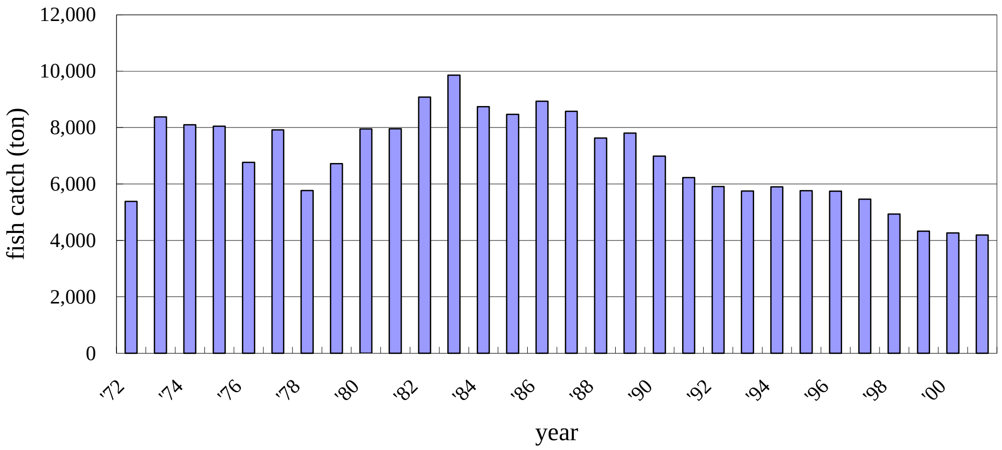

Figure 4. Total fish catch of coastal reef fisheries in Okinawa Island and surrounding islands from 1972 to 2001

According to the results of monitoring in 2003, conducted by Ministry of the Environment in cooperation with local researchers at 5 sites, i.e., Kerama Islands, Okinawa Island, Amakusa, Ashizuri and Kushimoto, coral communities in most of the sites are in healthy condition, except for Okinawa Island where coral damage by bleaching in 1998 was severe. Average coral cover was 30.9% at 10 stations in Kerama Islands, 8.5% at 17 stations in Okinawa Islands, 30.8% at 12 stations in Amakusa, 28.2% at 11 stations in Ashizuri and 48.9% at 14 stations in Kushimoto (table 3). Corals in Okinawa had not completely recovered from the damage caused by bleaching in 1998, but the juvenile colonies indicated constant supply of new recruitment from relatively dense source reefs.

One of the tropical coral species, Leptoseris papyracea was recently observed in the West Coast of Shikoku and large coral community of Acropora hyacinthus with coverage of 50 % was observed in Kii Peninsula, to the north area where distribution of the species had been formerly obserbed.

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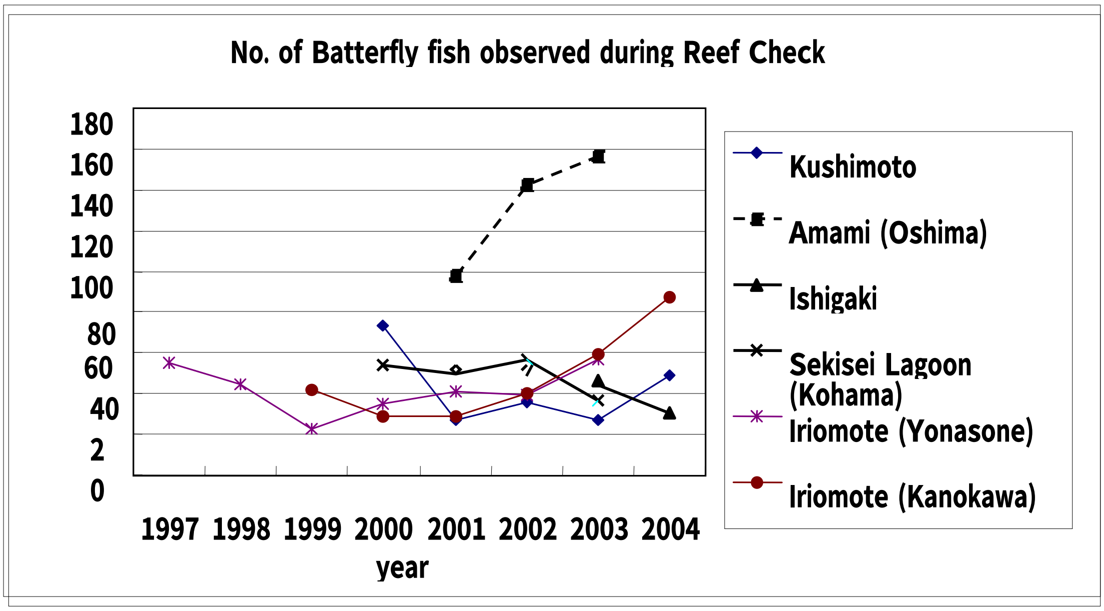

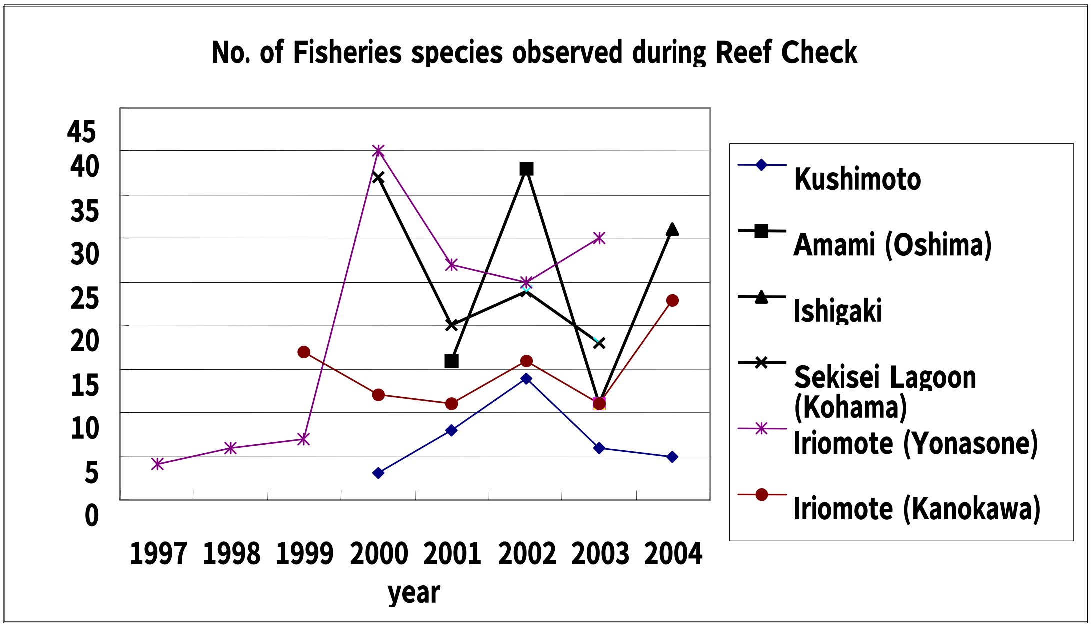

Figure 5. Number of fish observed during Reef Check in Japan from 1997 to 2004. All the data were cited from "Reef Check Japan" web site (http://hs.st41.arena.ne.jp/reefcheckjapan/) by Coral Network.

Status of reef fish

Statistic data of fish catch in Okinawa Prefecture showed a long-term trend of declination in Okinawa (fig. 4). According to the results of Reef Check, on the other hand, the number of fish observed indicated gradual increase of reef fish since 2002, except Sekisei Lagoon, which suffered coral bleaching in 2001and 2003 (fig. 5).

