

CAMBODIA REEF CONSERVATION PROJECT

Pilot Project Report

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In partnership with:



Report by

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A school of Longfin Spadefish (*Platax teira*) silhouette the surface waters around Koh Rong Island, Cambodia (image taken by Sarah King)

Executive summary

On the invitation of the Fisheries Administration of Cambodia, Coral Cay Conservation commenced a three-month pilot project in order to conduct a rapid assessment of the coral reef resources around Koh Rong and Koh Rong Semleou Islands in the Phnom Sihanouk Province.

A total of 34 Reef Check surveys were undertaken by CCC survey teams between the first of August and the 21st of September, 2009. Results from these surveys indicate that hard coral cover is around 23%. Other dominant substrates were rock and rubble; potentially suitable settling grounds for coral larvae. Anthropogenic impacts were generally low but high levels of sedimentation from land run-off were found at all survey sites, most likely a result of significant coastal development both on the mainland and on the island of Koh Rong. Macro-algal coverage was generally low and likely inhibited by high turbidity levels in the water. Coral diversity was dominated by *Massive Porites* and *Diploastrea heliophora* species. Few foliose and branching coral colonies were seen and overall coral diversity was low. Disease and coral bleaching levels were low.

Predatory fish abundances including Snappers and Groupers were low indicating significant fishing pressure on the reefs. The same holds true for Parrotfish abundances. Low visibility at many sites meant fish surveys were often omitted from the surveys and further surveying is needed to get a more accurate picture of the current fisheries status.

The abundance of long-spine (*Diadema*) sea urchins was very high at many survey sites indicating instability in the reef ecosystem, possibly as a result of overfishing of key predators. Lobster and Sea Cucumber abundances were low.

Some comparisons with similar surveys conducted in the area in 2003 showed that coral cover has remained the same. The same holds true for Parrotfish abundances while the abundances of Snappers and Groupers had fallen.

Initial management recommendations include the development of a network of no-take zones in order to protect key reef sites and allow for fish stocks to recover. In order to achieve this, community capacity building and educational programmes are essential in order to create awareness and empower communities to manage their coastal resources.

On a broader level, stakeholders including; the tourism and development sector, Cambodian Government and NGOs, need to develop a clear management plan that highlights the vulnerability of coral reefs to coastal development and incorporates strict mitigation measures in order to minimise land run-off and pollution.

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All the dedicated Coral Cay staff and volunteers that joined the project and contributed to its success.



Figure 1 Coral Cay staff and volunteers at the project site on Koh Rong Island

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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 1986, 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 running volunteer based conservation programmes in developing countries over the past 23 years with notable conservation successes in Belize (formation of the Belize Reef Marine Park and World Heritage Site) and the Philippines (creation of the Danjungan Island Marine Reserve in Negros Occidental).

1 Introduction

Cambodia's coastline is 435km long and includes 69 islands within the Gulf of Thailand (Touch, 1995). Coral reefs and associated seagrass beds and mangrove habitats fringe many of these islands, providing critical habitats for thousands of marine species. Moreover, coral reefs support fisheries and provide a variety of goods and services including eco-tourism and coastal protection to the thousands of people dependent on them. 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 the value per hectare of healthy coral reef to be anywhere between \$130,000 to \$1.2 million/hectare/year (www.diversitas-international.org). These services include; food, raw materials, ornamental resources, climate regulation, moderation of extreme events, waste treatment, biological control, cultural services (e.g. recreation / tourism) and maintenance of genetic diversity. Taken together, coral reef services worldwide have an average annual value estimated at \$172 billion.

Information about Cambodia's reef systems is sparse and poorly documented. There is an urgent need for accurate data on the current status of these critical habitats (Chou, 2003, Wilkinson, 2008). Furthermore, assistance is needed for long-term monitoring programmes supported by in-country commitment (Wilkinson, 2008).

Only limited research exists, and previous research efforts have been supported by international organisations, as there is inadequate in-country capacity to support such scientific studies. The first data on Cambodia's reef status was collected between 1997 and 1999 (Nelson, 1999). Further surveys were 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)

Future projections made by GCRM estimate that Cambodia's reefs will be either at 'high' (90% of reefs) to 'very high' (10% of reefs) risk (Wilkinson, 2008). These threats include: coastal development, marine-based pollution, sedimentation, overfishing and destructive fishing methods. Although illegal under the Cambodian fisheries law, dynamite and cyanide fishing continue to threaten the coral reefs of the area.

The islands of Koh Rong and Koh Rong Sanleom are found off the coastal Phrash Sihanouk Province. The islands are fringed by diverse shallow-water reefs that closely follow the contours of the coastline. Koh Rong Island has been designated for extensive, tourism-related development over the next 20+ years (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 Fisheries Administration (FiA) of the Ministry of Agriculture, Fisheries and Fisheries (MAFF) of the Kingdom of Cambodia invited Coral Cay Conservation (CCC) to their country to work in partnership with the Fisheries Conservation Department. The aim of this project was to conduct an initial assessment of the coral reef resources around the islands of Koh Rong and Koh Rong Sanleom. The project

was initiated through a 3-month pilot phase, the objective of which was to collect accurate scientific baseline data on the current status of reef, mangrove and seagrass systems around Koh Rong and Koh Rong Sanleom.

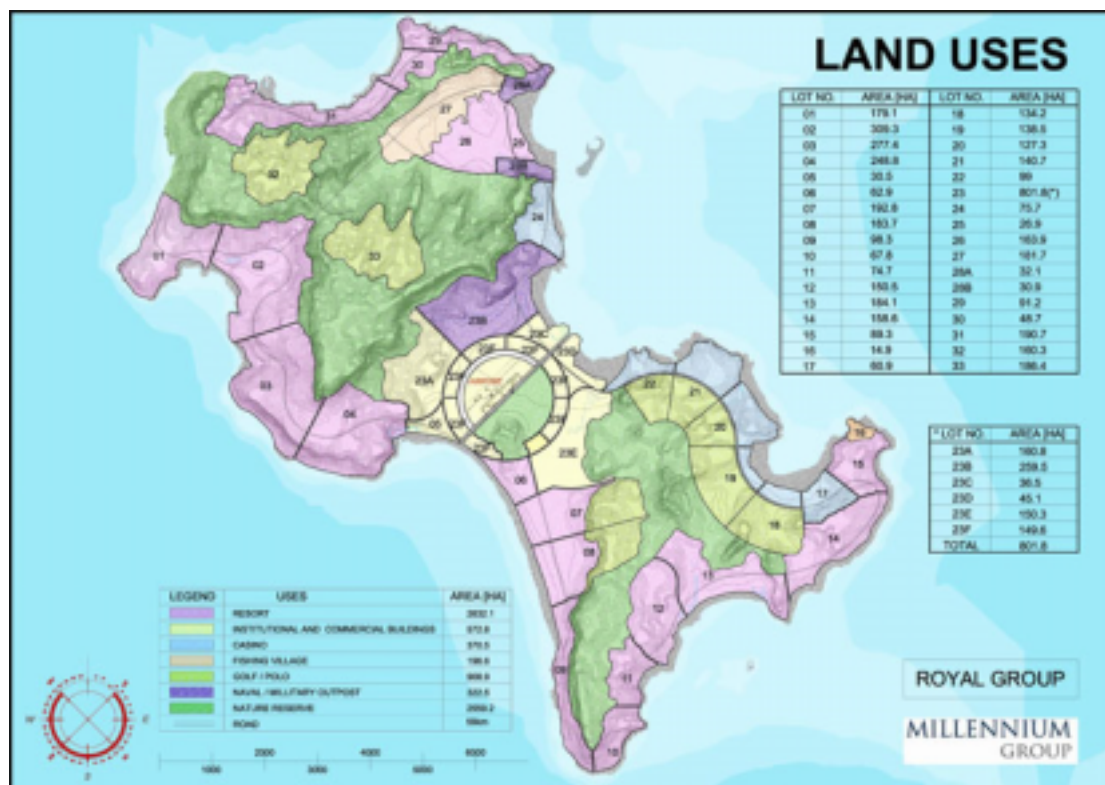


Figure 2 Proposed development plan for Koh Rong Island. Image taken from: http://www.millenniumgroup.net/?page_id=96

2 Methods

Reef Check methodology (Hodgson, et al., 2006) was used to survey 34 sites around Koh Rong, Koh Kon and Koh Rong Sanleom islands in order to quantify the abundance, diversity and composition of selected fish, invertebrate and benthic species (Figure 2). Local knowledge was used to select appropriate survey locations, that can be considered the best reefs sites in the area. At some sites, poor visibility led to exclusion of the fish survey component. Due to the geomorphology of the areas, only shallow transects were carried out between 2m and 10m.

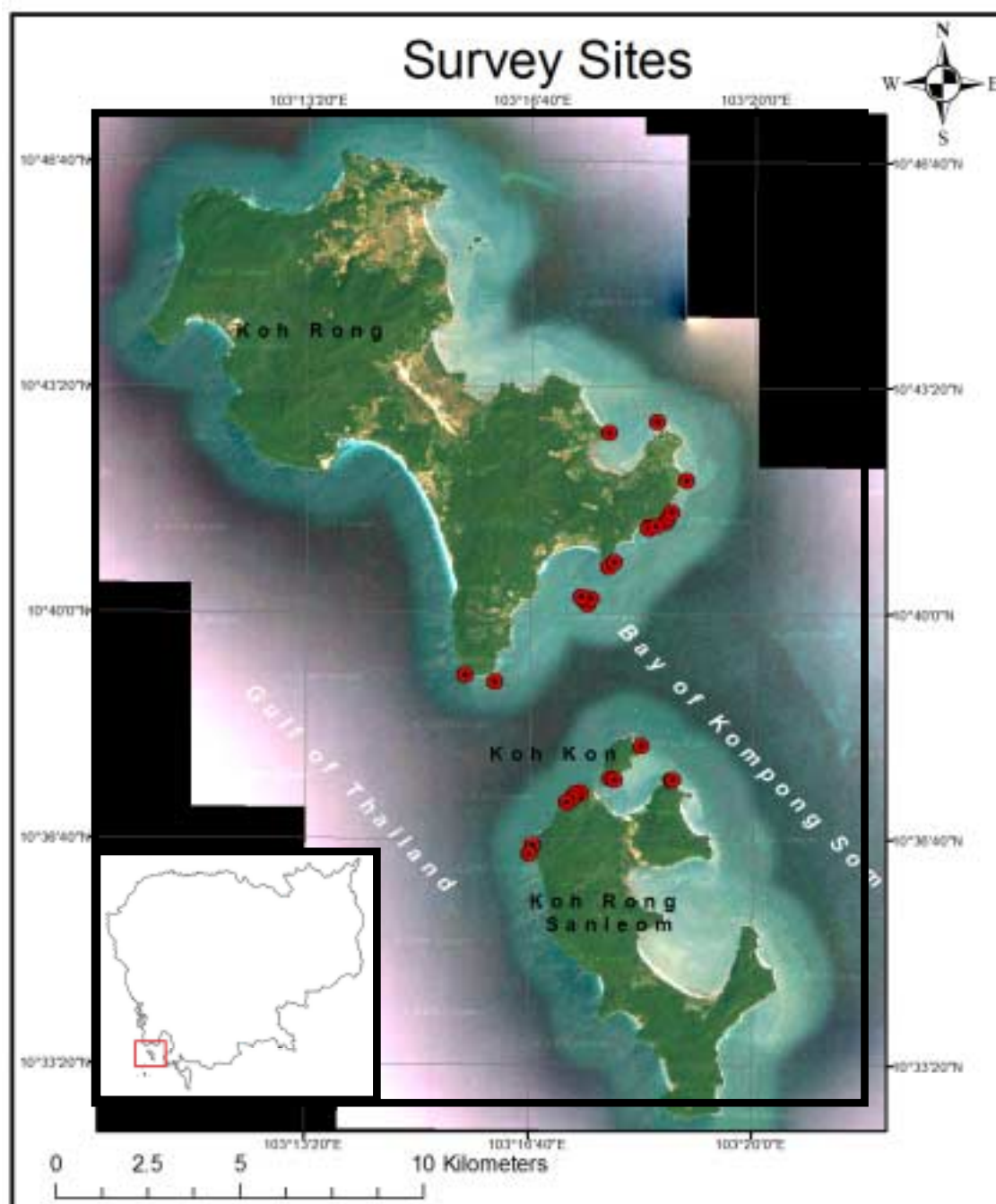


Figure 3 Locations of survey sites around the islands of Koh Rong, Koh Kon and Koh Rong Sanleom. Inset – Map of the Kingdom of Cambodia with the survey area highlighted in red.

