

CAMBODIA REEF CONSERVATION PROJECT

Year 1 Report

February 2010 – February 2011



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In partnership with:



Fisheries Administration,
Ministry of Agriculture, Forestry and Fisheries

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Executive summary

On the invitation of the Fisheries Administration (FiA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), Coral Cay Conservation (CCC), a UK-based conservation NGO, has been conducting detailed baseline marine assessments of the coastal resources around Koh Rong and Koh Rong Samloem Islands. This project, known as the Cambodia Reef Conservation Project, successfully carried out 126 individual 50-metre survey dives along the fringing reefs of the islands between February of 2010 and February of 2011. The surveys collected detailed data on reef health, human impacts and biotic and abiotic information including benthic, invertebrate and fish abundances and diversity. The work was carried out in order to support the development of a large Marine Protected Area around the island of Koh Rong. This area is undergoing significant development activities in order to support future tourism-related operations.

Results from the survey effort showed there to be a slight decrease in coral cover from 23% to 20% since 2009 when CCC conducted a 3-month Pilot Project. Coral species diversity was low and the area was dominated mainly by massive coral species. There was a low abundance of branching and foliose coral lifeforms. The 2010 mass-bleaching event that occurred in the Gulf of Thailand over the summer saw a high prevalence of bleached coral colonies between May and October. In May of that year, 90-100% of coral colonies observed were bleached with no discrimination between coral species, depth or site was detected. Ongoing surveying and monitoring will help establish the long-term implications of the mass-bleaching event in the area.

Anthropogenic impacts to the local reefs included sedimentation, pollution, overfishing and limited coral breakage due to anchors and fishing gear. Sedimentation from land run-off was found to be higher than the previous year, posing a serious threat to the reefs, hampering their recovery from the mass-bleaching event. Any effort to provide reefs with the best possible chance of surviving future impacts will therefore need to address the issue of sedimentation from both the islands and mainland Cambodia.

Although there was a higher abundance of some fish families such as Butterflyfish (Chaetodontidae) and Parrotfish (Scaridae), predatory fish families such as Groupers (Serranidae) and Snappers (Lutjanidae) showed marked declines compared to results from similar surveys done in the area in 2003. Commercially valuable species of invertebrates that included lobsters and sea cucumbers were found to be very low to non-existent on most reef sites. These results highlight the vulnerability of these key reef fish families to continued fishing and warrant the establishment of a no-take MPA as proposed by the Fisheries Administration.

In addition to the extensive survey work, CCC staff and volunteers promoted educational awareness through seminars and workshops to local communities on Koh Rong Island. Several lectures were also presented at the University of Phnom Penh and CCC will be taking on Cambodian scholars over 2011 to support in-country capacity building.

This report presents results from the first year of the project and provides recommendations in support of the establishment of a multiple-use Marine Protected Area that is guided by sound scientific information and under consultation of local stakeholders.

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Volunteers and local staff at the CCC project site, Koh Rong, Cambodia, 2010

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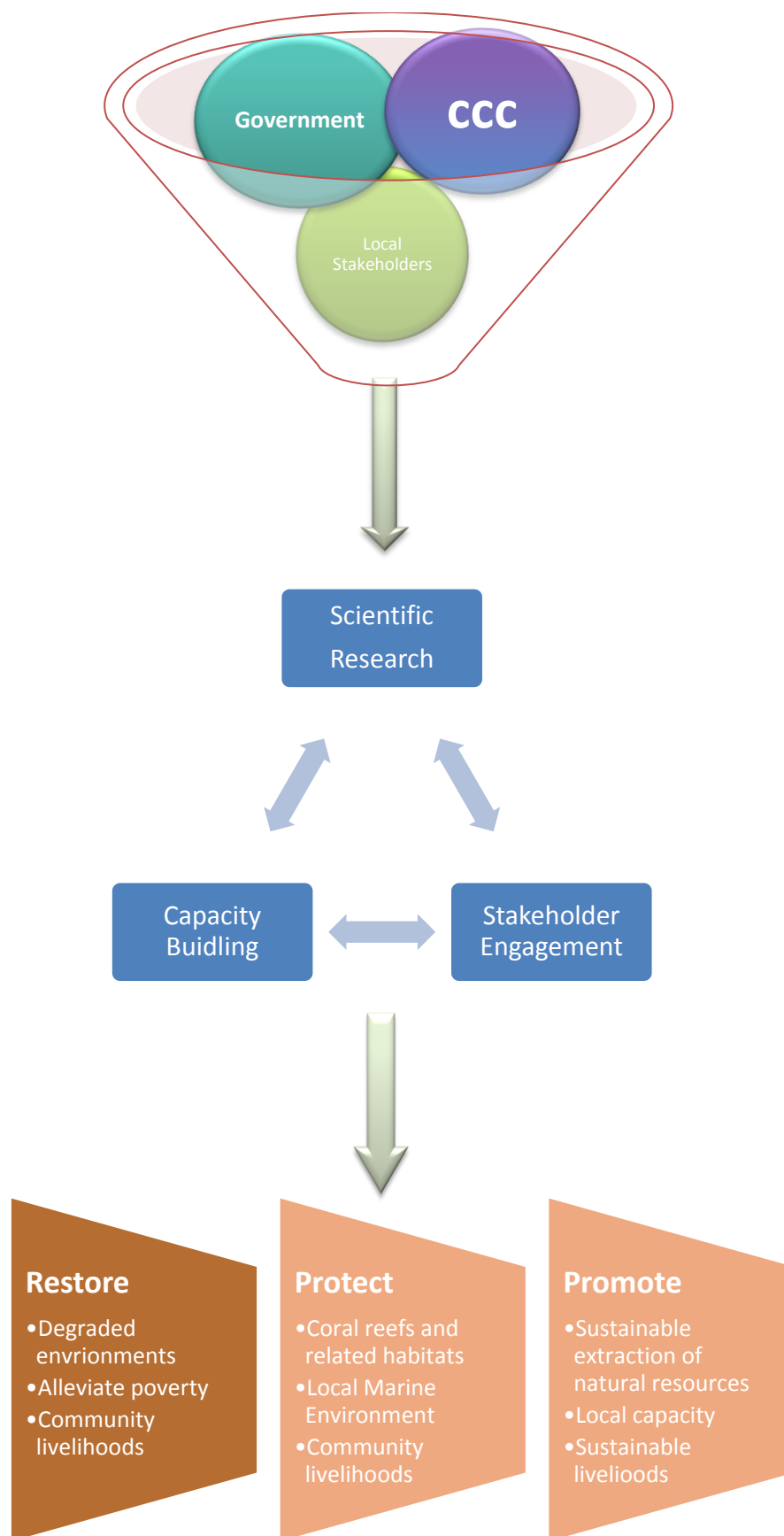
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Coral Cay Conservation

Effective coastal zone management, including conservation of coral reefs, requires a holistic and multi-sectoral approach, which is often a highly technical and costly process and one that many developing countries cannot adequately afford. With appropriate training, non-specialist volunteer divers are able to provide useful data for coastal zone management at little or no cost to the host country (Hunter and Maragos, 1992; Mumby et al., 1995; Wells, 1995; Darwall and Dulvy, 1996; Erdmann et al., 1997). This technique has been pioneered and successfully applied by Coral Cay Conservation (CCC), a British not-for-profit organisation.

Founded in 1985, CCC is dedicated to 'providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests'. CCC works in collaboration with government and non-governmental organisations within a host country and does not charge that country for the services provided. CCC is primarily self-financed through a pioneering volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs. Upon arrival at a project site, volunteers undergo a training programme in marine life identification and underwater survey techniques, under the guidance of qualified marine scientists, prior to assisting in the acquisition of data. Finances generated from the volunteer programme allow CCC to provide a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes. CCC is associated with the Coral Cay Conservation Trust (the only British-based charity dedicated to protecting coral reefs).

CCC has been successfully operating volunteer based conservation programmes in developing countries over the past 25 years with several internationally notable accomplishments, including the establishment of several Marine Protected Areas around the world. Examples of CCC action include the creation of the UNESCO World Heritage Site in Belize, the Danjungan Marine Reserve and Wildlife Sanctuary for Negros in Philippines, and the development of 12 no-take marine parks around Sogod Bay in the Philippines.



Flow process diagram of Coral Cay Conservation's implementation strategy



Rich and colourful diversity of marine life on Cambodia's coral reefs

1 Introduction

Cambodia's coastline is 435 kilometres long and includes 69 islands within the Gulf of Thailand (Touch, 1995, Kim et al., 2004). Coral reefs and other marine habitats such as seagrass beds and mangroves, fringe many of these islands providing a unique coastal environment that shelters a rich diversity of marine life (Kim et al., 2004). Moreover, coral reefs promote fisheries and eco-tourism practices, and provide a variety of goods and services including coastal protection to thousands of people depending on them and therefore supporting local economies (Vibol and Kluskens 2008). Although it is difficult to put a monetary value on coral reef resources, a recent study conducted by The Economics of Ecosystems and Biodiversity (TEEB) estimated that the value per hectare of healthy coral reef to be anywhere between \$130,000 to \$1.2 million/hectare/year (www.diversitas-international.org). The services provided by these reefs include food, raw materials, ornamental resources, climate regulation, moderation of extreme events, waste treatment, biological control, cultural services and maintenance of genetic diversity. If these reefs are effectively protected, they have the best possible chance of coping with local, anthropogenic impacts and recovering from regional ones. If however, they are not properly managed, it is quite likely they will disappear within the next few decades.

Current information about Cambodia's reef ecosystems is sparse and poorly documented and there is an urgent need for accurate data on the status of these critical habitats (Chou, 2003, Wilkinson, 2008). Only limited research exists and previous research efforts have been supported by international organisations, as there is currently not enough in-country capacity to support such scientific studies. The first surveys on Cambodia's reefs were completed between 1997 and 1999 (Nelson, 1999), followed by further surveys conducted in 2001 by Wetland International (Mam, 2001) and the Department of Fisheries and UNEP in 2002 and 2003 (UNEP, 2003). A team of scientists from the National University of Singapore conducted assessments of coral reefs around the Koh Sdach islands in Koh Kong in 2002 and 2003 (Chou et al., 2002, 2003). These surveys concluded that coral reefs in Cambodia provide both biological and socio economic benefits to the area, and recommended that long term marine conservation schemes should be implemented (Kim et al., 2004).

Although many cities in South East Asia are developing very rapidly, most people in Cambodia remain highly dependent on coastal resources for their livelihoods, inducing pressure on the marine environment (Wilkinson 2008). Anthropogenic impacts on Cambodia's coral reefs such as overfishing, coral extraction, coastal development and marine based pollution can cause significant and often, irreversible damage to the reefs (Gillet 2004, Sheppard 2006). These impacts, when coupled with the current global increase in temperatures, induce a severe threat to the survival of coral reefs (Wilkinson 2008). Future projections made by GCRMN (Global Coral Reef Monitoring Network) estimate that the level of risk in Cambodia's reefs range from 'high' (90% of reefs) to 'very high' (10% of reefs) (Wilkinson, 2008) (Table 1). Therefore there is a need for long term scientific monitoring programmes to assess the current status of coral reefs. This information will help in mitigating anthropogenic impacts and allow for the development of effective conservation management strategies (Wilkinson 2008). The next section provides further information on local and regional threats to Cambodia's coral reef habitats.

Table 1 Summary of Coral Reef Status in Cambodia (Research conducted by external organisations for global estimate of reef area, ** Data provided by the government of Cambodia for reef area, ↓ indicating a decrease in coral reef area). Adapted from Wilkinson 2008 pp136-137*

Cambodia	
General reef Statistics	
Reef Area (km ²) Global Estimate	150*
Reef Area (km ²) Country Estimate	28** ↓
Overall Reef Condition	
No of Hard Coral Species	111
Integrated threat index %	
Low	0
Medium	0
High	90
Very High	10
Threat Indicators	
Coastal Development	High
Marine-Based Pollution	High
Sedimentation	High
Over fishing	High
Destructive fishing	High
Marine Protection Status	
Total number of actively managed MPAs	2
Total number of MPAs with coral reefs	1
% of MPAs with good management ratings	10%

Anthropogenic impacts are expected to increase across the coastal areas of Cambodia, including the islands of Koh Rong and Koh Rong Samloem off the coastal Phrask Sihanouk Province of Cambodia (Figure 3). These islands are fringed by biologically rich shallow-water reefs that closely follow the contours of the coastline, and host a high number of endemic marine species. Koh Rong Island has been designated for extensive, tourism-related development over the next two decades (Figure 1. Also see http://www.millenniumgroup.net/?page_id=96). Plans include the construction of an airport, several resorts, a casino, golf course and a coastal road around the island.

The extensive use of resources along with the continuously increased temperatures, are likely to have a negative impact on the coral reefs. This can be illustrated by the mass bleaching event that took place in Cambodia during May of 2010. The National Oceanographic and Atmospheric Association (NOAA) reported this event as the biggest mass-bleaching episode since 1998 with increased coral mortality expected (Gray 2010). CCC surveys in Cambodia reported bleaching prevalence of around 90-100% of the coral population around the shallow coral reefs in Koh Rong and Koh Rong Samleom, where the water temperatures increased by 2°C above the mean water temperature.

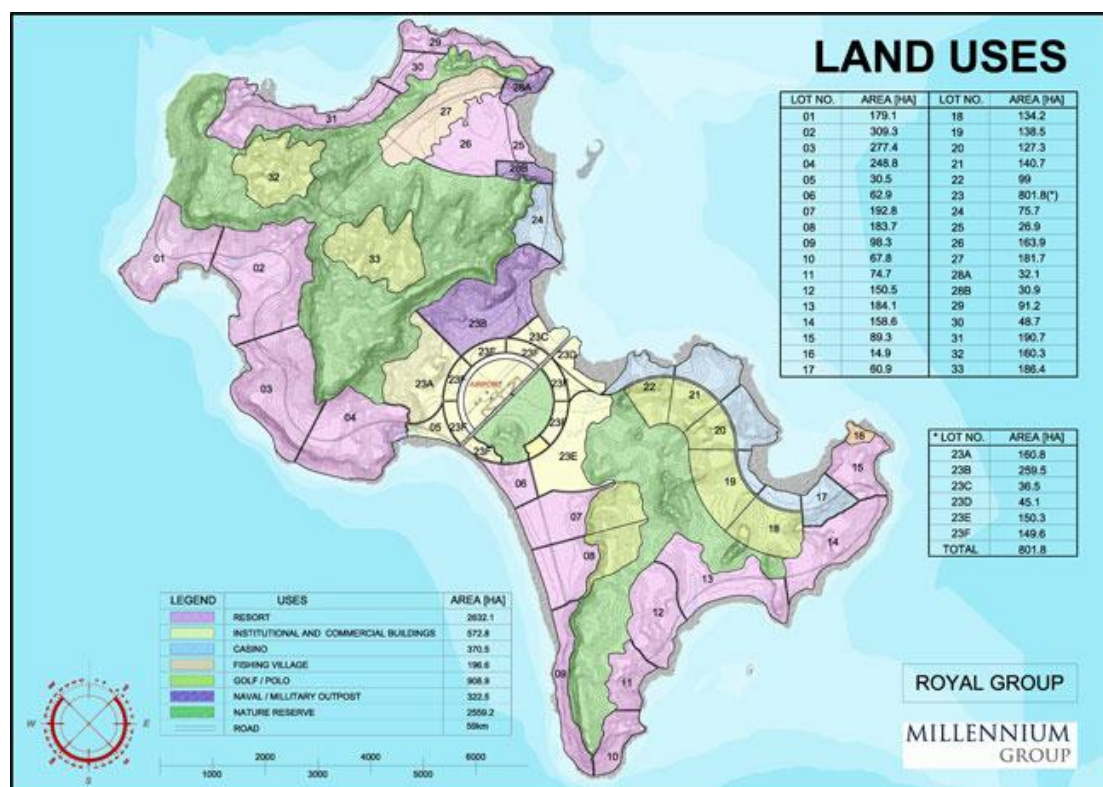


Figure 1 Proposed development plan for Koh Rong Island.

Image taken from: http://www.millenniumgroup.net/?page_id=96

1.1 Threats to the coral reefs of Cambodia

A variety of factors, exacerbated by an expanding population, are a serious threat to the coral reefs of Cambodia. The main regional and local, anthropogenic impacts are described below.

Global and Regional-Scale Threats and Impacts

Carbon Dioxide (CO₂) levels in the earth's atmosphere have been rising steeply since the industrial revolution, mainly due to the burning of fossil fuels. Based on realistic scenarios of future emissions this trend will continue and atmospheric CO₂ concentrations are expected to reach double pre-industrial levels by 2065 (Houghton et al., 2001). Global temperatures are expected to rise anywhere between 1.8 – 4.0°C by the year 2100 (IPCC, 2007).

Climate change is regarded as one of the major threats to the future of coral reefs (Hughes et al., 2003). Coral reefs have evolved in relatively stable climatic conditions for the last tens of thousands of years. It is this relative climatic stability that has allowed them to develop into a complex ecosystem comprised of thousands of species and many intricate inter-specific relationships. Coral reefs can recover from acute stress (e.g. bleaching events) and also tolerate chronic (e.g. sedimentation) ones to a certain degree. However, chronically stressed reefs are far less likely to recover from an acute stress (Kinsey, 1988). A series of acute stresses against a backdrop of continued chronic ones can result in a phase shift and a coral dominated community would be replaced by one dominated by macroalgae or some other non-reef system. Such ecosystem shifts have been well documented in the Caribbean (Buddemeier et al., 2004), and in some cases the combination of stresses has brought coral reefs to the point of local extinction. Coral reefs have accordingly been dubbed the “canaries in the coalmine of climate change”. What follows is a summary of some of the most concerning climate change induced phenomena that are impacting the coral reefs of Cambodia.