Status of Resource Use

e- *Tourism*

Marine tourism is a growing industry in coral reef regions (fig. 6). The number of visitors showed an increasing trend of tourism in the coral reef region. It also indicates potential pressure on coral reefs by tourism usage.

Recently, coral transplantation has become one of the purpose of tourism in Okinawa. Private tour operators conduct coral transplantation as a part of the diving trip, aiming to restore the damaged reefs damaged by bleaching and/or COTs.

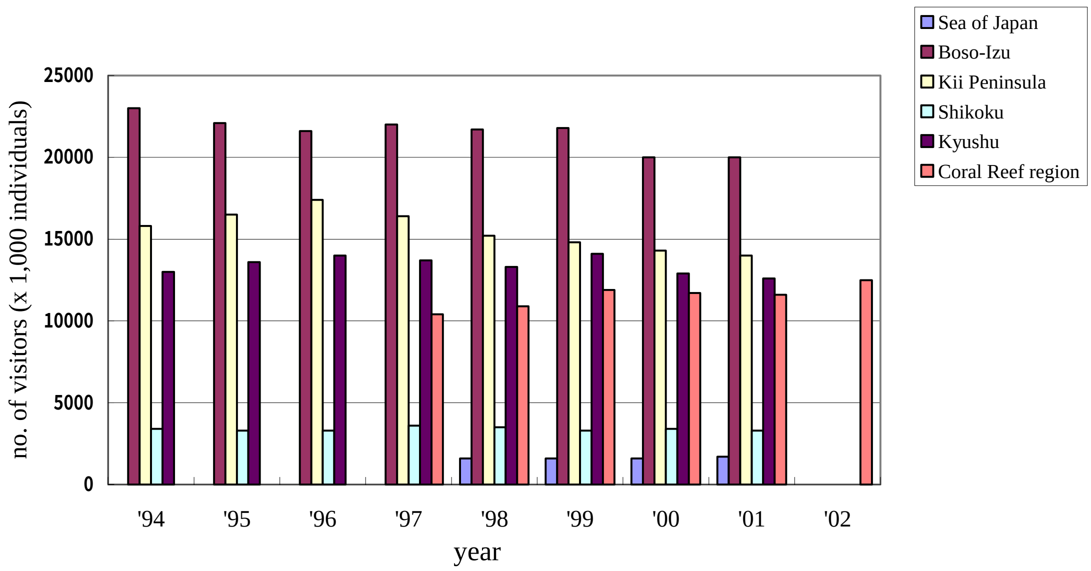

Figure 6. Number of visitors in each area from 1994 to 2002. All the data were compiled from statistics of local municipalities in each area.

ii) Fishery

Coastal fisheries in coral reef areas were active in the past but have recently declined. It is feared that overfishing has reduced the stock size. Aquaculture is one of the main usages of shallow coral reef waters. 'Mozuku', urosh brown algae and prawns are commonly farmed in Okinawa. On the other hand, aquaculture could be a tool to to enhance natural stocks. Hatchery-raised juveniles of desirable species (e.g., swimming crab, sea urchin, emperor fish, button shell and giant clam) have been released into the coastal waters of the Ryukyu Archipelago for resource management.

iii) Others Uses

Recently, industry to produce salt by drying out coastal seawater, is gaining local prominence as a viable business in Okinawa, Amami and Ogasawara Islands.

Education and Training

The International Coral Reef Research and Monitoring Center which was established by the Ministry of

the Environment in Ishigaki Island, Okinawa Pref. In 2000 develops educational materials and programs on coral reef conservation. Nago Elementary School in Okinawa Island conducts seven-year program focused on closer interaction with coral reefs. Since 1997, the Sea Farming Center of the city of Hirara also has run educational program for elementary school students, to raise environmental awareness of the need for the conservation of fishery resources. Although school education and public awareness is progressing, more educational publications and programs are required.
The Japan International Cooperation Agency (JICA) has run coral reef conservation courses every year since 1996 in order to train administrative officials and technical experts from other nations that have coral reefs in their waters.

Physical Environment
Mean monthly seawater temperature in midsummer (July and August) in 1998, 2001 and 2003 were much higher than those in 1999, 2000 and 2002 (fig. 7) in Ishigaki. Typhoons also frequently approach Okinawa and southern areas of mainland of Japan. Approximately 11 typhoons approach within 300km of Japan annually (Japan Meterological Agency 2001). They could directly destroy coral communities and also could be a cause of severe soil discharge to damage corals. Sedimentation is constantly measured with rapid method in Sekisei Lagoon and Ishigaki Island.

Stress and Damage to Coral Reefs

Sediments and Nutrients (land-based)
Sedimentation is still one of the threats on coral reefs and coral communities in various regions in Japan. The situation of sediments in coral reefs has not been improved in Ryukyus. Severe soil run off occurred in mainland Japan and damaged coral communities
Red soil runoff from Kohama, Iriomote, and Ishigaki islands continues to aggravate the reef environment, and to disturb opportunities for the healthy recovery of coral communities. Deposition of silts is relatively high and coral coverage is low in the sea area from the northeastern to the southern coasts of Kohama Island. The proportion of sedimentation that seems to be of red soil origin is almost same or a little increasing in Sekisei Lagoon and Ishigaki Island. Silt is also piling up on the sea floor at Yonara Waterway, where coral communities featuring high coverage of Acropora (Nature Conservation Bureau, Ministry of the Environment 2002). Also in Ishigaki Island, large scale and violent red soil runoff occurred in the Todoroki River mouth area, causing mass mortality of Porites in the neighboring coast (Nature Conservation Bureau, Ministry of the Environment 2001). Red soil also accumulated some 3 meters in the Fukuro Bay in Ogasawara Islands, leading a large amount of Lobophyllia hemprichii to death (Inaba and Horikoshi 2002). Soil runoff are originally caused mainly by land and farmland formations and/or road construction operations. Red soil runoff in Nakoudojima Island is considered to have stemmed from goats clearing native vegetation (Inaba et al, 2004)
There is concern that corals and other shallow water marine biotic community might be affected as red soil runoff has been observed on occasions of rainfall (Yamano et al. 2004).
During the Kochi southwest torrential rain that affected Tosashimizu, Otsuki, and Sukumo in September 2001, a large amount of soil flowed into the Ashizuri Sea at several different locations. The most heavily damaged area was the Tatsukushi Marine Park, where many corals inside Tatsukushi Bay died as a result of sedimentation (Kuroshio Biological Research Foundation 2002). At the Shirigai Marine Park, a landslide caused an influx of soil, burying corals (Machida 2001).

Damaging Fishing Methods
Distructive fishing methods are not at all used in Japan, since such methods as dynamite and cyanide fishing are strictly prohibited by Fisheries Laws. The effective management by the Fisheries Cooperative Associations, which all the fishers registered, is also working well (Ministry of the Environment and Japanese Coral Reef Society 2004).

Anchor and Trawler Damage, Others Kind of Damage (divers, trampling, etc)
Damages of coral reefs caused by overuse are commonly observed in several spots in Okinawa Prefecture. Inside Shiraho Reef in Ishigaki Island, where many tourists enjoy snorkeling and glass-bottom boat tours, damage of corals by divers and anchoring has been observed in some areas (Hasegawa and Yamano 2004).

In Yaeyama Islands, coral destruction by shipping vessels (Akimichi 2004) and some coral communities in shallow water area are reported to have been damaged by scraping of foreign vessels.

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

Coral distribution is decreasing in some small bays owing to destruction and sedimentation that has occurred during the construction of fishing ports in Tsushima and Iki islands.

Once supported well-developed coral communities in Higashi Bay, on Haha-jima of Ogasawara Islands, are thought to have disappeared through harbor development. But no further information is available as there had been no advance studies relating to this development project (Inaba 2004).