Along each depth contour, four 20m transect segments were marked out and surveyed to make up one complete segment (Figure 3). Each consecutive segment'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 first segment of the transect and the end point of the last segment was 95 metres (figure 3).

2.1 Types of data collected at each survey site/transect

(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:

Site Description - Anecdotal, observational, historical, location and other socio-economic data are recorded here. A boat marshal took a GPS reference of the start location of each survey. See Appendix for details.

Coral Bleaching, Trash and Damage – Along the transect line; divers estimated the total percentage of bleached coral cover as well as the estimated percentage of each individual coral colony that is bleached. 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, 3 = high). Trash was recorded and separated into general and fishing nets/traps. Coral damage types were broken down into boat/anchor, dynamite and other.

Fish Belt Transect – Fish families recognized as being good indicators of fishing pressure, aquarium collection and reef health were selected. Size minimums were placed on two families of food fish – Groupers and Parrotfish. A list of indicator species can be found in the Appendix. One diver recorded fish on one side of the transect, while their buddy recorded fish on the other side; their combined efforts surveying a 5 metre wide belt (figure 3). The fish belt transect was completed first since fish can easily be disturbed by divers. The divers waited 15 minutes in a location away from the transect before starting the survey. This allowed fish to resume normal behavior after being disturbed by the divers deploying the transect. Surveying was carried out by each diver swimming slowly along the transect and counting the indicator fish. The diver then stopped every 5 metre and waited 1 minute for the indicator fish to come out of hiding before proceeding to the next 5 metre stop-point. As with each of the surveys, there are four 5 metre gaps where no data was collected. Fish seen up to 5 metre above the line are included.

Invertebrate Belt Transect – The same four 5 metre wide by 20 metre long segments as used for the fish belt transect were sampled for selected invertebrate species typically targeted as food species or collected as curios (figure 3). The diver swam 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 lobster, sea urchins or other cryptic species.

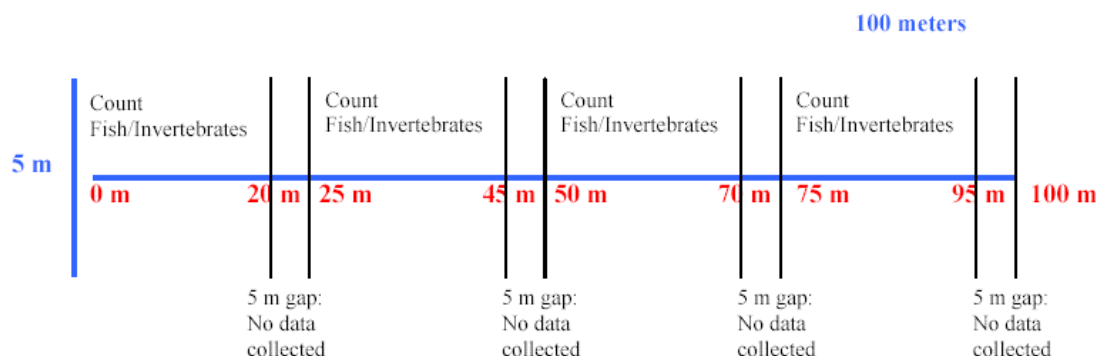


Figure 4 Fish and invertebrate belt transect count method (taken from Hodgson et al, 2006)

Substrate Line Transect- The same transect line as the fish and invertebrate belt transects was used, but this time, points were sampled at each 0.5 metre interval along the tape to determine the substrate types on the reef (Figure 4). To minimize bias, a 5 mm diameter nut or other small metal object was tied to a length of string for use as a plumb line. The object was dropped at each designated point and the substrate type underneath was recorded. Benthic categories were: sand, rock, rubble, silt, other, nutrient indicator algae, sponge, recently killed coral, soft coral and hard coral. Hard corals were noted to species level if it was a target species (see Table 1). Otherwise, a note was made of the coral lifeform.

Table 1- Target hard coral species

<i>Species</i>	
Brain Small	<i>Porites rus</i>
Brain Medium	<i>Turbinaria spp.</i>
Brain Large	<i>Galaxea spp.</i>
<i>Montipora foliose</i>	<i>Lobophyllia spp.</i>
Massive Porites	<i>Plerogyra spp.</i>
<i>Echinopora spp.</i>	<i>Favia spp.</i>
<i>Galaxea spp.</i>	<i>Favites spp.</i>
Pocillopora medium	<i>Diploastrea heliopora</i>
Pocillopora large	<i>Podabocia spp.</i>
<i>Goniopora/Alveopora spp.</i>	Pocillopora small
<i>Pavona decussata</i>	<i>Tubastrea micrantha</i>

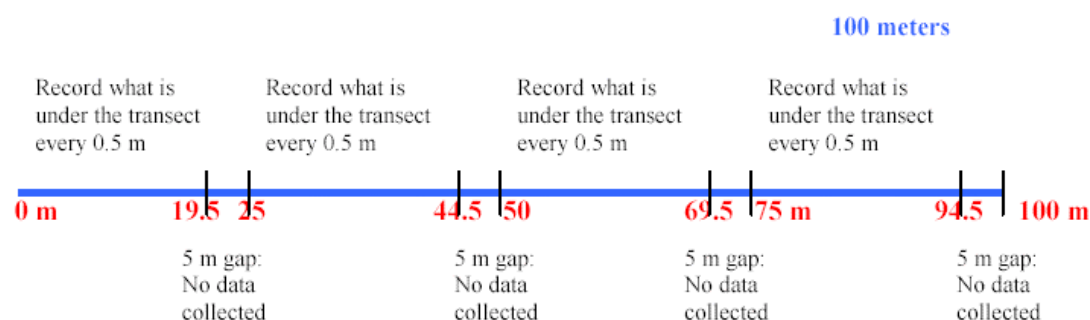


Figure 5 Point intercept transect count method to determine benthic cover (taken from Hodgson et al, 2006).

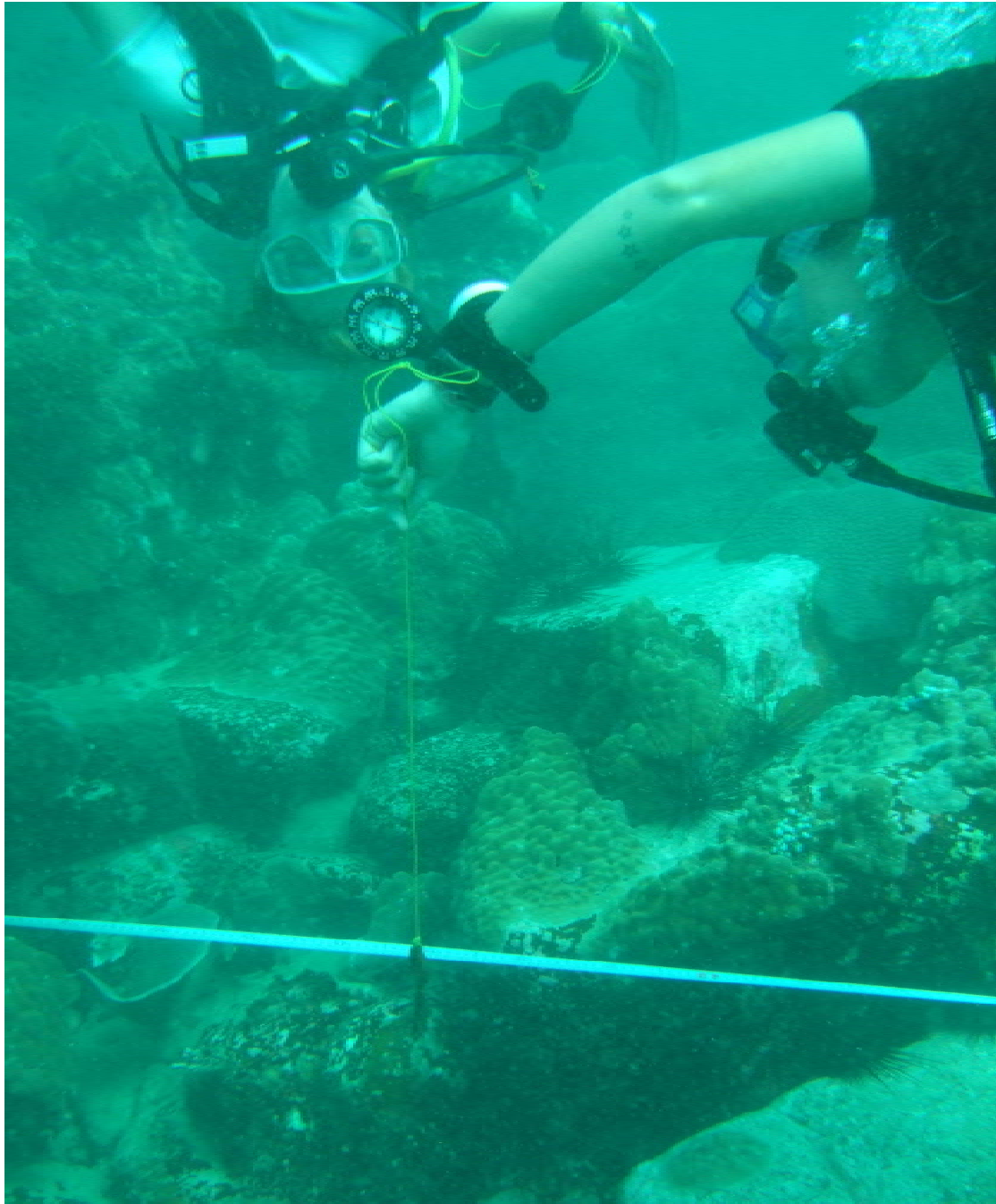


Figure 6 Coral Cay survey team using a plumb line to accurately determine the benthic substrate at 50 centimetre intervals along the survey line (*image taken by Helen Ranson*)

