

Coral Cay Conservation, 2012

Initial scientific findings to support the designation of a MPA around Koh Rong Isl., Cambodia

Presented to the Fisheries Administration, Ministry of Agriculture, Forestry and Fisheries



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1 Introduction

Cambodia has a rich abundance of fringing reef, but the overall status of these reefs is poorly researched and documented. On invitation of the Fisheries Administration (FiA) of the Cambodian Ministry of Agriculture, Forestry and Fisheries, Coral Cay Conservation, a British NGO, has conducted research on the state of coral reefs around the islands of Koh Rong, Koh Kon and Koh Rong Samloem, Phreah Sihanouk Province. With anthropogenic pressure likely to increase in the next decade as a result of a large scale tourism development on Koh Rong, the need for baseline data of reef health is vitally important. Abundance and diversity data of coral, fish, and invertebrates in addition to substrate composition data collected since 2009 indicate that there are certain sites around the islands that still maintain relatively good coral cover and high fish abundance. There are strong indications however, that coral reefs around the islands are deteriorating. In light of this and with the proposed tourism development on Koh Rong, the FiA is currently working with local stakeholders and NGOs to implement a multiple-use marine protected area.

1.1 Report aim

The purpose of this report is to provide an initial overview of the health of the reefs around Koh Rong and provide a review of the baseline data gathered thus far. This information will then be used to help create a management tool to inform the effective implementation of multiple-use zoning schemes around the island, as proposed by the FiA. Findings from this report will be combined with work done by Marine Conservation Cambodia (MCC) and others in order to provide a complete picture of the current status of coastal resources around Koh Rong and Koh Rong Samloem.

It should be noted that this report does not present results from the mass-bleaching event that occurred in the area between March-June of 2010. For information on this, please see the previous Year 1 project report, available for download from the Coral Cay website, www.coralcay.org.

2 Methods

Reef Check methodology (Hodgson, et al., 2006) was used to survey reef sites around Koh Rong island 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. For the purposes of this project, specific indicator species were selected to provide more comprehensive information on the diversity of reef sites. 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) transects (Figure 1).

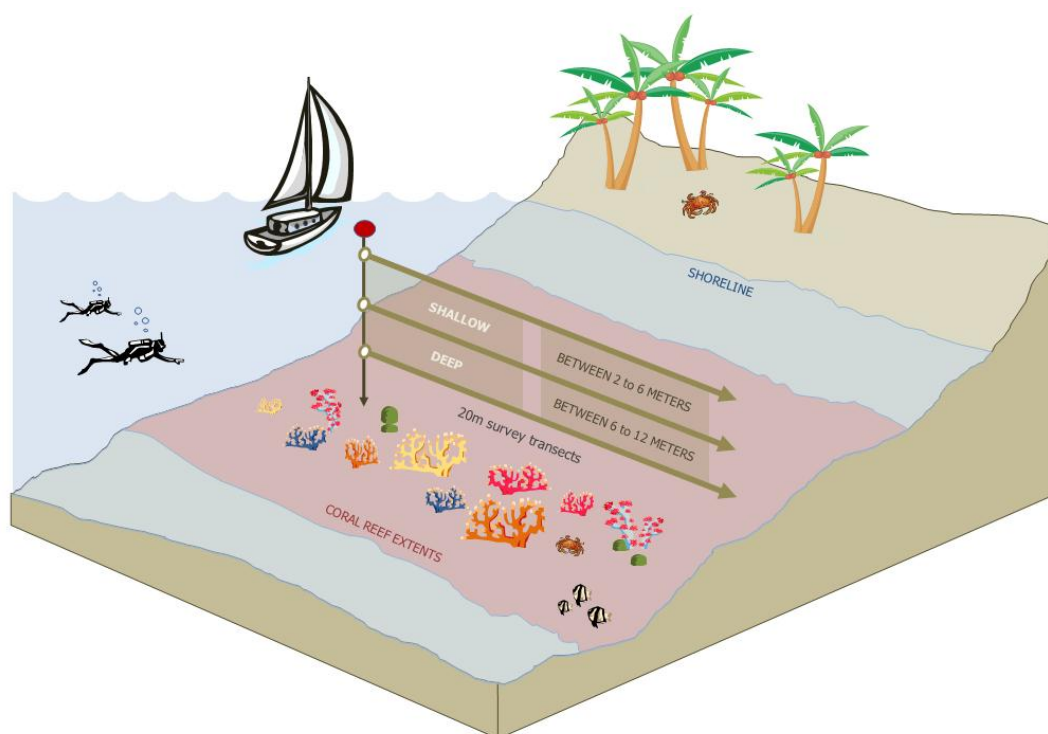


Figure 1 Schematic diagram of the survey depths, conducted parallel to the shoreline

Along each depth contour, four 20m transect replicates were marked out and surveyed to make up one complete survey (Figure 2). 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.

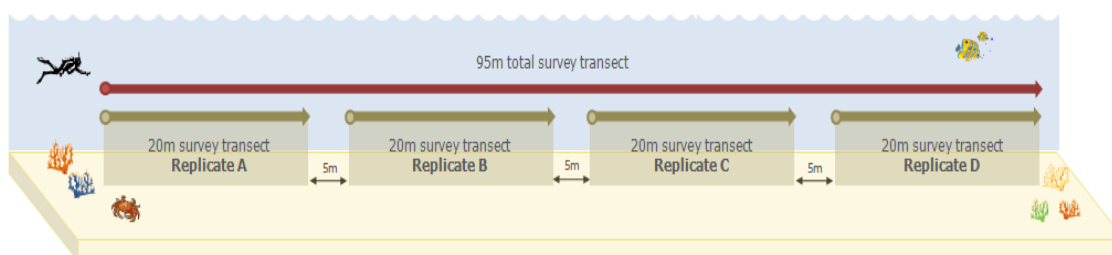


Figure 2 Schematic diagram of the transect setup

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 A 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 were 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 3). 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 3). 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 3). 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 Table1). Otherwise, a note was made of the coral life form.

5. Coral Bleaching, Trash and Impact Damage— 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 3). 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.

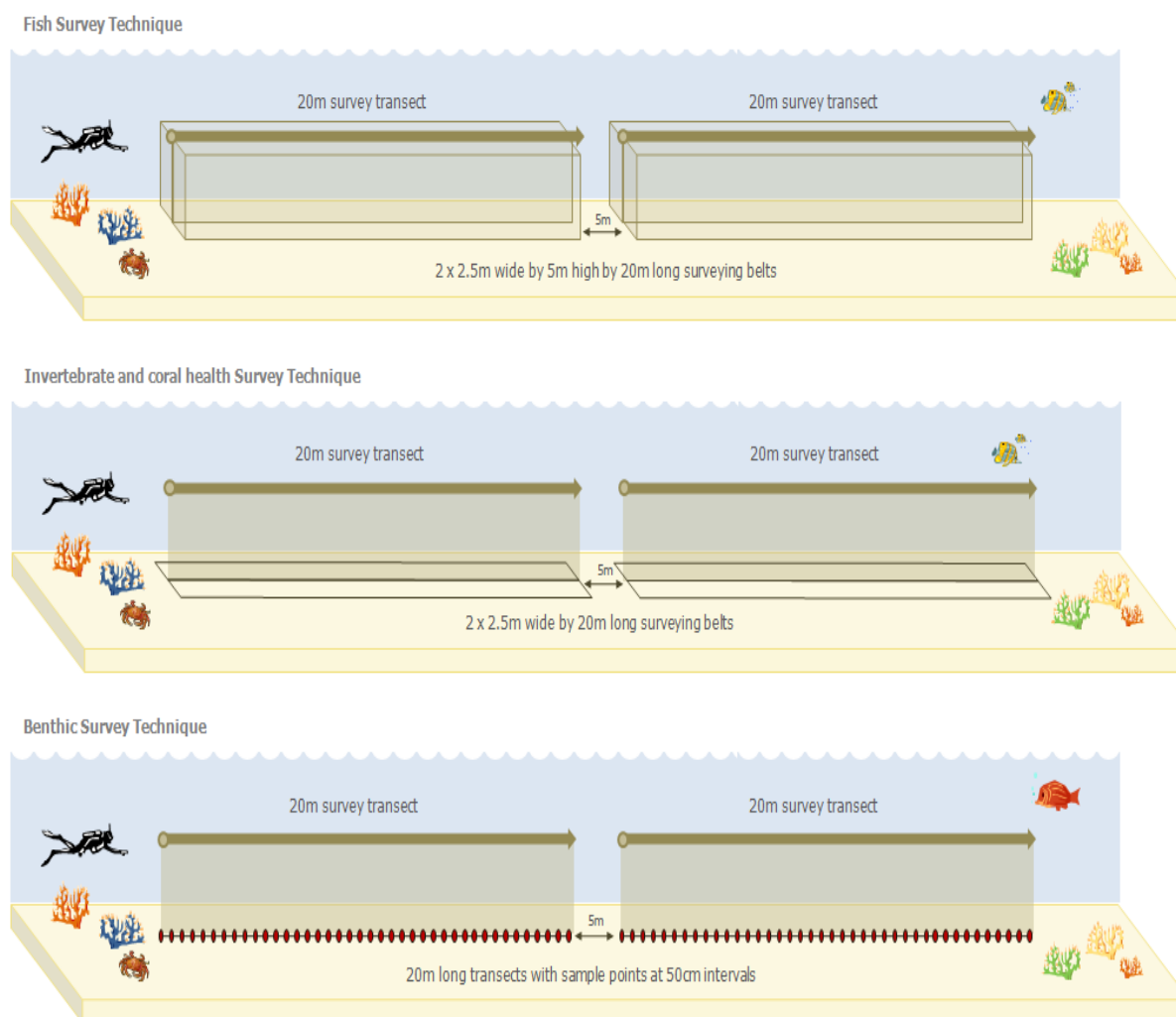


Figure 3 Schematic diagrams of the 3 survey roles – Fish surveyor (top), Invertebrate and Coral Health (middle) and Benthic surveyor (bottom). This diagram displays two of the four 20-metre replicates conducted as part of one complete depth contour at each survey depth

2.2 Data entry and analysis

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 and fish 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 from around Koh Rong into different sectors (23 sectors in total) (Figure 4 and Table 1) 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. In some cases, no information was gathered from deep sites as the reef did not extend to more than 6 metres. All deep sites were found on the western side of the island.

In order to simplify both the analysis and graphical representation of certain data sets, some target groups where no individuals were recorded or where the numbers recorded significantly biased the analysis, were omitted. A total of 14 coral life forms were looked for during the survey dives. However, only 5 (non-acropora encrusting, massive, foliose, sub-massive and mushroom) were observed on deep transect and 7 (those mentioned previously plus, acropora branching and tabulate) on shallow transects. Furthermore, fusiliers were omitted from the predatory fish analysis due to their high tendency to form large schooling aggregations that distorted survey results, where observed.