Coral Bleaching

Coral species and their associated microscopic algae are highly sensitive creatures with a limited ‘tolerance zone’ within which they can thrive. Stressors such as increased UV light and thermal stress can threaten their survival. Coral bleaching refers to the loss of the symbiotic algae (zooxanthellae) from the coral tissue as a result of stress. Without these algae, the coral colony appears white. The zooxanthellae provide the bulk of the coral's nutrition via photosynthesis. If a coral colony is not able to regain its population of symbiotic algae and so photosynthesize, it will starve.

Although there have been records of coral bleaching since 1870 (Glynn, 1993), extensive or regional bleaching appears to be a relatively new phenomenon, with a significant increase in the levels and extent of bleaching recorded in the past 20 years or so (Winter et al, 1998). Recent examples of corals reefs' responses to elevated sea surface temperatures in the Indo-Pacific were demonstrated in 1998 when bleaching due to the El Niño Southern Oscillation (ENSO) event effectively killed 16% of the

world's coral reefs. Such events are expected to become bi-annual within the next 20-50 years if drastic measures are not taken to reduce carbon emissions (IPCC, 2007). Within Sogod Bay, large scale bleaching has not been observed since 2002, and the region was not significantly affected during the mass bleaching event of 1998. Taylor et al. (2004) suggested that the lack of bleaching was related to the upwelling of cooler water from the deeper parts of the bay to the warmer shallow areas producing a mixed, less stratified water column. A similar effect occurs in the Red Sea where coral bleaching has been minimal.

Ocean Acidification

In addition to rising sea surface temperatures, another phenomenon is expected to affect the very structure and growth capabilities of hard corals through a process known as oceanic acidification. As the oceans absorb more carbon dioxide, their marine chemistry changes. Dissolved in water, CO₂ becomes carbonic acid, reducing the amount of carbonate available to calcifying organisms such as reef building (Scleractinian) corals that need carbonate to create a calcium carbonate (limestone) skeleton. In the last 200 years the surface ocean has absorbed about half of the CO₂ produced by industry, causing a fall in pH of 0.1, which equates to a 30% increase in Hydrogen (H⁺) ion concentration (Royal Society, 2005). The predicted changes in seawater chemistry could have severe consequences for calcifying organisms, making it increasingly difficult for hard corals to maintain their limestone skeletons (Orr et al. 2005).

Coral Diseases

Disease outbreaks and subsequent mortality among corals and other reef organisms have been a major cause of the recent increase in coral reef degradation (Buddemeier et al., 2004) and are an emerging problem in the Indo-Pacific region (Aeby, 2007). For example, Black Band Disease, previously known only from the Caribbean, has now been recorded in the Indo-Pacific. Black Band Disease was first reported in the Philippines in 1985 and has also been recorded in Australia (Great Barrier Reef), Sulawesi, Indonesia and Fiji (Aeby, 2007).

There is a lack of knowledge about the causative agents of many diseases affecting corals but studies have shown that microbial pathogens are a source of coral diseases such as Black and White-Band disease (Cervino et al., 2004). Some of these pathogens have been linked to sewage and agricultural outputs (Voss et al., 2006, Smith et al., 1996) providing strong evidence for proper waste management in order to minimise disease impacts on coral reefs. Coral disease has not had a significant impact in Sogod Bay to date, but their prevalence over the coming years should be closely monitored.

Precipitation and Storm Damage

Another concerning effect of global climate change is the expected dramatic changes in weather patterns. Tropical precipitation has increased over the past century by 0.2–0.3 % per decade in the 10°S-10°N region (Houghton et al., 2001), and the frequency of heavy precipitation events is expected to increase (IPCC, 2007). Increased

precipitation can lower salinity and increase sediment discharge and deposition near river mouths, sometimes leading to mass mortalities on nearby coral reefs (Wolanski et al., 2003). Proper management and restoration of natural watersheds can greatly minimise direct runoff from rainwater.

Typhoons are also becoming stronger and more unpredictable (Webster 2005). Healthy reefs can recover from infrequent damage caused by tropical storms but already weakened and stressed reefs can suffer further degradation with little opportunity for recovery.

Intermediate and Local-Scale Threats and Impacts

Although climate change is now considered to be the overarching threat to tropical marine ecosystems, impacts to coral reefs are exacerbated by local, anthropogenic events. To maintain hard coral populations on reef systems around the world it will be necessary to carefully manage direct pressures such as pollution, sedimentation, overfishing and coastal development, and anticipate that some coral species are able to adapt to the warmer environment (Wilkinson and Souter, 2008). Studies conducted on relatively undisturbed coral reefs, in the absence of direct human pressures, have indicated that such reefs have a greater ability to recover from bleaching events. This was demonstrated in the remote archipelago of Chagos following the 1998 ENSO event (Sheppard et al., 2008). Threats to reef health caused by local anthropogenic factors are briefly discussed below and include:

- Changes in water quality due to input of nutrients
- Siltation from construction, dredging and runoff from upland deforestation and agriculture
- Overfishing to the extent where key groups of species are removed and it is no longer sustainable.
- A reduction in coral reef diversity and hard coral cover due to Crown of Thorns Starfish

Pollution and Nutrification

Tropical waters are generally nutrient poor environments (oligotrophic) and anthropogenic-induced nutrient inputs can upset the water chemistry of coral reefs (McCook, 1999). The impact is further exacerbated if overfishing removes key herbivores which normally help to keep algae populations under control. Knock-on effects have been known to weaken the physiological resistance of corals and make them more susceptible to disease; recent studies have shown a link between increased nutrient levels and the rate of disease spread (Voss et al., 2006).

Excess concentrations of nutrients (nutrification) in the coastal waters can arise from discharge of untreated effluent and from agricultural run-off containing fertiliser. Pollution may be a particular problem in bay areas where flushing rates are slow and nutrients are not quickly dispersed. Furthermore eddies within coral reef areas can

create water circulation patterns which prevent removal of nutrients to the open ocean and result in localised concentrations.

Nutrification stimulates the growth of marine algae because nutrients such as nitrogen and phosphorous which, under normal conditions limit algal growth, are in excess. Fast growing algae compete with and can overgrow corals, resulting in a phase shift from a coral-dominated to an algal-dominated community. Certain macroalgae (such as *Lobophora* spp. and *Dictyota* spp.) respond to high levels of nutrients by increasing the growth of their rigid tissue which can contain toxic secondary metabolites. These compounds cannot be easily digested by herbivores, and can therefore result in an almost complete lack of herbivory for these algae on the coral reefs (Hay et al., 1996). Mangrove removal has exacerbated the problems of sedimentation and pollution. Mangroves are important nursery grounds for juvenile fish and invertebrates and their roots help retain and filter nutrients from sediments. Like coral reefs, they also play an important role in coastal stability.

Sedimentation

Over much of South East Asia, extensive deforestation has resulted from the harvesting of tropical hardwoods (Hodgson, 1999) and land clearance for agriculture. Sedimentation is expected to be considerable around Cambodia's coastal zones where upland deforestation and coastal construction have been on the increase.

Resuspension of sediments near the coasts is also caused by both wind and wave action. The resuspended sediments may be siliclastic or marine based. That is, the sediments that well up and settle during each tidal cycle, are likely to arise from the movement of natural marine-derived limestone deposits.

Siltation, as a result of natural processes or anthropogenic interference, is thought to be the most important factor influencing the condition of coral reefs (Jacinto et al., 2000). Sedimentation may cause coral mortality and lower recruitment rates leading to decreased rates of accretion of coral reefs and overall habitat degradation. Corals rely on a high level of light irradiance to survive, and increased sediment loading in the water column reduces the light available for photosynthesis by the symbiotic algae (zooxanthellae) living in the coral tissue. Sedimentation also physically smothers coral polyps and removal of sediment requires the production of large amounts of mucous, which is a high energy demanding activity. Excess mucous production over long time periods stress the coral host, further reducing growth and reproductive capacities. Subsequent coral mortality and decreased coral reef growth rates can have knock-on effects by reducing the diversity of invertebrate and fish life.

Fishing Pressure

Overfishing, the unsustainable fishing or collection of marine resources, is a global problem with a long history of impacts across the entire marine ecosystem (Jackson et al., 2001). Increased fishing pressure poses a major threat to the integrity of coral reefs, the functions they perform, as well as to the services they provide. In particular the use of destructive fishing techniques reduces the long-term survival of coral reef communities by causing inadvertent damage to non-target fish, invertebrate and coral species.

In parts of the Caribbean for example, widespread overfishing of reefs has removed many of the herbivorous fish that keep algae in check, upsetting the competitive balance between corals and seaweeds, often leading to a fundamental change in the marine community structure. Consequently, management of fish stocks is a key component in preventing phase shifts and managing reef resilience (Hughes et al., 2007). There is now evidence that chronic overfishing of top predators such as sharks can have top-down effects on reef productivity (Myers et al., 2007).

Local stewardship of fisheries, under guidance of management experts, can be an effective means for conservation of reefs and improved local fish stocks. Recommendations, including implementing and enforcing permanent closures, seasonal protection of spawning sites, fishing gear restrictions and catch limits can all guide effective conservation and management of near shore fisheries.

1.2 Project Aim

The Fisheries Administration (FiA) of the Ministry of Agriculture, Fisheries and Fisheries (MAFF) of the Kingdom of Cambodia, has invited Coral Cay Conservation (CCC) to Cambodia, in order to assess the status of the marine resources around Koh Rong and Koh Rong Samloem Islands (Figure 3). **The Cambodia Reef Conservation Project (CRCP)** commenced in February of 2010, following an initial 3-month assessment of the same area in 2009.

The main objective of the CRCP is to collect accurate scientific baseline data in order to develop natural resource maps of the coral reefs, mangrove forests and seagrass beds of the islands. This information will then be used to create a management tool for the effective implementation of multiple-use zoning schemes around the islands.

In addition to this, the CRCP has been gathering detailed scientific data from the mass coral bleaching event which affected the Gulf of Thailand between May and October of 2010 (Figure 2). The research includes the continued assessment of coral recovery from this event and will serve as a valuable baseline dataset for the ongoing research and monitoring of the area.

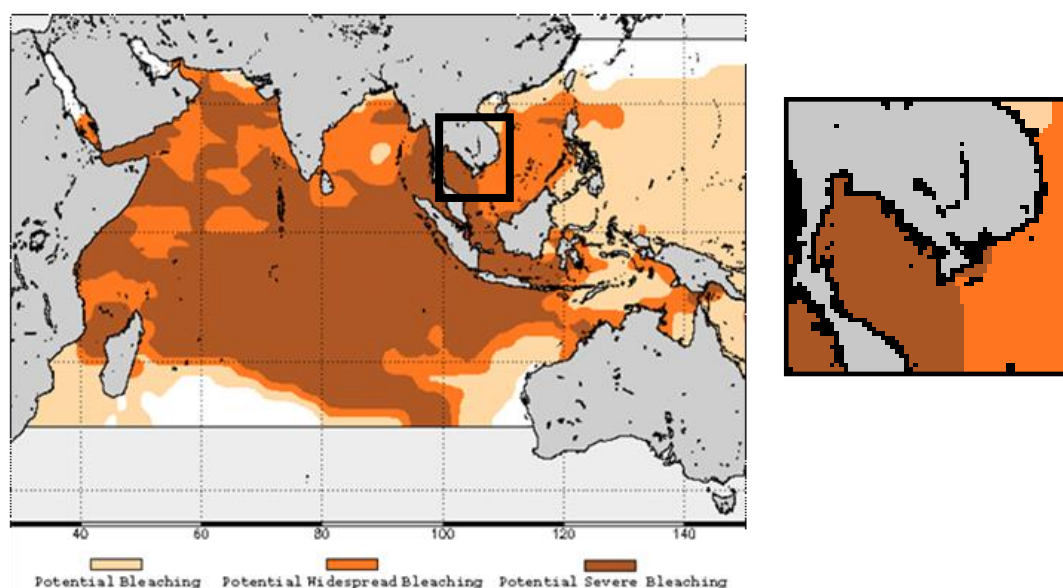


Figure 2 NOAA Coral Reef Watch: Coral Bleaching Thermal Stress March-June 2010 with the Gulf of Thailand facing 'Potential severe bleaching' threat level (inset).

Adapted from: <http://coralreefwatch.noaa.gov/satellite/index.html>

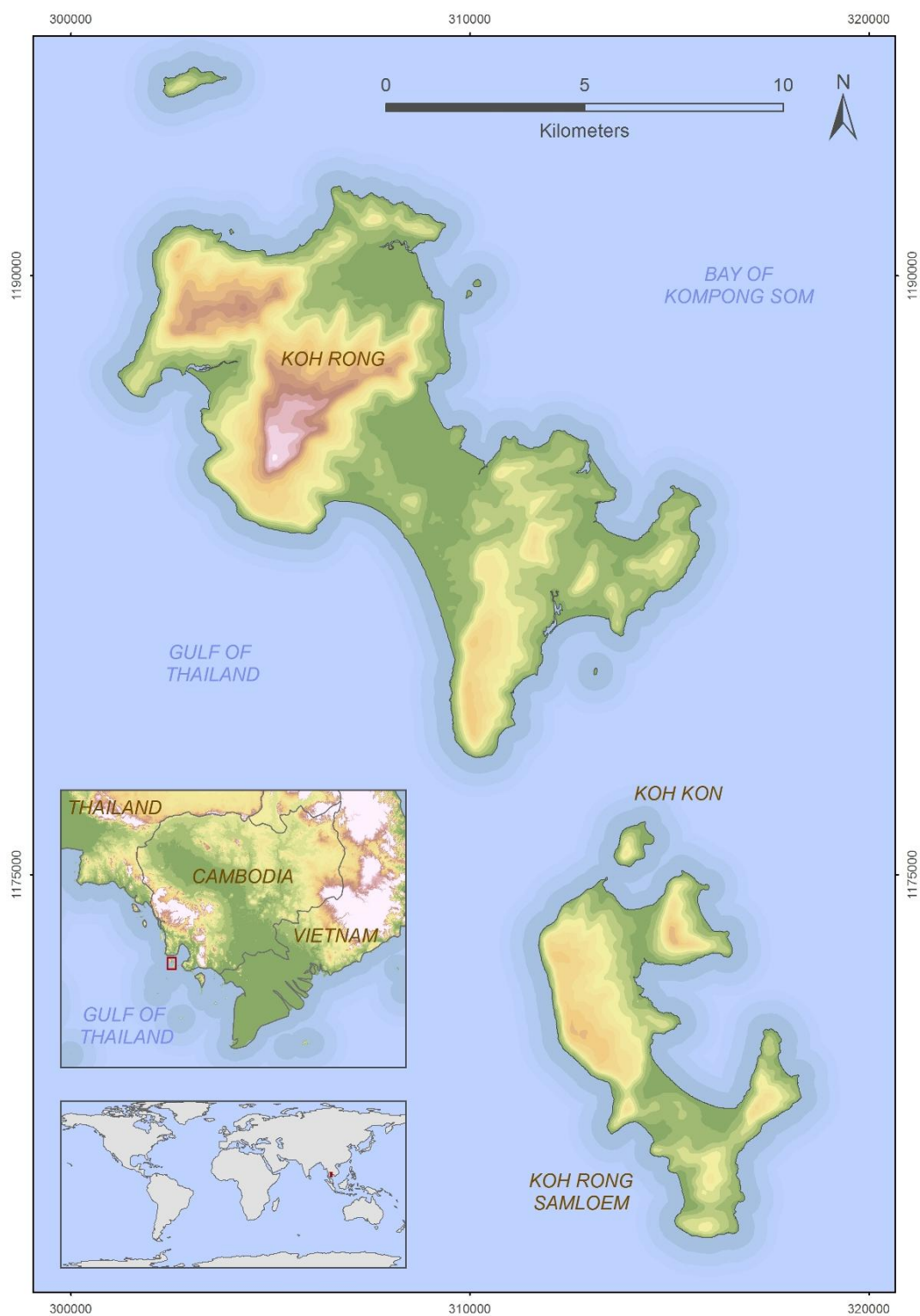


Figure 3 *The islands of Koh Rong and Koh Rong Samloem, found off the coastal Phrash Sihanouk Province of Cambodia.*

2 Methods

Reef Check methodology (Hodgson, et al., 2006) was used to survey sites around Koh Rong, Koh Kon and Koh Rong Samloem islands in order to quantify the abundance, diversity and composition of selected fish, invertebrate and benthic species. Reef Check is a method for monitoring the general health of a reef status and provides a synoptic view of the health of a particular reef site. Data are gathered from volunteer divers, trained and led by scientists on site, to assess the biological and physiological characteristics of reef communities. Volunteer surveyors work in four-man teams, surveying along a transect parallel to the shore along a 100 metre (m) long transect line. The surveys were carried out at two different depth bands ranging from 2-6 m (shallow) and 6-12 m (deep) (Figure 4).