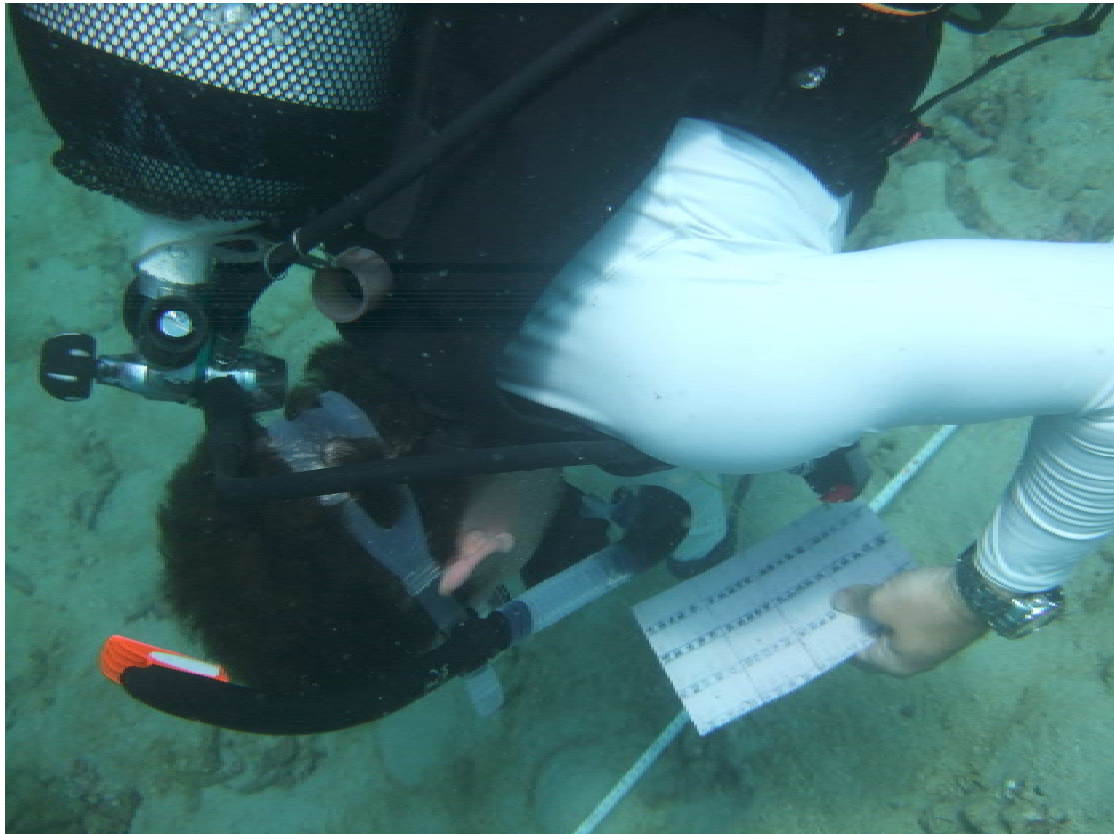


Figure 7 A Coral Cay volunteer assessing benthic substrates along a 100 metre line intercept transect (*image taken by Helen Ranson*)

2.2 Data Entry

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

3 Results

The outputs from these surveys are in graphical and G.I.S. format and aim to provide a general picture of the status of coral reefs around the islands and draw some initial management recommendations from this. Data analysis is based on 34, 100 metre Reef Check surveys, conducted by CCC survey teams along the fringing reefs of Koh Rong and Koh Rong Sanleom between the 1st of August and the 21st of September, 2009.

It is not possible (nor necessarily useful) to undertake an exhaustive analysis of all of the data gathered during the pilot period, within this report. A more thorough analysis can be made when more baseline surveys around the islands have been completed and comparisons can be made between all sites. This will produce a clearer picture of the state of Cambodia's marine resources. An overall impression of the areas can be given however, as has been done in this report.

Survey sites in close proximity of one another were grouped and labelled as 'sectors'. This allowed for a larger dataset from geographically similar areas to be compared rather than comparing every survey site individually.

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 anthropogenic impact data (3.1).
- Results from biological indicators. Benthic (3.2), Reef Fish Families (3.3) and Invertebrates (3.4)
- Comparisons with Reef Check data collected by the Department of Fisheries in 2003 (3.5)

3.1 *Anthropogenic impact data*

Coral damage was generally found to be low. Sector 1 and sector 8 had the highest amount of coral damage (Figures 8 and 9). Sectors 1 and 8 in particular had high anchor and boat damage, most likely due to the popularity of this site for dive vessels. The effects of fishing in the form of discarded nets were found on all reefs. Indications of heavy fishing were found around Koh Rong (sectors 1, 7, 8 and 9) and sector 4. Other trash such as cans and plastic were generally low on all reefs apart from sector 11.

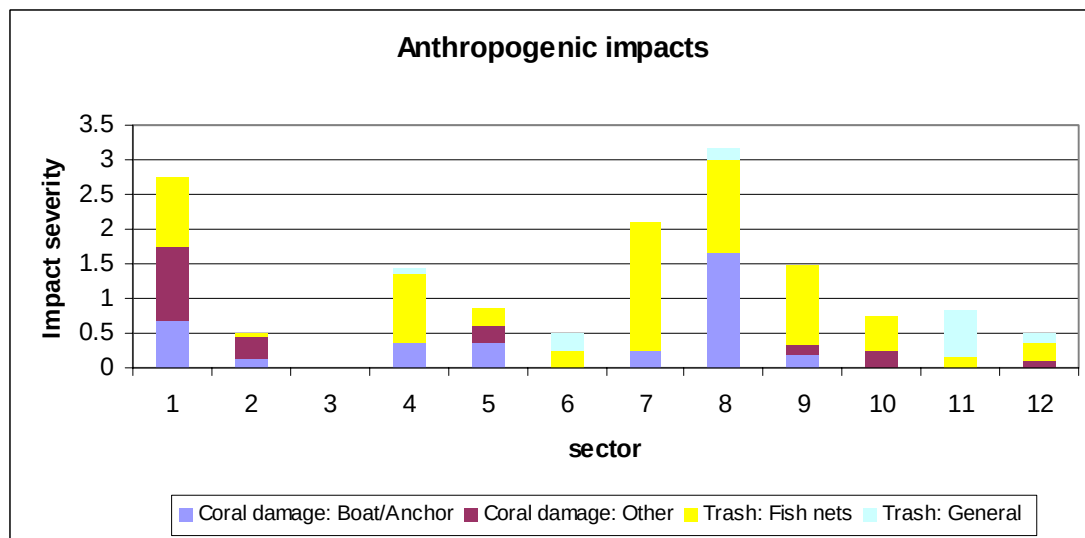


Figure 8 Anthropogenic (human caused) impacts on the reef. The impact severity is based on a categorical observation between 0 and 3 (0 = low, 3 = Very high) for each impact.

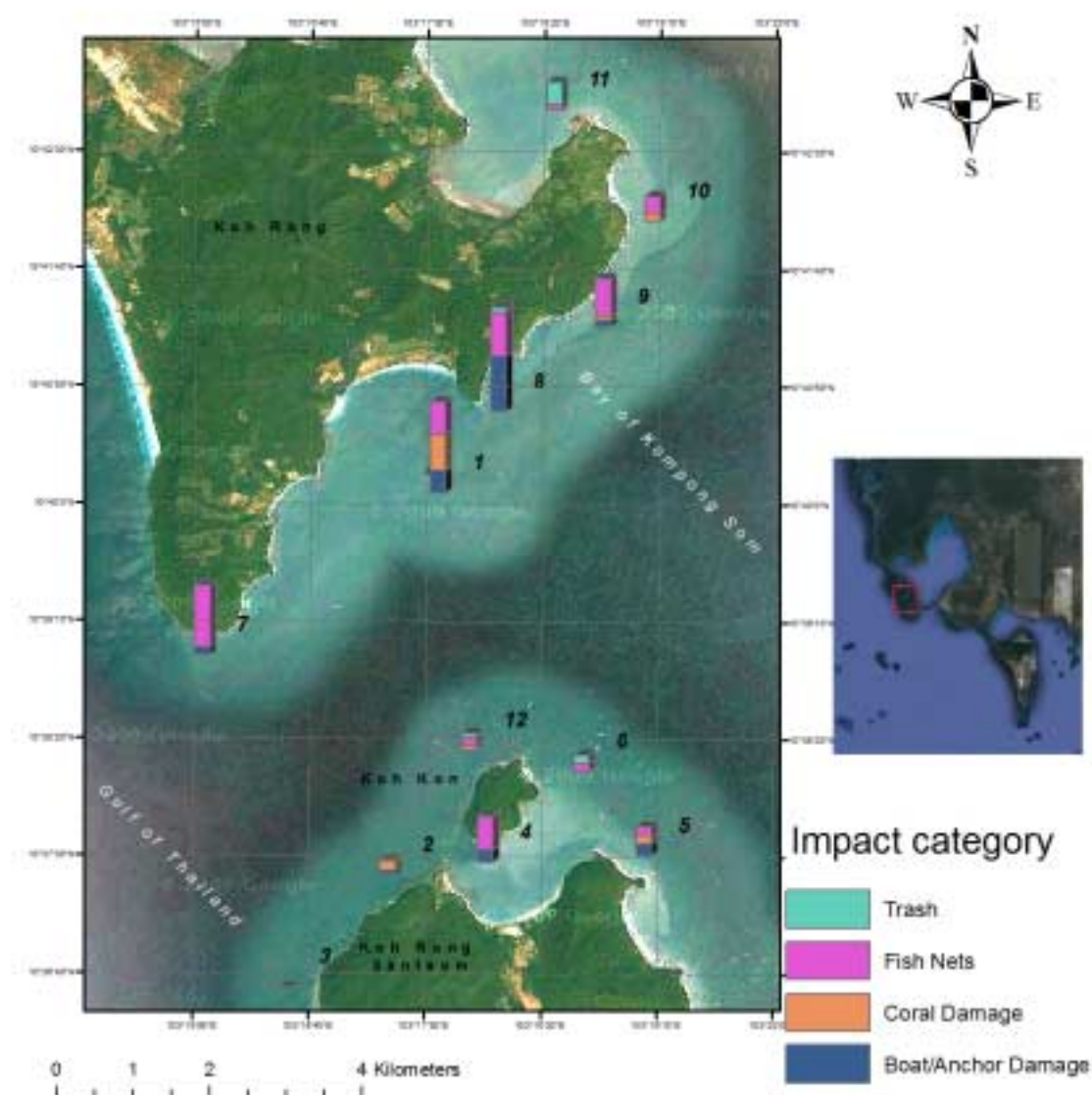


Figure 9 GIS map of anthropogenic impact levels at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. Stacked bars indicate the level of each impact category. The height of the bar represents the overall impact factor for that sector.

Coral bleaching and disease prevalence was found to be low for all survey sites. The highest bleaching and disease prevalence was found to be 5% and less than 0.5% on average. Disease and bleaching levels should be closely monitored in the future to assess the resilience of reef systems to regional, climate-change related impacts.

3.2 Benthic composition

The main substrates encountered on surveys were rock, coral, sand and silt (figure 10). Average hard coral cover was found to be 23% for all sites surveyed. Hard (Scleractinian) coral cover is a useful indicator of general reef health. It is generally accepted that reef fish species diversity is directly related to hard coral cover and diversity. Highest coral cover was found around zone 2. Zones 1, 4 and 12 all displayed high coral cover (figures 11 and 12). Rock and dead coral were also

dominant substrates potentially providing a settling ground for coral larvae. Sector 3 in particular, had over 50% rock cover.

There was a low percentage of recently killed coral (<1% for all sites). Siltation was very high in sectors 6 and 11 (64% and 63% resp.). These areas were surveyed when there was a high amount of sedimentation from land runoff. This is likely to be a seasonal occurrence.

The ‘Nutrient Indicator Algae’ category included species that are thought to be nutrient-indicators, such as brown “fleshy” algae. *Halimeda spp.* are 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 as most of them respond in a similar manner to macroalgae in terms of environmental conditions that promote/inhibit their growth. The levels of nutrient indicator algae were generally low for all sites (1.3% on average). Cover of sponges, soft corals and other animals such as hydroids, anemones, gorgonians and ascidians were all low (less than 2%).