Table 1 number of shallow and deep sites per sector area.

Sector	Shallow sites	Deep sites	Total sites	Sector	Shallow sites	Deep sites	Total sites
1	2	0	2	13	4	0	4
2	3	0	3	14	1	0	1
3	3	3	6	15	3	0	3
4	4	3	7	16	2	0	2
5	5	4	9	17	1	0	1
6	3	3	6	18	1	0	1
7	2	1	3	19	2	0	2
8	4	1	5	20	2	0	2
9	5	3	8	21	3	0	3
10	3	3	6	22	3	0	3
11	3	0	3	23	4	0	4
12	3	0	3				

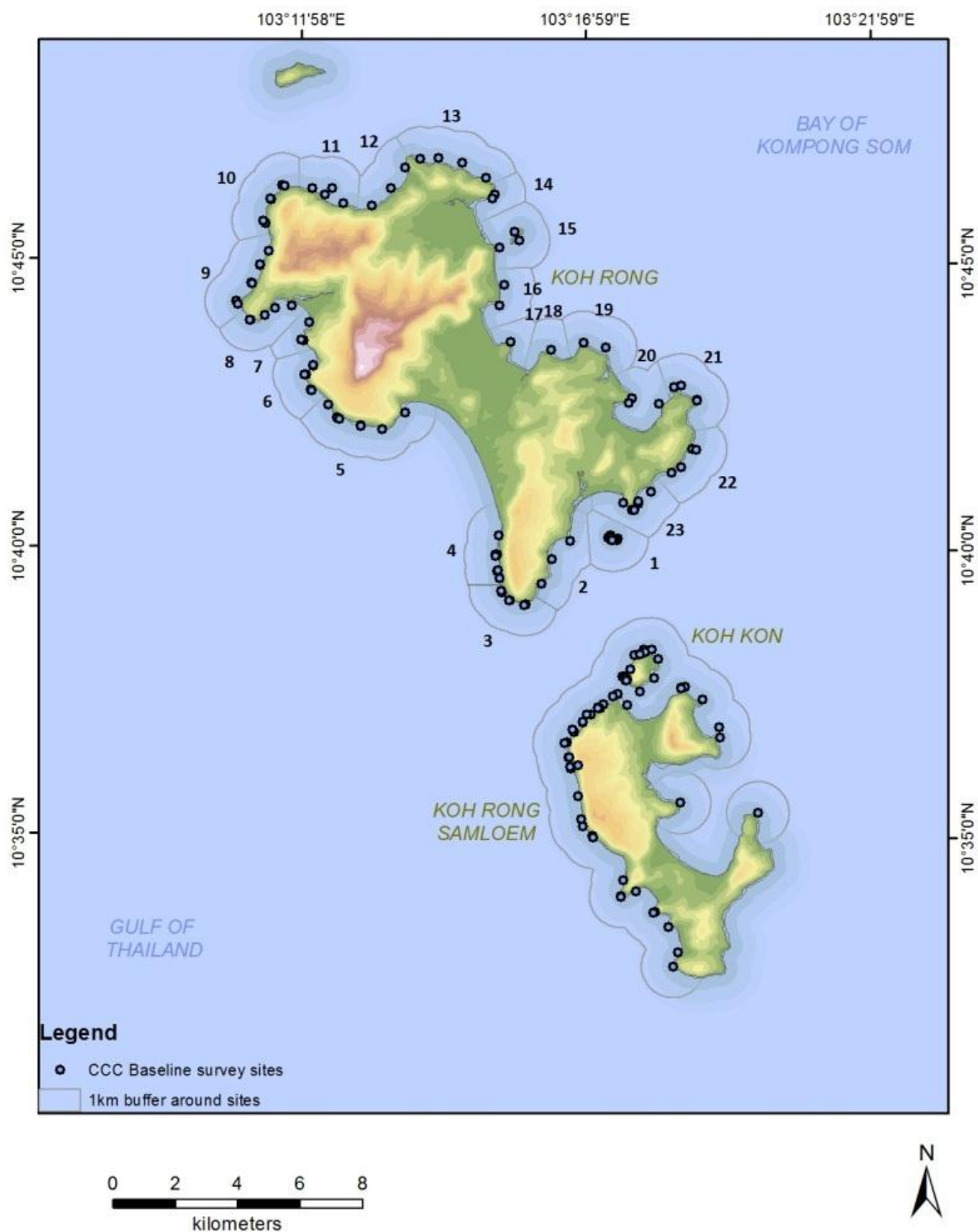


Figure 4 GIS map of CCC survey sector locations around Koh Rong. Sites surveyed around Koh Rong Samloem and Koh Kon have also been included into this map.

3 Results

The outputs from the surveys are presented in graphical format for around Koh Rong and in GIS format for Koh Rong (KR), Koh Kon (KK) and Koh Rong Samloem (KRS) islands. These aim to provide a general picture of the current status of coral reefs around the islands and inform the positioning of multiple usage zones within the marine protected area. The analysis is based on 189 individual survey dives conducted by CCC survey teams between July 2010 and February 2012.

The data are represented in a number of ways:

- Biological indicators, i.e. Benthic composition (Section 3.1) and Reef fish families (Section 3.2)
- Reef Health, i.e. Anthropogenic impacts (Section 3.3)

3.1 Benthic cover and composition

The dominant substrates observed on surveys were rock, sand and live hard coral (Figure 5-6, 10-11). 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 shallow transects and 23% for deep transects with a large variation between survey sectors. Highest coral cover on shallow transects was found to be at sector 3 (40%) with sectors 1, 7, 8 and 11 also displaying high coral cover (Figure 7). Sectors 2, 14, 18 and 20 all had hard coral cover of less than 10%. For deep transects, sector 7 (48%) displayed the highest coral cover with sector 8 also displaying high cover (Figure 8). Sectors 5 and 6 had the lowest coral cover of less than 15%. Across shallow sites non-acropora massive life form corals were dominant with non-acropora encrusting also frequently observed. On deep sites non-acropora encrusting is the dominant life-form.

Rock and sand were also dominant substrates across both deep and shallow sites with sector 20 on shallow transects displaying 70% sand cover and sector 6 on deep transects displaying 52% rock cover.

Recently killed coral was less than 1% for all sectors, and at all depth ranges (Figures 10 and 11). Additionally the levels of nutrient indicator algae, soft coral and sponge were low across all sectors at all depth ranges (2%, 2% and 7% respectively).

Coral species diversity was generally low across all sectors and depth ranges and comprised mainly massive colonies such as *Porites* colonies (27%) and *D. heliopora* (13%). *Favites* and *Favia* colonies were also relatively high with 10% and 7% respectively (Table 3).

Coral diversity was estimated through a Shannon Weiner Diversity Index. Coral diversity was higher on deep sites than shallow sites in all but one sector (9) (Figure 12) Sector 2 and 20 had the lowest diversity with index values under 1.

Table 2 Life form and substrates with codes.

Lifform Code	Lifeform
CE	Non-Acropora encrusting
CF	Non-Acropora foliose
CM	Non-Acropora massive
CS	Non-Acropora submassive
CMR	Non-Acropora mushroom
ACB	Acropora branching
ACT	Acropora tabulate

Substrare Code	Substrate
SC	Soft coral
SP	Sponge
RKC	Recently killed coral
RC	Rock
SI	Silt/mud
RB	Rubble
SD	Sand
OT	Other
NIA	Nutrient indicator algae
LHC	Live hard coral

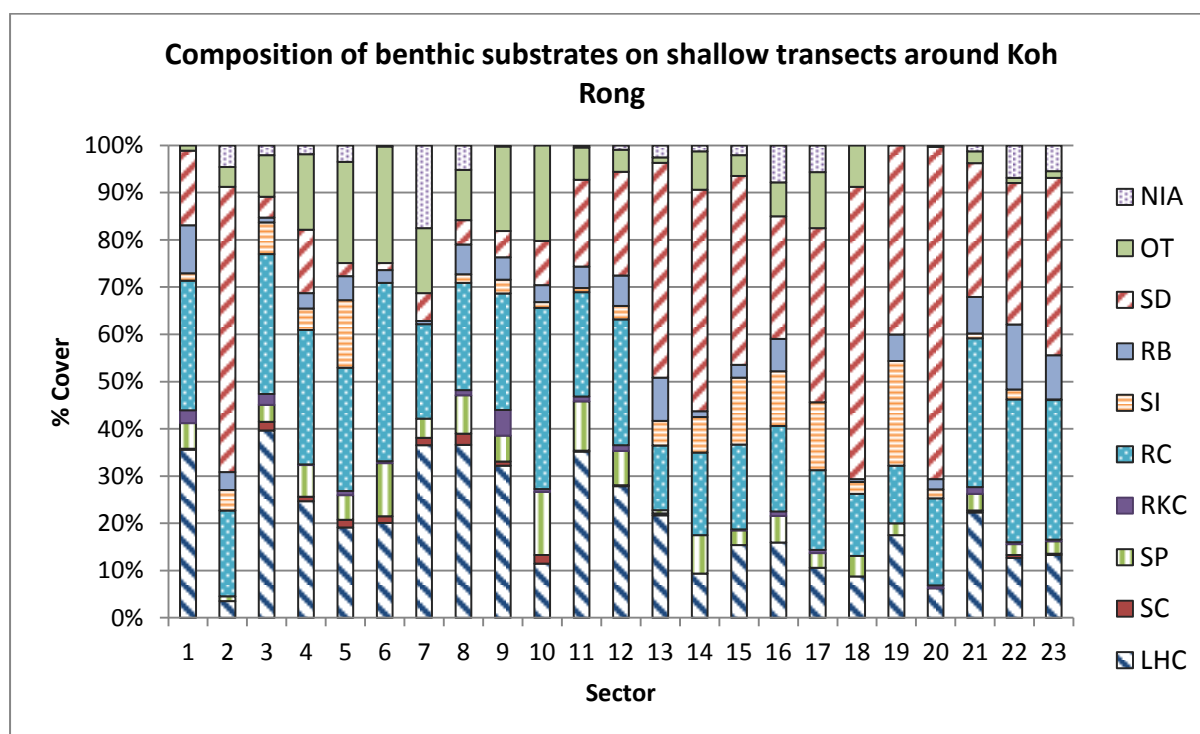


Figure 5 Composition of 10 benthic substrates (biotic and abiotic) at 23 shallow survey sectors around Koh Rong.