Coral Bleaching

Monthly average sea temperature around Ishigaki in Yaeyama Islands in 1998, 2001 and 2003 was much higher thatn that in 1999, 2000 and 2002 (fig. 7). Coral reef bleaching caused by high water temperature occurred in 2001 and 2003 in Japan after a mass bleaching event in 1998. In 2001, a warm water mass developed near Okinawa and bleaching event was observed in Ryukyu Archipelago (Strong et al. 2001). Bleaching occurred in Kerama Islands by the end of July 2001. The mortality rate of corals was 10% in Maenohama, while it was approximately 25% in 1998 (Taniguchi 2002). Corals in Kerama Islands showed little damage from bleaching in 2003. Coral bleaching occurred in Sekisei Lagoon during summer in 2001 and 2003. The average rates of bleached coral in coral communities were 21.6% in 2001 and 28.3% in 2003. Mortality of corals was low, 2.7% in 2003. However, some of the colonies had stayed pale in color until 2003 since 2001's bleaching. This long-term influence from bleaching indicated that the condition of corals in Sekisei Lagoon might be still under the stress. Corals of all the monitoring sites in Ishigaki were affected by the thermal stress in 2003 and average bleaching rate was 13%. Mass coral bleaching event was recorded at Haha-jima in 2003, although minimal bleaching and mortality was reported in 1998 on Chichi-jima and Haha-jima of Ogasawara islands. Many colonies of Acropora donei, one of the dominant coral species, died in 2003 while Porites colonies recovered after bleaching. There was also little bleaching occurred in Amakusa and no bleaching observed in Ashizuri and Kushimoto in mainland Japan in 2003.

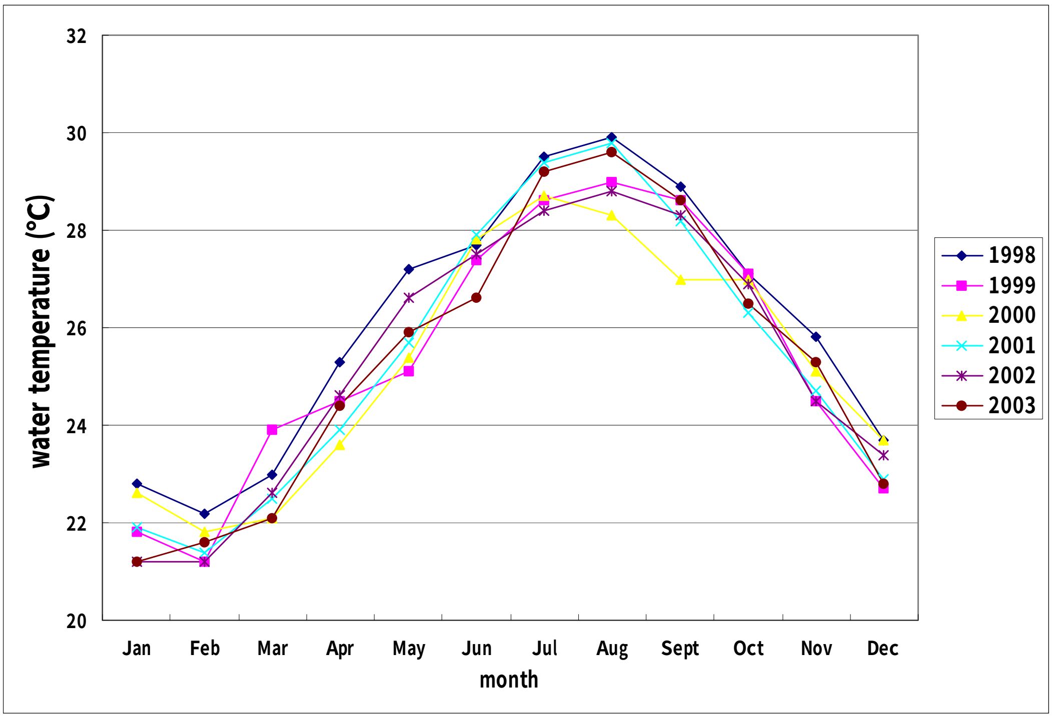

Figure 7. Monthly means of sea water temperature measured at 1000 at Ishigaki Bay from 1998 to 2003. All the data were compiled from Japan Meterological Agency (http://www.data.kishou.go.jp/marine/ocean/cst/average/montab47918.html).

Coral Diseases

Coral disease is also an uroshim threat to coral reefs in Ryukyu Islands. A new type of tumor was identified on Porites lutea in Okinawa in 2002. A large coral community with tumors was found off Yonaguni Island and around the Kerama Islands in 2003 (Yamashiro 2004). Different types of disease were also reported in Sekisei Lagoon during annual monitoring. They include Tumor, Black Band Disease, and White Syndrome on branched, tabulate and corinbose Acropora (Ministry of the Environment 2004). Coral disease were observed observed in 30% of the monitoring sites in 2003. The cause of the diseases are still unknown and further studies and researches are urgently required.

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

e- ***COTs***

Outbreak of Crown-of-thorn starfish (COTs) occurred from 1970s to early 1980s in Ryukyu Archipelago and destroyed most of the coral communities. Then since the late 1990s, another outbreak of COTs has been occurring. The outbreak of COTs is conspicuous in Amami Archipelago this time, in the new uroshima . More than 220 thousands COTs were removed from the Amami Archipelago by Amami Oshima Marine Park Marine Resource Conservation Association staff and volunteers from local nature conservation groups from 2000 to 2002 (Ministry of the Environment 2003). Okinawa Island has also been affected by continuous increase of COTs since the 1970s. An outbreak of COTs was observed art Onna Village, along the West Coast of Okinawa Island in the middle of 1990s and it has continued to spread around the Island. There were many aggregations of COTs observed in Kerama Islands in 2001 and along the East Coast of Okinawa Island in 2002 (Yokochi 2004). Local diving operators in Kerama Islands removed some 120,000 of COT individuals in 2002 and 2003 (Iwao 2004). There was a sign of increase in population of COTs in Yeayama Archipelago in 2001. A result of annual monitoring showed an increase of COTs number in 2001 and the number has been increasing rapidly. Sixty-six individuals were observed during the monitoring in 2003, the number representing 4 times as many as the number observed in 2002 (fig. 9). There are still aggregations of COTs observed in this area in 2004. Some groups of COTs were also observed in Kumamoto, Miyazaki and Kagoshima in Kyushu, Kochi in Shikoku and Wakayama in mainland Japan from 2001 to 2003 (Ministry of the Environment 2003). It is considered that COT larvae had been dispersed along the Kuroshio Current from the Ryukyu Archipelago.

ii) Drupella

Drupella, a coral eating Gastropods, is another threat to corals especially for high-latitude coral communities. A severe outbreak of Drupella occurred in Miyake Island in Izu Islands, Miyazaki and Kumamoto in Kyushu, and the West Coast of Shikoku in the late 1970 to 1980s. Some of the areas still suffer from disturbances caused by these Gastropods since their outbreak. Predation damage by Drupella was reported along the eastcoast of Shikoku in 2001. Approximately 100,000 to 200,000 individuals of Drupella were collected per year in the West Coast of Shikoku at the peak of extermination program during 1995 to 2000 (Sanyo-Shikoku RONC, Ministry of the Environment 2003). In Kyushu, more than forty thousands Gastropods were removed in Ushibuka Marine Park in 2003. Drupella also damage corals in coral reef region, but the impact is smaller than that by the COTs. Aggregations of Drupella were observed at some areas in Sekisei Lagoon in 2002 and 2003. These areas suffered from other disturbance, such as soil runoff, bleaching, typhoon, etc. before the damage of Drupella occurred.

iii) Diadema

Although there are no significant predation damages to corals by Diadema in Ryukyus, severe predations were reported in coral communities in the Suruga Bay Area (Okubo et al. 2003).