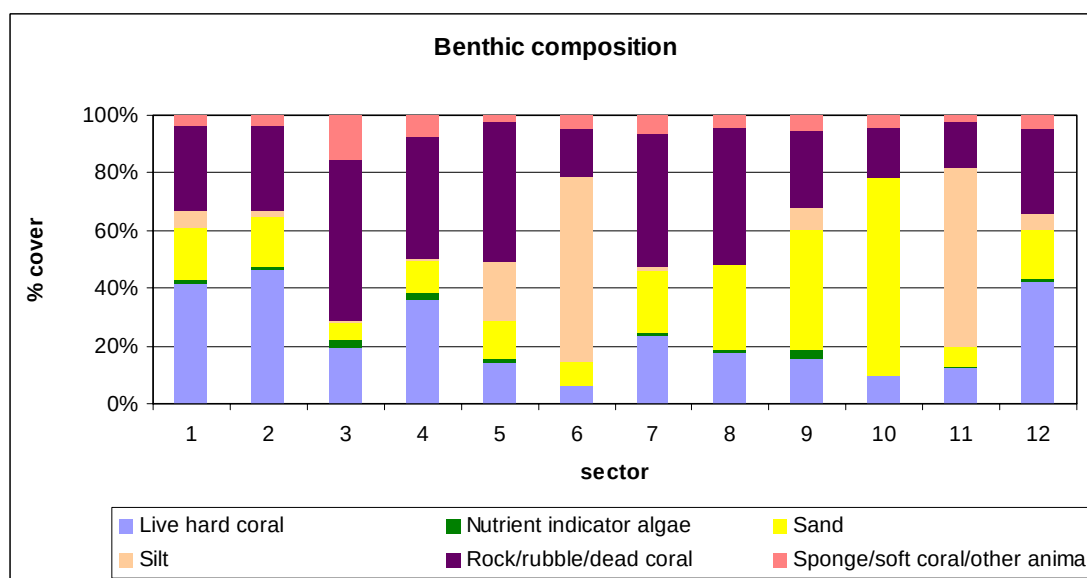


Figure 10 Composition of 6 benthic substrates (biotic and abiotic) at 12 survey sectors.

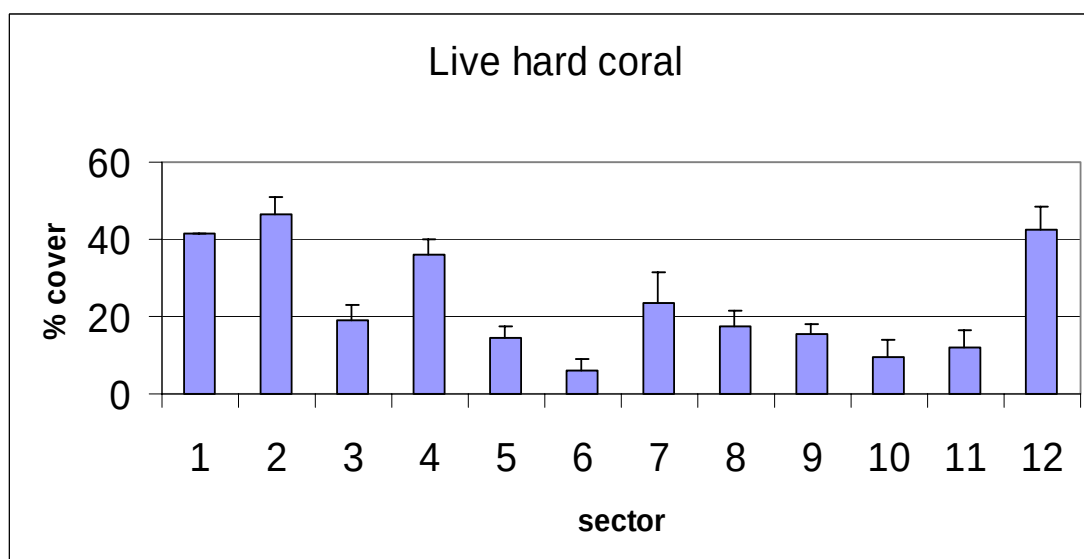


Figure 11 Average hard coral cover at the different survey sectors. Error bars indicate standard error.

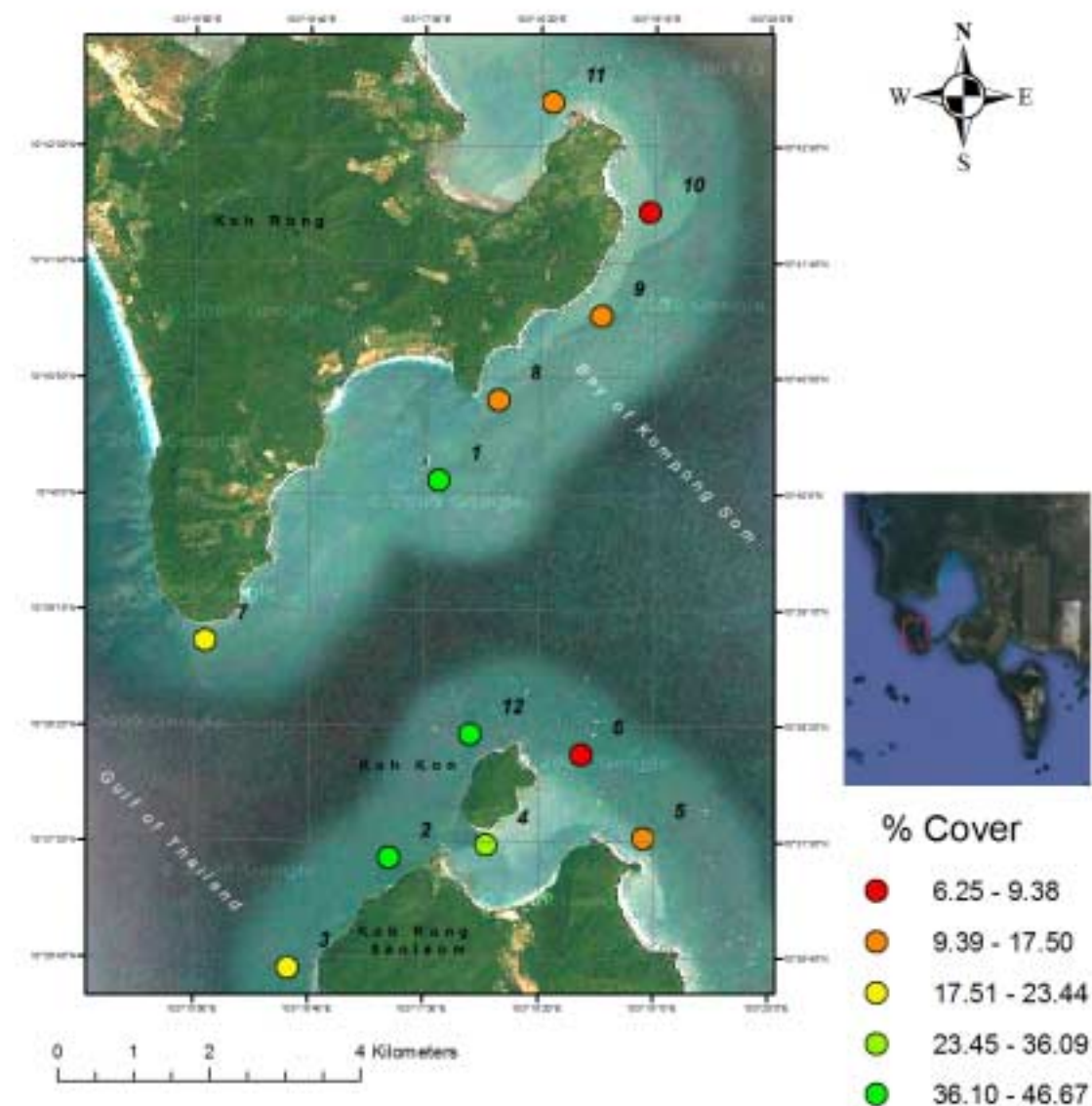


Figure 12 GIS map of hard coral cover at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. Coloured circles indicate the percentage coral cover for each sector on a gradient from red (low) to green (high).

Coral species diversity was generally low and comprised mainly of massive colonies such as *Porites* massive and *D. heliopora* (figure 13). Branching corals were rarely encountered. Foliose corals were comprised mainly of *Turbinaria* and *Montipora* species but were rare. The dominance of massive coral lifeforms was apparent at all survey sites. These types of corals, although slow-growing, are generally the most robust and can withstand higher levels of sedimentation. Coral diversity was estimated through a Shannon Weiner Diversity Index (figure 14). Highest coral diversity was found at sectors 1, 4, 8 and 9 ($H' = 0.6 - 1.1$).

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

Figure 13 Coral species composition as a percentage of all target coral species and groups encountered on surveys.

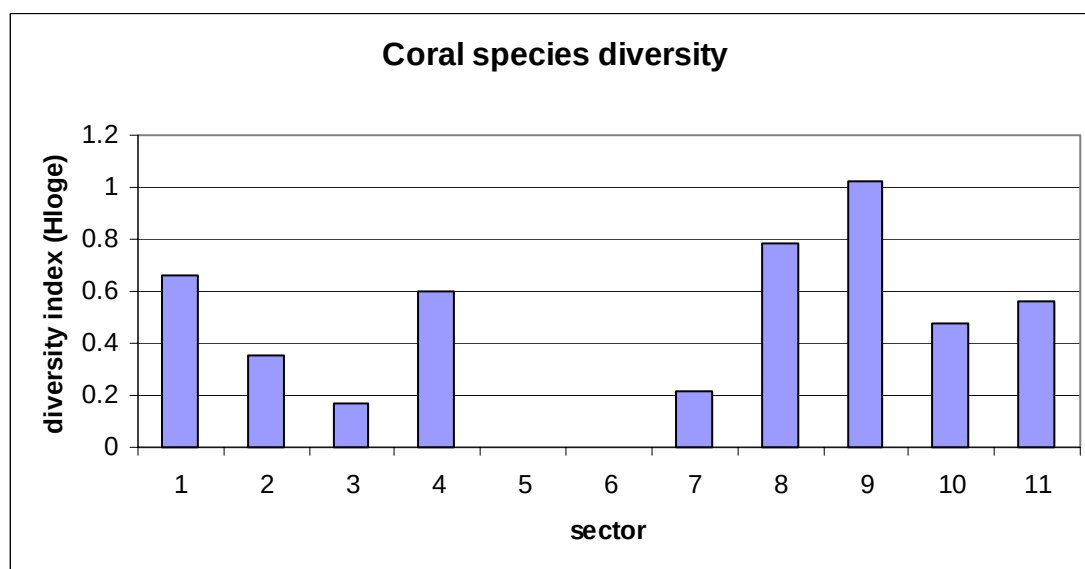


Figure 14 Diversity of hard coral species (Shannon Weiner Diversity Index) for each survey sector.

3.3 Reef Fish Families

Butterflyfish (Chaetodontidae) are obligate corallivores, making them good indicators of reef health. A high abundance and diversity of Butterflyfish species is usually associated with a diverse reef. Variation in Butterflyfish was high between survey sites. At least a part of this can be attributed to the low visibility on some of the surveys (figures 15 and 17). The highest densities were found in sector 1. This coincides with the high coral cover seen in sector 1.

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 keep macroalgae in check. Furthermore, some species feed on live hard corals and by doing so, help to maintain coral diversity. Within the classical trophic chain, their herbivorous lifestyle strategy enables greater numbers of individuals within a population when compared to the large carnivores such as groupers. Their abundance was generally low for all survey sectors except 5 where their density was 500 individuals per hectare (figures 16 and 17). Parrotfish were not encountered on many surveys. As with Butterflyfish sightings, this is likely to be related to the poor visibility on many of the surveys.