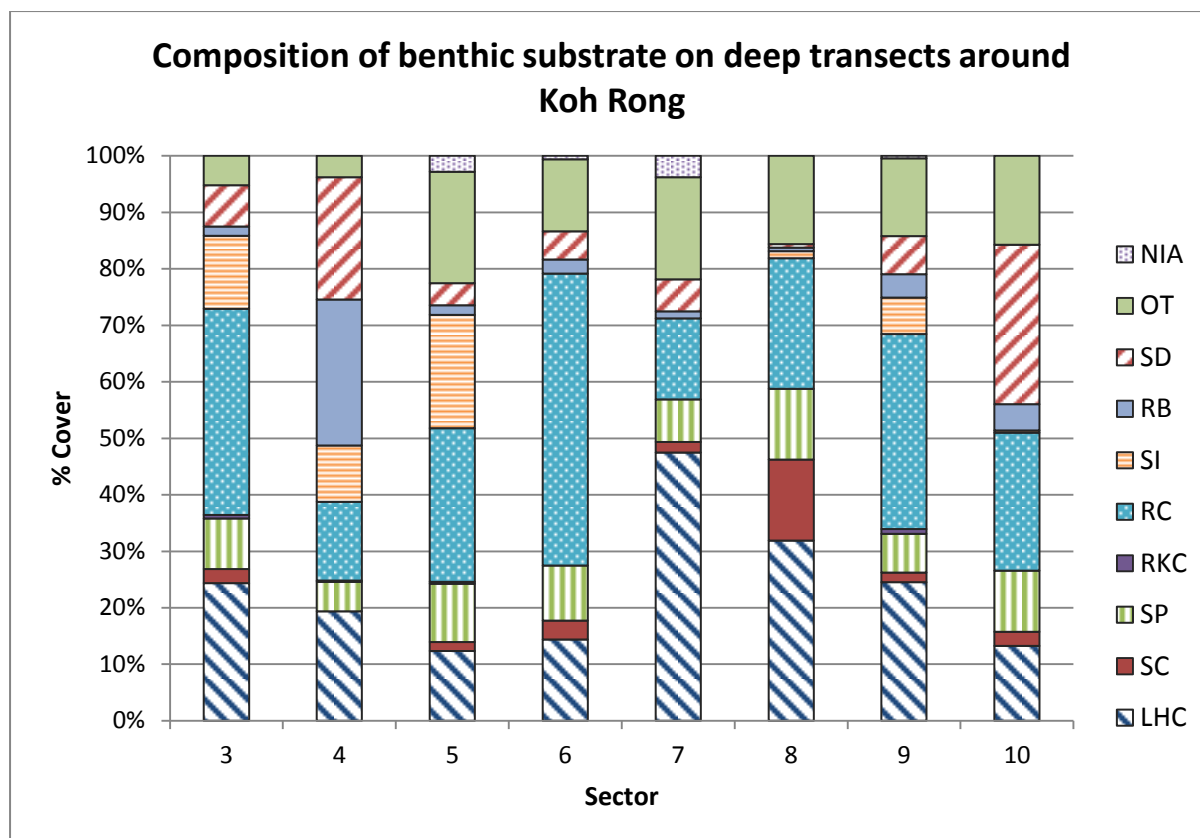


Figure 6 Composition of 10 benthic substrates (biotic and abiotic) at 8 deep survey sectors around Koh Rong.

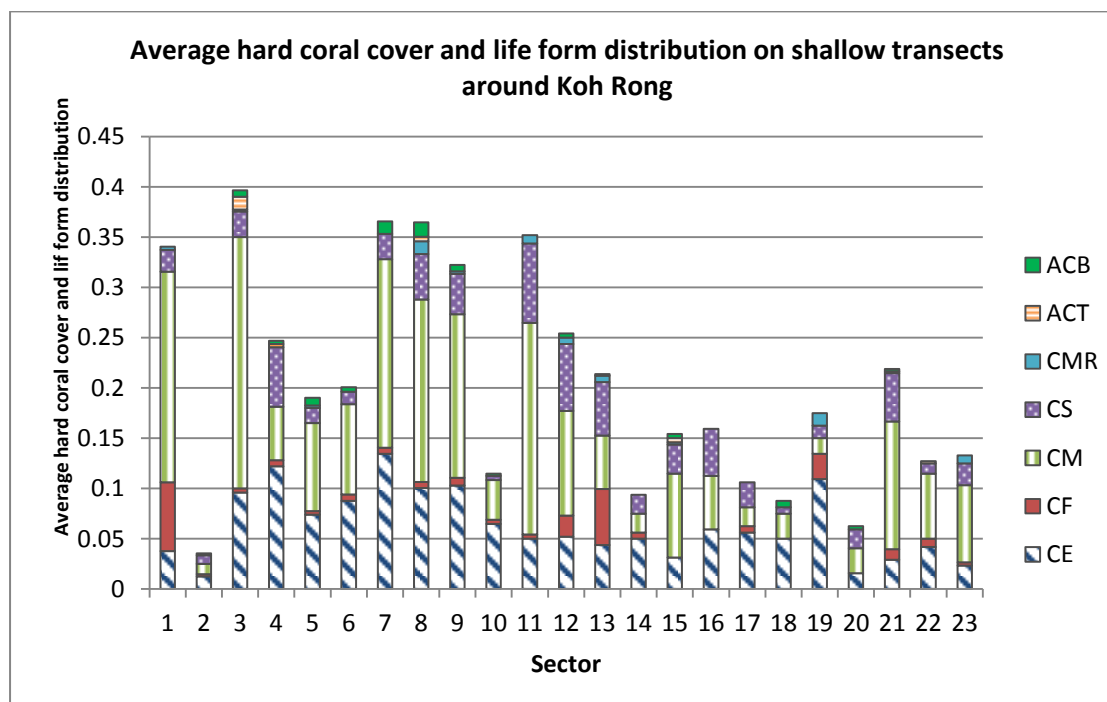


Figure 7 Percentage cover of hard coral and life form distribution on shallow sites

