Koh Karang Marine Environmental Assessment

Kep Province, Cambodia

Photo 1: Juvenile seahorse at Koh Karang, Kep Province, Cambodia (Brayden Cockerell, June 2016).

Marine Conservation Cambodia

August 2016

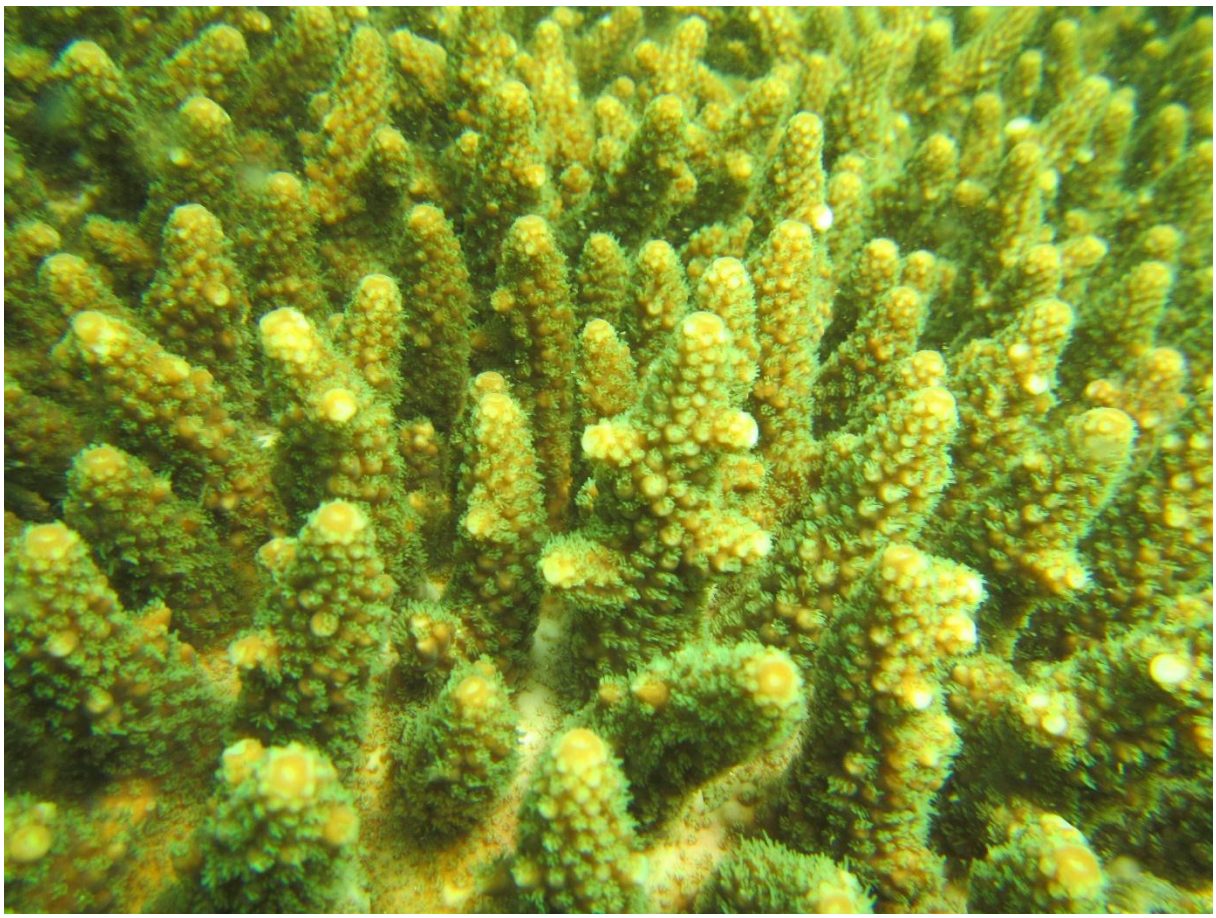

Photo 2: A branching hard coral colony at Koh Karang, Kep Province, Cambodia (Brayden Cockerell, July 2016).