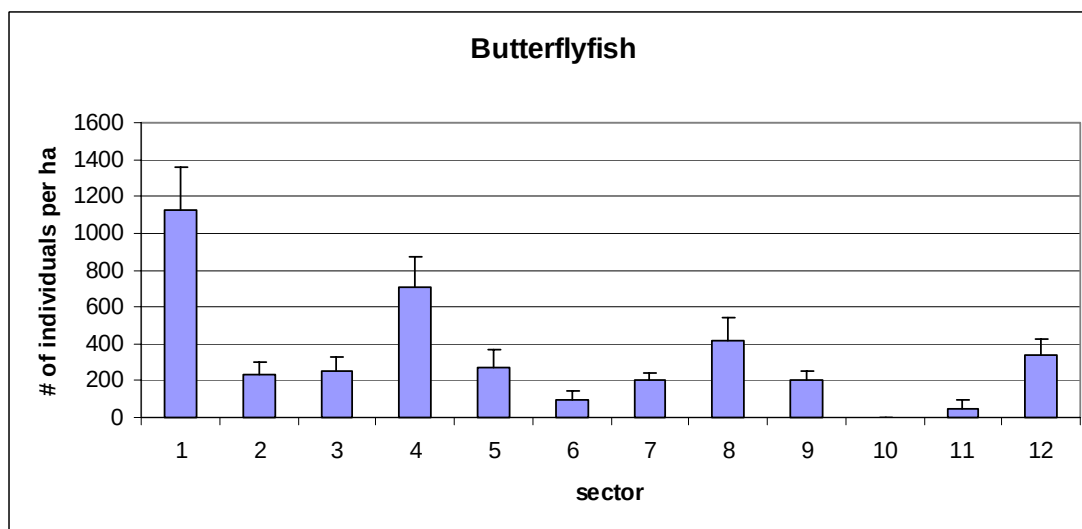


Figure 15 Butterflyfish densities per survey sector. Error bars indicate standard error.

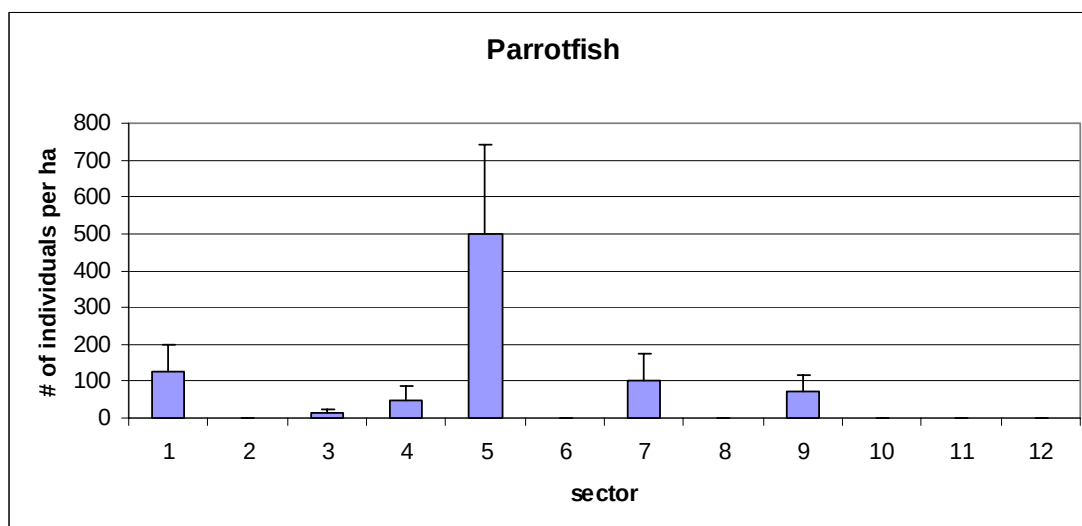


Figure 16 Parrotfish densities per survey sector. Error bars indicate standard error.

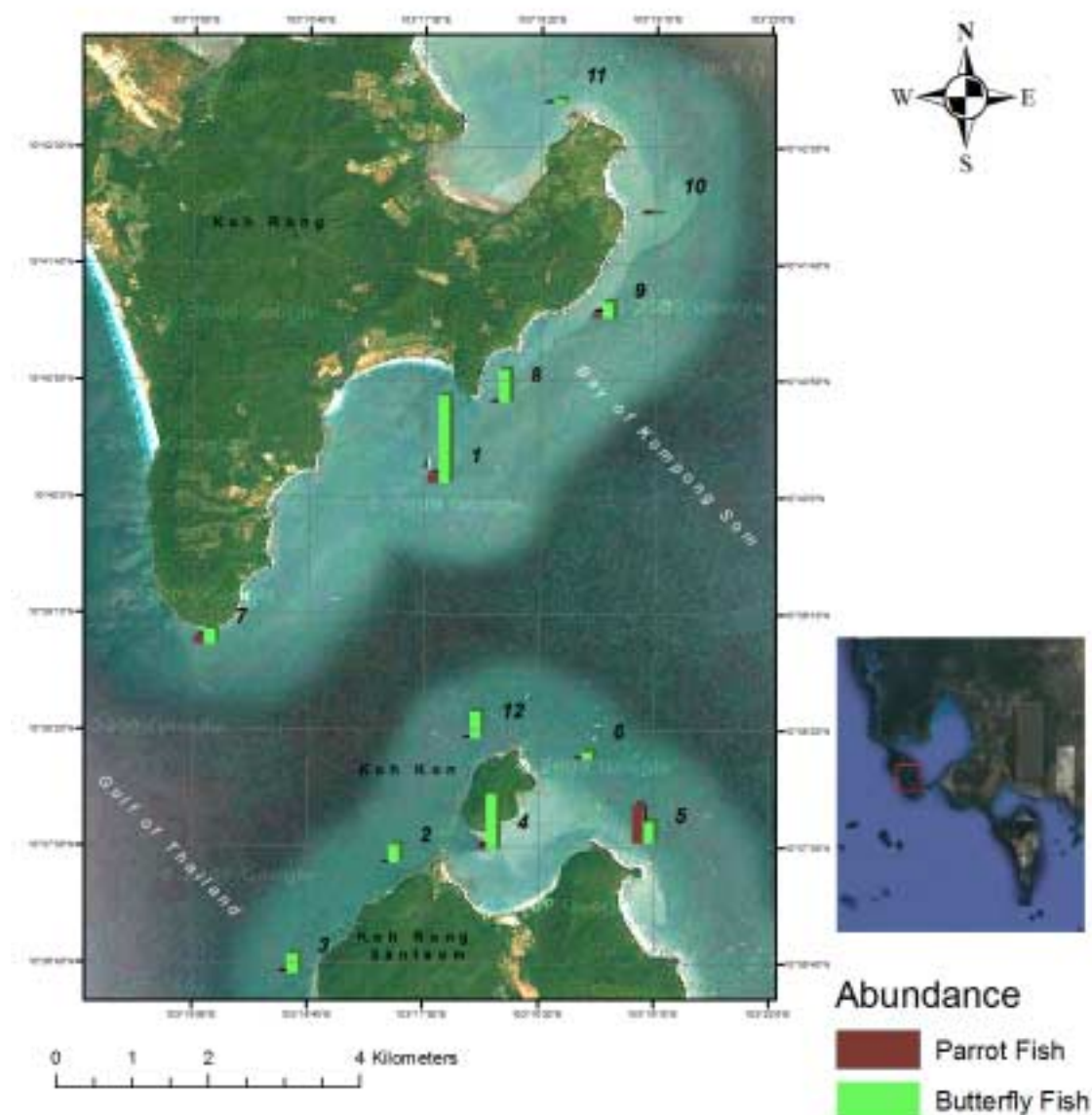


Figure 17 GIS map of Butterflyfish and Parrotfish abundance at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. The height of the bar indicates their abundance per survey sector.

Abundances of three key predatory fish families; Groupers (Serranidae), Snappers (Lutjanidae) and Sweetlips (Haemulidae), were estimated in order to get an indication of fishing pressure on these key reef fish. Groupers are commercially important and very popular food fish all over the world. They spawn in aggregations at a late age (5-7 years), and are extremely vulnerable to over-exploitation. Spawning occurs in large aggregations in order to optimise fertilisation, minimise egg predation, facilitate dispersal and maximise recruitment. The effects of fishing tend to reduce the abundance of the target species, lower their average size and modify their species composition (Van't Hof, 2001). This occurs by selectively removing larger individuals due to an ever-increasing requirement for the export of these fish. Grouper densities were low (~40 individuals per hectare) with the highest abundance found in sector 12 where there were an estimated 125 individuals per hectare (figures 18 and 19).

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 1 and 5 (~190 individuals per hectare). Sweetlips are brightly coloured predatory fish of a medium size. They were not seen on most surveys except for in sectors 2, 6 and 9.

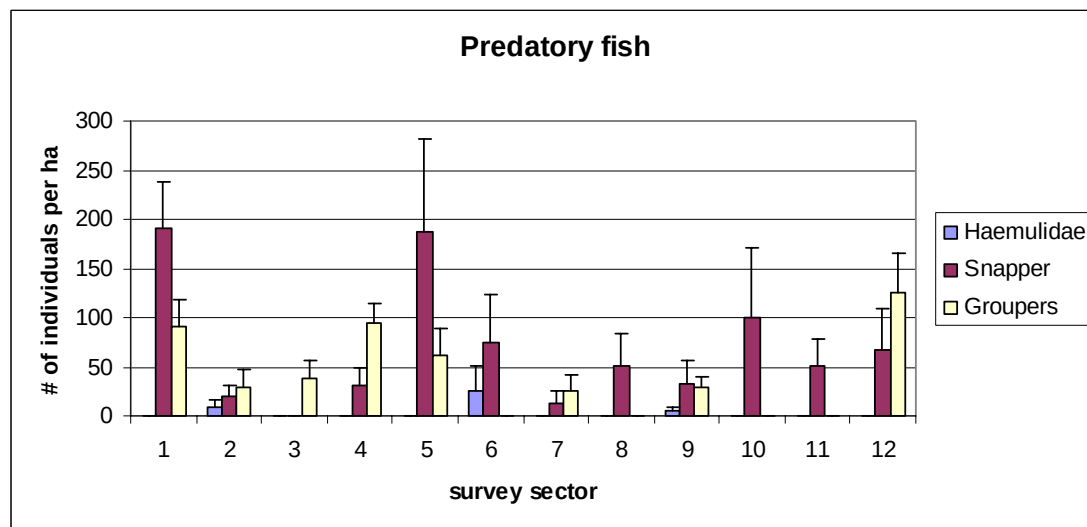


Figure 18 Densities of three predatory fish families per survey sector. Error bars indicate standard error.