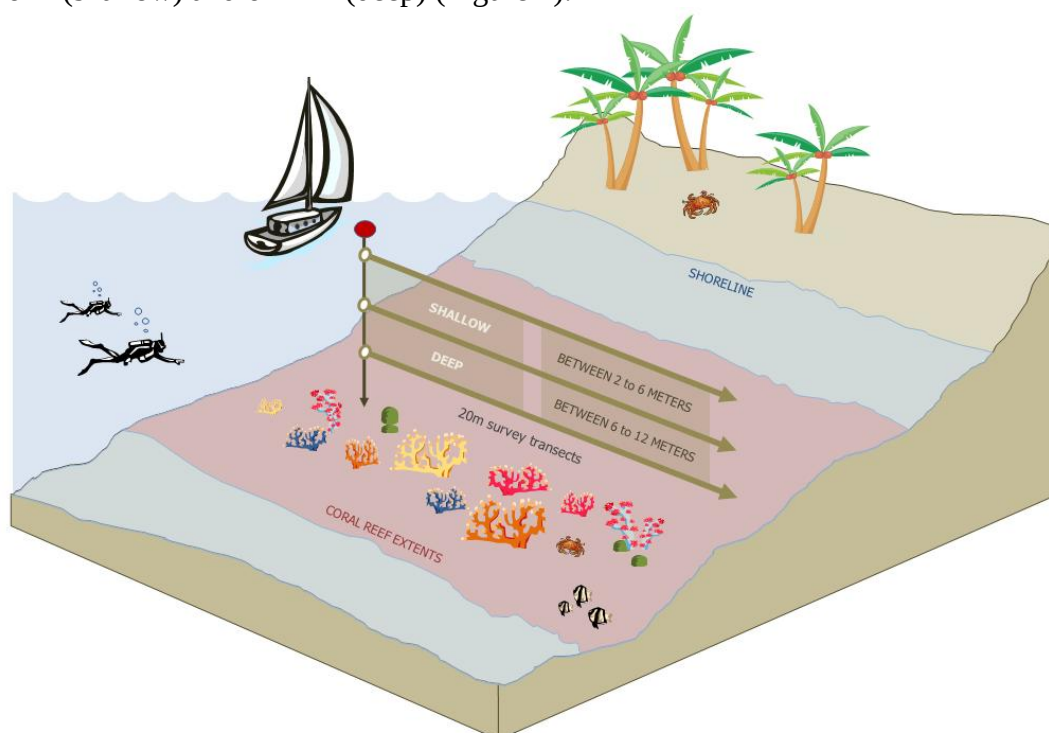


Figure 4 *Schematic diagram of the survey depths, conducted parallel to the shoreline*

Along each depth contour, four 20m transect replicates were marked out and surveyed to make up one complete survey (Figure 5). Each consecutive replicate's start and end point were separated by a minimum gap of 5m. These gaps were necessary to ensure independence between the samples which is important for reliable statistical testing. Therefore, the distance between the start point of the transect's first replicate and the end point of the last replicate was 95 metres.

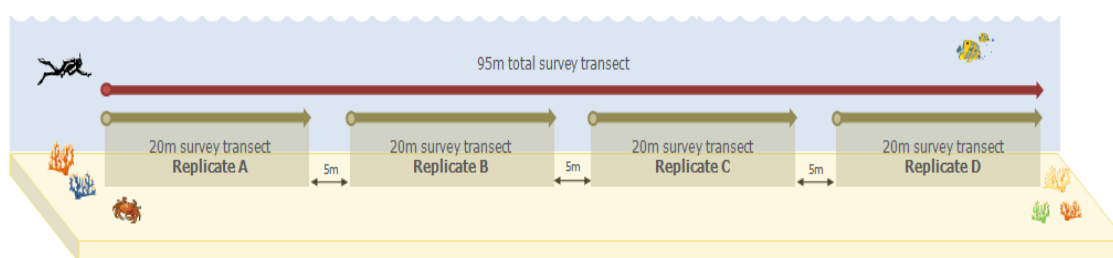


Figure 5 *Schematic diagram of the transect setup*

The surveys collected various types of data and include:

1. Site description
2. Fish abundance, Size and Diversity
3. Invertebrate Abundance, Size and Diversity
4. Benthic composition (Substrate)
5. Coral disease, bleaching and anthropogenic impacts

Volunteer divers collected this data using a variety of survey methods, outlined in the next section.

2.1 Types of data collected at each survey site

(See Appendix for further details)

Certain target taxa or abiotic categories have been shown to be effective indicators of overall reef health (Hodgson, 1999). Depending on the particular target, these variables can indicate a history of overfishing, nutrient pollution, sedimentation and the removal of organisms for the curio or aquarium trade. Indicators recorded on surveys are therefore recognised as robust gauges of general reef health. Five types of data are recorded and later transferred to standard data forms:

1. **Site Description** - Basic descriptive information about the site were recorded as well as GPS recordings of the start of the survey transect and any impacts observed in the area.
2. **Fish Belt Transect** - Selected fish families and species recognized as being good indicators of fishing pressure, aquarium collection and reef health were included. Size minimums were placed on two families of commercial fish – Groupers (Serranidae) and Parrotfish (Scaridae).

Fish data was recorded along a 'belt' transect, where fish were counted within an imaginary 5m³ box along the four 20m replicates (Figure 6). Surveying was carried out by each diver swimming slowly along the transect and counting the indicator fish. The diver then stopped every 5 metres and waited 1 minute for the indicator fish to come out of hiding before proceeding to the next 5 metre stop-point.

3. **Invertebrate Belt Transect** - The same segments used for the fish belt transect were used to sample selected invertebrate species typically targeted as food species or collected as curios (Figure 6). The diver swims slowly along the transect counting the indicator invertebrates in a slow transverse wave pattern. Divers looked in holes and under overhangs to detect organisms such as lobsters, sea urchins or other cryptic species.
4. **Benthic Substrate Line Transect** - Benthic diversity was measured by estimating the coral cover, sponges, algae and other substrate types such as rock, sand or rubble. Along the transect line, benthic organisms and substrate types were recorded in 50cm intervals marked on the transect line (Figure 6). To minimize bias, a plumb line was dropped at each designated 50cm point and the substrate type underneath was recorded. Every replicate contained 20 benthic points, equating to 80 points in total.

Benthic categories were: sand, rock, rubble, silt/mud, nutrient indicator algae, sponge, recently killed coral, soft coral, hard coral and any other biotic lifeforms. Hard corals were noted to species or genus level if the coral was a target species (see Table 2). Otherwise, a note was made of the coral life form.
5. **Coral Bleaching, Trash and Damage Impact** – Along the line transect divers estimated the total percentage of bleached coral cover as well as the estimated percentage of each individual coral colony that was bleached (Figure 6). Coral diseases were recorded as a percentage of the colony infected and where possible, the disease was identified. Damage was recorded on a categorical scale from 0 to 3 (0 = none, 1=low, 2= medium, 3 = high). Impact on the site from trash was recorded and separated into general and fishing nets/traps. Coral damage types were divided into boat/anchor, dynamite and other.

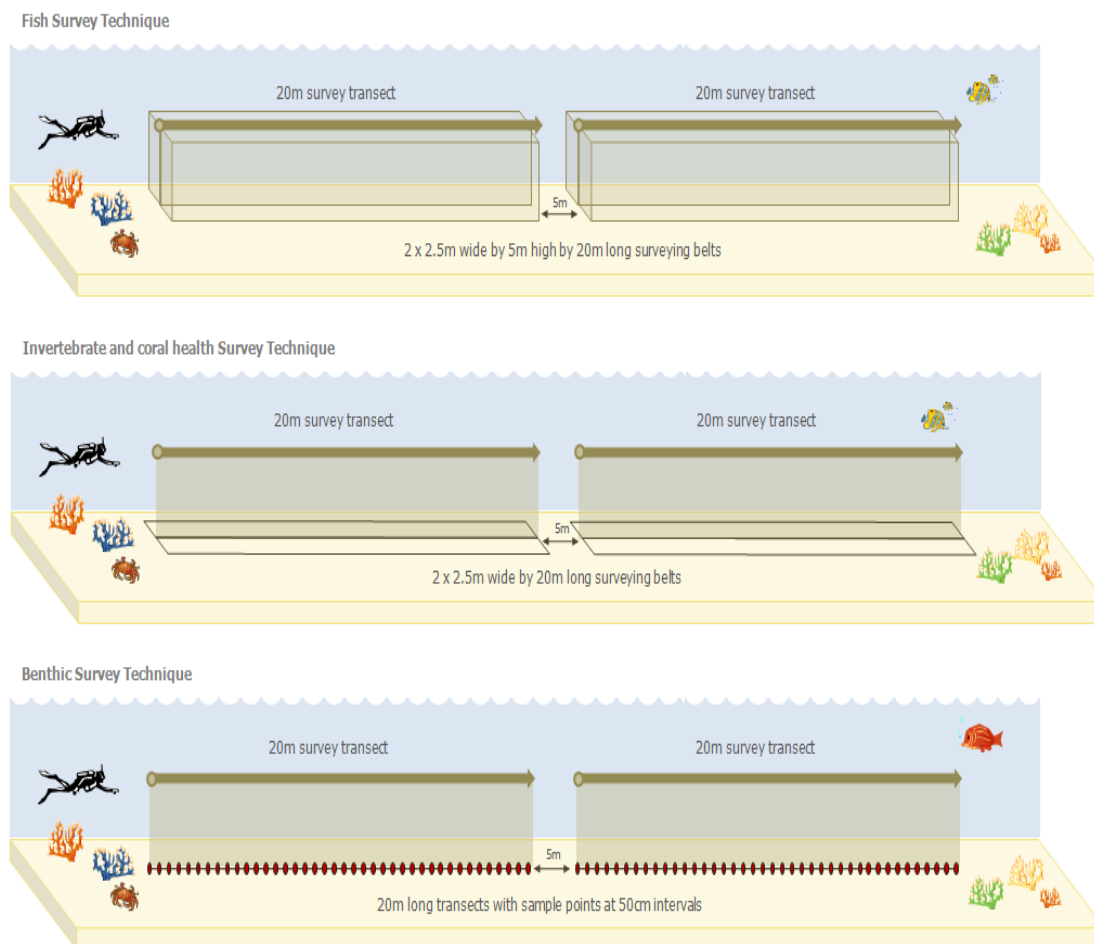


Figure 6 Schematic diagrams of the 3 survey roles – Fish surveyor (top), Invertebrate and Coral Health (middle) and Benthic surveyor (bottom). This diagram displays 2 of the 4 20-metre replicates conducted as part of one complete depth contour at each survey site

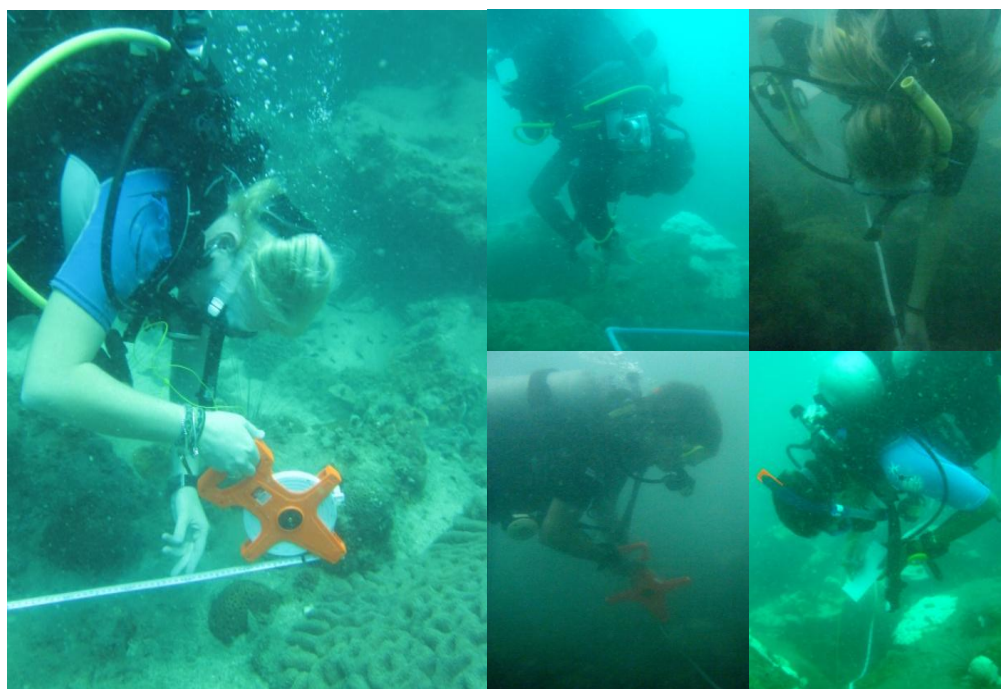


Figure 7 CCC volunteers setting up transect lines and conducting surveys

Table 2 Target hard coral target species

Coral Species	Coral Species
<i>Astreopora</i> spp.	
Brain coral large*	<i>Montipora foliose</i>
Brain coral medium**	<i>Pavona clavus</i>
Brain coral small***	<i>Pavona decussata</i>
<i>Ctenactis echinata</i>	<i>Pectinia</i> spp.
<i>Diploastrea heliophora</i>	<i>Plerogyra</i> spp.
<i>Echinopora</i> spp.	<i>Pocillopora Large</i> (e.g. <i>Pocillopora eydouxi</i>)
<i>Favia</i> spp.	<i>Pocillopora Medium</i> (e.g. <i>Pocillopora verrucosa</i>)
<i>Favites</i> spp.	<i>Pocillopora Small</i> (e.g. <i>Pocillopora damicornis</i>)
<i>Galaxea</i> spp.	<i>Podabocia</i> spp.
<i>Goniopora/Alveopora</i> spp.,	<i>Porites rus</i>
<i>Herpolitha limax</i>	<i>Seriatopora</i> spp.
<i>Lobophyllia</i> spp.	<i>Tubastrea micrantha</i>
Massive Porites	<i>Turbinaria</i> spp.

* Depth of ridges >1cm, (e.g. *Symphyllia radians*, *Symphyllia agaricia*) ** Depth of ridges between 0.5cm and 1cm (e.g. *Platygyra lamelina*, *Symphyllia recta*), ***Depth of ridges <1cm (e.g. *Platygyra ryukyuensis*)

2.2 Data entry and analysis

The field data was entered into an MS Excel database. ArcGIS (ERSI Software) was used to facilitate data analysis and display survey results onto Geographic Information System (GIS) maps. The Shannon-Wiener diversity index was used in order to calculate coral diversity and it was generated in PRIMER-5 software (Plymouth Routines in Multivariate Ecological Research).

Data from all transect replicates were averaged and imported in GIS to produce coverage and abundance maps for benthic and belt surveys. Graphs were produced by grouping up transects into different sectors (twelve sectors in total) (Figure 8 and Table 3) to get an indication of anthropogenic impacts and other biological indicators in the area surveyed. A sector consists of a group of survey sites in close proximity to each other. This provides the opportunity to compare a larger dataset from geographically similar areas, and the ability to draw more general conclusions for the sites.

Table 3 Number of surveys taken within the 12 sectors situated by Koh Kon (KK), Koh Rong (KR) and Koh Rong Samloem (KRS)

Sector	Number of 50-metre surveys	Location	Sector	Number of 50-metre surveys	Location
1	12	KR	7	48	KR
2	32	KRS	8	12	KR
3	12	KRS	9	8	KR
4	16	KK	10	4	KR
5	12	KRS/KK	11	4	KR
6	4	KRS	12	16	KK

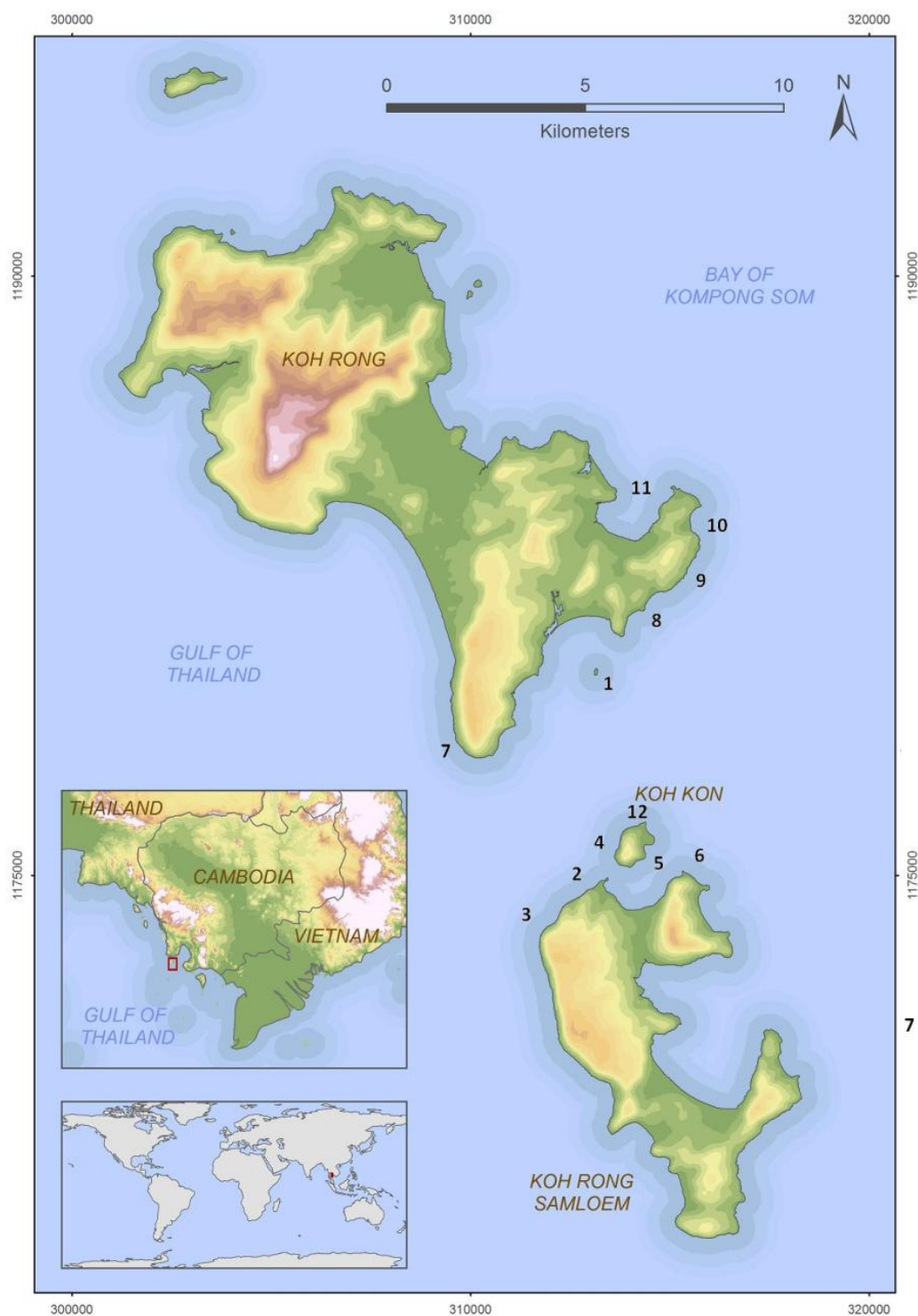


Figure 8 GIS map of CCC survey sectors locations

3 Results

The outputs from these surveys are presented in graphical and GIS format and aim to provide a general picture of the current status of coral reefs around the islands. The outputs are then used to develop management recommendations for the sustainable use of the coastal habitats. Data analysis was based on 126 individual 50-metre survey dives, conducted by CCC survey teams at 37 survey sites along the fringing reefs of **Koh Rong (KR)**, **Koh Kon (KK)** and **Koh Rong Samloem (KRS)** Islands between February 2010 and February 2011 (Figure 9).