Coral Damage from Natural Events (storms, volcano eruption, etc)

Typhoon often approach Okinawa and the southern part of Honshu, causing damages to coral reefs in the areas. 11 Typhoons in average approach within 300km of Japanese Archipelago annually, mostly in August and September (Japan Meterological Agency 2001). Damages by typhoons vary according to the locality. In 2002 and 2003, the highest mortarity rate of corals caused by typhoons was less than 10% in Sekisei Lagoon.

A volcanic eruption occurred in Miyake Island in 2000, and up to 20 cm of volcanic ash accumulated on the sea floor. Most of Acropora colonies in the reefal area died and 80% of tablate Acropora were considered to have been killed (Ministry of the Environment and Japanese Coral Reef Society 2004).

Potential Threats to Coral Reefs (Reef at Risk Threat Indicators)

“Reef at Risk Threat Indicators”, developed by World Resources Institute, is a measurement method designed to measures the degree of risk, which world coral reefs are exposed to, by using the following 5 indicators. 1) Coastal Development, 2) Marine-Based Pollution, 3) Sedimentation and Nutrient-Inputs, 4) Over-fishing and 5) Destructive Fishing.

The potential threats to coral reefs in Japan of the year 1999 and 2000 were surveyed using this method, and the result of the survey showed that nearly 80 % of Japanese coral reefs are affected by human activities, more than 70 % threatened by overfishing and 40% by sedimentation (Burke et al. 2002).

Constant monitoring of reefs, applying the Risk Threat Indicators in the suitable way to fit to the situation of Japanese coral reefs, to accurately understand the changes, either improving or degrading, of coral reefs, is needed from now on.

Management

Marine Protected Areas

Marine protected areas (MPAs) in Japan are classified according to the laws and regulations as followes: National Parks and Quasi-national Parks designated based on the Natural Parks Law, Nature Conservation Areas protected under the Nature Conservation Law and The Fisheries Protected Waters regulated by the Fishery Regulation of prefectural government. As of June, 2004, there are 42 Marine Parks (2333.8 ha), 1 Nature Conservation Area (128.9 ha) and 4 Fisheries Protected Waters (397.7 ha) respectively, each of which holds coral communities.

Also, local community initiated MPA has been established in Kerama Islands, Okinawa Prefecture. This MPA has been designated by local Fishery Cooperative in Zamami village to protect coral reefs from overuse by diving. The access to and use of this area has been restrictec for a few years to enhance recovery of corals. Zamami village also designated protect areas to control COTs when thre has been an outbreak of COTs in 2001 in Kerama Islands.

Monitoring

Reef Check has been conducted in Japan since 1997. Coral Network, an NPO, uroshi coordinate the activities of Reef Check in Japan. The number of monitoring sites and participants has been increasing and more than 300 participants have surveyed 22 sites. Several monitoring programs on corals have been conducted by local groups of volunteers. The programs are conducted in Yaeyama Archipelago (Yaeyama Coral Reef Conservation Council), around Ishigaki Island (WWF Japan), at Ushibuka in Kumamoto Prefecture (Ushibuka Diving Club), at Otsuki in Kochi Prefecture (Otsuki Park Volunteers) and around Yaku Island (Yakushima Marine Organism Research Workshop).

Research Institutes also conduct their own monitoring. The Amami Marine Museum in Naze, Amami Archipelago, the Akajima Marine Science Laboratory in Kerama Islands and the Ishigaki Tropical Station of Seikai National Fisheries Research Institute in Ishigaki have own monitoring programs around their institutions. There are monitoring programs conducted by the Marine Laboratory of Universities, such as the Sesoko Marine Station of University of Ryukyus amd the Amakusa Marine Biological Laboratory of Kyushu University.

There are some local governments that also conduct monitoring program for coral conservation and management. Hirara City in Miyako Island has been monitoring coral damage caused by tourists on Yabiji Reefs. Okinawa Prefectural government has developed a monitoring manual to watch the reefs and COTs to collect information to minimize the damage.

Ministry of the Environment, as a government activity, took over and has continued annually conducting the long-term annual monitoring program on corals in Yaeyama Archipelago, which had been initiated by the Yaeyama Marine Park Research Center in 1983. The Ministry has been developing a national monitoring program on corals at 24 sites in all the regions of Japan, from Tokyo Bay area to Sekisei Lagoon since 2004.

Legislation
There are several laws and ordinances to protect coral reef ecosystems in Japan. Natural Parks Law and Nature Conservation Law are applied to protect certain designated areas, intending to protect the Nation's significant natural environments including corals and coral reefs. The Law for Conservation of Endangered Species restricts the capture and trade of rare species. Fisheries Law and the Law for Conservation of Aquatic Resources prohibit coral harvest in some areas. To prevent soil runoff to coral reef areas, Okinawa Prefecture drew up the Red Soil Erosion Prevention Ordinance in 1995. Kagoshima Prefecture established the 'Amami Region Red-clay Outflow Prevention Measures Promotion Conference' to prevent red-soil runoff from public construction works in 2000 and has promote surveillance and countermeasuring activities.

Action Programs
e- ***To control COTs***
To counteactr the outbreak of COTs, Okinawa Prefecture has conducted a program to exterminate COTs in Kerama Islands, Okinawa Island, Miyako Archipelago and Yaeyama Archipelago with assistance of local municipalities, fishermen and diving operators. Kagoshima Prefecture has also started a program to counter the outbreak of COTs in Amami Archipelago. Ministry of the Environment is also taking necessary measures to protect Sekisei Lagoon in Yaeyama Islands, a National Park, from the outbreak of COTs.

ii) To prevent red soil runoff
Okinawa Prefecture has been attempting to implement water quality control measures on Ishigaki Island with the methods like lessening the gradient of arable land, constructing drainage channels to filter out the red clay, and repairing sedimentation ponds. Ishigaki City has also been attempting to control redsoil runoff by constructing grit chambers and by decreasing the gradient of the fields, covering crops and mulching, planting sugar cane in spring, and developing green belts around the fields.

In 1999,38 groups including administrative bodies and private organizations were organized into Council for Conservation Measures for the Sea Arount Ishigaki Island. This council attempts to prevent red soil runoff by planting sunflowers and other crops during the sugar cane fallow period, as well as plants around farmlands.

iii) Program to prevent overuse of tourists
The city of Hirara is promoting environmental conservation, fishery protection, and tourism as part of a project monitoring the impacts of the annual Yabiji Reef landing tour in Miyako Islands. Volunteer reef guides have been introduced and guidelines regulating tourism on this reef have been developed.

Considering the deterioration at several diving localities, Zamami village fishery cooperative closed three diving sites in Kerama Island for three and a half years from 1998. Mooring buoys were installed when the sites re-opened at Nishihama to prevent anchor damage and limit the number of boats to the area at any one time.

iv) Reef Restoration
Artificial reef restoration has been tried on coral reefs in various areas, that have been damaged by reef bleaching, outbreak of COTs and so forth. New methods of restoration are developed recently, using sexual reproduction of corals. Activities of transplanting are also conducted by volunteers and/or local fishers for enhancement and awareness purposes. However, impact of transplanting and harvesting of mother corals are concerned. Japanese Coral Reef Society and Okinawa Prefectural government have developed a guideline for those activities.

A diving society was established in Kerama Islands in 2001 and conducted a coral rescue program. Coral colonies were removed from the east coast of Geruma Island, where road construction planned, and transplanted to another island in 2002. There were a few case studies on coral transplanting in Shikoku. Coral transplantation projects have been undertaken in Tatsukushi Marine Park in Ashizuri Uwakai National Park since 2000, with the aim of restoring the underwater scenery along a glass-bottomed boat route. Similarly, coral transplantation projects have been ongoing since 2001 in the Uwa Sea Marine Park to aid in the recovery of coral communities damaged by Drupella predation and by a typhoon in 1993.