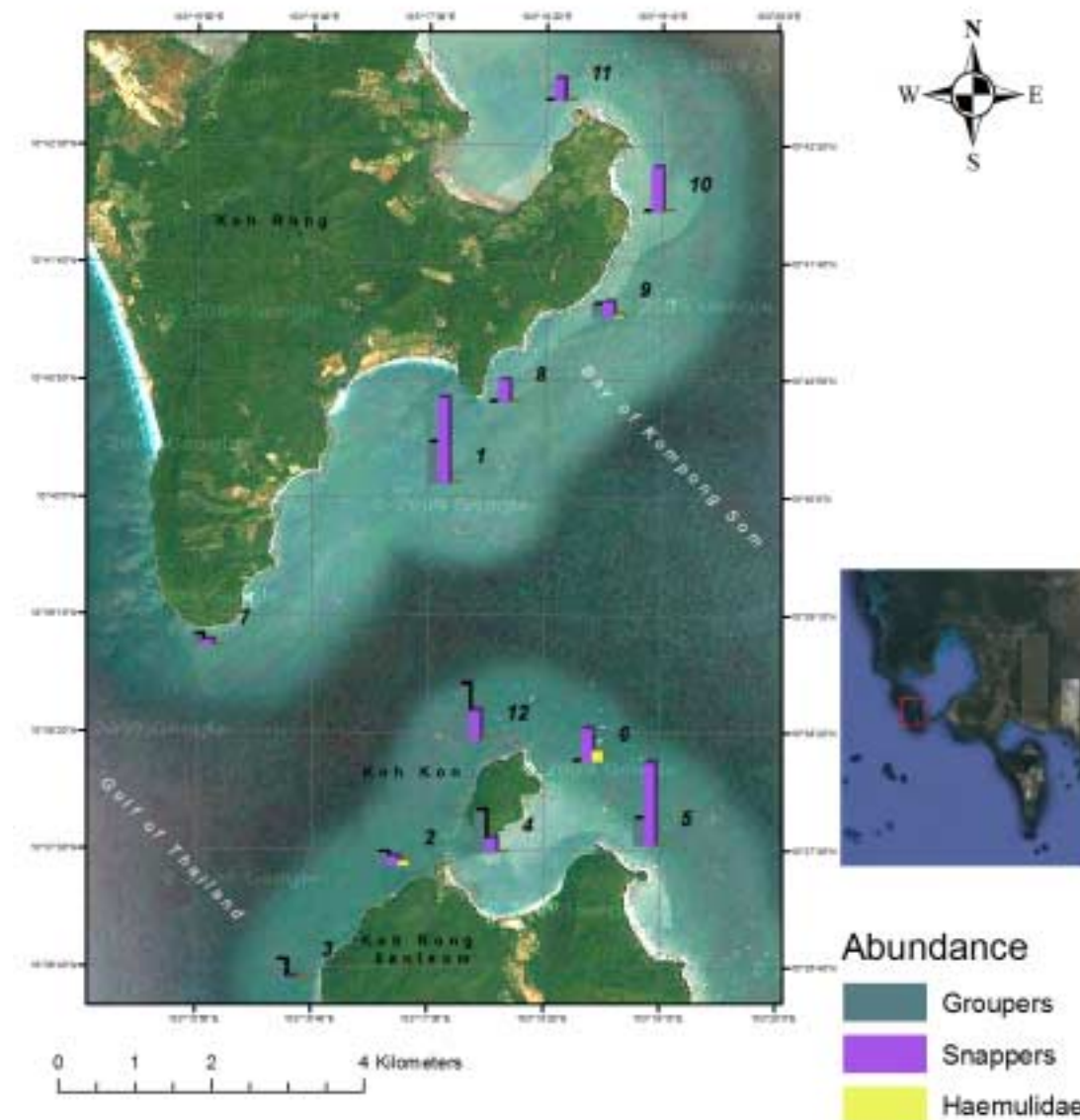


Figure 19 GIS map of abundances of 3 predatory fish at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. The height of the bar indicates their abundance per survey sector.

3.4 Invertebrate indicators

High abundances of long-spine (*Diadema*) sea urchins were found on most surveys (figure 20 and 21). Sectors 3, 4 and 12 had particularly high densities of these algal-grazing urchins. *Diadema* 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.

Giant clams (*Tridacna* spp.) are an important local food source and have been traditionally harvested for centuries. They are important reef filter feeders that 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 8 (435 individuals per hectare). Other sectors showed little or no giant clams (sectors 10 and 11) indicating over-harvesting in these areas (figures 22 and 23).

Certain gastropods are good indicators of reef health and are often overharvested by the curio trade. Abundance of Collector Sea Urchins was relatively high at around 38 individuals per hectare (figure 24). Sea Cucumber and Lobster abundances were 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 found in sectors 3 and 12 in low abundance (<17 individuals per hectare).

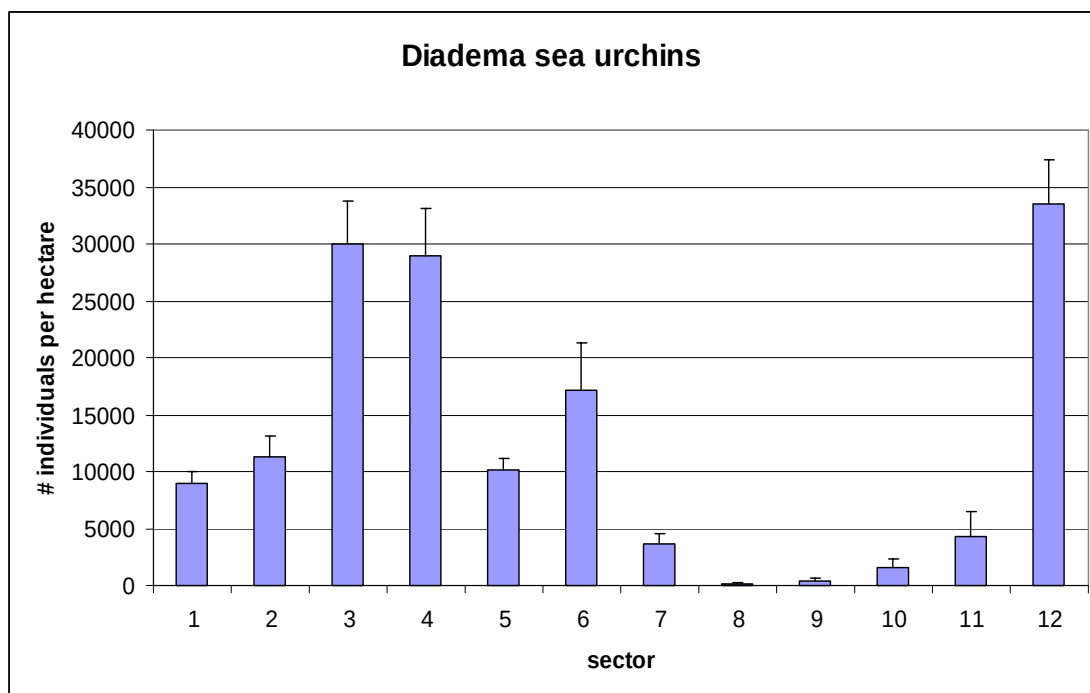


Figure 20 Diadema sea urchin densities per survey sector. Error bars indicate standard error.

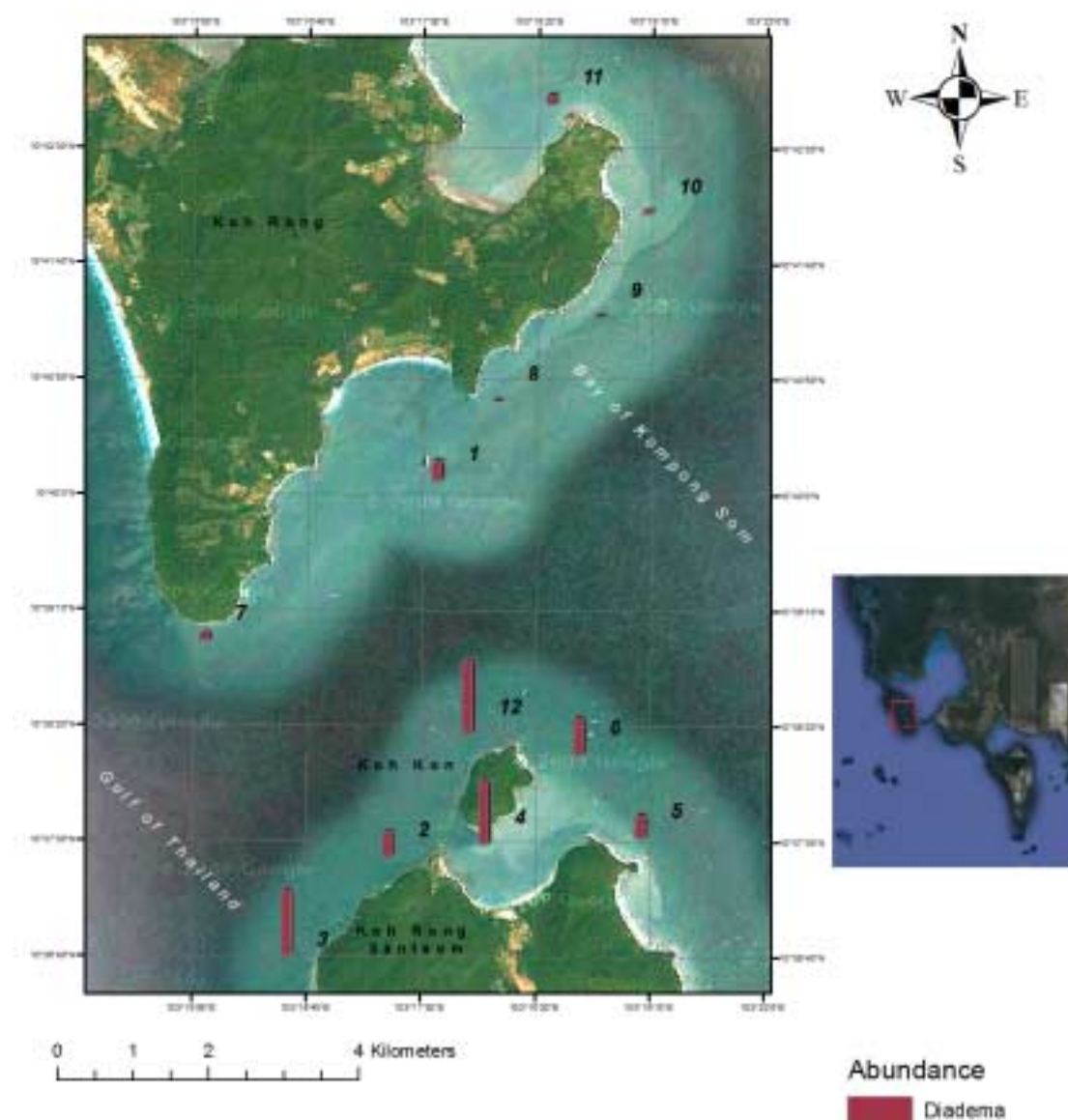


Figure 21 GIS map of abundance of long-spine, *Diadema* sea urchins at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. The height of the bar indicates their abundance per survey sector.

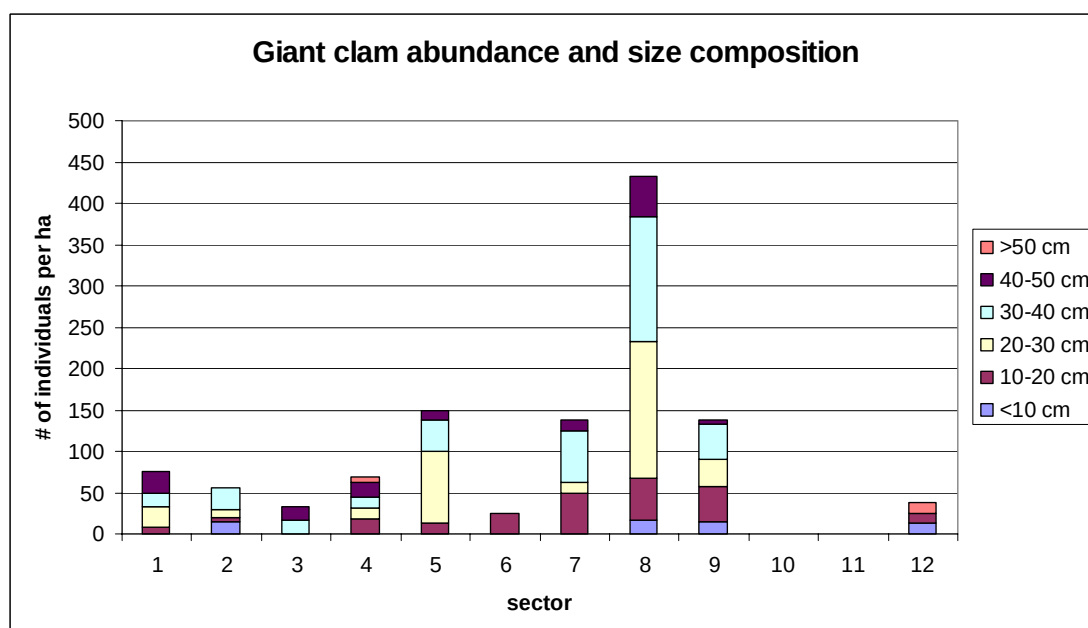


Figure 22 Abundance and size class of Giant clams (*Tridacna spp.*).