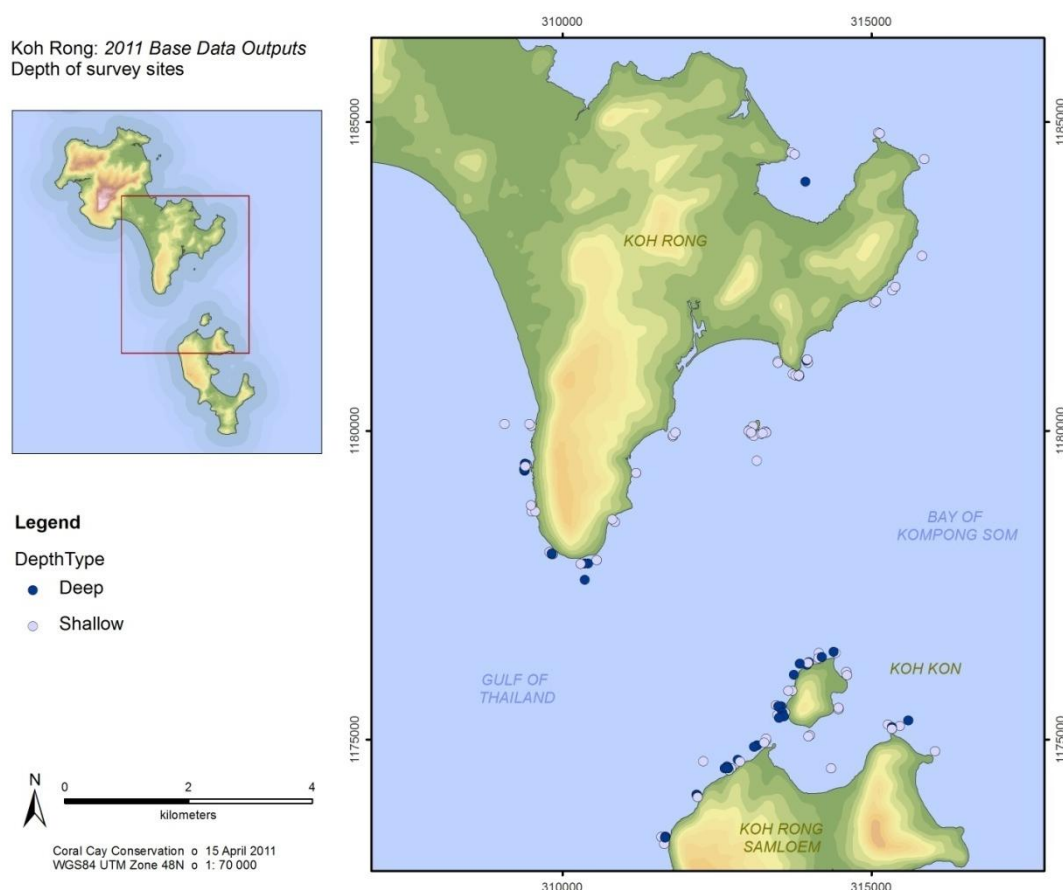


Figure 9 Locations of deep (blue) and shallow (grey) survey sites around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. Inset – Map of the Kingdom of Cambodia with the survey area highlighted in red.

All the data are made freely available in a GIS compatible meta-database, allowing interested parties to undertake further analysis of any particular dataset.

The survey data are presented in a number of ways, namely:

- Results from biological indicators, i.e., benthic (Section 3.1), reef fish families (Section 3.2) and invertebrates (Section 3.3)
- Results from coral reef health data (Section 3.4)
- Comparisons with previous data collected by CCC and the Department of Fisheries in 2003 and 2009 (Section 3.5)
- Results from the 2010 bleaching event in Cambodia (Section 3.6)

3.1 Benthic cover and composition

The main substrates encountered on surveys were rock, sand and live hard coral (Figure 10). Hard (Scleractinian) coral cover is a useful indicator of reef health, and it is generally accepted that reef fish species diversity is closely related to hard coral cover and diversity. Average hard coral cover was found to be 20% for all sites surveyed with a large variation between survey sites. Highest coral cover was found around sector 4 (Koh Kon, 38%), with sectors 1, 2, and 12 also displaying high coral cover (Figure 11). Sectors 3, 5 and 6 all had hard coral cover of less than 10%. Rock and sand were also dominant substrates, especially in sector 3 which had approximately 72% rock cover. There was a low percentage of recently killed coral (<2% for all sites).

The levels of nutrient indicator algae were generally low for all sites (<1% on average). Cover of sponges, soft corals and other animals such as hydroids, anemones, gorgonians and ascidians were all low in all sectors (6%).

Coral species diversity was generally low and comprised mainly of massive colonies such as *Porites* colonies (56%) and *D. heliopora* colonies (13%) (Table 4). Apart from a few isolated sites, branching corals were rarely encountered. Foliose corals were comprised mainly of *Turbinaria* and *Montipora* species but were rare, comprising less than 1% of the corals.

Coral diversity was estimated through a Shannon Weiner Diversity Index. Coral diversity was similar at surveyed sites and generally high at KK (Figure 12).

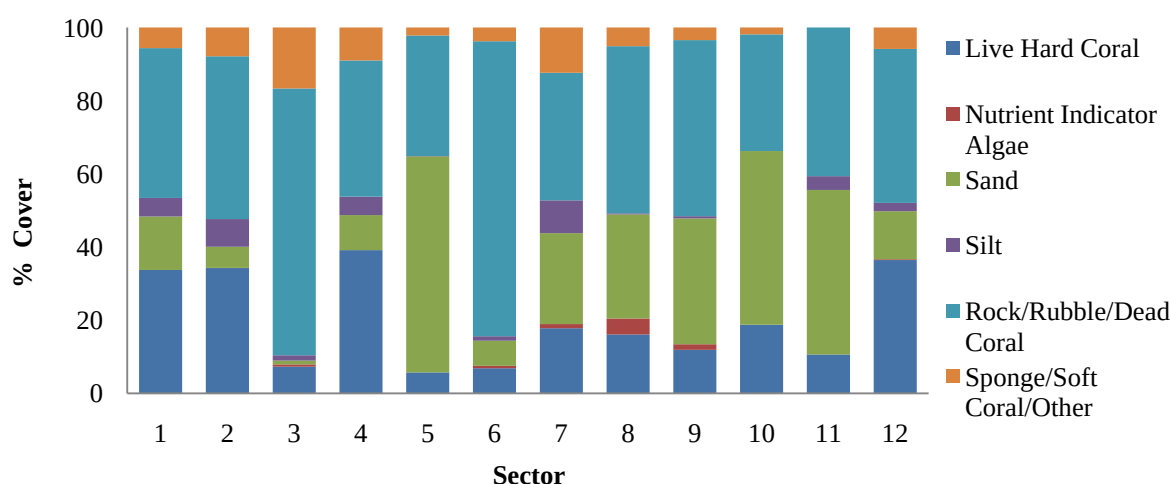


Figure 10 Composition of 6 benthic substrates (biotic and abiotic) at 12 survey sectors.

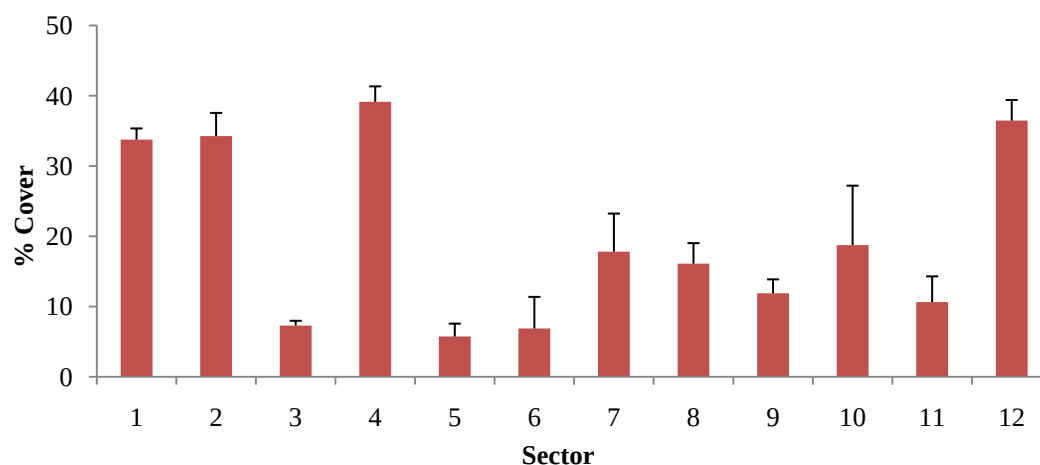


Figure 11 Average hard coral cover at the different survey sectors. Error bars indicate standard error.

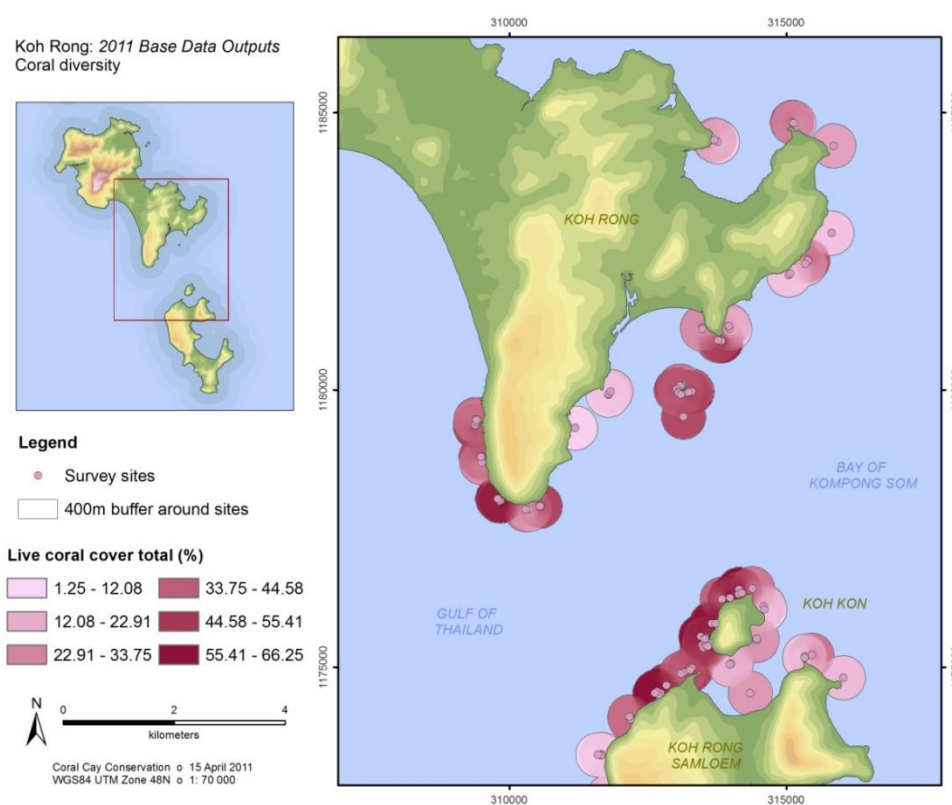


Figure 12 GIS map of live hard coral cover around KR and KRS. The darkness of the coloured buffer around each survey site indicates the coral cover as a percentage.

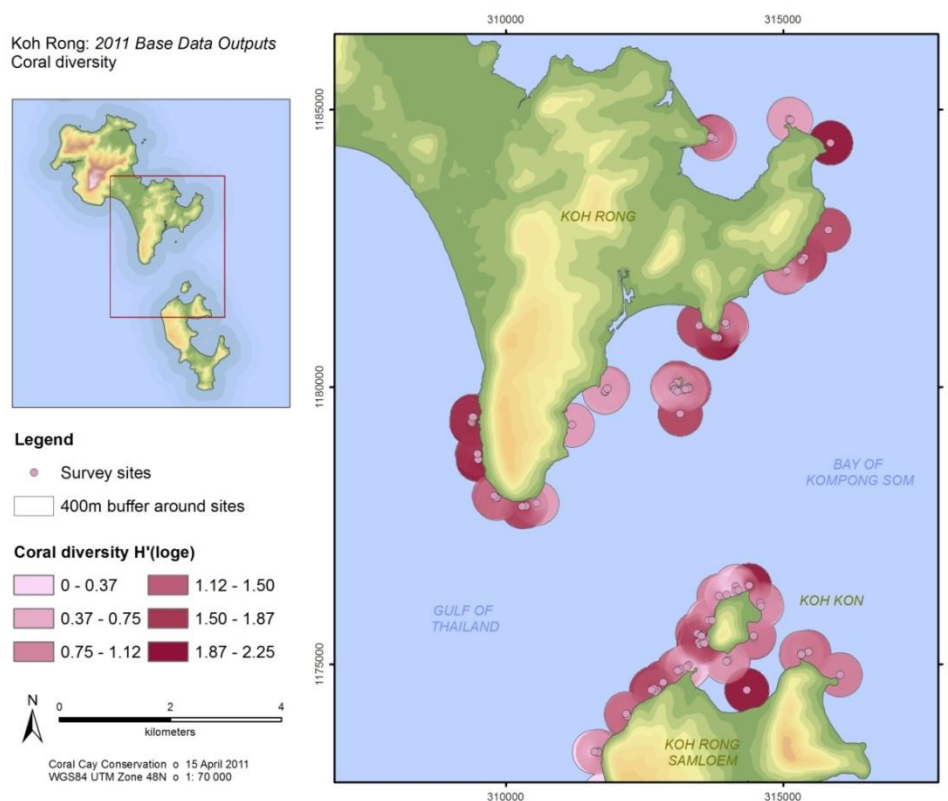


Figure 13 GIS map of hard coral diversity (Shannon Wiener Diversity Index) around KR and KRS. The darkness of the coloured buffer around each survey site indicates the diversity of coral species ($H'(\log_e)$).

Table 4 Coral species composition as a percentage of all target coral species and groups encountered on surveys.

Coral Species	% Cover
<i>Porites massive</i>	56.1
<i>Diploastrea heliopora</i>	13.2
<i>Pavona decussata</i>	4.7
<i>Favia spp.</i>	4.2
<i>Galaxea spp.</i>	3.0
<i>Favites spp.</i>	2.9
<i>Pocillopora "medium"</i>	2.6
<i>Goniopora/Alveopora spp.</i>	2.0
Brain "Small"	1.9
<i>Lobophyllia spp.</i>	1.6
<i>Podabocia spp.</i>	1.0
Brain "Medium"	0.9
<i>Echinopora spp.</i>	0.6
<i>Pocillopora "small"</i>	0.6
<i>Turbinaria spp.</i>	0.5
Brain "Large"	0.4
<i>Montipora foliose</i>	0.4
<i>Porites rus</i>	0.4
<i>Plerogyra spp.</i>	0.1

3.2 Reef Fish Families

Butterflyfish (Chaetodontidae) feed almost exclusively on corals and a high diversity of this family is therefore an indication of a diverse, healthy reef. Variation in Butterflyfish abundance was high between survey sites (Figure 14). The highest densities were found in sector 1 and 4. This coincides with the high coral cover seen in these two sectors (Figure 15).