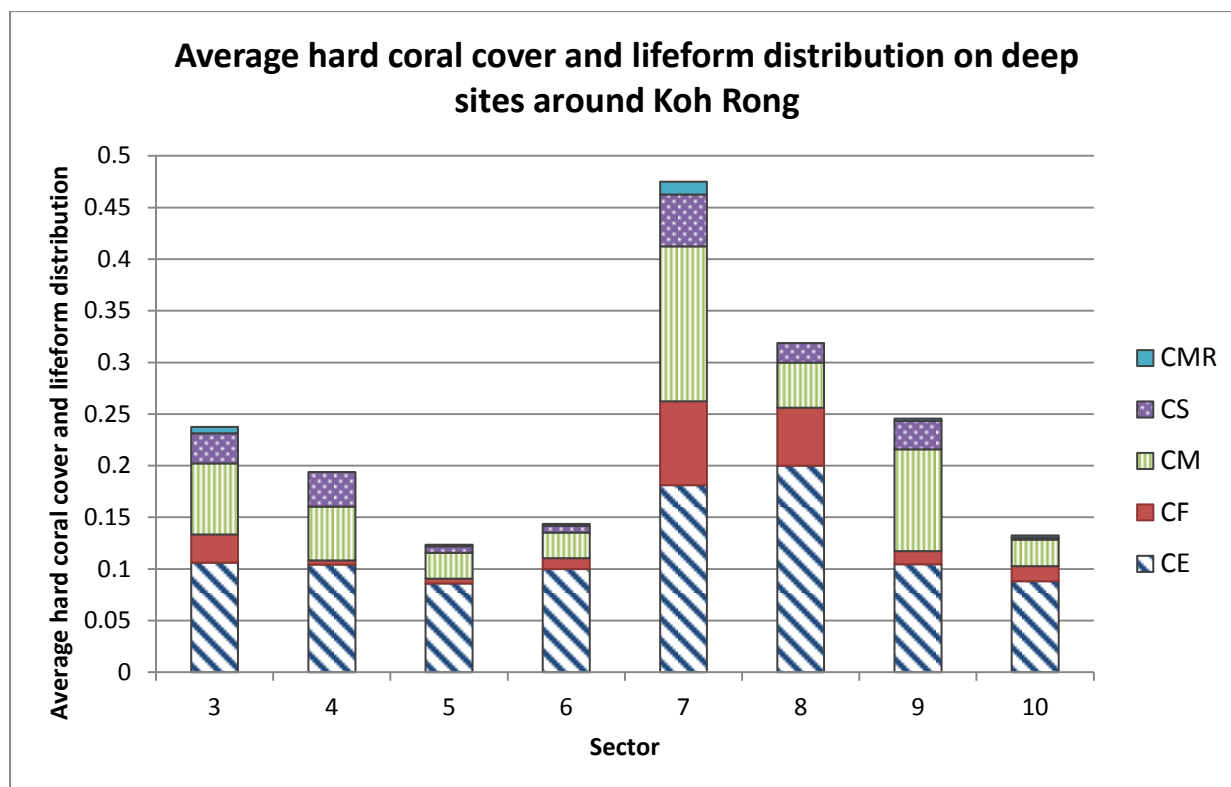


Figure 8 Percentage cover of hard coral and life form distribution on deep sites

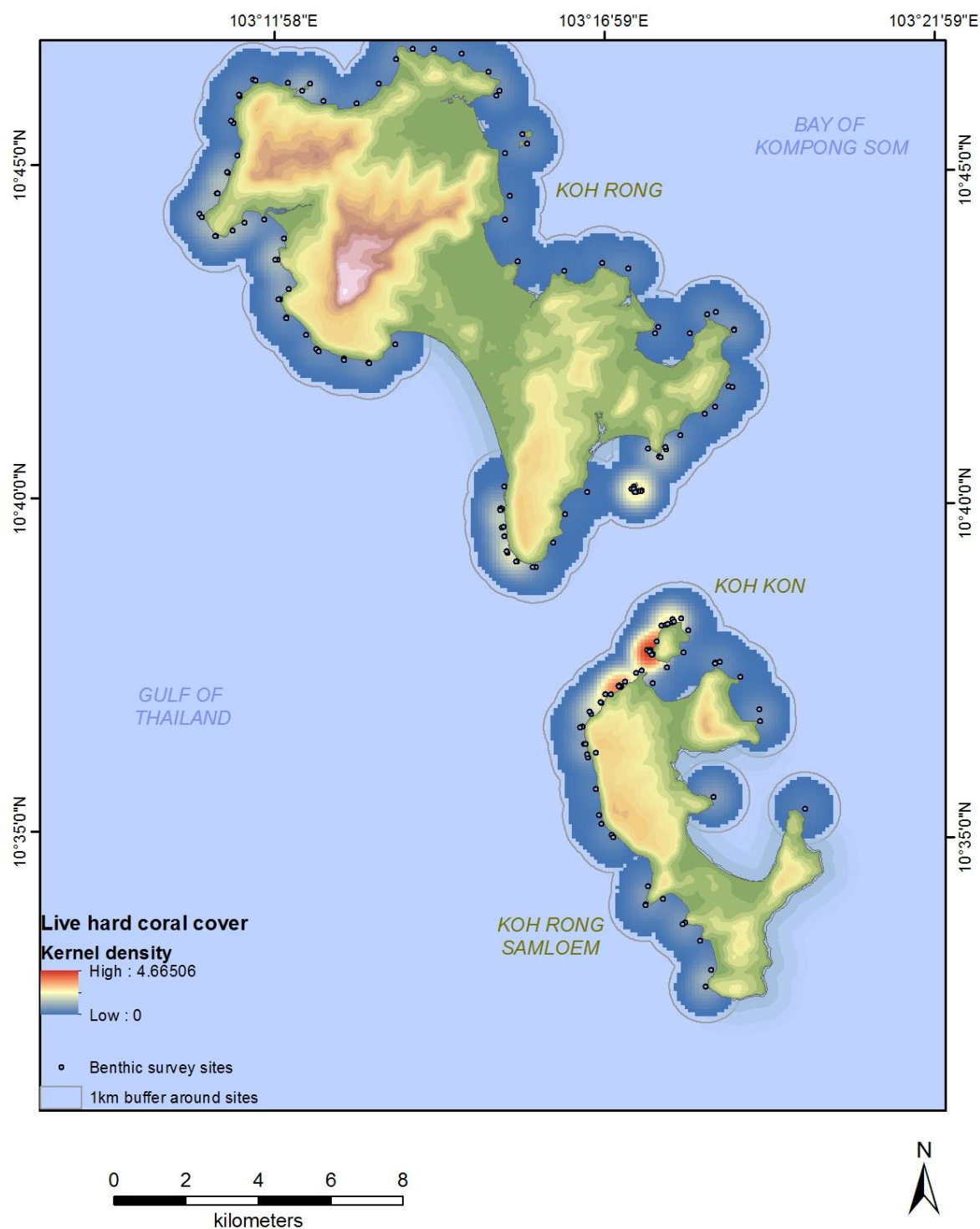


Figure 9 GIS map of kernel density of live hard coral cover around Koh Ron, Koh Kon and Koh Rong Samloem.

Mean percentage of substrate cover around Koh Rong island on shallow transects

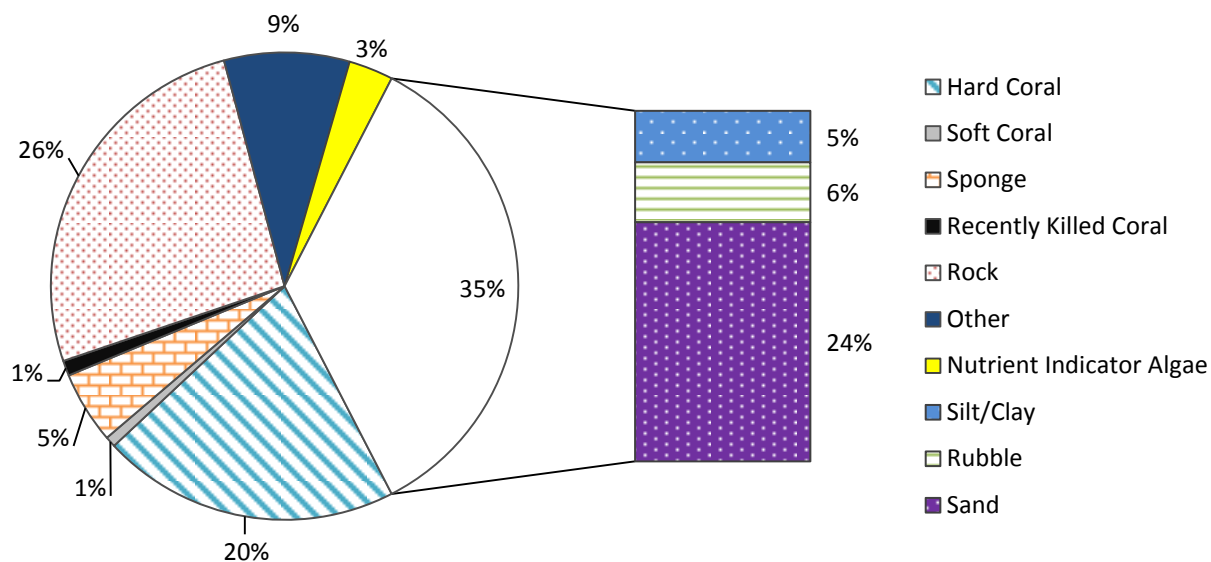


Figure 10 Composition of total benthic substrates for shallow sites

Mean percentage of substrate cover around Koh Rong island for deep transects

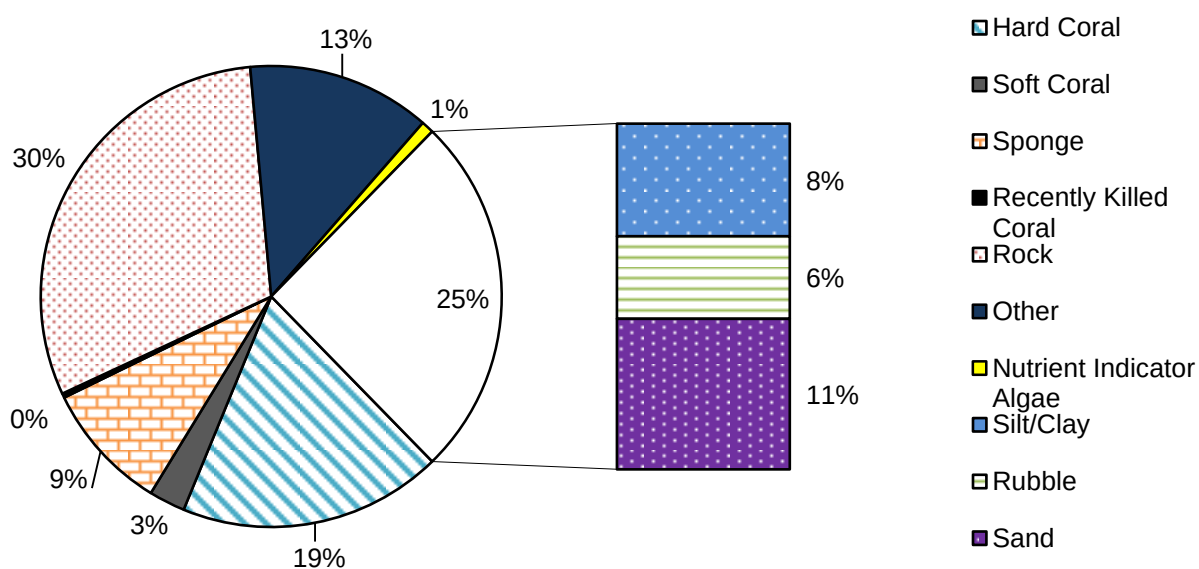


Figure 11 Composition of total benthic substrates for deep sites

Table 3 Coral species composition as a percentage of all target coral species and groups observed on surveys at all depth ranges.

Coral Species	Coral Species code	% Cover
Massive Porites	MP	26.6
Diploastrea h.	DH	13.2
Favites	FVT	9.6
Favia	FVA	7.3
Pseudosiderastrea	PSS	5.8
Galaxea	G	5.6
Goniopora/Alveopora	GA	5.0
Turbinaria	T	4.9
Podabocia	PB	4.4
Pavona decussata	PD	4.2
Astreopora	AS	3.6
Lobophyllia	L	2.1
Brain Small	BS	2.0
Brain Large	BL	1.1
Brain Medium	BM	1.0
Porites rus	PR	0.9
Pavona clavus	PC	0.6
Polyphyllia talpina	PT	0.6
Echinopora	E	0.5
Pocillopora medium	PM	0.4
Plerogyra	PLE	0.3
Montipora encrusting	ME	0.2
Herpolitha limax	HL	0.2
Ctenactis echinata	CE	0.1

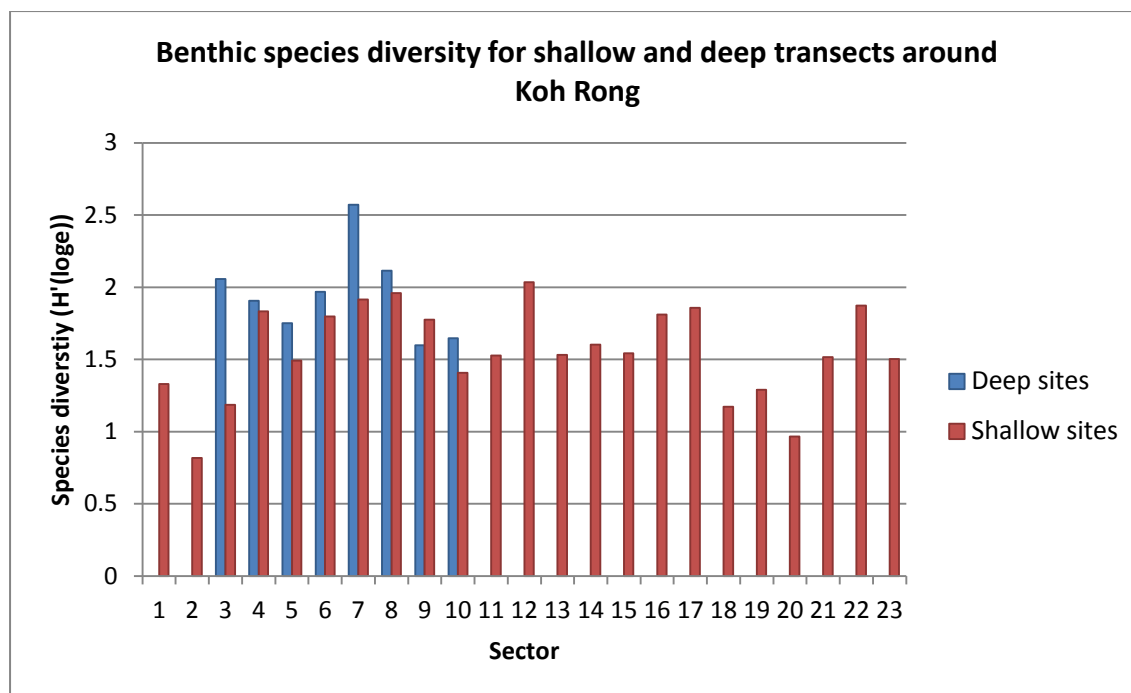


Figure 12 Benthic diversity for deep and shallow transects using the Shannon Weiner Index.