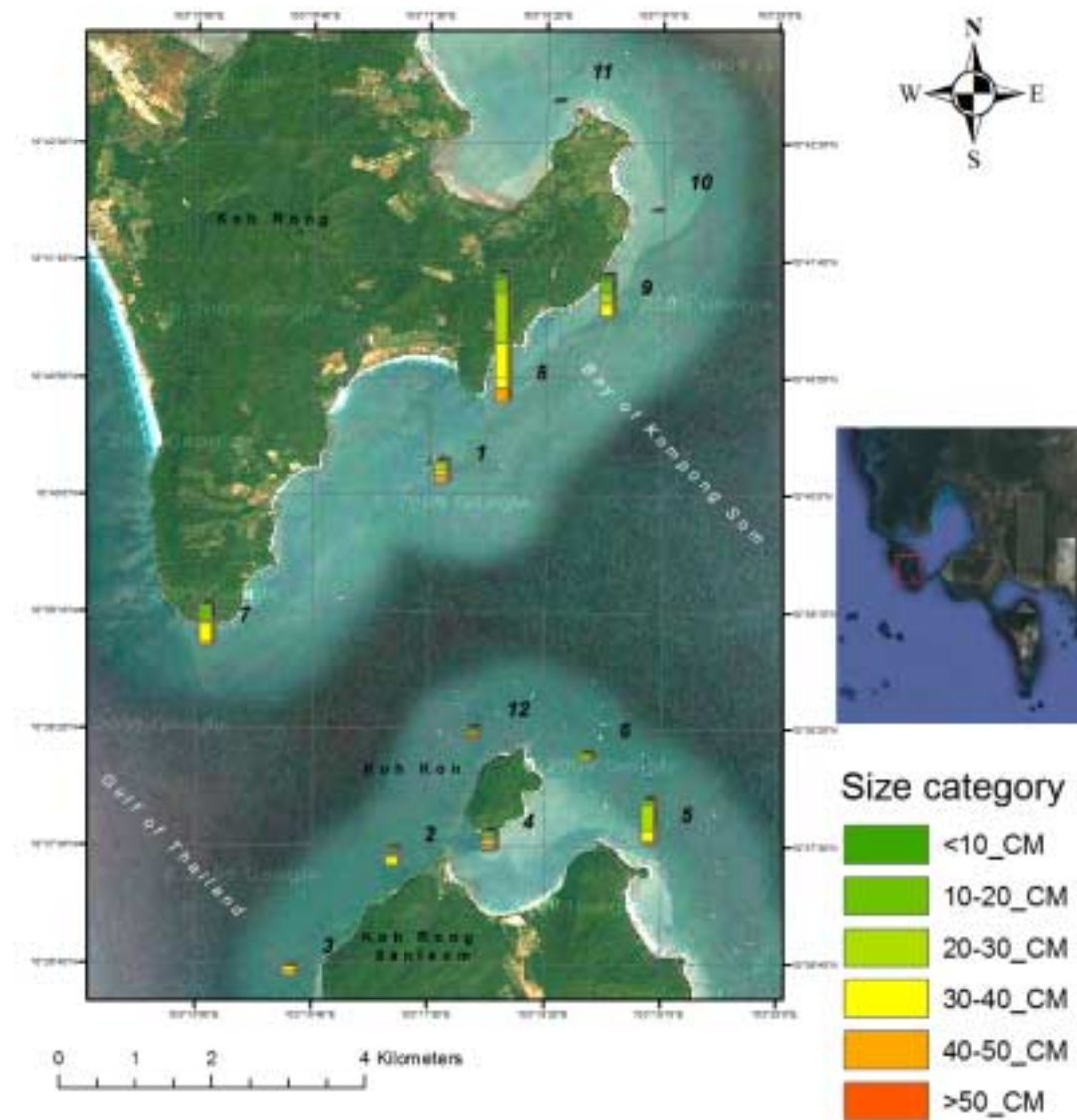


Figure 23 GIS map of abundance of giant clams (*Tridacna* spp.) at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. Stacked bars indicate contribution of each size class. The height of the bar indicates their abundance per survey sector.

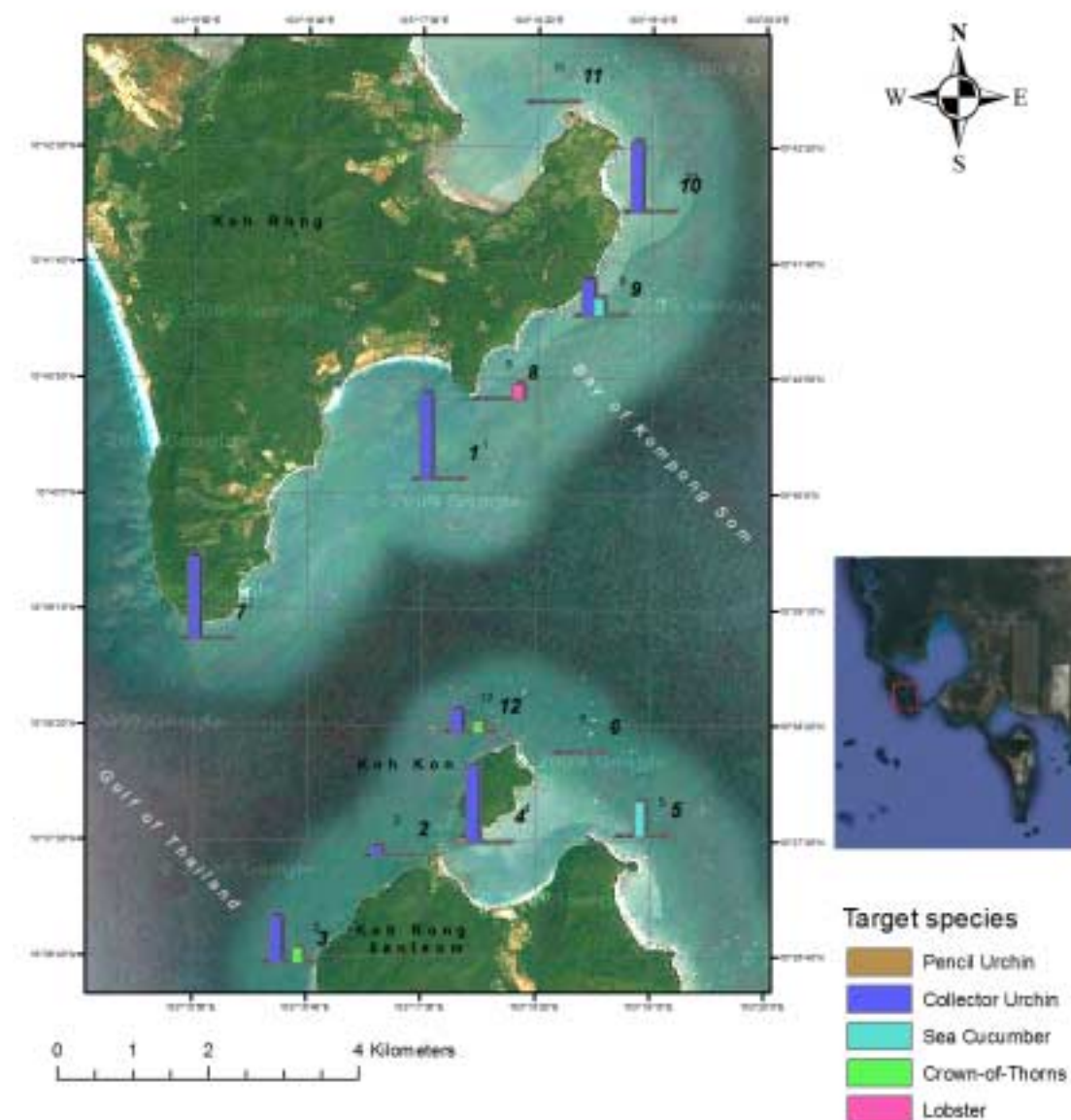


Figure 24 GIS map of abundance of 5 key indicator species invertebrates at 12 different survey sectors around Koh Rong and Koh Rong Sanleom. The height of the bar indicates their abundance per survey sector.

3.5 Comparisons with data collected in 2003

Density of Butterflyfish was estimated to be higher in 2009 compared to UNEP/Dep. of Fisheries data from 2003 (table 2). The density of key commercially fished species dropped for both Grouper and Snappers indicating continued and unsustainable fishing of these species. Parrotfish densities remained similar. Densities of long-spine *Diadema* sea urchins were estimated to be lower in 2009. It should be noted that survey data from 2003 is very limited and the sites surveyed were different between the periods making accurate comparisons difficult.

Table 2 Comparisons of the densities of 4 fish families and *Diadema* Sea urchins in 2003 and 2009

Family (# of individuals per 100m²)	2003	2009
Butterflyfish	1.75	3.25
Snapper	6.5	0.7
Grouper	2.25	0.41
Parrotfish	0.75	0.71
<i>Diadema</i> sea urchins	213	124

4 Discussion and Conclusions

High turbidity due to heavy rainfall during much of the 3-month pilot project severely hampered the scientific survey efforts. In some cases, benthic surveys were conducted but fish transects were omitted due to low underwater visibility. On some occasions, surveys had to be aborted completely due to less than 1 metre visibility. In spite of these challenges, a large amount of detailed data was gathered from around the fringing reefs of the islands.

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. However, the impact of greatest concern was the high level of siltation smothering the reefs. 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.

Coral cover was around 23% on average for all reef sites surveyed. High coral cover (~40%) was found around the north-western side of Koh Kon Island as well as the northern side of Koh Rong Sanleom 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 western side 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. In 2003, surveys carried out by the Department of Fisheries also found 23% hard coral cover although this was based on a few surveys, some of which were not plotted by GPS. Therefore, no exact comparisons can be made.

Our results showed that coral diversity was generally low and most corals were more robust massive or encrusting forms. Some sites along the south-eastern coast of Koh Rong Island has 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 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. There are also several shops along the beach which sell corals and shells.



Figure 25 Corals and shells being sold on Sihanoukville beach

Dead coral, rock and rubble cover was around 33%, slightly lower than the percentage recorded in 2003. It is likely that the high sedimentation levels during the recent surveys meant that levels of silt were much higher than they would be for the rest of the year. Underlying substrates could therefore not be determined. Nutrient indicator (fleshy) algae were found at very low levels. High sedimentation levels may be inhibiting their growth. Coral disease and bleaching levels were generally low although further surveying and monitoring are needed.