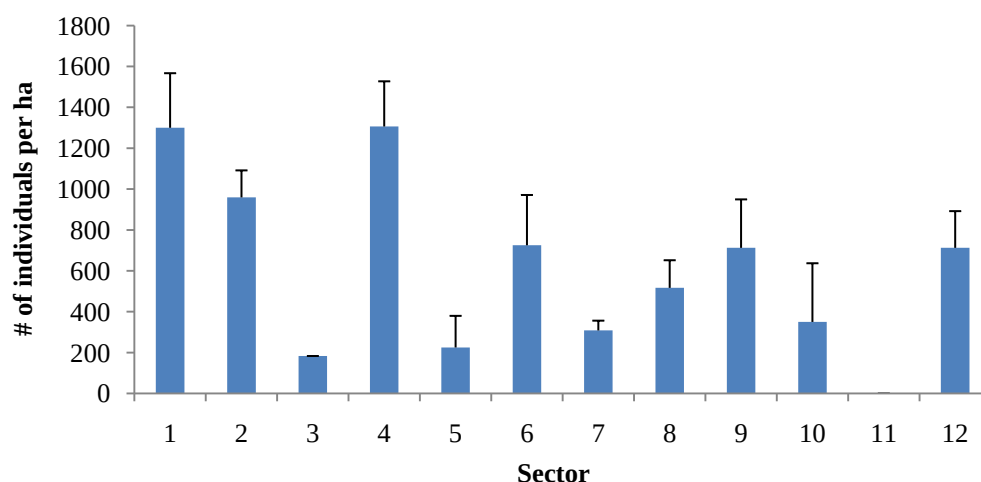


Figure 14 *Butterflyfish (Chaetodontidae) densities (#/ha) per survey sector. Error bars indicate standard error.*

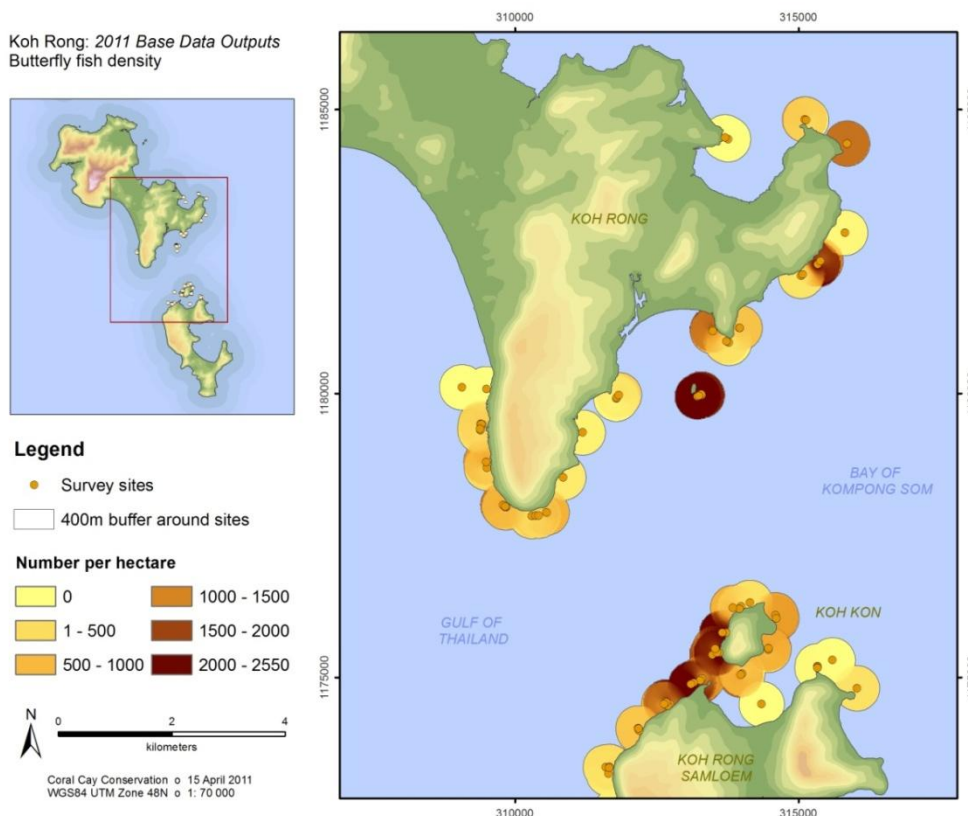


Figure 15 *GIS map of abundance of Butterflyfish (Chaetodontidae) around KR and KRS. The darkness of the coloured buffer around each survey site indicates the density of fish (#/ha).*

Parrotfish (*Scaridae*) are indicators of reef health as well as being targeted by artisanal fisheries. They are important herbivores, grazing on the reef and help to control macroalgae growth. Parrotfish biomass on healthy reefs is significant compared to other fish families; their herbivorous lifestyle strategy enables greater numbers of individuals within a population when compared to the large carnivores such as groupers. Their biomass was highest in sector 8 (691 individuals per hectare), followed by sector 4 (500 individuals per hectare) (Figure 17). Parrotfish were rarely encountered in sectors 6, 10 and 11 indicating severe overfishing of the species in these areas.

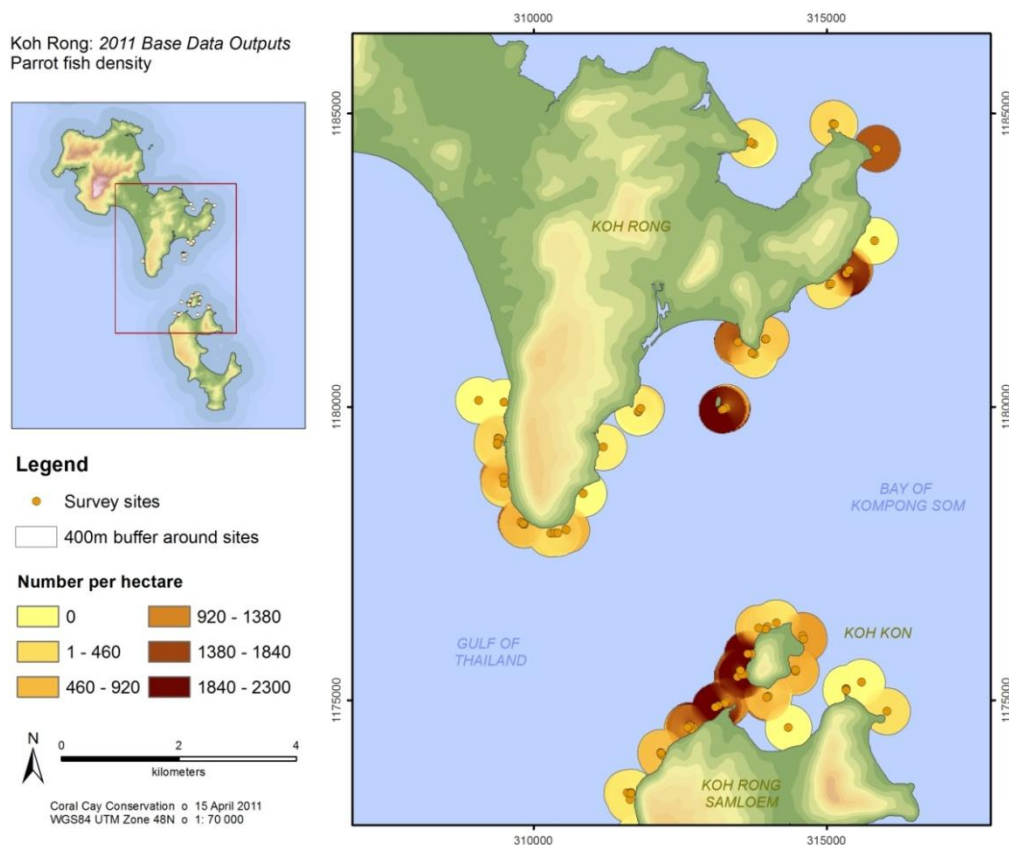


Figure 16 GIS map of abundance of Parrotfish (*Scaridae*) around KR and KRS. The darkness of the coloured buffer around each survey site indicates the density of fish (#/ha).

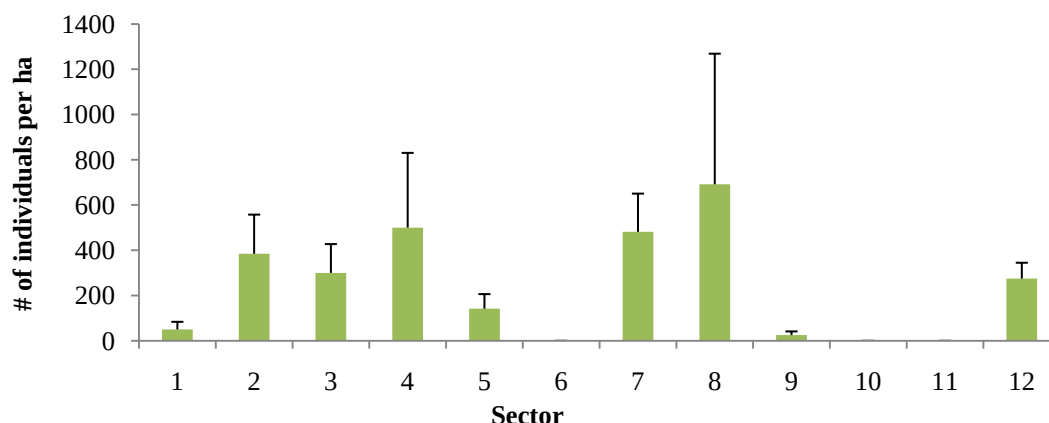


Figure 17 *Parrotfish (Scaridae) densities (#/ha) per survey sector. Error bars indicate standard error.*

Abundances of key predatory fish families including Groupers (*Serranidae*) and Sweetlips (*Haemulidae*), were estimated in order to get an indication of the abundance and fishing pressure on these commercially exploited reef fish. Both these families are popular food fish, making them a valuable catch for fishermen who often sell them on to the international markets. Densities of both Grouper and Sweetlips families were generally low with the highest abundance of Groupers found in sector 4 (estimated 50 individuals per hectare) (Figure 18). Sweetlips are brightly coloured predatory fish of a medium size. They were seen on most surveys except for in sectors 1, 9, 10 and 12 (KR). The highest abundance of Sweetlips was observed in sector 5.

Like Groupers, Snappers are medium to large sized predatory fish and are important targets for artisanal reef-associated fisheries. Depletion in their stocks can indicate overfishing over the whole range of commercially targeted fishes. Snappers were the most common family of predatory reef fish encountered on surveys. Their abundance were highest in sectors 3 (3550 individuals per hectare), followed by sector 7 (1169 individuals per hectare). This data indicate an increase from the highest abundance recorded during 2009 which was approximately 190 individuals per hectare.

When combining all commercially important fish families and mapping their total densities onto GIS maps, we find relatively high abundances of 12,000 individuals per hectare and over around KK Island and some more sheltered sites around KR and KRS (Figure 19). Total fish species diversity varied widely between all reef sites with the highest fish diversity found on the south-western peninsula of KR (Figure 20).

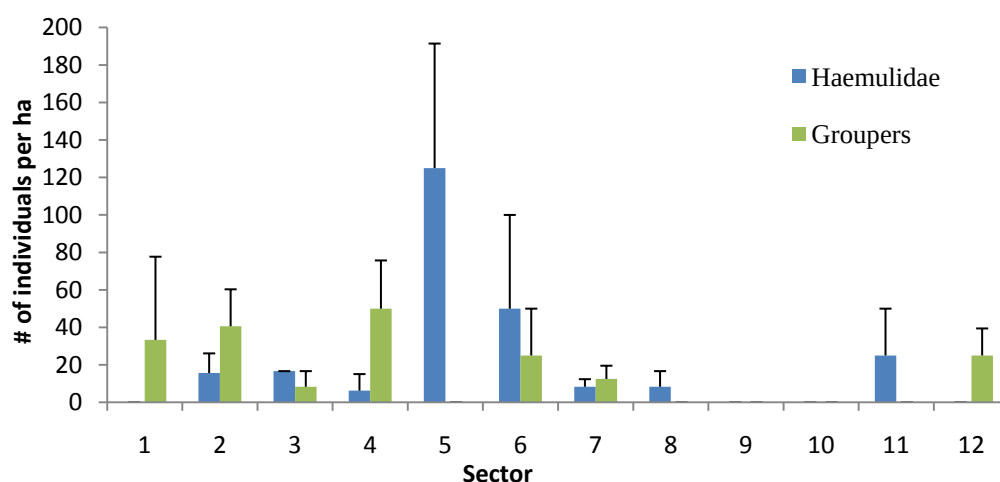


Figure 18 Densities (#/ha) of two predatory fish families – Groupers and Sweetlips (*Serranidae* and *Haemulidae*) per survey sector. Error bars indicate standard error.

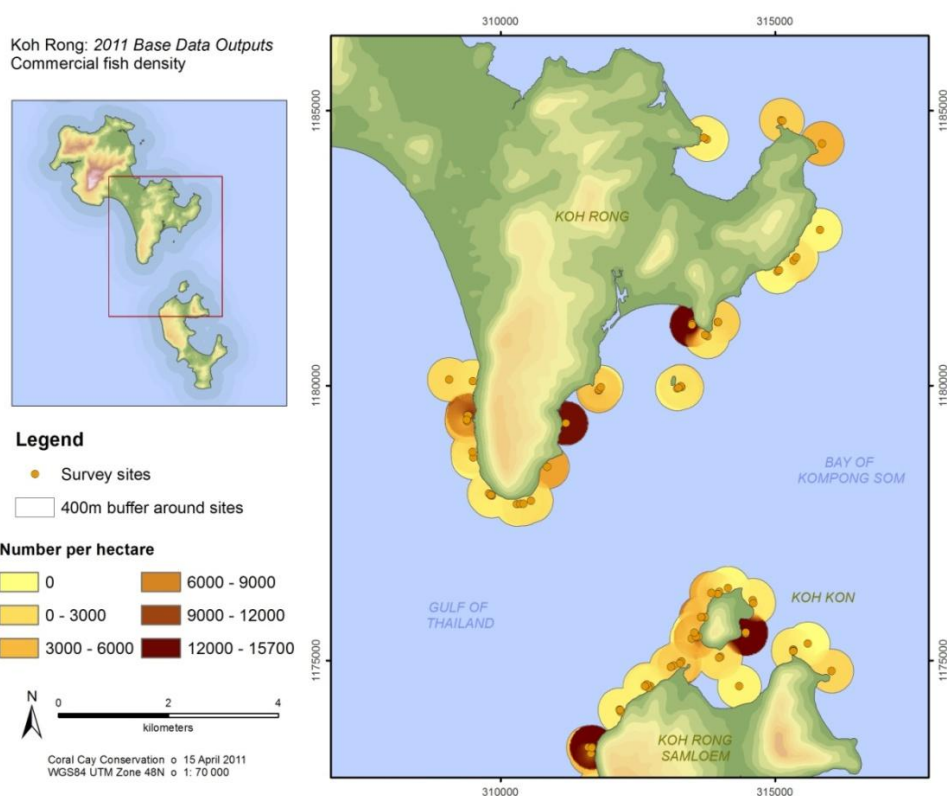


Figure 19 GIS map of abundance of commercially important fish such as Groupers, Snappers, Parrotfish, Jacks and Sweetlips around KR and KRS. The darkness of the coloured buffer around each survey site indicates the density of fish (#/ha)

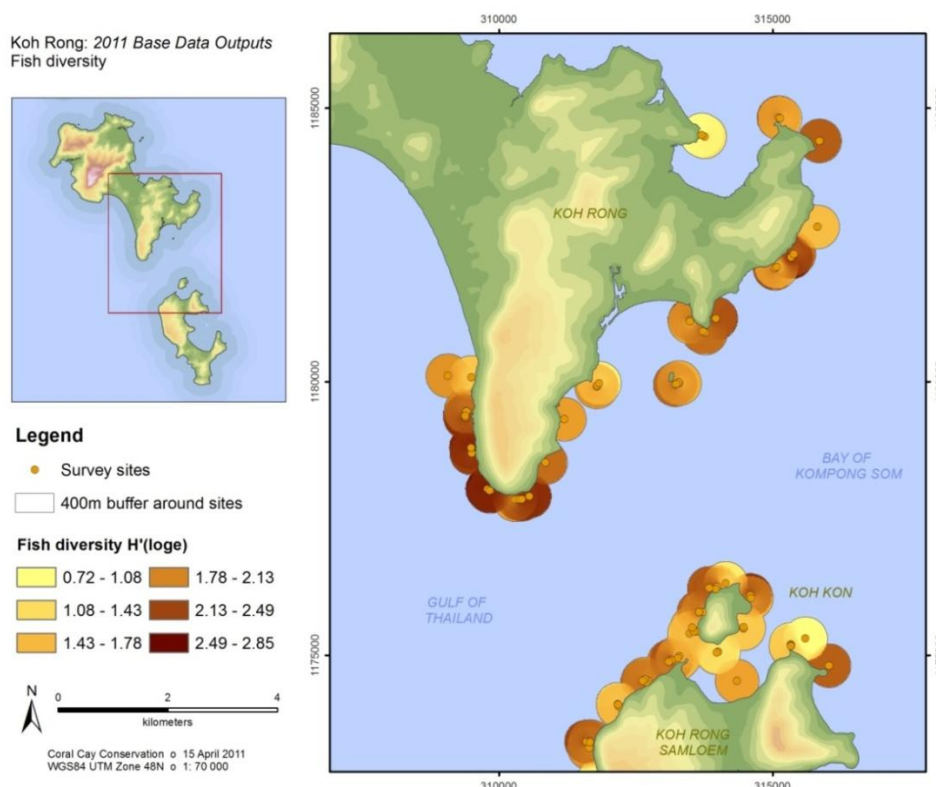


Figure 20 GIS map of fish diversity (Shannon Wiener Diversity Index) around KR and KRS. The darkness of the coloured buffer around each survey site indicates the diversity of fish species ($H'(\log_e)$)

3.3 Invertebrate indicators

Diadema (longspine) sea urchins can play an important role in keeping the reefs clean of algae when there are few herbivorous fish around to fulfil this role. They may also be abundant on seagrass beds and sandy areas. High abundances of Diadema sea urchins were found on most surveys around the islands (Figure 21). Sectors 6 (KRS) had particularly high densities reaching nearly 24,000 individuals per ha.