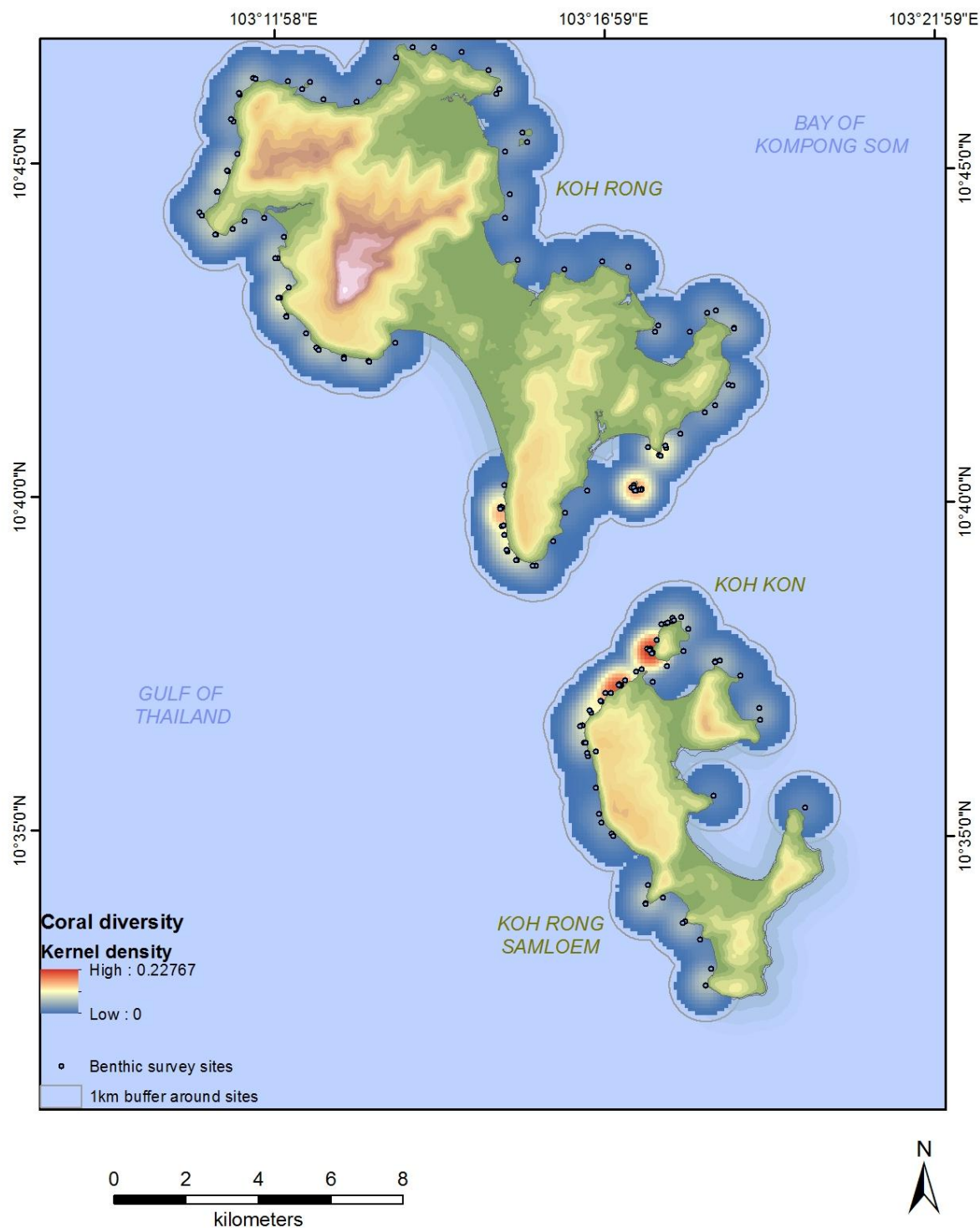


Figure 13 GIS map of kernel density of coral diversity ($H'(\log_e)$) around Koh Rong, Koh Kon and Koh Rong Samloem.

3.2 Fish

Predatory Fish

High abundances of predatory fish are indicative of a healthy reef as this suggests a high level of prey species. Key commercial species such as Grouper (*Serranidae*) and Sweetlips (*Haemulidae*) are highly prized by fishermen, making them vulnerable to overfishing. Densities of these two families were low across all sectors and depth ranges with the highest abundance of Grouper found in sector 3 for both depth ranges and Sweetlips in sector 6 for shallow and sector 8 for deep transects (Figures 14 and 15). Other less commercially prized species such as Barracuda, Jacks and Trevallys, and Emperors were rarely observed across all sectors and depth ranges.

Snappers were the most common family of predatory fish observed on the surveys. Their abundances were highest in sectors 11 for shallow sites and 7 for deep sites (approximately 5750 and 2300 individuals per hectare respectively)

When considered together, abundances of all predatory families/species on shallow sites were generally low (<2000 individuals of all species per hectare), with the exception of sectors 2 and 11. There were no predatory fish found in sectors 14 and 18 on shallow sites possibly suggesting high fishing pressure or unsuitable (degraded) habitats in these areas. On deep sites abundance was slightly higher with four sectors above 2000 individuals per hectare (4, 5, 7, 8).

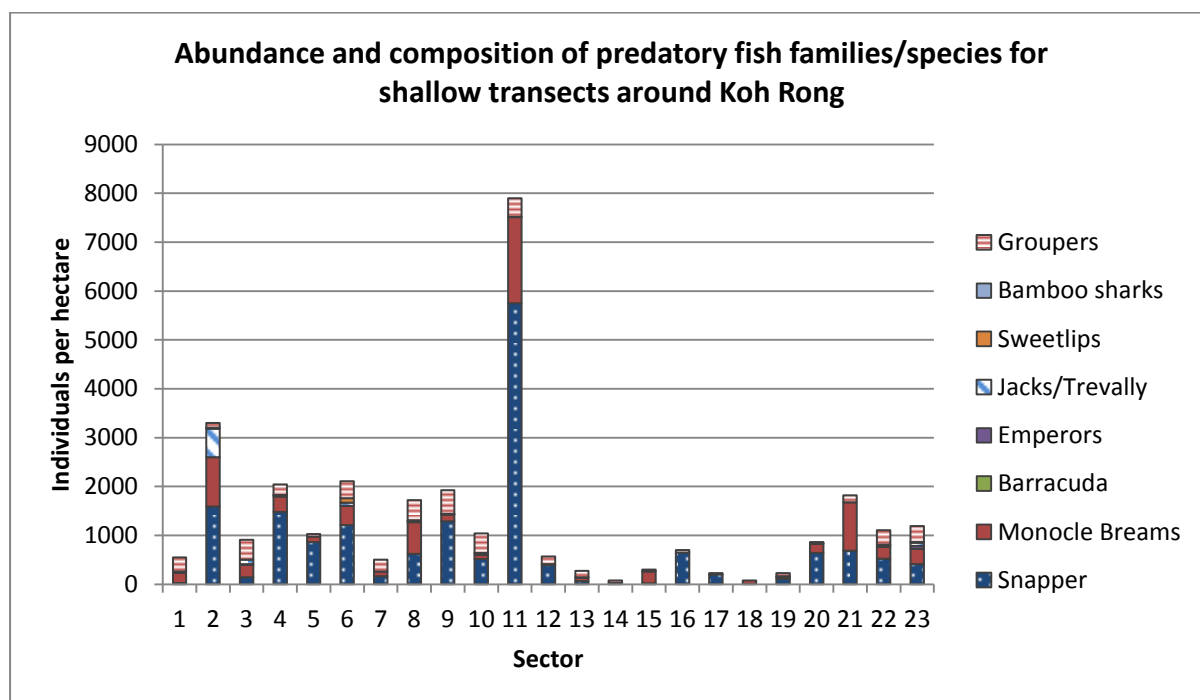


Figure 14 Densities (#/ha) of predatory fish per survey sector with species distribution on shallow sites

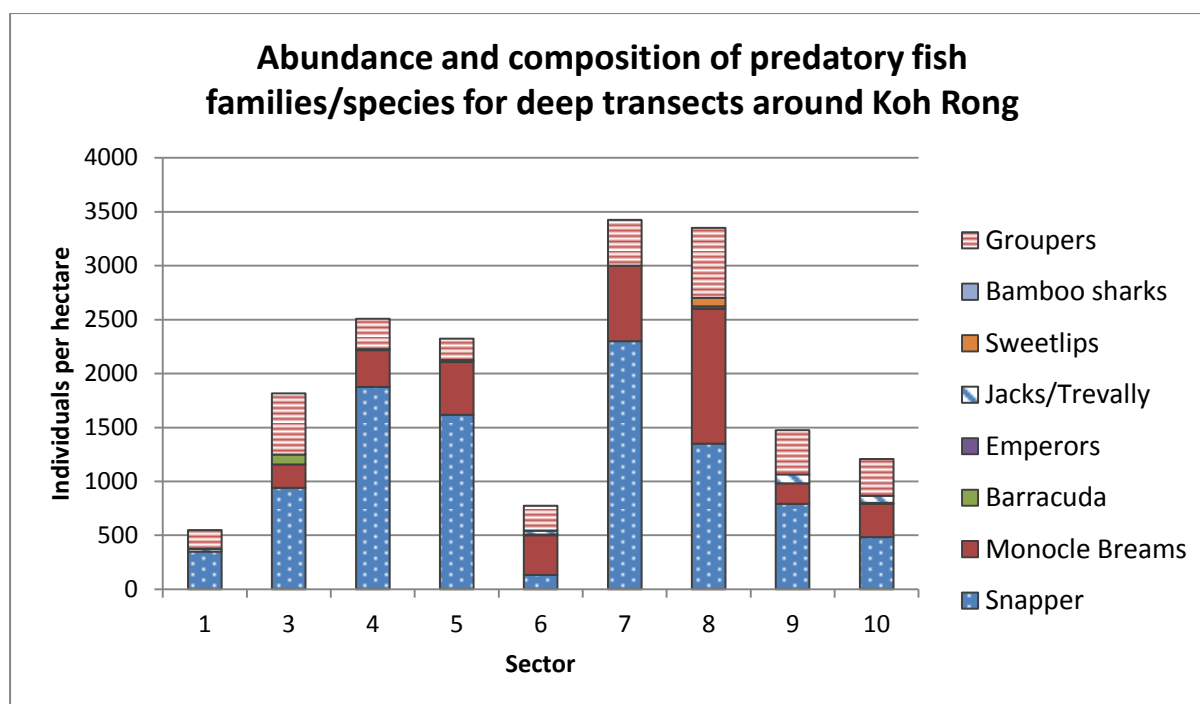


Figure 15 Densities (#/ha) of predatory fish per survey sector with species distribution on deep sites

Grouper are apex predators and vital keystone species in reef communities. Due to their role in reef systems they are considered important indicators of reef health with an abundant and diverse population being indicative of a healthy reef. Furthermore, as a prized commercial species targeted by fishermen, sites with high numbers of grouper may suggest lesser human impact through fishing and a correspondingly healthier reef system.