The presence or absence of certain reef fish families is an important indicator of overfishing or coral 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 severe population declines in overfished areas. These families were generally quite low in abundance and although not expressed here, 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 (see Toral-Granda et al., 2008).

4.1 Recommendations

Capacity building and education

A lack of in-country capacity to conduct scientific and socio-economic assessments of the fisheries status and community needs means that Cambodia continues to rely on external expertise to address its marine conservation management needs. Through its well-established scholarship training programmes, CCC can assist the FiA in developing in-country capacity, thereby reducing its dependence on foreign expertise for effective coastal monitoring and management.

On a local level, communities can be empowered to get actively involved in the management of their marine resources through similar capacity building programmes. For example, marine park rangers can be provided with training in SCUBA diving and scientific monitoring of coral reefs in addition to informing visitors about the rules and regulations of the park. Similar strategies have been tremendously successful in the Philippines where CCC has assisted in the installation of several small-scale, community-led marine protected areas that have improved local fish stocks in addition to providing income to the communities through a user-fee system.

Public awareness, education and participation of local stakeholders have all been highlighted as key recommendations by the Fisheries Administration. These programs need to be implemented in order to create more community awareness about the importance, value and benefits of sustainable coral reef management. CCC therefore proposes to lead the community engagement through its extensive experience in implementing educational awareness campaigns. These include teacher training workshops, a series of open days for local schools, school visits, beach cleanups and participation at local festivities which will all help increase the environmental awareness and appreciation of the youths.

Scientific surveying and monitoring

The low abundance of key reef fish families such as Parrotfish, Snappers and Groupers warrants the implementation of no-take marine reserves. Such no-take zones protect coral reef biodiversity and allow fish stocks to recover and grow to a size where they produce significantly more offspring than when they are still at a sub-adult size. If allowed to grow to adult size, many reef fish will produce considerably more offspring. A 12.5kg snapper for example, will produce as many offspring as 212 snappers weighing 1.1kg each (Bohnsack, 1990). Increased abundance of commercially targeted fish outside these no-take zones through a 'spill-over' effect will promote a more sustainable, artisanal fishing industry.

Baseline surveys conducted during the pilot phase have provided a substantial database of accurate scientific information from which initial management recommendations can be made. However, most surveys focused on the reef systems close to the project site, mainly on the eastern side of the islands where the seas were calmer. Due to time and weather limitations, the vast majority of reef systems around

the islands were not surveyed. A more complete picture and a better understanding of the status of local reefs in relation to the regional reef health can be gained by expanding the survey programme around the islands. The survey methodologies used during the project are compatible with similar efforts around the Indo-Pacific making comparisons between regions possible.

In addition to baseline surveys, several monitoring stations should be set up at key reef sites so that the areas can be assessed on a quarterly basis in order to monitor the overall reef and fisheries health in addition to sedimentation levels. This information will allow for management plans to be continually assessed and adapted where needed.

Thirdly, a comprehensive inventory should be made of all species of fish, coral, algae, invertebrates etc. This will significantly aid in the understanding of the diversity and distribution of coral reef life, not only in Cambodia but also for the Indo-Pacific region as a whole. Such knowledge would also help to underline the importance of this region for future conservation.

4.2 Management

Survey results presented in this report highlight the need for the implementation of an effective management plan for the area that minimises disturbance to the reef systems (Ing, T., 2003). A crucial step in the implementation process will be to actively engage local communities and empower them to assist in securing their marine resources. This can be achieved through workshops, public events and meetings, capacity building programmes and conservation education.

It is strongly recommended that a management proposal is drafted which can increase local fish stocks and secure areas of high conservation value. For this to be accepted, meetings will need to take place with all stakeholders including the local communities, tourism and development sector, Cambodian Government and NGOs so that clear agreements can be made about the future conservation of the island's marine resources.

Survey results showed varying levels of anchor damage, particularly at popular dive sites. It is advised that mooring buoys are installed at these sites so that dive vessels no longer have to throw out their anchors, thereby limiting the damage to these reefs from recreational activities. CCC can assist in designating appropriate locations and installing the buoys.

4.3 Conclusions

The proposed development plans for Koh Rong Island will put a significant amount of stress on the area's coral reef resources. Mitigation measures aimed at minimizing the amount of land run-off, sewage outfall and direct impacts to the reef need to be implemented as part of the development plans.

A high variation in coral reef health was found across the area surveyed with some sites displaying reefs with a high abundance and variety of coral and fish species. The

magnificent beauty and diversity of both marine and terrestrial life around the islands, coupled with some stunning scenery make it a prime location for visitors from around the world. Promoting this area as an eco-destination will help to provide income to the local communities and encourage the sustainable management of the natural resources on which they depend.

The implementation of a holistic management approach to the successful preservation of the marine habitats of Koh Rong and Koh Rong Sanleom in the face of considerable coastal development and human-induced climate change is essential. 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.



Figure 26 The reefs around the islands off Phrash Sihanouk Province are a paradise for underwater macro-life enthusiasts (*image taken by Sarah King*)

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Appendix - Reef Check Survey Forms

Survey Site Form

Site name:							
BASIC INFORMATION							
Country:		State/Province:		City/town:			
Date:		Time: Start of survey:		End of survey:			
Latitude (deg. min. sec):		Longitude (deg. min. sec):					
From chart or by GPS? (If GPS, indicate units):		Chart:		GPS:		GPS units:	
Orientation of transect:		N-S:		E-W:		NE-SW:	
Temperature (°C):		Air:		surface:		at 3m:	
						at 10m:	
Distance from shore (m):				from nearest river (km):			
River mouth width:		<10 m		11-50 m		51-100 m	
						101-500 m	
Distance to nearest population center (km):				Population size (x1000):			
Weather:		sunny:		cloudy:		raining:	
Visibility (m) :							
Why was this site selected:				Is this best reef in the area?		Yes: No :	
IMPACTS:							
Is this site sheltered?:		Always:		Sometimes:		Exposed:	
Major coral damaging storms		Yes:		No:		If yes, when was last storm:	
Overall anthropogenic impact		None:		Low:		Med:	
						High:	
Is siltation a problem		Never:		Occasionally:		Often:	
						Always:	
Blast fishing		None:		Low:		Med:	
						High:	
Poison fishing		None:		Low:		Med:	
						High:	
Aquarium fishing		None:		Low:		Med:	
						High:	
Harvest inverts for food		None:		Low:		Med:	
						High:	
Harvest inverts for curio sales		None:		Low:		Med:	
						High:	
Tourist diving/snorkeling:		None:		Low:		Med:	
						High:	

Sewage pollution (outfall or boat)	None:	Low:	Med:	High:
Industrial pollution	None:	Low:	Med:	High:
Commercial fishing (fish caught to sell for food)	None:	Low:	Med:	High:
Live food fish trade	None:	Low:	Med:	High:
Artisinal/recreational (personal consumption)	None:	Low:	Med:	High:
How many yachts are typically present within 1km of this site	None:	Few (1-2):	Med (3-5):	Many (>5):
Other impacts:				
PROTECTION:				
Any protection (legal or other) at this site?	Yes:	No:	If yes, answer questions below	
Is protection enforced	Yes:	No:		
What is the level of poaching in protected area?	None:	Low:	Med:	High:
Check which activities are banned:	Spearfishing Commercial fishing Recreational fishing Invertebrate or shell collecting Anchoring Diving Other (please specify)			
Other comments				
TEAM INFORMATION				
Submitted by	Regional Coordinator: Team Leader: Team Scientist: Team Members:			

Line Transect Form

Site

name:

Country/Island:

Depth:

Date:

TS/TL:

Data recorded by:

Time:

Substrate Code

HC hard coral

SC soft coral

RKC recently killed coral

NIA nutrient indicator algae

SP sponge

RC rock

RB rubble

SD sand

SI silt/clay

OT other

(For first segment, if start point is 0 m, last point is 19.5 m)

SEGMENT 1			SEGMENT 2			SEGMENT 3			SEGMENT 4		
0 - 19.5 m			25 - 44.5 m			50 - 69.5 m			75 - 94.5 m		
0	10	25	35	50	60	75	85				
0.5	10.5	25.5	35.5	50.5	60.5	75.5	85.5				
1	11	26	36	51	61	76	86				
1.5	11.5	26.5	36.5	51.5	61.5	76.5	86.5				
2	12	27	37	52	62	77	87				
2.5	12.5	27.5	37.5	52.5	62.5	77.5	87.5				
3	13	28	38	53	63	78	88				
3.5	13.5	28.5	38.5	53.5	63.5	78.5	88.5				
4	14	29	39	54	64	79	89				
4.5	14.5	29.5	39.5	54.5	64.5	79.5	89.5				
5	15	30	40	55	65	80	90				
5.5	15.5	30.5	40.5	55.5	65.5	80.5	90.5				
6	16	31	41	56	66	81	91				
6.5	16.5	31.5	41.5	56.5	66.5	81.5	91.5				
7	17	32	42	57	67	82	92				
7.5	17.5	32.5	42.5	57.5	67.5	82.5	92.5				
8	18	33	43	58	68	83	93				
8.5	18.5	33.5	43.5	58.5	68.5	83.5	93.5				
9	19	34	44	59	69	84	94				
9.5	19.5	34.5	44.5	59.5	69.5	84.5	94.5				

What percentage of recorded RKC is a result of bleaching?

Comments:

Belt Transect Form - Fish

Site Name: _____ Depth: _____ Date: _____	Country/Island: _____ Team Leader: _____ Time: _____
---	--

Fish

Data recorded by:

	0-20m	25-45m	50-70m	75-95m
Butterflyfish (Chaetodontidae)				
Sweetlips (Haemulidae)				
Snapper (Lutjanidae)				
Barramundi cod (<i>Cromileptes altivelis</i>)				
Humphead wrasse (<i>Cheilinus undulatus</i>)				
Bumphead parrotfish (<i>Bolbometopon muricatum</i>)				
Other parrotfish (Scaridae) only >20 cm				
Moray eel (Muraenidae)				
Grouper (Serranidae) sizes (cm) (count ONLY >30cm):	0-20m	25-45m	50-70m	75-95m
30-40 cm				
40-50 cm				
50-60 cm				
>60 cm				
Total # grouper				
Rare animals sighted (type/#)				
Comments:				

Belt Transect Form - Invertebrates

Site Name: _____		Country/Island: _____		
Depth: _____		Team Leader: _____		
Date: _____		Time: _____		
Data recorded by: _____				
<u>Invertebrates</u>	0-20m	25-45m	50-70m	75-95m
Banded coral shrimp (<i>Stenopus hispidus</i>)				
Diadema urchins (including <i>Echinothrix</i> spp.)				
Pencil urchin (<i>H. mammilatus</i>)				
Collector urchin (<i>Tripneustes</i> spp.)				
Sea cucumber (Holothuridae)				
Crown of thorns (<i>Acanthaster planci</i>)				
Triton (<i>Charonia tritonis</i>)				
Lobster (Palinuridae)				
Giant clam (<i>Tridacna</i> sp.) sizes	0-20m	25-45m	50-70m	75-95m
<10 cm				
10-20 cm				
20-30 cm				
30-40 cm				
40-50 cm				
>50 cm				
Total # giant clams observed				
<u>Impacts: Coral Disease/ Bleaching/Trash/Other</u>	<i>0 = none, 1 = low, 2 = medium and 3 = high</i>			
	0-20m	25-45m	50-70m	75-95m
Coral damage: Boat/Anchor				
Coral damage: Dynamite				
Coral damage: Other				
Trash: Fish nets				
Trash: General				
Bleaching (% of coral population)				
Bleaching (% of colony)				
Coral Disease (% of coral affected if yes)				
Rare animals sighted (type/#)				