Another transplantation project has been conducted by a volunteer organization in the Shirigai Marine Park since 1999 to recover coral communities.

Ministry of the Environment reviewed current practices of reef restoration in Japan and published a manual for reef restoration in Japan in 2004.

v) Integrated Management Program

The "Law for the Promotion of Nature Restoration" was established in 2002. The Law aims to make human coexist with nature by preserving biodiversity and provides a framework for nature restoration by defining restoration as a joint effort among various actors/stakeholders. It is a first law to improve integrated management for environmental conservation. Nature Restoration Projects have been initiated by the Ministry of the Environment. Two projects and 15 preliminary studies are in operation in 2003. Two of these preliminary studies involve the restoration of coral reef ecosystems, which are in Sekisei Lagoon in Okinawa Prefecture, and in Tatsukushi Bay in Kochi Prefecture.

Conclusions and Recommendations

During the 10th International Coral Reef Symposium held in 2004 in Okinawa, all the participants agreed on "Okinawa Declaration on Conservation and Restoration of Endangered Coral Reefs of the World" to reduce the reduction of coral reef ecosystems for conservation and sustainable use of coral reefs. The declaration suggests four key strategies: 1) achieve sustainable fishery on coral reefs, 2) increase effective marine protected areas on coral reefs, 3) ameliorate land-use change impacts, and 4) develop technology for coral reef restoration. And states that such efforts must be fostered and sustained through stewardship and cooperation among scientists, managers, policymakers, non-governmental organizations, and the general public.

Based on the declaration and the sprit of it, the writers of this report strongly recommend the following.

- It is needed to involve both integrated management approach by the national government and local based activities on coral reef conservation. It will be more effective to involve local activities into the scheme of the integrated management. It is also necessary to include effective measures against outbreaks of COTs and/or soil runoffs into overall management of coral reefs and natural environment.
- It must be implemented to develop region-wide monitoring mechanisms to understand the current conditions and problems on cral ecosystems in each region in Japan. It must be a part of national and global network for coral reef monitoring.
- Continuous contributions to the international community are necessary to desciminate national activities and exchange the practices to learn.

References

Akimichi, T. 2004, 2-6 Inappropriate activities around coral reefs. Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp69-76.

Burke, L, E. Selig and M. Spalding 2002. Reefs at Risk in Southeast Asia, 50-51, World Resource Institute, 72pp.

Environment Agency 1994, The report of the marine biotic environment survey in the 4th national survey on the natural environment, vol.3 Coral Reefs, 262pp. (in Japanese)

Environment Agency 1998, The report of the survey of coastal areas in the 5th national survey on the natural environment. (in Japanese)

Fujiwara, S. et al., 2000, Status of Coral Reefs of East and North Asia: China, Japan, and Taiwan, Status of Coral Reefs of the World: 2000, Wilkinson, C.139pp.

Maragos, J., C. Birkeland, and G. Hodgson, 1998, Status of Coral Reefs in the Northwest Pacific Ocean: Micronesia and East Asia, Status of Coral Reefs of the World: 1998, 114pp.

Igarashi, T. 2003, Izu Islands, 6-2-1 Boso Peninsula, Izu Peninsula and Izu Islands, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp237-239.

Hasegawa, H.and H. Yamano 2004, Ishigaki Island, 6-1-7 Yaeyama Archipelago, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp212-218.

Inaba M. and K. Horikoshi 2002, Report on Monitoring of Sea Bottom Environment in Fukuro Bay, Muko-jima, In: Ogasawara Islands Branch Office of the Tokyo Metropolitan Government (eds) Vegetation Recovery Project Report of the Ogasawara National Park in 2001, pp81-92. (in Japanese)

Iwao, K. 2004, Kerama Islands, 6-1-4 Okinawa Islands, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp185-189.

Iwase, H. 2004, Ashizuri-Uwakai, 6-2-4 Shikoku, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp266-269.

Japan Meterological Agency 2001, web site of Japan Meterological Agency, http://www.kishou.go.jp/know/typhoon/1-4.html

Kakuma, S. 2004, 4-4 Fishery, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp117-121.

Kuroshio Biological Research Foundation 2002, Report on investigation to recover coral community in Tatsukushi Marine Park Zone, Kuroshio Biological Research Foundation, Kochi, 13pp. (in Japanese)

Machida, K. 2001, Report on Damage of the Heavy Rain of Southwestern Kochi at Shirigai Marine Park Area in Ashizuri-Uwakai National Park, CURRENT, 2(3):2-6. (in Japanese)

Marine Parks Center of Japan 1988. vol. 5 Shell Guide, Field Guide of Marine Organisms in Okinawa, vol. 5, Southern Press Co. Ltd. (in Japanese)

Ministry of the Environment 2003, A report of marine parks conservation program in 2002 fiscal year, 205pp. (in Japanese)

Ministry of the Environment and Japanese Coral Reef Society 2004b. Appendix 4 A list of Hermatipic corals in Japan, Coral Reefs of Japan. Pp296-298.

Nature Conservation Bureau, Ministry of the Environment. 2003, Mannual for restoration of coral reefs, edited by M. Omori.

Ministry of the Environment and Japan Wildlife Research Center 2003, Report of Survey on Planning of Marine Parks in Iriomote National Park , 2002, 174pp. (in Japanese)

Nakabou, T. 2002.　Fishes of Japan with pictorial keys to the species, 2nd edition, Tokai University Press.

Nature Conservation Bureau, Ministry of the Environment 2001, Annual report of coral reef monitoring around Ishigaki Island, 2001. (in Japanese)

Nature Conservation Bureau, Ministry of the Environment 2002, Annual report of coral reef monitoring in Sekisei Lagoon and neighboring areas, Iriomote National Park, 2001. (in Japanese)

Nishimura, S. 1992. Guide to Seashore animals of Japan with Color Pictures and Keys, Vol. I, Hoikusha, 425pp. (in Japanese)

Okubo A., Y. Funakoshi, T. Atobe and S. Ueno 2003.　Growth of Acropora tumida population and grazing effects by Diadema setosum in Suruga Bay, central Japan.　Bulletin of Institute of Oceanic Research and

Development, Tokai University, 24:51-57 (in Japanese with English abstract)

Sanyo-Shikoku RONC 2003, 30th Anniversary Booklet of Ashizuri-Uwakai National Park, Sanyo-Shikoku Regional Office for Nature Conservation, Nature Conservation Bureau, Ministry of the Environment, (in Japanese)

Spalding, M.D., C.Ravilious and E. P. Green 2001, World Atlas of Coral Reefs, University of California press, Copy right: UNEP World Conservation Monitoring Centre, 424pp.

Strong, A.E, G. Liu, T. Kimura, H. Yamano, M. Tsuchiya, S. Kakuma and R. van Woesik 2002, Detecting and monitoring 2001 coral bleaching events in Ryukyu Islands, Japan using satellite bleaching HotSpot remote sensing technique, Proceeding of International Geoscience and Remote Sensing Symposium 2002, CD-ROM

Takahashi, K. and T. Kimura 2004, 4-2 Regal systems, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp110-112.

Taniguchi, H. 2002, Coral bleaching occurred around Akajima Island in recent 6 years: observation after and during the coral bleaching events and outbreaks of crown-of-thorns starfish. Midoriishi, 15:16-19. (in Japanese)

Yamano, H., K. Hori, M. Yamauchi, O. Yamagawa and A. Ohmura 2001, Highest-latitude coral reef at Iki Island, Japan, Coral Reefs, 20:9-12.