In partnership with:

Report by:

Brayden Cockerell – B.Sc (Zoology), Team Scientist

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Paul Ferber – Managing Director and Project Founder, MCC

1 Abstract

Knai Bang Chatt sustainable resort and the Ministry of Environment requested Marine Conservation Cambodia (MCC) to undertake a marine assessment of the reefs encompassing Koh Karang and its sister island in Kep Province, Cambodia. The purpose of this was to gain knowledge concerning the distribution of the coral reefs surrounding the island, as well as to indicate the state of the marine ecosystems which the reefs constitute. Following this, the feasibility of establishing a Marine Protected Area (MPA) for increased marine eco-tourism at Koh Karang will be assessed by Knai Bang Chatt, in addition to other relevant stakeholders and parties. During July 2016, MCC scientists assessed two survey sites using an adapted and more in-depth version of the globally recognized Reef Check methodology (Hodgson *et al.* 2006). Data assembled from the 2016 reef surveys of Koh Karang signified that the coral reef ecosystems here were in a degraded and vulnerable state. Many functionally key species were not documented or observed, and invertebrate diversity was relatively low. On a positive note, a moderate diversity of fish species was recorded, with notable herbivorous and predatory fish present. Moreover, both reef sites contained comparatively moderate-high coverage of live coral. Concerted restoration efforts could likely result in a thriving and productive marine environment encompassing Koh Karang. Reinforcing this notion is the fact that MCC has successfully undertaken similar marine habitat rehabilitation projects on the islands of Koh Seh and Koh Rong Samloem. A fundamental underpinning of these restoration efforts was/is the safeguarding of habitats against illegal and destructive fishing techniques, which have and do cause extensive damage to marine ecosystems in Cambodia. MCC strongly recommends the implementation of the Koh Karang Marine Protected Area (MPA) proposed by Knai Bang Chat authorities. Ideally, this measure would be coupled with the formation of MCC's proposed stage 1 Marine Fisheries Management Area (MFMA) encompassing the Kep Archipelago (MCC 2016). This MFMA and MPA combination will, with high likelihood, synergistically deliver the protection desperately needed to induce notable recovery of marine ecosystems in Kep Province.

I. Acknowledgements

Marine Conservation Cambodia (MCC) has been working towards environmental conservation and securing community livelihoods in collaboration with the Royal Government of Cambodia Fisheries Administration (RGC FiA), local authorities and coastal communities since 2008. Our marine monitoring, marine research and socio-demographic programs around Koh Rong and Koh Rong Samloem supported the creation of the first Marine Fisheries Management Area in Cambodia, and we are currently assisting Kep Provincial Authorities in the creation of a second (MCC 2016).

Close collaboration with the provincial and national FiA, local government bodies and international institutions is the key to MCC's success. MCC is a respected and credited leader in conservation and community work in Cambodia. As such, we were requested in 2014 to set up a continued monitoring program and a Coral Reef Restoration Pilot Project on the islands Koh Seh, Koh Mak Prang and Koh Angkrong. As a result of this, MCC was requested by Knai Bang Chatt resort to undertake a marine assessment of Koh Karang, which is described in this paper. MCC is extremely grateful for its support, without which this research could not have taken place. To date, we have conducted the three sets of reef surveys; the results of which demonstrate the success of enforced fisheries management and great potential of the Coral Reef Restoration Project.

H.E. Ken Sokha	Governor, Kep Province
H.E Som Piseth	Deputy Governor, Kep Province
H.E Tep Yuthy	Deputy Governor, Kep Province
H.E. Eng Cheasan	Director General of the Fisheries Administration
Mr. Ouk Vibol	Director of Fisheries Conservation Division
Mr. Sar Sorin	Director of Kampot Fisheries Cantonment
Mr. Kuch Virak	Director of Kep Fisheries Cantonment
Mr. Sinath Chak	Deputy Director of Kep Fisheries Cantonment
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II. Research Team

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V. List of Abbreviations and Acronyms

FiA	Fisheries Administration
MCC	Marine Conservation Cambodia
MFMA	Marine Fisheries Management Area
MPA	Marine Protected Area
PS	Per 20 meter Segment
RGC	Royal Government of Cambodia
USD	United States Dollar
Substrates:	
HC	Hard Coral
NIA	Nutrient Indicator Algae
OT	Other
RB	Rubble
RC	Rock
RKC	Recently Killed Coral
SC	Soft Coral
SD	Sand
SI	Silt
SP	Sponge
ZO	Zoanthid

2 Introduction

Coastal and marine ecosystems across the globe are undergoing critical damage due to activities such as unsustainable fishing practices, lack of waste management infrastructure, and unchecked coastal development (van-Bochove *et al.* 2011). As global fisheries landings have been declining since the 1980s, the present trends in fisheries combined with a low degree of marine protection virtually guarantee the collapse of more fish stocks (Pauly *et al.* 2002).