Giant clams (*Tridacna* spp.) are an important local food source and have traditionally been harvested for centuries. Ecologically, they are important reef filter feeders that help maintain clean water and contribute to the reef structure and rugosity. Giant Clams were measured to the nearest 10cm in length. The highest abundance of giant clams was found in sector 11 (454 individuals per hectare), while in sector 5 no clams were observed (Figures 22 and 23).

Certain gastropods are good indicators of reef health and are often overharvested by the curio trade. Sea Cucumber and Lobster abundances were very low (<5 individuals per hectare) for all survey sectors indicating severe over-harvesting. Crown of Thorns starfish can form a major threat to coral reefs when they reach unusually high numbers. Fortunately, they were only observed in low abundances in sectors 3 and 12 (<17 individuals per hectare).

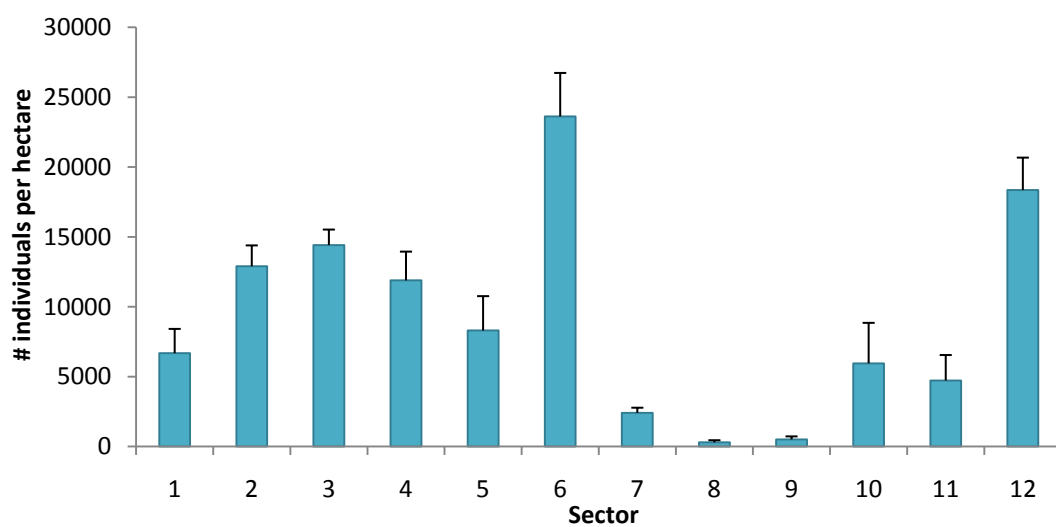


Figure 21 *Diadema* sea urchin densities (#/ha) per survey sector. Error bars indicate standard error.

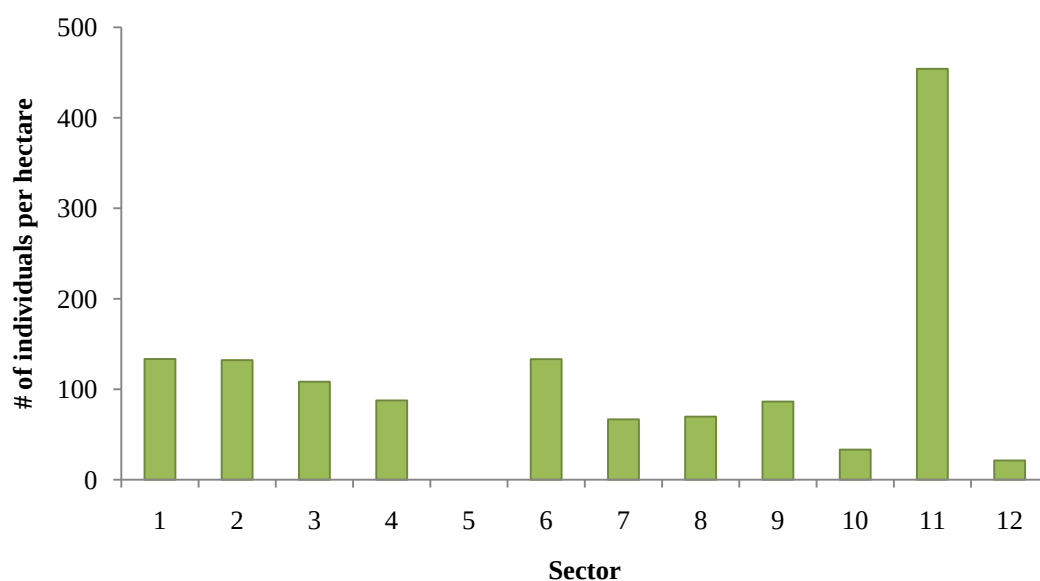


Figure 22 Densities (#/ha) of Giant clams (*Tridacna* spp) at 12 survey sectors.

Koh Rong: 2011 Base Data Outputs
Giant Clam density

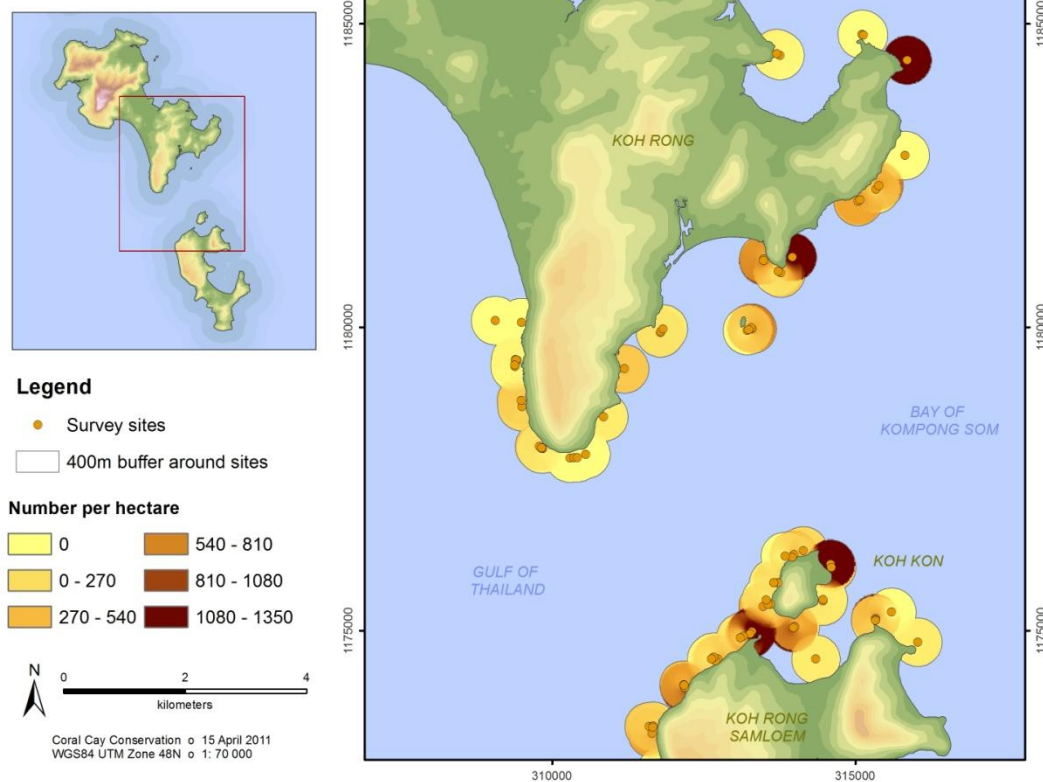


Figure 23 GIS map of abundance of giant clams (*Tridacna* spp.) around KR and KRS. The darkness of the coloured buffer around each survey site indicates the density of giant clams (#/ha).

3.4 Coral reef health data

Human (anthropogenic) impact was measured in terms of coral damage (through boat, anchor or diver breakage) and trash (fish nets or trash in general). Coral damage was generally found to be low in all sectors (Figure 24). Impact from discarded fish nets and trash in general were more severe in sectors 5, and 7-10 (KR). Indications of heavy fishing were found around KK (sector 5), and KR (sectors 7 to 10). Other trash such as cans or plastic bags were generally low on all sectors apart from sector 5 (impact severity of 2 i.e. medium), 7 and 10 (impact severity of 1 i.e. low). When taking into account all the impacts, it can be concluded that the waters just south of KK were most heavily impacted (Figure 25).

The ‘Nutrient Indicator Algae’ category included species that are thought to be indicators of pollution and include “fleshy” algae such as *Sargassum*, *Dictyota* and *Turbinaria*. *Halimeda* is an exception as they have a calcareous structure which helps to ‘cement’ the reef. Although not actually algae, cyanobacteria (a.k.a. blue-green ‘algae’) have been included in the nutrient indicator algae category, as most of them respond in a similar manner to macroalgae in terms of environmental conditions that promote/inhibit their growth. Nutrient indicator algae levels were generally low, covering less than 5% of the benthic area surveyed (Figure 26). Higher algal levels were found around the rocky outcrops on the far south side of KR whereas algal levels around KRS were minimal.

Siltation levels changed dramatically throughout the survey period with the onset of heavy rainfall and all reef sites suffered from elevated sediment levels. High levels of siltation of over 20% were found both around KR and KRS (Figure 27).

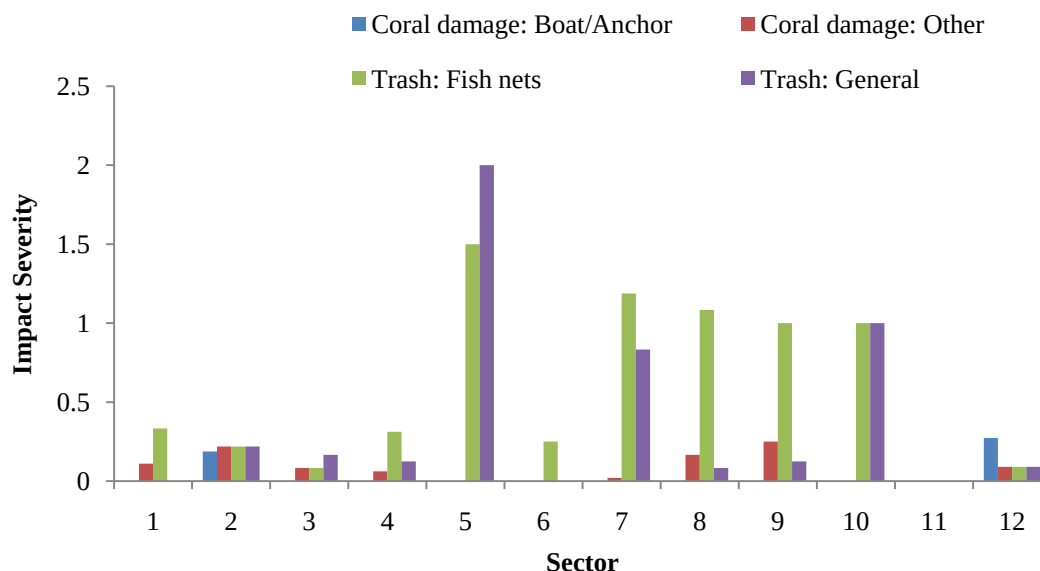


Figure 24 Composition of 4 human-caused impacts at 12 survey sectors.

Koh Rong: 2011 Base Data Outputs
Coral composition and damage

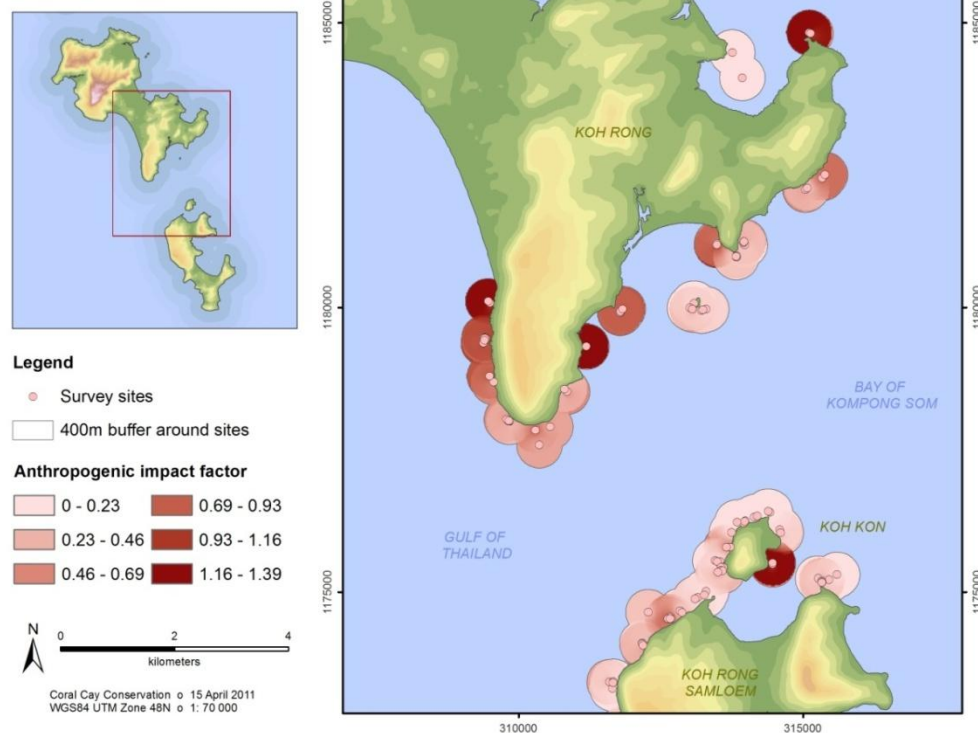


Figure 25 GIS map of anthropogenic impact levels around KR and KRS. The darkness of the coloured buffer around each survey site indicates the anthropogenic impact factor.

Koh Rong: 2011 Base Data Outputs
Coral composition and damage

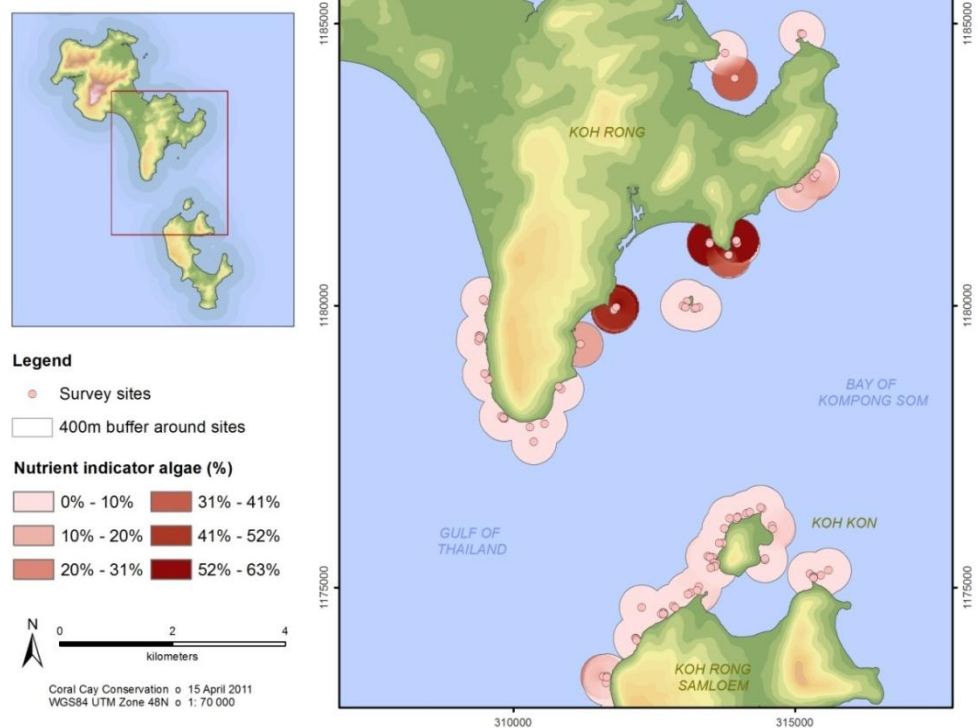


Figure 26 GIS map of nutrient indicator algae around KR and KRS. The darkness of the coloured buffer around each survey site indicates algal cover as a percentage.