Yamano, H., K. Sugihara, T. Nakai and O. Yamakawa 2004, Iki Islands, 6-2-2 Sea of Japan, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp242-244.

Yamashiro, H. 2004, 2-3 Coral Diseases, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp56-59.

Yokochi, H. 2004, 2-2 Predation damage to corals, Coral Reefs of Japan, Ministry of the Environment and Japanese Coral Reef Society, pp49-55.

Yoshida, T 1998, Marine Algae of Japan, Uchida Rokakuho. 1248pp. (in Japanese)

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3.5. KOREA

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Abstract

It is well known that Korean waters do not have any typical coral reefs by reef building stony corals (scleractinians) (ICRI, 1996). The coral species of Korea is classified into 134 species, of which 91 species is distributed in Jejudo. But 15 species of stony corals were recorded. Soft coral researches have been conducted mainly on Jeju Island (Jeju-do), due to high concentration of distribution. Up to now, there is no long-term research and monitoring project for the corals. Corals in Korea summarized based on the latest researches. Temperate, tropical, and subtropical species are gathered in Jejudo, which enrich the biodiversity and colorful scenery under water. The unique communities of soft coral highly evaluated in terms of scientific research as well as tourism. The increase of tourists for SCUBA diving and tourist submarine has become to cause destruction problems. Southern coast of Jeju-do were designated as MPA in the name of Wetland Protection Areas by MOMAF (Ministry of Maritime Affaires and Fisheries) as well as Man and Biosphere (MAB) by UNESCO in 2002. Regional and National development plans are overlapped with conservation plans. Monitoring programs are preparing as component of management plan for each designation purpose. Overlapping of designation of protected area and development plan in different level (agencies) made local stakeholders have confused perception. Legislation in local/national level needs to be well coordinated in complementary integration way.

A map of Korea.

Introduction

Since 1974, species of Anthozoa Geographical distribution of corals are surveyed within the country. The coral species of Korea is classified into 134 species, of which 91 species is distributed in Jejudo (Ministry of Education & Human Resources, 2004). Especially, 65 coral species is restricted to the Jejudo area in Korean water. 15 species were classified into stony coral, such as *Psammocora profundacella* (Seogwipo), *Caryophyllia japonica* (Munseom, Supseom, Uleungdo, East sea, Korean strait, eastern and southern coast of Korean Peninsular), *Flabellum distinctum* (Bumseom), *Tubastraea aurea* (Munseom), *Tubastraea coccinea* (Munseom), *Culicia japonica* (Korean Strait, Supseom, Munseom), *Alveopora japonica* (Seogwipo, Supseom, Munseom), *Dendrophyllia cribrosa* (southern coast of Korean Peninsular, East Sea, Korean Strait), *Rhizopsammia minuta* (Yellow Sea, East Sea, Koran Strait, Uleungdo), *Dichopsammia granulosa* (Korean Strait), *Oulangia stokesiana* (Yellow Sea, Korean Strait).

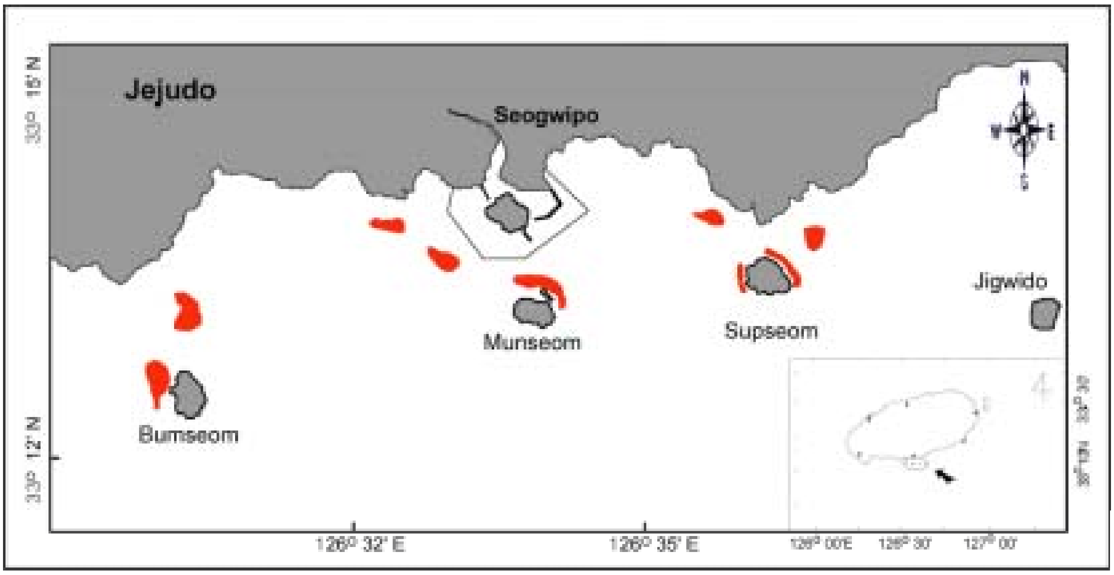

Figure 1. A map showing main habitats of corals in southern coast of Jejudo

In Korea, coral distributions are restricted within a few waters affected by warm current, Kuroshio. Although the corals occur in Uleungdo and southern coast of Korea, the abundance and number of species are limited. Southern coast of Jejudo is representing important habitats for corals (Fig. 1). Jeju island (Jejudo) located in the southern tip of Korea has some distinct soft corals with tropical and subtropical elements because of a branch of warm current, Kuroshio, which passes mainly through the southern part of the Island. Especially, around three islets, Munseom, Bumseom and Supseom in the southern area, there is a variety of soft corals with vertical zonation on volcanic rocks. The corals in these areas are mainly distributed between 10 and 40m in depth (Fig. 2). Some of vertical distribution of dominant coral species in Munseom showed in Fig. 3.

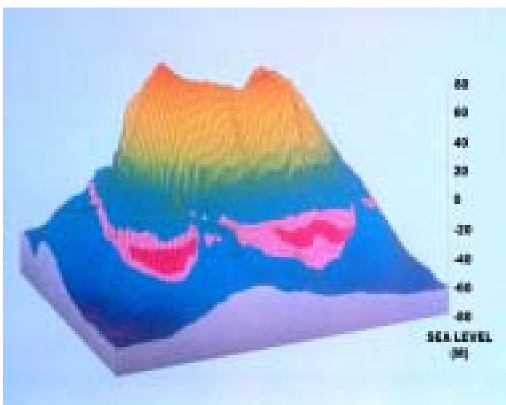

Figure. 2. Soft coral zones of Munseom shown in light color from 0 to –40m in depth (from Seogwipo city, 2000)

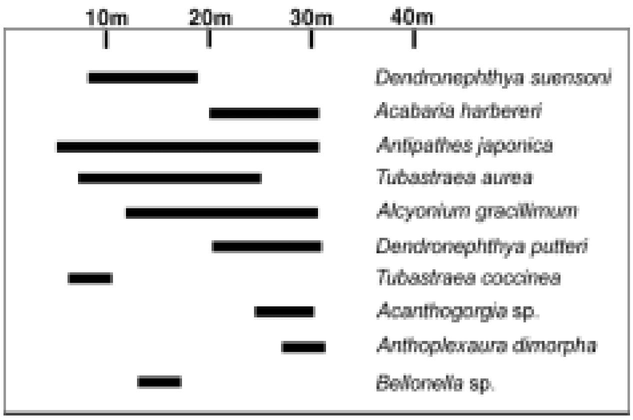

Figure 3. Vertical distribution of dominant coral species in Munseom (from Seogwipo city, 2000)

Various organisms from tropic and subtopic waters have been occupying this area as a habitat. Jejudo is considered as an ecological refuge for the tropical and subtropical marine species and is northern limitation of their distribution as well. There are 15 coral species preserved by the Natural Environment Preservation Act (Table 1), all of which are present in Jejudo.