The South China Sea, within which Cambodian waters are situated, is a diverse marine environment with highly valuable coral reefs, sea grass beds and mangrove ecosystems. The nations bordering the South China Sea are home to 5% of the world's human population (Talaue-McManus 2000), and heavily rely upon the resources and services provided by the marine ecosystems. These include seafood production, employment in fisheries and tourism industries, as well as numerous ecological services such as prevention of coastal erosion, carbon sequestration, and various nutrient cycles (carbon, nitrogen, phosphorus etc.). Human-induced impacts, including destructive fishing, sedimentation, nutrient runoff, overfishing, physical damage (anchors, boats etc.) and waste pollution, are resulting in habitat destruction and rapidly decreasing biodiversity in both Cambodia's marine environment (van-Bochove *et al.* 2011), and across the South China Sea. The consequences of this are the loss of ecosystem services, reduced livelihood for fishers and detrimental economic impacts. Effective management is urgently required to mitigate and regulate human activities that are directly or indirectly causing these consequences.

Coral reefs are complex, highly productive and biologically diverse ecosystems that provide a sheltered habitat and breeding ground for a multitude of both commercial and non-commercial marine species. Unfortunately, these ecosystems are highly susceptible to environmental alterations. Anthropogenic impacts, such as destructive fishing activities (e.g. overfishing, trawling, anchoring, dynamite, poison, long-lines, small mesh nets etc.), nutrient loading (e.g. untreated waste input, agricultural run-off), and pollution (Pauly *et al.* 2002) can therefore cause devastating effects. In fact, due to destructive fishing techniques and overfishing, 90% of coral reef ecosystems in Cambodia are at high risk, whilst 10% are at very high risk, according to the Indicator Threat index used by Rizvi & Singer (2011).

Not only do these anthropogenic activities decrease the biodiversity of the system, but they also negatively alter the coral reef quality and structure. Coral bleaching, disease and predation constitute potentially damaging stressors that can be strongly exacerbated by human activities, such as those listed above. These stressors have great implications within Kep Province, where numerous shallow fringing reefs are situated and relatively warm water temperatures occur all year round. Given the significance of coral reef habitat to many marine species, including most of the commercially important fisheries species, these impacts have widespread ecosystem consequences (van-Bochove *et al.* 2011).

Coral reef habitats act as natural wave barriers, protecting coastal communities from the effects of coastal erosion and flooding. Defense against such issues are an important aspect of the developing 2016 integrated coastal management (ICM) for Kep Province. The ICM aims to protect highly valuable shorelines - including fishing communities, aquaculture projects and tourism developments. Strengthening of coral reefs will provide a natural and affordable, soft engineering solution.

Seagrass meadows are among the most diverse and highly productive coastal ecosystems in the world (Duarte *et al.* 2004). Seagrasses play an important role in the general health of the surrounding marine environment, primarily owing to the range of ecological services and roles in which they are involved. Seagrasses are highly influential in ocean productivity and a variety of nutrient cycles, such as carbon, phosphorus and nitrogen. Ocean productivity refers to the production of organic matter by phytoplankton, predominately organic carbon (Sigman & Hain 2012). Seagrasses are responsible for around 15% of the carbon storage in the ocean, and additionally act to export on average 24.3% of their net production to adjacent ecosystems (Duarte 2002). Decaying seagrass enriches the surrounding water with detrital food and nutrients, both of which are fundamental inputs into productive marine ecosystems. Seagrasses function as a habitat, food supply and nursey ground for many different commercial and non-commercial species. The blades of seagrass give juvenile fish and benthic invertebrates a place to hide from predators, and provide a settling substrate for sessile organisms. This is important as greater survival by juvenile individuals results in population restoration, leading to enhanced ecosystem health. Commercial landings of seagrass-utilizing species in the US in 2005 resulted in a net $126

million (Hughes *et al.* 2009). A locally important commercial species that utilizes seagrass is the world renown blue swimmer crab (*Portunus pelagicus*), which brings economic and livelihood benefits to Kep Province as a whole, including coastal communities, tourism industries, restaurants and many other parties. Unfortunately, blue swimmer crabs are reducing in size and number, with a continuation of this trend posing a risk to commercial and small-scale fishers. Numerous fishers agree that the primary factor causing this decline is the frequent presence of illegal fishing in Kep Province (Cane & Muong 2015).