The highest abundance of grouper on shallow sites occurred in sector 9 (485 individuals/ha) with sectors 8 and 3 also having high abundance (Figure 16). For deep sites the greatest abundance was observed at sector 8 with sector 3 also high (Figure 17). The lowest abundances were observed at sectors 17 and 18 for shallow sites with no individuals seen and at sector 1 for deep sites. For both deep and shallow sites the majority of individuals were observed were in size categories up to 20cm. Very few individuals were observed above 40cm.

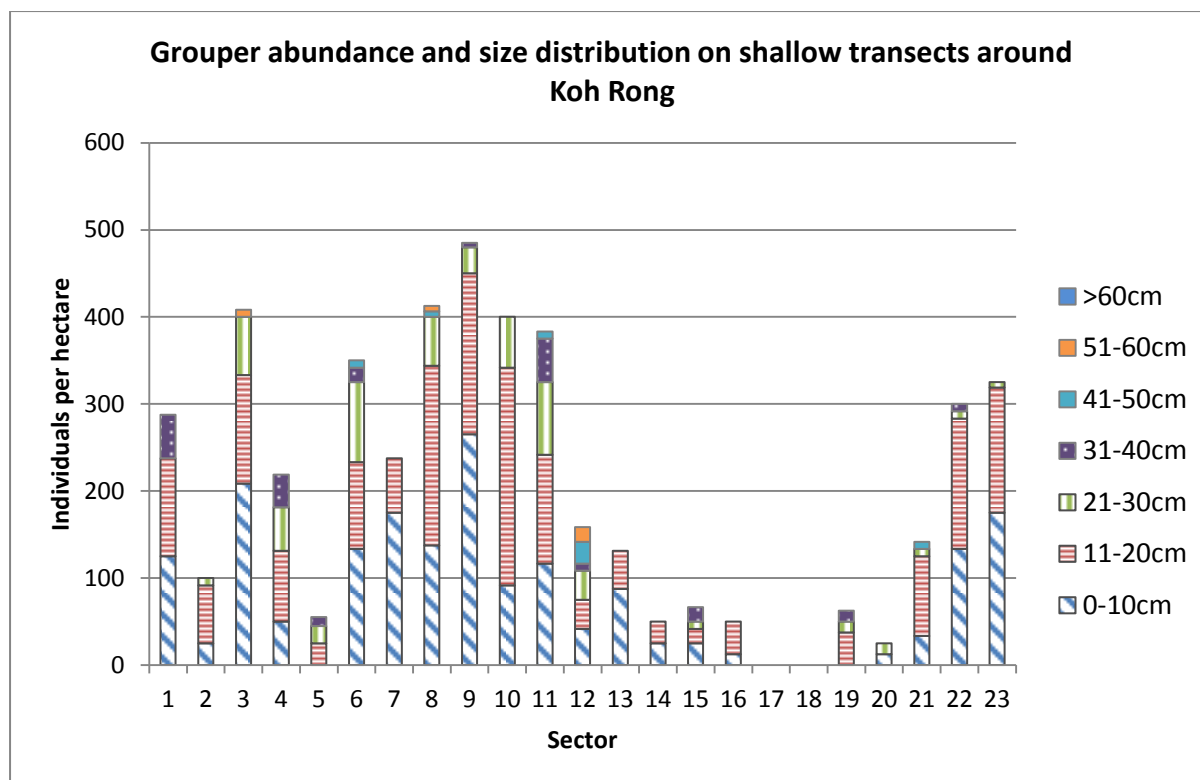


Figure 16 Densities (#/ha) of Grouper (*Serranidae*) per survey sector with size-class distribution on shallow sites

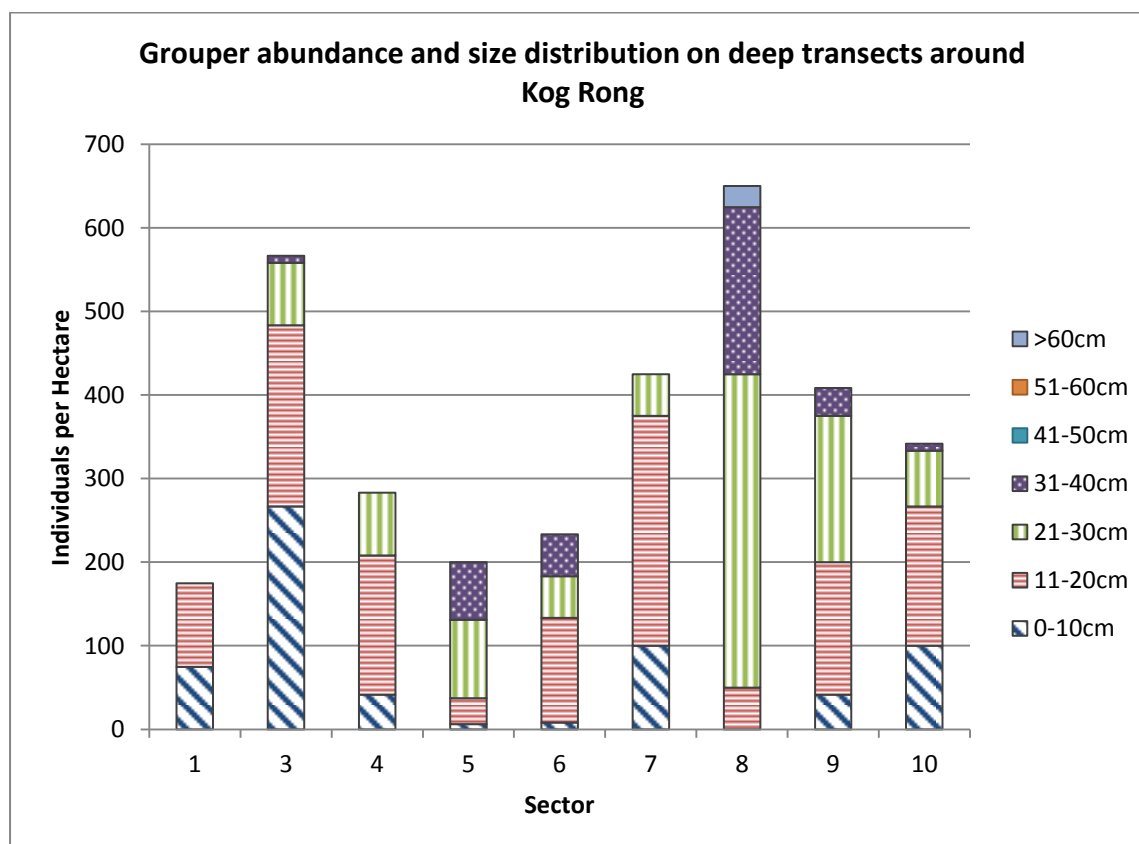


Figure 17 Densities (#/ha) of Grouper (*Serranidae*) per survey sector with size-class distribution on deep sites

Herbivorous Fish

Herbivorous fish play an important role in reef communities by controlling the amount of macro-algal cover. Their biomass was very high in sector 6 (~7500 individuals per hectare) on shallow transects with 96% of this comprising Parrot fish (Figure 18). On deep transects their biomass was high in sector 6 (~1300 individuals per hectare) (Figure 19).

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. In comparison to other sectors, Parrotfish biomass was very high in sector 6 for both shallow and deep transects (6933 and 1325 individuals per hectare respectively) with other sectors much less. There were very few observations of parrotfish in the eastern sectors (13-23) possibly suggesting overfishing of this species in this area.

For both the shallow and deep sites the majority of individuals observed were in the size categories up to 20cm. Very few individuals above 40cm were observed.

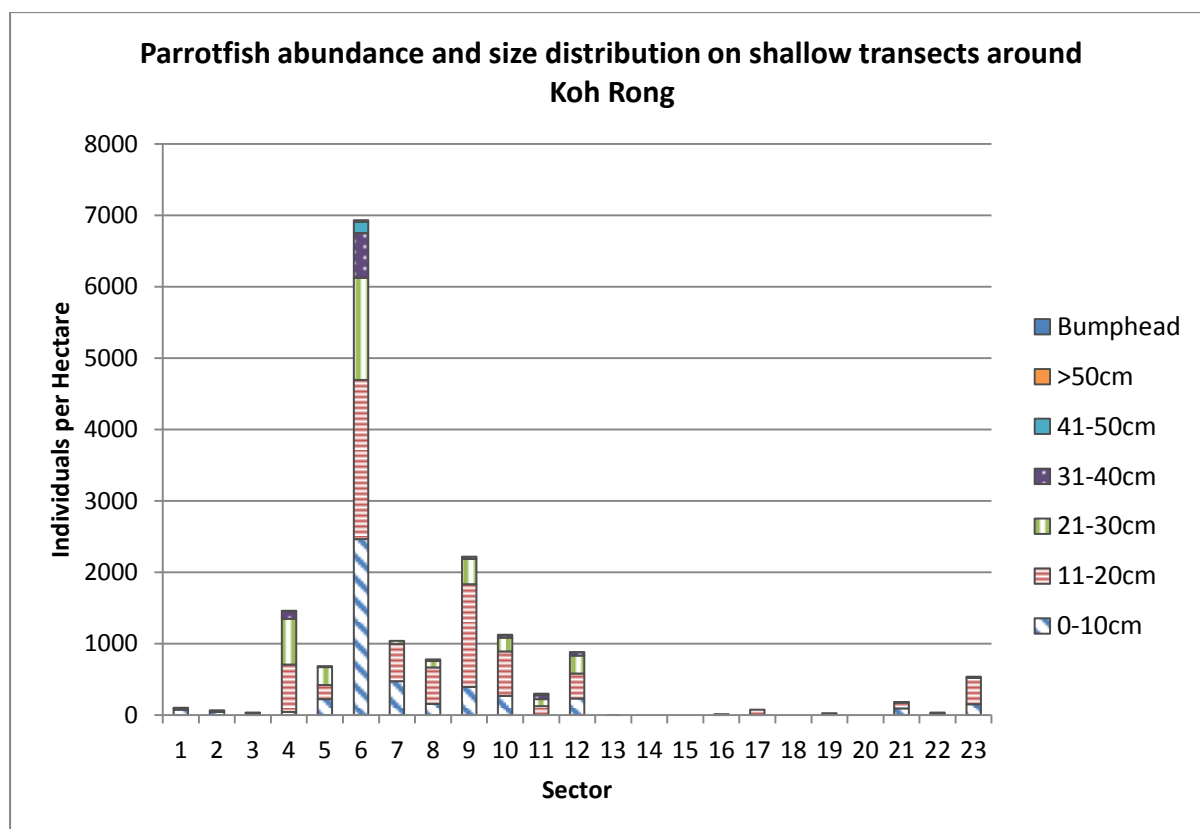


Figure 18 Densities (#/ha) of Parrotfish (*Scaridae*) per survey sector with size-class distribution on shallow sites