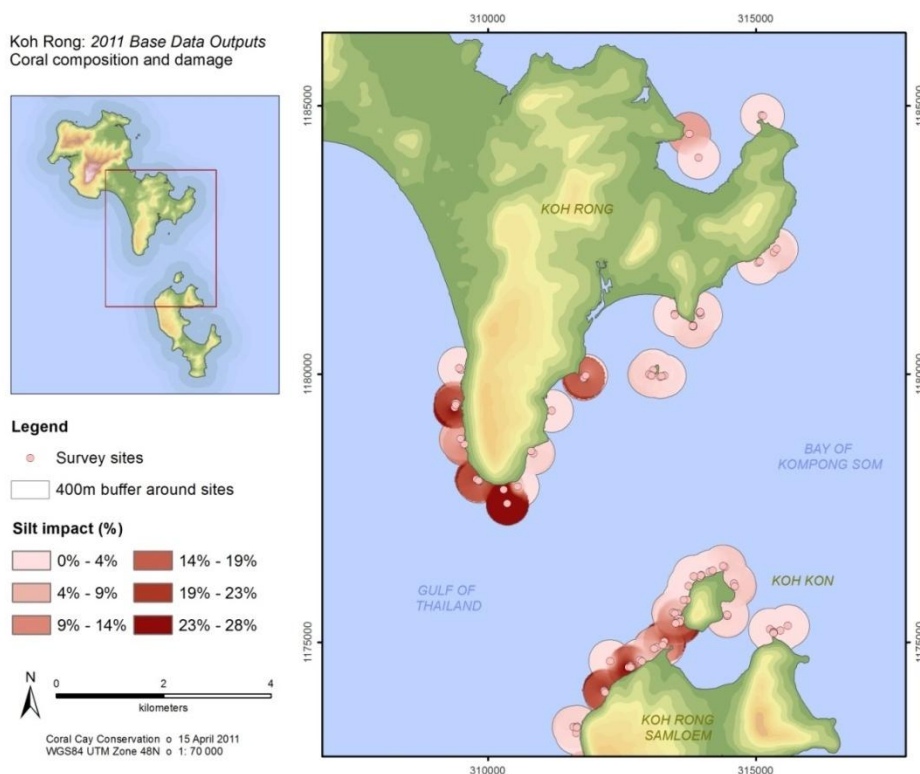


Figure 27 GIS map of siltation levels around KR and KRS. The darkness of the coloured buffer around each survey site indicates siltation cover as a percentage.

3.5 Comparisons with data collected from previous years

Data collected during the first year of the project were compared with previous datasets, indicating a sharp increase in both the number of Butterflyfish and Parrotfish species (Figure 28). However, numbers of predatory species such as Groupers and Snappers species are observed to be decreasing.

Live hard coral cover was estimated to be similar in 2010 (23% cover) as in 2009 (20% cover) for all surveys conducted. When looking at specific survey sectors which were both surveyed in similar intensity, there was a clear coral decline between the two years (Figure 29). Rock cover in 2009 was 30% whereas 2010 results show rock cover around 40%, indicating an increase in this substrate (Figure 30). Also, there was an increase in siltation levels from 3% in 2009 reaching to 14% in 2010.

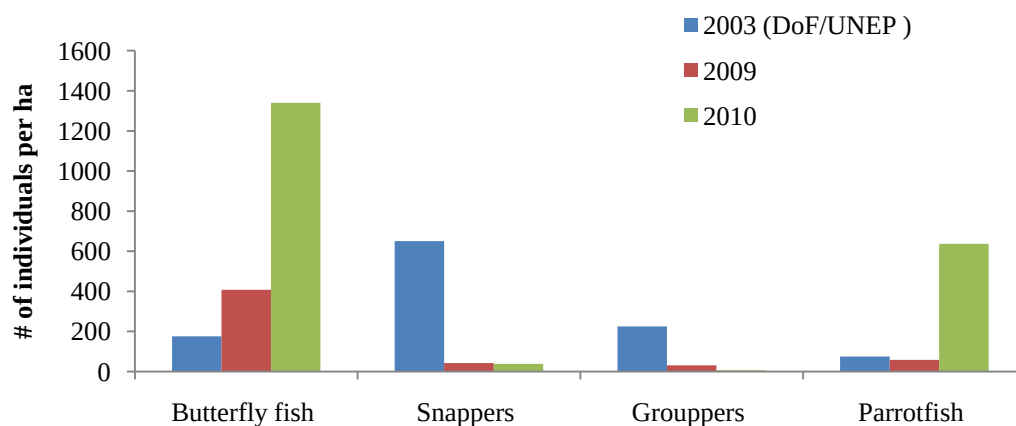


Figure 28 Fish species comparisons between 2003, 2009 and 2010

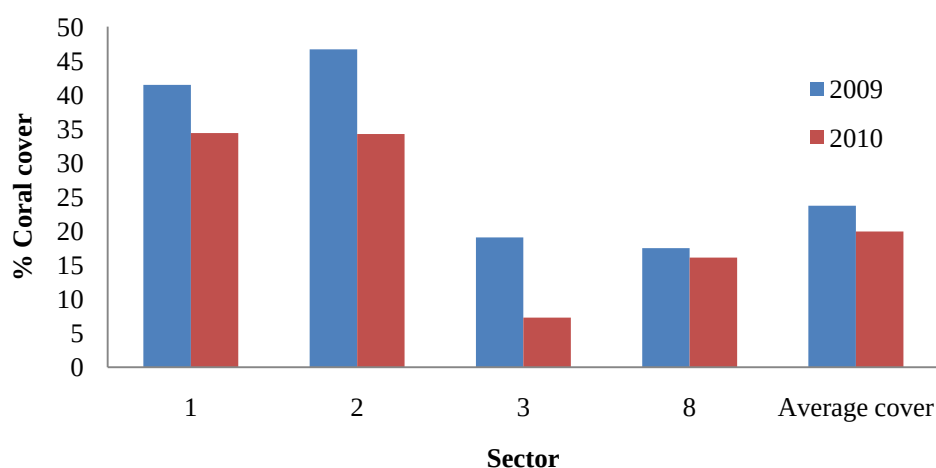


Figure 29 Coral Cover comparison data between 2009 and 2010 for 4 survey sectors and the average cover for all surveys.

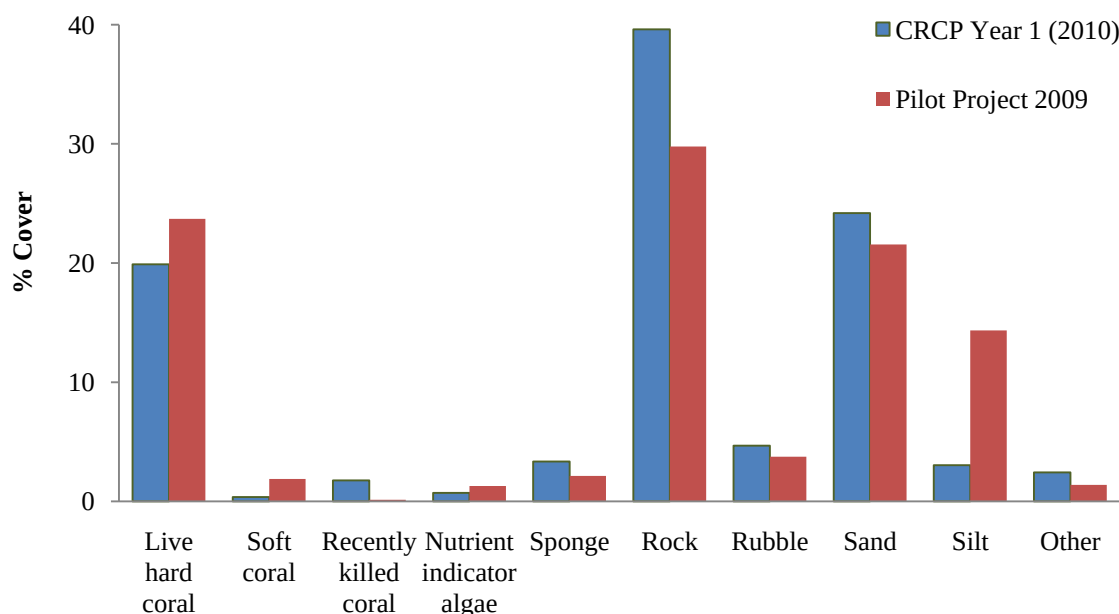


Figure 30 Benthic cover comparisons between 2009 pilot project and 2010 (includes all sites surveyed for both years)

3.6 Impact of the 2010 bleaching event in Cambodia

During May of 2010, sea surface temperatures in Cambodia rose by 2°C above the average temperatures, causing significant stress to the corals and inducing the onset of a mass bleaching event in the area. This event was recorded by international agencies such as NOAA, and CCC survey teams helped in documenting the extent of bleaching and the effect it will have on the health and resilience of the reef. Data were collected from 101 50-metre baseline surveys between May and November of 2010. This data has been summarised and plotted in GIS maps on the next page (Figure 33). In May of 2010, coral bleaching levels were between 90-100% at all sites surveyed. Bleaching levels remained above 50% in June and July and then slowly declined between August and November.

The percent of bleached corals from 131 50-metre surveys between May 2010 and January 2011 was also calculated and plotted in a graph below. Bleaching percentages reached up to 100% of coral colonies in May 2010, stressing the severity of this bleaching event. Bleaching levels remained high across all reef sites surveyed between May and October of 2010. Bleaching levels finally dropped to less than 20% between November of 2010 and January of 2011 (Figure 31).

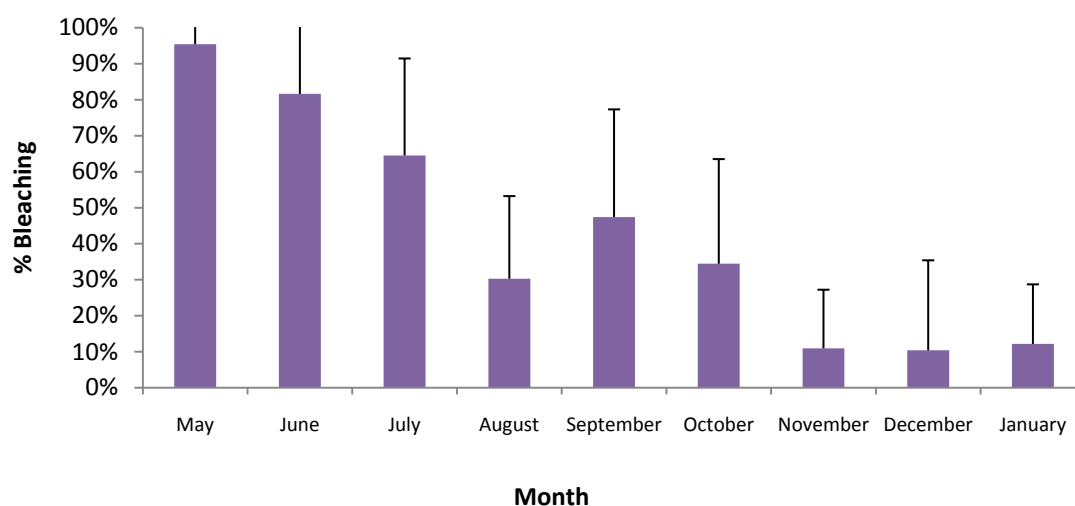


Figure 31 Monthly coral bleaching levels (% of colonies bleached) around KR and KRS between May 2010 and January 2011. Taken from 131 baseline surveys. Error bars indicate Standard Deviation



Figure 32 Coral colonies that suffered bleaching – *Plerogyra* (left) *S. Hystrix* (right)

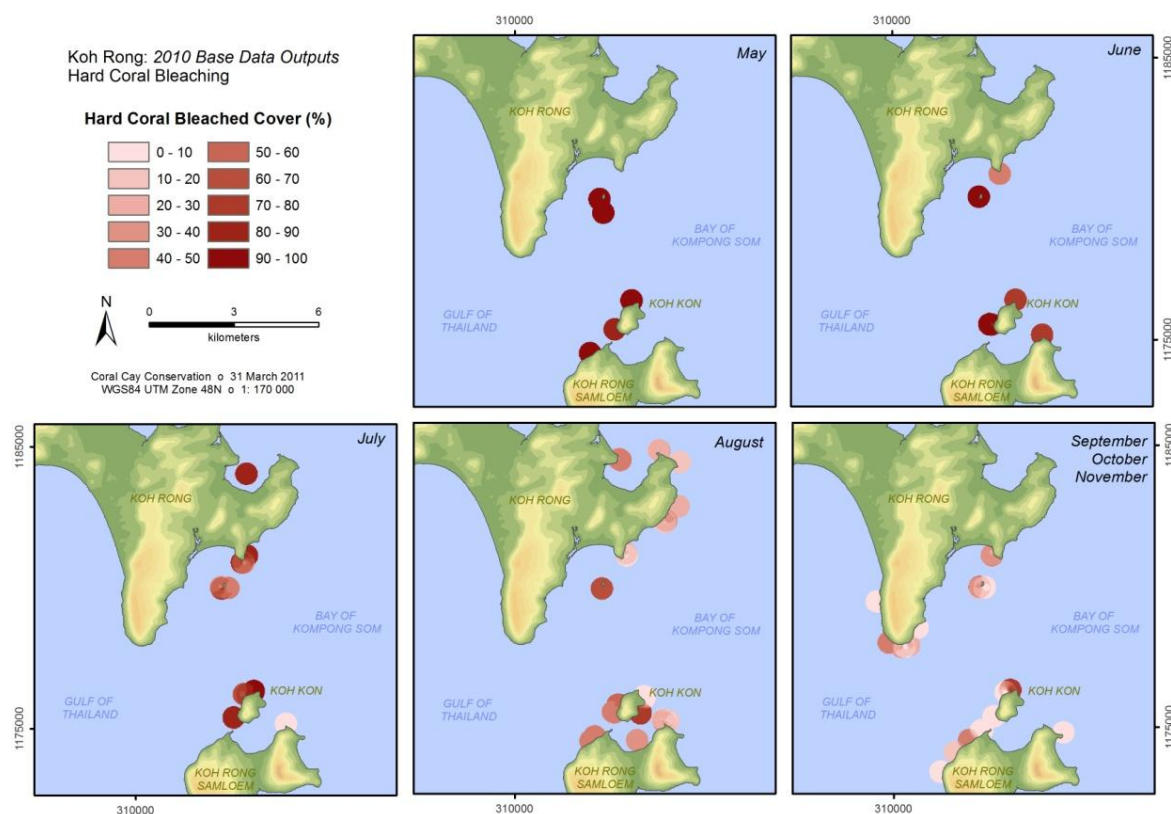


Figure 33 Coral bleaching Impact (% of colonies bleached) around KR and KRS between May and November, 2010



Figure 34 Coral colonies during mass bleaching event

4 Community activities

During the first year of the research project in Cambodia, CCC volunteers and staff worked extensively with the community, promoting coral reef awareness through education. Working with the local communities is a key objective of the CRCP project. One example of giving back to the community includes the medical clinic that started operating in February 2010 by CCC's medical officers, and helped many local people that needed basic medical assistance. Beach cleanups have been regularly occurring throughout the duration of the project, involving local businesses and local people in the process. These activities create a sense of awareness and help communities to be involved in conservation efforts.

During April 2010, CCC staff presented a talk to the Royal University of Phnom Penh (RUPP), about Cambodia's marine life and what can be done to protect it and manage it efficiently. The room was filled with students and other people who were interested in learning more about Cambodia's coastal and marine environment. The presentation was followed by discussions about the future of Cambodia's coral reefs. Presentations were also given to the Fisheries Department of RUPP in June 2010, where CCC staff talked to second and third year students about the scientific research currently undertaken by CCC. In November 2010, a presentation was carried out at the RUPP where Coral Cay outlined the current progress of the research and provided a summary of the scientific results so far.

One of the main activities undertaken by CCC volunteers throughout the year was to teach English to local children thereby providing future generations with a useful skill, since tourism activities are a source of income around the islands. CCC staff worked with local children enhancing their awareness about the marine environment and engaging them in environmental activities such as beach cleaning. A few of the local children also joined in species identification and data entry lessons. Some of them even took a PADI Emergency First Response Course where they learned about basic First Aid techniques!



Figure 35 Community work by CCC (Top Left: Local children learning first aid, Top Right: Species Identification and Data Entry, Bottom Left: RUPP Seminar November 2010, Bottom Right: Local children learning about marine environment)

5 Discussion and Conclusions

A major issue during the first year of the CRCP project was the lack of flexibility in visiting survey sites. Having to plan survey dives around the needs of visiting tourists often meant most surveys were done in the vicinity of the project site and at popular dive spots. Fortunately, CCC is now using a dedicated survey vessel which will allow surveying to be conducted on sites that are located further away in order to complete the baseline survey effort. It should also be noted that survey data from 2009 and 2010 were not in the exact same locations, making accurate comparisons difficult. Comparisons were made between the general sectors. This should not deter us from making general observations and indicating trends in coral health over the two years.

Coral cover was around 23% on average for all reef sites surveyed. This is 3% less than the percentage calculated over the 3-month pilot project between August – October of 2009. Although this might not be considered a significant change, there was an indication of dramatic changes in coral cover at some of the same sectors surveyed over the 2 years. This is highly likely to be a result of the mass-bleaching event that occurred over the summer period. Continued surveys will need to establish how the reefs recover over the coming years with continuous monitoring of the sites. A concern is that as a result of the bleaching, coral colonies are now more vulnerable to coral diseases.

High live coral cover (~40%) was found around the north-western side of Koh Kon (KK) Island as well as the northern side of Koh Rong Samloem (KRS) Island. Lower coral cover (6-20%) was found along the fringing reefs on the eastern side of the islands. Further surveys will need to be conducted on the far south of KRS and north of Koh Rong (KR) Island to determine coral health there. Once a comprehensive baseline assessment has been made of all of the reefs around the islands, key sites for conservation management can be highlighted.