Table 1. List of 15 corals among 21 preserved invertebrate species by Natural Environment Preservation Act (Ministry of Environment).

Class Anthozoa		
Order Gorgonacea	**Family Ellisellidae**	***Verrucella stella*** **Nutting**
	Family Paramuriceidae	***Pletauroidea complexa*** **Nuttin**
		Plexauroidea reticulata **(Esper)**
	Family Plexauridae	***Euplexaura crassa*** **Kukenthal**
	Family Primnoida	***Plumarella adhaerans*** **Nutting**
		Plumarella spinosa **Kinoshita**
Order Alcyonacea	**Family Nephtheidae**	***Dendronephthya alba*** **Utinomi**
		Dendronephthya castanea **Utinomi**
		Dendronephthya mollis **(Holm)**
		Dendronephthya putteri **Kukenthal**
		Dendronephthya sueusoni **(Holm)**
Order Scleractinia	**Family Dendrophyllidae**	***Dendrophyllia cribrosa*** **M. Edw. et H.**
		Dendrophyllia micranthus **(Ehrenbeg)**
		Tubastraea coccinea **(Hemprich et Ehrenberg)**
Order Antipatharia	**Family Antipathidae**	***Antipathes janpnica*** **Brook**

Status of Coral Reefs

Status of Reef Benthos (especially corals)

Between 1998-2000, coral benthos monitoring conducted as marine and coastal Biodiversity of Jeju Island: for conservation and sustainable use (KORDI 1998, 1999. 2001). In Munseom, Supseom and Bumseom area, soft coral and oyster reef systems of different substrate types have a variety of invertebrates (Fig. 4), which show the highest diversity among the habitats of Jejudo (KORDI 2001, MOMAF 2003). Oyster reef provided large fish with desirable space for refuge before. Uncontrolled collection and fishing led to decrease in the coverage of reef and abundance of fish.

Intertidal and underwater surveys for zoobenthic diversity of rocky shores were carried out at four sites from three different islets around Seogwipo in 1999. A total of 318 benthic species were identified during the survey.

In 2000, 170 benthic animal individuals were collected from three subtidal sandy bottoms that have quite differences among their species compositions. A total of 1,470 benthic animal individuals reported in previous works and occurred in this study were listed. As a baseline study for conserving coastal and marine biological diversity in the coast and adjacent seas of Jejudo, zoobenthic species diversity was investigated during two years (1999-2000) from four subtidal rocky shores and three subtidal sandy bottoms in southern part of Jejudo. The major faunal groups were mollusks with 138 species (26%), crustaceans with 83 (26%) and polychaetes with 38 species (12%). Other groups had less than 21 species: 21 echinoderms, 9 sponges etc. The benthic animals were vertically distributed and significantly zoned along the tidal level and depth as follows: *Granulilittorina exigua, Heminerita japonica, Chthamalus challengeri, Septifer keenae, Pollicipes mitella* and *Tetraclita japonica* in intertidal zone and algae dominant zone above 5m in depth, oyster reef zone between 5～15m, soft corals and Ecklonia cava zone between 10～25m and sponges dominant zone below 25m in sub tidal zone. The animal diversity of oyster reef was highest among the sub tidal zones. The result of clustering using simple matching coefficient was similar to vertical distribution patterns and the sampling stands were divided into three different groups :

the stand group in oyster reefs with high biodiversity, shallow stands and deep stands usually more than 10m in depth (Je et al, 2002).

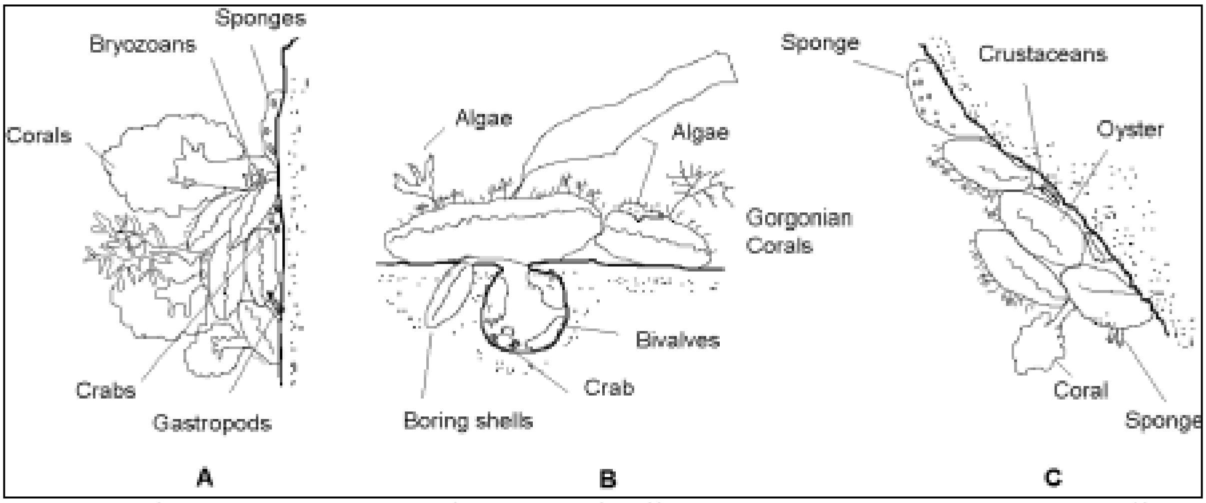

Figure 4. Soft coral and oyster reef systems of different substrate types (A. vertical cliff, B. horizontal cliff, C. oblique cliff)

Status of Reef Fish

Fishes observed in Munseom MPA are approximately 250 species (MOMAF 2003). Commercial important food fish and aquarium fish are included. Latest research on ichthyoplankton and adult fish in southern coast of Jejudo found 693 species belong to 36 Order, 168 Family. It falls into about 83% of marine fish in Korea. Warm water species and midwater species were found in the water off Jejudo. Among them, lots of larval fishes were the unreported species in Korea.

Status of Resource Use

Traditionally, *Antipathes japonica* were widely used for ornament of belt or pendant hanging on the ceiling of door in house on the belief of driving away the demon. Recently, soft corals are supposed to attract the other marine living life as function of incremental animal, which can produce the sources of new materials from such as sponges. As part of marine technology, soft corals and attached lives are developing for new material sources. Under water scenery with soft coral have unique advantage to attractive to tourist. Especially, temperate, tropical, and subtropical species are gathered in Jejudo, which enrich the biodiversity and colorful scenery under water. In particular, Munseom area, the southern coastal area of Jejudo, is important for the habitat of corals and fisheries. The underwater scenary around Munseom is one of the grandest sights imaginable with colorful soft corals and various benthic organisms. Since 1988 the areas have, therefore, been used for tourist submarine. Since then, 888,721 people visited for submarine tour (Daekuk submarine 2002 unpublished data). However, the soft coral communities have been under destruction. The increase of tourists for SCUBA diving and tourist submarine has become to cause destruction problems. Up to now, there is no long-term research and monitoring project for the corals.

Physical Environment

In southern Jeju Island's coast, the soft corals were dominant only on vertical bottoms whereas the brown algae on horizontal bottoms form 5m to 25m in depth. Maybe since 2000, the soft corals have been replaced instead of algae. Recently, some soft coral species already covered all horizontal rocks in around 15m in depth of Munseom Islet in the coast of southern Jeju Island. It might be caused from turbidity change due to a construction for harbor extension.

Stress and Damage to Coral Reefs

Sediments and Nutrients (land-based)

Major factors of 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, current between main island (Jejudo) and Munseom islet are unexpectedly changing reported by local divers.