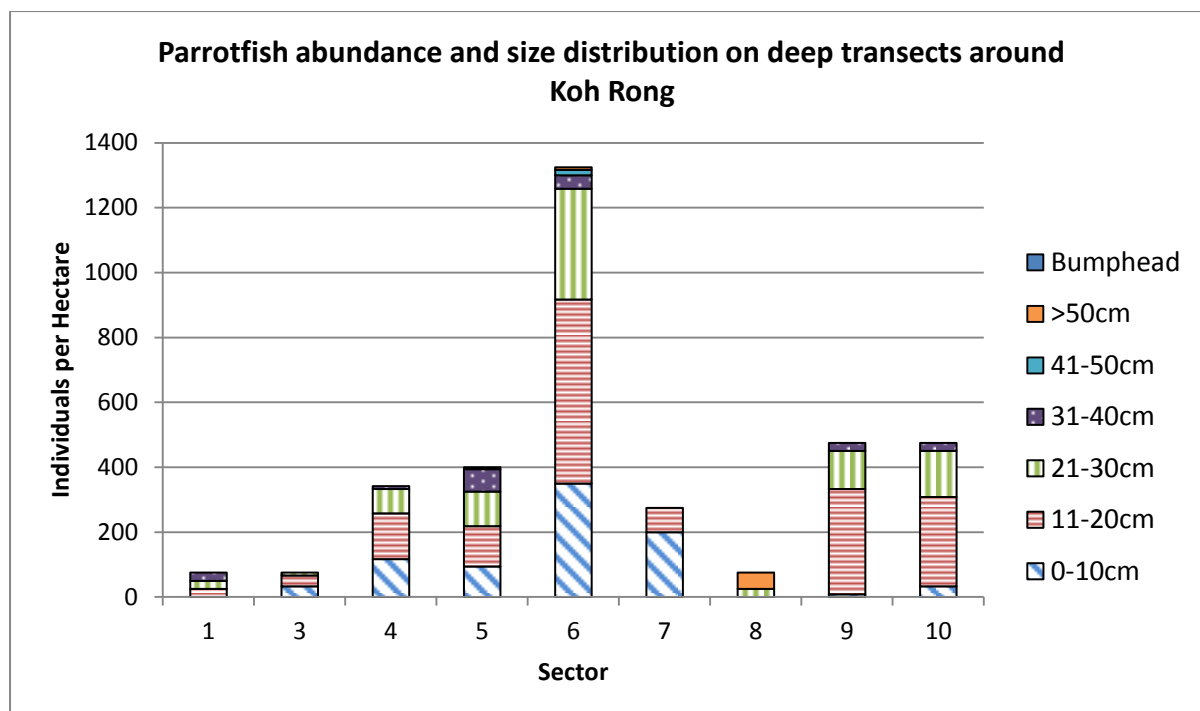


Figure 19 Densities (#/ha) of Parrotfish (*Scaridae*) per survey sector with size-class distribution on deep sites

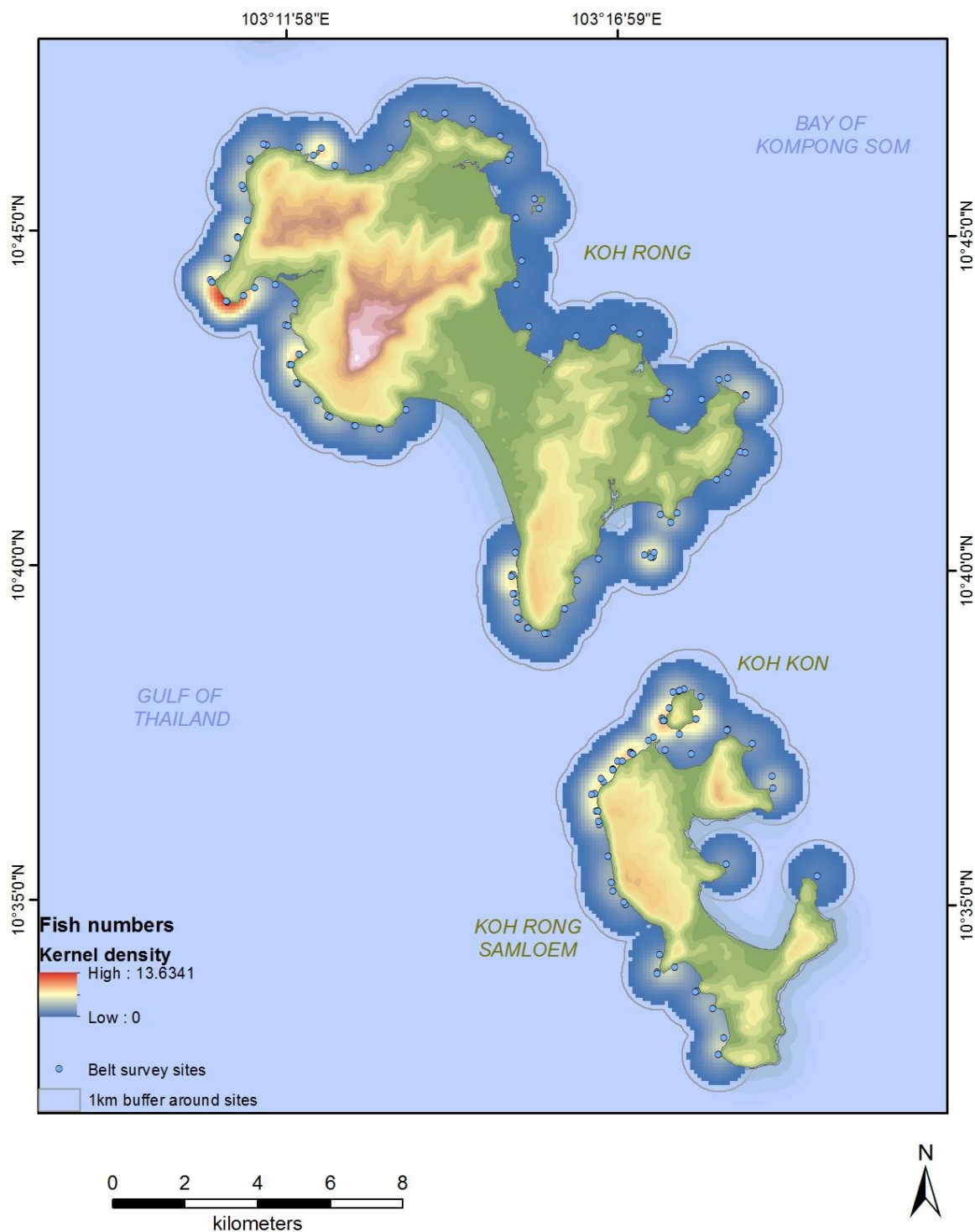


Figure 20 GIS map of kernel density of fish numbers around Koh Rong, Koh Kon and Koh Rong Samloem.

Total fish species diversity varied widely between all sectors with the highest fish diversity found in sectors 3 and 4 on the south western peninsular of Koh Rong (Figure 21). The lowest diversity on deep sites was found in sector 8 and for shallow sites in sector 20 and the eastern side of Koh Rong.

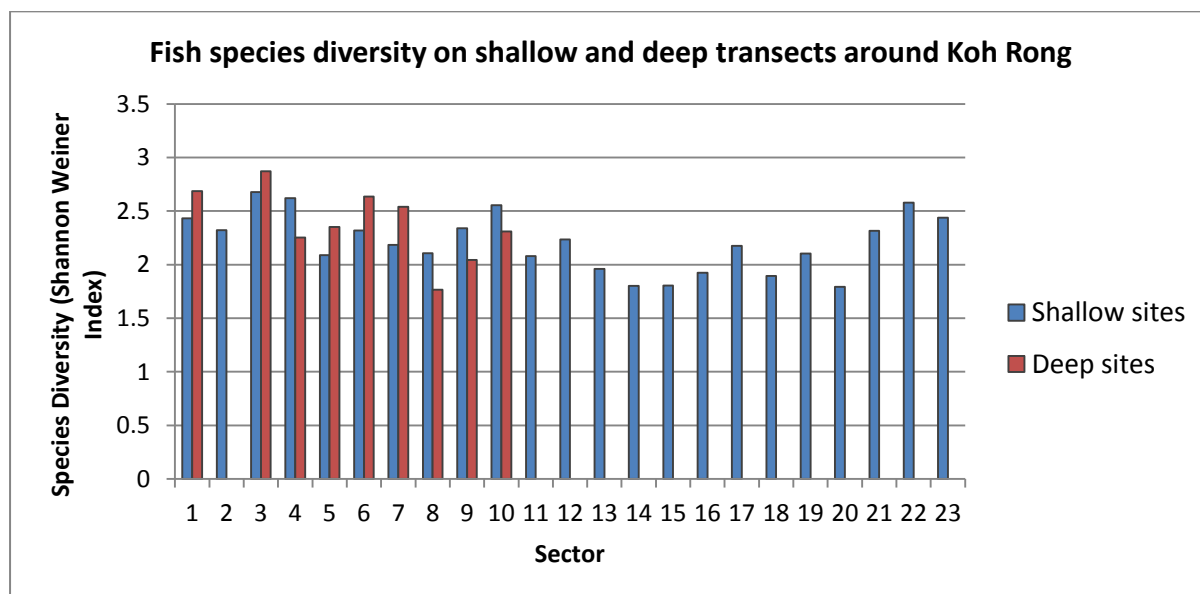


Figure 21 Diversity of fish species across all sectors and depth ranges.