Our results showed that coral diversity was generally low and most corals were more robust massive or encrusting lifeforms. The dominance of massive coral lifeforms, particularly *Porites* species, was apparent at all survey sites and comprised over half of the coral cover. These types of corals, although slow-growing, are generally the most robust and can withstand higher levels of sedimentation. Some sites along the south-eastern coast of KR have relatively high coral cover with a high variety of coral lifeforms. Foliose and branching corals, which form important habitats for many reef species, were not commonly seen and have most likely been harvested and sold as souvenirs, removed in coral mining activities or died from high sedimentation levels. Coral collection for the tourist industry does occur although the trade is not on a big scale as it is not very profitable (CZM, 1999). This may help explain the scarcity of branching and foliose corals at most reef sites. According to the World Resource Institute, coral collection has been declining since the Department of Fisheries tightened controls and confiscated corals from vendors (Burke et al., 2002). In Phrash Sihanouk Province however, the sale of corals to tourists on the beaches seemed to be a frequent occurrence, albeit on a small scale. There are also several shops along the beach which sell corals and shells.

Dead coral, rock and rubble cover was around 40%, 10% higher than the percentage recorded in 2009 (30%). There was also a marked increase in the levels of sedimentation on many of the reefs visited, from 3% in 2009 to 14% in 2010. Although the corals around the islands are adapted to withstand some levels of turbidity (Nelson, 1999), this impact is likely to be exacerbated by coastal development around the islands and mainland of Phrash Sihanouk Province. Furthermore, dredging activities in the area would have certainly contributed to the high siltation levels. Most likely, a combination of high sedimentation levels in and the impact of the mass bleaching event reduced live, biotic cover of substrates such as coral, sponges and anemones, that were being replaced by rock. Nutrient indicator (fleshy) algae were found at very low levels. High sedimentation levels (and thus low light levels) may be inhibiting their growth.

Fortunately, anthropogenic (human induced) impacts on the reefs were generally low. Some sites had clear indications of fishery related impacts such as anchor damage, nets and direct damage to the corals and other popular dive sites showed diver-related impacts but generally, these types of impacts were not the main factor contributing to reef degradation.

The presence or absence of certain reef fish families is an important indicator of overfishing and overall reef health. Commercially targeted families such as Snappers (Lutjanidae), Groupers (Serranidae) and Parrotfish (Scaridae) form an important part of the reef ecosystem and are often the first to suffer population declines in overfished areas. Groupers and Snappers spawn in aggregations at a late age (5-7 years), making them vulnerable to over-exploitation. Spawning occurs in large aggregations in order to optimise fertilisation, minimise egg predation, facilitate dispersal and maximise recruitment. Fisheries often target these species and selectively remove larger individuals, reducing the abundance of these species, decreasing the average size of the population and modifying their species composition (Van't Hof, 2001).

Data collected during the first year of the project indicated an increase in both the number of Butterflyfish and Parrotfish species in all sites which is encouraging. High abundances of these fish were observed around KK Island compared to the previous year, and the increased abundance in general may be attributed to the diffusion of the individuals from KK to other sites. However, numbers of predatory species such as Groupers and Snappers species are currently in decline. Groupers, Snappers and Sweetlips (Lutjanidae) families were generally quite low in abundance and although not expressed directly in the results, their sizes were rarely that of a mature individual. Furthermore, a lack of historical data makes it impossible to accurately quantify any long-term temporal changes. Comparisons with data collected in 2003, although limited, indicate that commercially valuable fish families were more abundant in 2003.

Very high levels of *Diadema* (long-spine) sea urchins were observed on most surveys. At these levels, *Diadema* sea urchins may highlight shifts in the balance of the ecosystem. A reduction in other important reef herbivores such as Parrotfish and Surgeonfish means that the reef ecosystem becomes more reliant on *Diadema* spp. and as a result, more vulnerable to disturbances as the functional diversity of the system is reduced. Giant clams, although abundant at some sites, were generally small in length (<30cm). Most of the large clams have most likely been harvested over a

long period of time. There is still ample room for recovery of these important bivalves if they are protected to some degree. Other key reef invertebrates such as sea cucumbers and lobsters were rarely encountered indicating that they have been overharvested. Effective management can help to recover these populations over several years. Sea Cucumber farming has been particularly effective as a local, sustainable livelihood in many regions in the Indo-Pacific and could be a possible solution in Cambodia (see Toral-Granda et al., 2008).

During the summer of 2010, sea surface temperatures in Cambodia rose by 2°C above the average temperatures, causing significant stress to the corals and the onset of a mass bleaching event in the area. In May of 2010, coral bleaching levels were between 90-100% at all sites surveyed. Bleaching remained above 50% in June and July and then slowly declined between August and November. The results from these surveys indicate how significant and prolonged the mass-bleaching event was. Most coral can only survive for 2-3 weeks without their symbiotic algae and so high coral mortality from the bleaching event is to be expected. Surveys that will be conducted over 2011 will be important for the assessment of coral reef recovery in the area, as well as assessing which reefs are more resilient against bleaching episodes.

5.1 Recommendations

After the 2009 Pilot Project, it was suggested that the combination of local stressors combined with potential regional stressors were seriously threatening the survival of Cambodia's reef systems. The mass-bleaching event that hit Cambodia's reefs over the summer of 2010 gave a stark warning of this threat. The mass-bleaching event has further degraded an already vulnerable ecosystem and the long-term effects of this should be the cause for serious concern. The capacity of coral reefs to bounce back from regional events is inhibited by local stressors such as over-fishing, sedimentation and pollution, all of which are a compounding threat to the coral reef systems of the area. Therefore, it is of high importance that every effort is made to minimise and remove these local stressors through proper coastal management and marine conservation. Any effort to conserve key coral reef sites around the islands should be coupled with an effective and sustainable development plan that minimises anthropogenic impacts, and involve the local community in the whole process.

Management recommendations proposed in the 2009 Pilot Project report are still applicable one year later. Progress has been made by both the FiA and NGOs such as Flora and Fauna International and DANIDA as well as local dive centres and resorts (e.g. Song Saa and Dive Shop Cambodia) who have actively been conducting capacity building and community awareness programs. Encouragingly, there is a lot of support for the implementation of a multiple-zone marine park around the island of Koh Rong. It is important that the establishment of this park is supported by sound scientific guidance and is under the consultation from and support of local stakeholders. This will significantly increase the chances of the reserve to meet the conservation goals set, as well as satisfying stakeholder needs.

What is needed now is the further development of programmes that will provide government employees and local community members with the awareness and technical expertise to support the implementation of the MPA that is proposed around

KR. CCC can provide a variety of scholarship programmes that will provide local participants with training in SCUBA diving and performing survey methodologies.

The proposed MPA will be a very good step towards the protection and conservation of some of the fragile coastal habitats around the islands. The most effective MPAs are both strongly enforced through the government and supported both locally and by the private sector. Furthermore, there needs to be flexibility to allow for adaptive management and long term sustainability. This can only be achieved through ongoing scientific monitoring and stakeholder empowerment and support. When well-managed, MPAs have shown to offer both social and economic benefits to local stakeholders. A recent study conducted by The Economics of Ecosystems and Biodiversity (TEEB) estimated that the value per hectare of healthy coral reef to be anywhere between \$130,000 to \$1.2 million/hectare/year (www.diversitas-international.org). This would mean that the total value of the coral reefs around Koh Rong and Koh Rong Samloem would be somewhere between 117 - 500 million US dollars per year, assuming that effective protection is in place and the reefs do not suffer from further decline in their health in the following years.

5.2 Conclusions

A high variation in coral reef health was found across the coastal areas surveyed with some sites displaying reefs with a high abundance and variety of coral and fish species while others had been degraded through high sedimentation, bleaching and overfishing. The magnificent beauty and diversity of both marine and terrestrial life around the islands, coupled with some stunning scenery make it a prime destination for visitors from around the world. Promoting this area as an eco-tourism destination will help to provide income to the local communities and encourage the sustainable management of the natural resources on which they depend. The steps that the FiA has proposed for the designation of a large-scale MPA are timely and proof of the Royal Governments efforts to protect their dwindling natural resources.

The implementation of a holistic management approach to the successful preservation of the marine habitats of Koh Rong and Koh Rong Samloem in the face of considerable coastal development and human-induced climate change is essential and good progress has been made to this end. Coastal development, deforestation, land-based pollution and agricultural development must be managed if reefs are to retain their resilience and ability to absorb impacts of regional stressors. It is only through a complete ‘ridge to reef’ approach, involving stakeholders from all sectors, whether local, environmental or corporate, that the coral reefs of these beautiful islands can be secured for the future benefit and enjoyment of the people of Cambodia and those people fortunate enough to visit them.

References

- Bohnsack, J.A. 1990 The potential of marine fishery reserves for reef fish management in the U.S. Southern Atlantic. NOAA Technical Memorandum NMFS-SEFC-261, Miami, USA
- Buddemeier, R., Kleypas, J., Aronson, R. 2004. Coral Reefs and Global Climate Change – Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems. Pew Center on Global Climate Change, Arlington USA.
- Burke, L., Selig, E., Spalding, M. 2002. Reefs at Risk in South East Asia. World Resource Institute. 10th Street, Washington, DC 20002, USA.
- Cervino, J.M., Hayes, R.L., Polson, S.W., Polson, S.C., Goreau, T.J., Martinez R.J. and Smith, G.W. (2004) Relationship of *Vibrio* Species Infection and Elevated Temperatures to Yellow Blotch/Band Disease in Caribbean Corals. *Applied and Environmental Microbiology*, p. 6855–6864
- 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.
- Darwall, W.R.T. and N.K. Dulvy. 1996. An evaluation of the suitability of non-specialist volunteer researchers for coral reef fish surveys. Mafia Island, Tanzania – A case study. *Biological Conservation* 78: 223-231
- Department of Fisheries 1990. Compiled Theme of Fishery Laws. Department of Fisheries. Phnom Penh.
- Erdmann, M.V., A. Mehta, H. Newman and Sukarno 1997. Operation Wallacea: Low-cost reef assessment using volunteer divers. *Proceedings of the 8th International Coral Reef Symposium* 2: 1515-1520.
- Gillett, R., 2004 The marine fisheries of Cambodia, FAO/FishCode Review, No.4, Rome FAO 2004
- Glynn, P. 1993. Coral reef bleaching ecological perspectives. *Coral Reefs* 12: 1-17.

Gray R 2010 Coral reefs suffer mass bleaching, Telegraph, Accessed 18/07/2010

Toral-Granda, V., Lovatelli, A., Vasconcellos, M. eds. 2008. Sea cucumbers. A global review of fisheries and trade. *FAO Fisheries and Aquaculture Technical Paper*. No. 516. Rome, FAO. 317 pp.

Hay, M.E. 1996 Marine chemical ecology: what is known and what is next? *J. Exp. Mar. Biol. Ecol.* 200, 103-134.

Hodgson G. 1999. A global assessment of human effects on coral reefs. *Marine Pollution Bulletin* 38: 345-355

Hodgson, G., Hill, J., Kiene, W., Maun, L., Mihaly, J., Liebeler, J., Shuman, C. and Torres, R., 2006. Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring. Reef Check Foundation, Pacific Palisades, California, USA

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, and D. Xiaosu eds. 2001. IPCC Third Assessment Report: Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge, UK, 944 pp.

Hunter, C. and J. Maragos. 1992. Methodology for involving recreational divers in long-term monitoring of coral reefs. *Pacific Science* 46: 381-382.

Hughes, T. et al. 2003. Climate change, human impacts, and the resilience of coral reefs. *Science* 301: 929-933.

Hughes, T. et al. 2007. Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change *Current Biology* 17: 360-365

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.

IPCC 2007. The Physical Science Basis. Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 18 pp.

Kim, S., Chou, L.M., Tun, K. 2004 The coral reefs of Cambodia: present state of information and management capacity

Kinsey, D.W. 1988. Coral reef system response to some natural and anthropogenic stresses. *Galaxea* 7: 113-128.

Mam, K. 2001. Coral Reef and Seagrass Survey In Cambodia. Lower Mekong Basin Program of Wetlands International Asia Pacific. Ministry of Environment. Phnom Penh.

McCook, L.J. 1999. Macroalgae, nutrients and phase shifts on coral reefs: Scientific issues and management consequences for the Great Barrier Reef. *Coral Reefs* 18: 357-367.

Mumby, P.J., A.R. Harborne, P.S. Raines and J.M. Ridley. 1995. A critical assessment of data derived from Coral Cay Conservation volunteers. *Bulletin of Marine Science* 56: 737-751.

Myers, R., Baum, J., Shepherd, T., Powers, S. and Peterson, C. 2007. Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. *Science* 315: 1846-1850.

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

Royal Society. 2005. Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide. The Royal Society, London, UK
[<http://www.royalsoc.ac.uk/displaypagedoc.asp?id513539> accessed 19 July, 2008].

Sheppard, C. 2006 Trawling the sea bed. *Marine Pollution Bulletin* 52, 831–835

Sheppard, C.R.C., Harris, A. and Sheppard, A.L.S. 2008. Archipelago-wide coral recovery patterns since 1998 in the Chagos Archipelago, central Indian Ocean. *Marine Ecology Progress Series* 362: 109-117.

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

Orr, J. et al. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437 29: 681-686.

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.

Van't Hof, T. 2001. Tourism Impacts on Coral Reefs: Increasing Awareness in the Tourism Sector. UNEP Publication.

Vibol O. and Kluskens B. 2008 Management of Coral Reef Ecosystems in the Kingdom of Cambodia, Fisheries Conservation Division Fisheries Administration, Marine Conservation Cambodia

Voss, J., Richardson, L. 2006. Nutrient enrichment enhances black band disease progression in corals. *Coral Reefs* 25: 569–576

Webster, P., Holland G., Curry, A., Chang, H. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 309: 1844-1846.

Wells, S.M. 1995. Reef assessment and monitoring using volunteers and non-professionals. University of Miami.

Wilkinson, C., Souter, D. 2008. Status of Caribbean coral reefs after bleaching and hurricanes in 2005. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre, Townsville, 152 p.

Winter, A., Appeldoorn, R., Bruckner, A., Williams, E. and Goenaga, C. 1998. Sea surface temperatures and coral reef bleaching off La Parguera, Puerto Rico. *Coral Reefs* 17: 377-382

Wolanski, E., Richmond, R., McCook, L. and Sweatman, H. 2003. Mud, marine snow, and coral reefs. *American Scientist* 91: 44-51.

Appendix – Target species lists

BENTHIC SPECIES		
INVERTEBRATES	HARD CORALS	SOFT CORALS
<u>Feather Duster Worms</u>	Brain Small	Deadman's Fingers
<u>Christmas Tree Worms</u>	Brain Medium	Leather
<u>Flatworms</u>	Brain Large	Tree
<u>Crustaceans</u>	Massive Porites	Pulsing
Banded Coral Shrimp	Echinopora	Sea Fan
Mantis Shrimp	Galaxea	Bamboo
Anemone Shrimp	Pocillopora medium	Flower
Lobster	Pocillopora large	HARD CORAL LIFEFORMS
True Crabs	Goniopora/Alveopora	<u>Acropora</u>
<u>Gastropods</u>	Pavona decussata	Branching
Conch	Porites rus	Encrusting
Cone Shell	Turbinaria	Submassive
Cowries	Seriatopora	Digitate
Drupella	Lobophyllia	Tabulate
Murex	Plerogyra	Branching
Nudibranch	Favia	<u>Non-Acropora</u>
Topshell	Favites	Encrusting
Triton	Diploastrea h.	Foliose
<u>Cuttlefish</u>	Podabocia	Massive
<u>Octopus</u>	Pocillopora small	Submassive
<u>Squid</u>	Tubastrea micrantha	Mushroom
<u>Seastars</u>	Astreopora	<u>Heliopora</u>
<i>Acanthaster planci</i> (COTS)	Pavona clavus	<u>Millepora</u>
<i>Culcita novaguineae</i>	Pectinia	<u>Tubipora</u>
<i>Protoreaster nodosus</i>	Herpolitha limax	
Brittle	Ctenactis echinata	
Basket	Polyphyllia talpina	
Feather	Montipora encrusting	
<u>Urchin</u>	Montipora Sub mass	
Collector	Montipora foliose	
Diadema spp.	Pseudosiderastrea	
Flower		
Pencil		
<u>Sea Cucumber</u>		
Prickly Redfish		
Greenfish		
Pinkfish		
Synaptid spp.		
<u>Sea Pen</u>		
<u>Giant Clams</u>		

FISH	
<u>Butterflyfish</u>	<u>Groupers</u>
Eight-Banded	Blue-lined
Bannerfish	Chocolate
Long-beaked	Honeycomb
<u>Blueringed Angelfish</u>	Peacock
<u>Rabbitfish</u>	Squairetail
Coral	
Golden	<u>Blenny</u>
Java	<u>Boxfish</u>
Vermiculated	<u>Cardinal</u>
Virgate	<u>Emperors</u>
<u>Damselfish</u>	<u>Filefish</u>
Sergeant spp.	<u>Fusiliers</u>
Anemone spp.	<u>Goatfish</u>
<u>Snapper</u>	<u>Goby</u>
Blacktail	<u>Jacks/Trevally</u>
Checkered	<u>Lizardfish/Sandperch</u>
Red	<u>Porcupinefish</u>
<u>Spinecheeks</u>	<u>Pufferfish</u>
Bridled	<u>Scorpionfish</u>
Whitestreak	<u>Squirrel/Soldierfish</u>
<u>Barracuda</u>	<u>Sweepers</u>
Yellowtail	<u>Triggerfish</u>
Great	<u>Seahorse/Pipefish</u>
<u>Wrasse</u>	<u>Moray eel</u>
Checkerboard	<u>Sweetlips</u>
Crescent	<u>Bamboo Sharks</u>
Humphead	<u>Blue-spotted Ribbontail Ray</u>
Red-breasted	<u>Parrotfish</u>
Tripletail	<u>Batfish/Spadefish</u>