Damaging Fishing Methods

Over-fishing and damaging fishing methods like harpoon are still prevailed though the activities decreased, most information mainly depends on the information from observations and reports from divers, fishers, government agencies, NGOs. Commercial fishing in fish disporting farms are increasing nearby MPA area due to the economic income and tourism. Over-fishing and uncontrolled collecting are expended even to SCUBA diving.

Anchor and Trawler Damage, Others Kind of Damage (divers, trampling, etc)

There is no control in harpooning by local diver or fishers and collection for scientific purposes.

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

Extension of harbor construction indirectly change the current, which cause changes of distribution of coral in and nearby MPA.

Coral Bleaching

Coral bleaching have not been reported in Korea.

Coral Diseases

Coral Diseases have not been reported in Korea.

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

Outbreaking or invasive organisms have not been reported in Korea.

Coral Damage from Natural Events (storms, etc)

Annually, 3.1 in average of typhoon come to Korean peninsular from the southern coast of Jejudo. The reason of harbor extension in Seogwipo is due to the hurricane or typhoon in summer rainy season. Strong storm sometime remove the corals from the rocky cliff and disturb physical distribution temporarily. Measurable stress and damage are not surveyed at regional or national level.

Potential Threats to Coral Reefs (Reef at Risk Threat Indicators)

It is hard to make an assessment by five RRSEA indicators recommended, as regular monitoring system is not established either integrated. Each item can be commented briefly. Coastal Development

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, two islets, Munseom and Bumseom of Jejudo were designated as Natural Monument Protection Areas. These managed areas along Jejudo were the first kind of protected areas for marine life including corals. The southern coast of Seogwipo including Munseom, Bumseom and Supseom were investigated for designation as a Biosphere Reserve Area by UNESCO and a Marine Protected Area by Ministry of maritime Affairs and Fisheries (MOMAF). All islets were designated as MPA in the name of Wetland Protection Area under Wetland Protection Act by MOMAF and MAB (Man and Biosphere) by UNESCO in 2002 (Fig. 5).

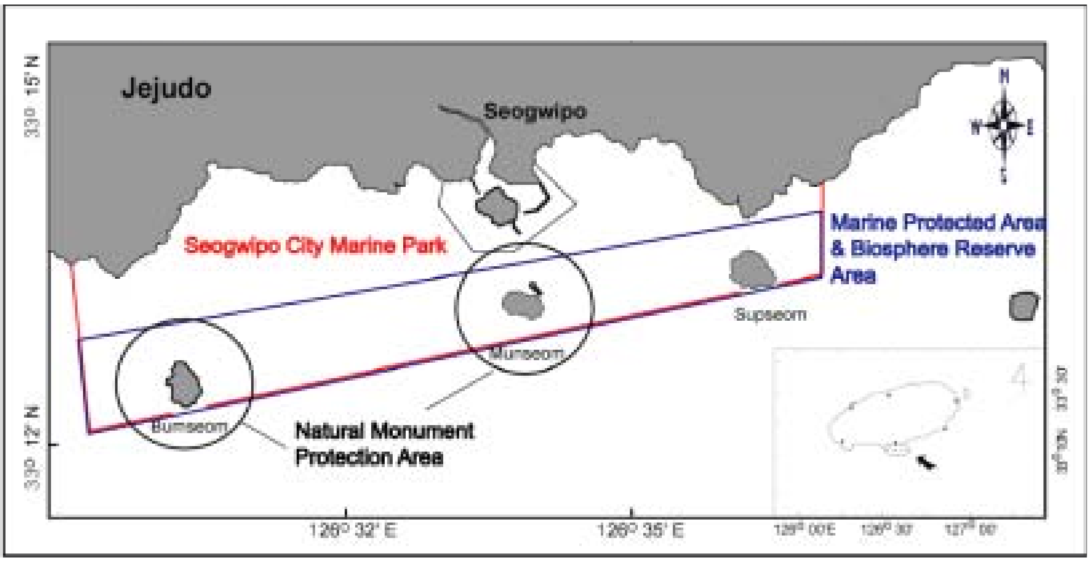

Figure 5. Some Managed Areas along the Seogwipo coast.

9 wetland protected area have been designated since 2001. Seogwipo coastal area is mainly protected for purpose of coral and underwater scenery. Overlapping of protection designation will lead to public awareness for local stakeholder and conservation planning in local government as well as central government. The draft of management plan for wetland protected area by MOMAF are being reviewed for budget and planning. Korea Environment Institute (KEI) under Ministry of Environment (MOE) are preparing the management plan for MAB by UNESCO. MPA in Korea are multi ministries involved with different name and level described as above such as Natural Monument Protection Areas, Wetland Protection Area, Seogwipo City Marine Park and MAB. As the MPA sits for coral conservation were designated recently and management plan under progress or draft reviewing, calculation of score for management effectiveness (recommended by World Bank) is difficult to carry out.

Monitoring

Regular monitoring and report for the management of Wetland Protected Area by MOMAF are expecting. At the moment, regular monitoring work is not established. Occasionally, local diver comment about the change. Due to warm temperature, tropical or subtropical species are reported by observation of local scuba divers. The effect of submarine tourism on benthic community including corals was not fully considered. Submarine operation is the main factor to destroy coral community in the southern coast of Jejudo.

Legislation

Principle acts and regulations affecting coral in Jeju island and protected area as followings. They are consisted for conservation and development as well. National Land Planning and Utilization Act, Public Waters Reclamation Act, Coast Management Act, Conservation of Wetlands Act, Prevention of Marine Pollution Act, Public Waters Management Act, Framework Act on Marine Fishery Development, Natural Parks Act, Protection of Cultural Properties Act, Natural Environment Conservation Act, Special Act on Jeju Free International City

Conclusions and Recommendations

Overlapping of designation of protection area and development plan in different level cause local stakeholders to confusion. Legislation in local / national level need to be well coordinated in complementary integration 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 researches 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 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.

References

ICRI. 1996. Country reports in ICRI East Asian Seas for the regional workshop.

Je, J.-G., B.J. Koo, H.-G. Lee, B.-I. Kim, S.-H. Shin, S.-W. Lee and J.-H. Lee., 2002. Habitats and zoobenthic species diversity in the coastal of Jeju Island, Korea : As a baseline study for conserving coastal and marine biological diversity. Underwater science & Technology, 3(1): 7-117 (in Korean).

Je, J. G. 1999. Marine protected areas in Korea: present and future. Proceeding of international workshop on marine conservation for new millennium: Marine protected areas, Jejudo, Korea: 39-68. (in Korean)

KORDI. 1995. Marine biota of southern coast of Cheju-do. 155pp.

KORDI. 1998. Marine and Coastal Biodiversity of Cheju Island: Conservation and Sustainable Use. 354pp.

KORDI. 1999. Marine and Coastal Biodiversity of Cheju Island: Conservation and Sustainable Use. 331pp.

KORDI. 2001. Marine and Coastal Biodiversity of Cheju Island: Conservation and Sustainable Use. 452pp.

MOMOF. 2003. Management plan for MPA near Munseom islet. 114pp.

Ministry of Environment, ROK. 1994. Environment Protection in Korea. 292pp.

Ministry of Education & Human Resources. 2004. Illustrated encyclopida of Fauna and Flora of Korea. Vol. 39. Anthozoa. 643pp.

Seogwipo City, 2000. Marine ecosystem surveys for sustainable use and conservation of Seogwipo City Marine Park (in Korean).

Song, J.-I. 2000. Animals of Korea, Series 5: Cnidaria 2, Anthozoa. 332pp., Korea Research Institute of Bioscience and Biotechnology, Korea. (in Korean)

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