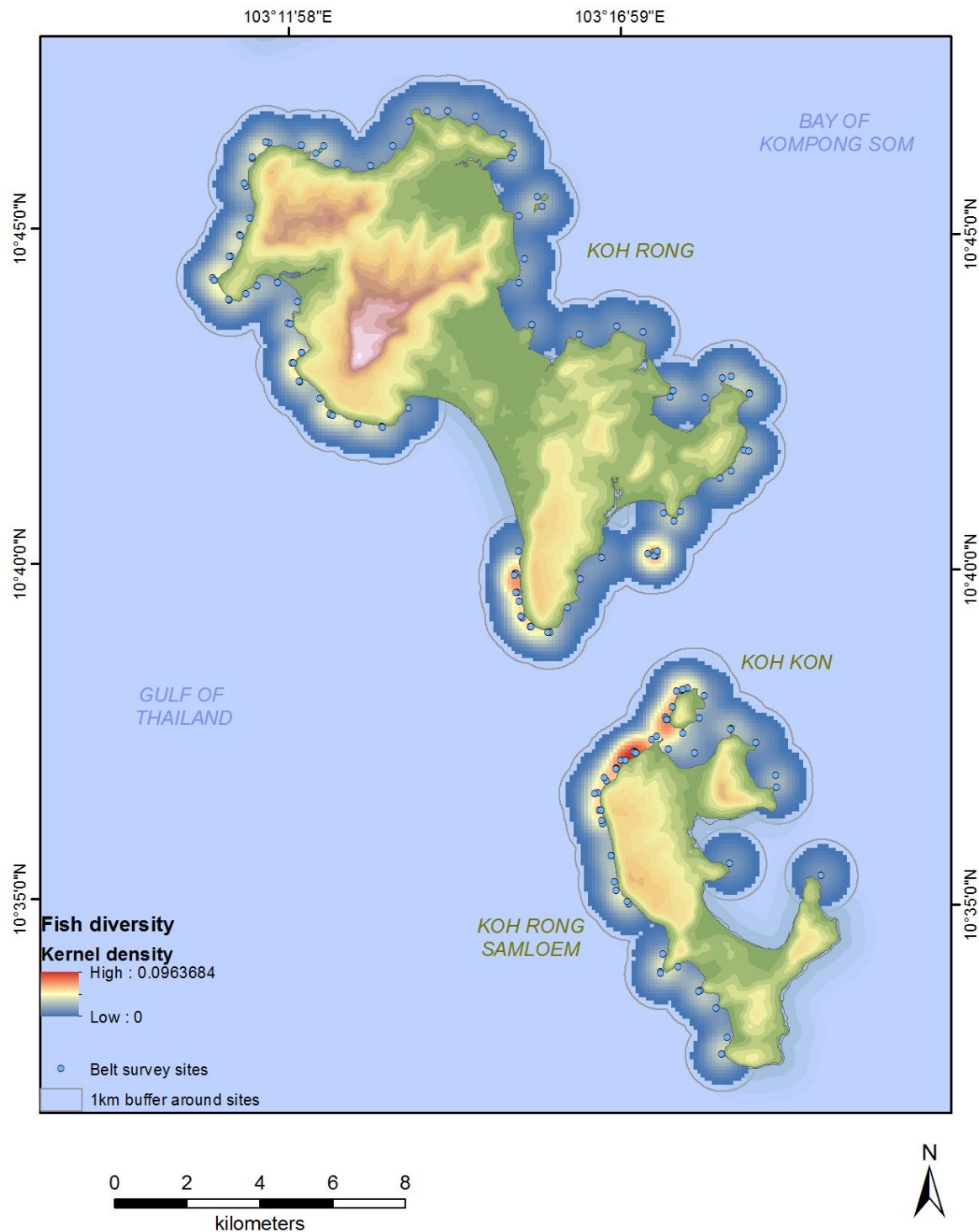


Figure 22 GIS map of kernel fish diversity ($H'(\log_e)$) around Koh Rong, Koh Kon and Koh Rong Samloem.

4 Reef Health

Anthropogenic (human caused) factors can have a devastating impact on the health of reef communities. From over fishing and the removal of important species to the physical impact of certain fishing practices human reef interaction can often lead to damage. Five common impacts were looked for on the survey dives. Trash and cast off fish nets were the most commonly encountered with high impact severity on sectors 2, 4, 7 and 21 (Figure 23). Boat or anchor damage and other types of damage were rarely observed and had only a minimal impact. Damage from dynamite was not observed at any sites.

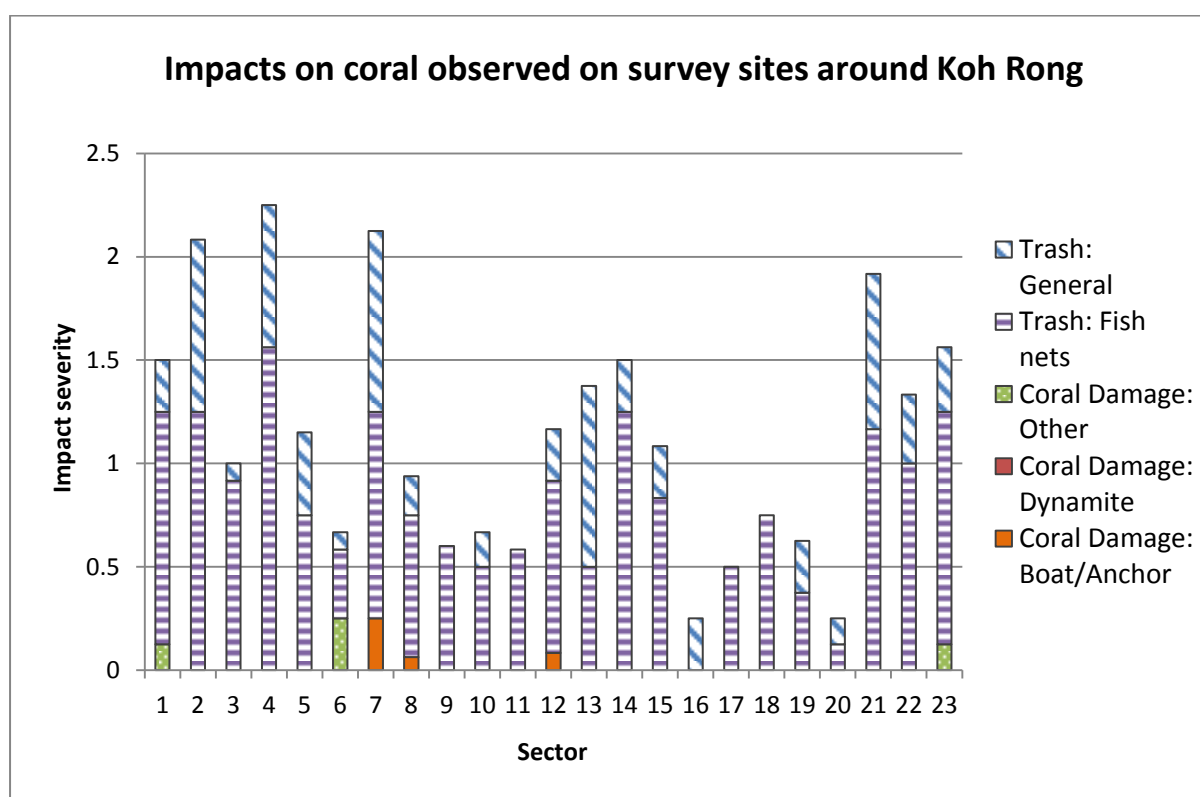


Figure 23 Average severity of anthropogenic impacts on survey sectors around Koh Rong.

5. Discussion and conclusions

This report aimed to continue the baseline assessment of the state of coral reefs around Koh Rong Island, Phreah Sihanouk Province. At the request of the Cambodian Fisheries Administration (FiA) of the Cambodian Ministry of Agriculture, Forestry and Fisheries, this report is also intended to form the foundation of a management tool to help inform the locations of different usage zones within the Marine Protected Area around the island. In light of the planned tourism development of the island over the next decade, the implementation of management plans is vital to safeguard the reefs and ensure their long term survival.

Coral cover was around 20% on average for all sites surveyed around Koh Rong. The highest live hard coral cover (~35%) was located on the south western peninsular of the island. Cover was also high along the western side of the island (~25%). The lowest coral cover was found along the eastern side of the island with figures ranging from ~7 – 20%. The eastern side of the island contained no deep sites as the area is comprised largely of shallow sandy bottom. This may be a factor affecting the cover as there is less suitable habitat for coral to colonise. In addition the Cambodian mainland is located to the east of the island. Sediment run off from the main land could play a role in limiting coral cover by smothering coral and limiting growth.

The results show that coral species diversity was fairly low across all sites, with most corals being more robust massive or encrusting life forms. Massive life form corals such as *Porites* species and *Diploastrea Heliopora* dominated most sites and were the most commonly seen comprising around 40% of coral cover across all sites. Their dominance and the lack of more sensitive life forms could be an indicator of the effects of sedimentation in the area. Tabulate and branching lifeforms which are important habitat for many juvenile fish species were rarely observed on the survey dives. The highest abundance of these life forms was found south western edge of the southern peninsular where the highest diversity and coral cover were located.

Anthropogenic impacts were relatively low across most sites surveyed. There were however a couple of sectors where damage caused by fishing nets and other general trash was high. As these observations were fairly uncommon it is unlikely that these anthropogenic impacts are a major factor in reef degradation.

The presence or absence of large predatory fish such as Grouper (*Serranidae*) and Snapper (*Lutjanidae*) is an important indicator of reef health as high diversity and abundance suggest a balanced and healthy reef community. It is important to consider that whilst individuals may be present, the population structure may be distorted by the removal of large mature adults leaving sexually immature juveniles and rendering the population susceptible to decline.

The highest abundances of all species were located on the south western side of the southern peninsular and around the western point of the island. The results are in line with the highest values for coral diversity and cover and indicate that these areas may be the healthiest sections of reef around the island. Furthermore these areas are fairly isolated in terms of their distance to local

fishing villages. Despite fishing being on a small scale around the island, this relative isolation may be a factor in maintaining higher fish diversity and abundance.

5.1 Initial Recommendations

It is very important that there is continued monitoring of reef health on all sites around Koh Rong in the coming years. The baseline data collected so far can only be used as a guide to inform the location of the new proposed MPA. What is needed now is to conduct regular monitoring activities along permanent stations. This information will provide important feedback on the success or failure of the MPA to protect coral reefs and associated habitats. It will also allow for adaptive management practices to be implemented if needs be.

One of the key factors to be addressed in the next decade will be minimising the impact of anthropogenic stressors to allow the reefs to recover from the mass coral bleaching event that took place in the summer of 2010. It will be important to reduce the undue stress and preserve the existing diversity. The proposed multi-use MPA will provide some level of protection to the reefs but care must be taken to ensure appropriate zones are applied to the correct areas around the island.

The highest diversity and abundance of species was located on the south western side of the southern peninsular and around the north western point of the island. It is therefore logical that these areas should have the highest level of protection under the MPA zoning. A No Take Area or No Access Area would provide greatest protection but may not be feasible when considering the new tourism development.

The most successful MPAs are well enforced and supported strongly by local stakeholder involvement. Furthermore there needs to be flexibility in the operation of the MPA to allow adaptive management, informed by on-going monitoring. It is imperative over the next decade that stakeholders such as land developers consider the impact that the developments will have on the reefs. Increased sediment runoff, pollution, trash and boat activity may all impact the reefs reducing their viability and overall health. This is not only important for local communities who depend on the reefs for food but also for the tourist companies who will rely on the attraction of the reefs as a pull for clients. In light of this, it would be useful to conduct a monetary evaluation of the coral reef resources around Koh Rong in order to provide an economic value for the significant ecosystem services they provide.

The next steps will be to develop a multiple-use zonation scheme including no-take, recovery, recreational, mooring and limited fishing zones. By pooling together baseline information gathered by both Coral Cay Conservation and Marine Conservation Cambodia, such a plan can be developed. Once this is complete, steps can be taken towards the implementation of the Marine Protected Area.