Seagrass meadows host a vast array of internationally and locally endangered species, such as dolphins, turtles, dugongs, manatees, fan mussels and seahorses. On average, there is more than one threatened associated species for every seagrass species across the globe (Hughes *et al.* 2009). Seagrass is a key food source for mega-herbivores (Orth *et al.* 2006) such as dugongs and turtle, both of which were in the past sighted in Kep's regional waters, and may also return with genuine and continuous environmental improvement. Seahorses frequently use seagrass for camouflage and as a holdfast. Four species of seahorse (*Hippocampus kuda, H. monhikei, H. spinosissimus* and *H. trimaculatus*) can be found within the seagrass bed of Kep Province, which forms the highest reported concentration of seahorse species in Cambodia.

Cambodia's economy is largely dependent on its coastal and marine sector (Wheeler *et al*. 2000), and thus, on its coral reef and sea grass ecosystems. In addition to providing valuable ecological services (e.g. carbon sequestration, nutrient cycling, habitat, sediment stabilization), seagrasses present the potential for acquisition of money from carbon credits, and additionally support commercially valuable marine species. With the imminent threat of global warming, the expansion of seagrass beds will greatly contribute to reducing Cambodia's carbon footprint. Carbon credit revenue from seagrass ecosystems represents a commonly overlooked opportunity. These ecosystems hold the potential for development of payment for ecosystem service (PES) schemes, which in conjunction with carbon credits, help to combat climate change, improve livelihoods and conserve seagrass (Hejnowicz *et al.* 2015). This should be a priority for Cambodia, given a recent prediction by Chevillard J. (Cambodia Climate Change Alliance and the UN Development Program) that 'The Kingdom's GDP could decrease by 3.5% per year by 2050 if access to climate concerned finance is not a priority' (Chevillard

2014). Steps such as acquiring carbon credits will become increasingly necessary within Cambodia, in order to strengthen its economy whilst facing the impacts of climate change and ocean acidification in the near future.

Coral reefs contribute to Cambodia's economy by providing ecosystem services that are essential to the fisheries industry and by drawing tourists to the region. In 2003, the net annual value of coral reef ecosystems globally was USD$29.8 billion (Cesar *et al.* 2003), whilst sustainable coral reef fisheries in South-East Asia alone were valued in 2002 as being worth over USD$2.4 billion per year (Burke *et al.* 2002). Kep Province, and Cambodia as a whole, present viable economic opportunities for further profit from coral reef ecosystems through the increase in commercial marine species stock, which will generate more revenue for fishers and the local economy. Additionally, the expansion of tourism industries will provide alternative livelihood for illegal fishers, as well as small-scale fishers whose main fishery has collapsed due to unsustainable fishing practices. An economic analysis of recreational opportunities related to coral reefs in Cambodia's Ream National Park, estimated the 2008 value of the best protection scenario is up to $699,636 per km^2 of healthy coral reef ecosystem (Conservation International 2008). Underpinning this is the need for a greater level of protection against human-induced impacts, in doing so enabling habitat restoration, heightening fish diversity and density, and therefore a greater potential tourism market.

Coral reefs and seagrass meadows are useful in symbolizing ecosystem health, and will be among the first species to reflect any change in the intensity of anthropogenic impacts, thus forming an ideal candidate for studying long-term environment trends (Bjork *et al.* 2008). The dramatic decline in coral reefs and seagrass extent and health in Cambodian waters should be taken as a warning sign. This decline indicates the need for management actions aimed at decreasing anthropogenic stressors and preserving remaining coral reefs and seagrass habitat. The primary cause of coral and seagrass decline in Kep Province, as well as throughout Cambodia, is daily destructive fishing practices. This is specifically relevant to the activities of illegal, unregulated and unreported (IUU) vessels, with emphasis on the intense illegal trawling activity that frequently occurs in critically endangered habitats. Trawling in Kep Province breaks numerous important fisheries laws, in particular Article 49; prohibition of trawling in inshore areas (<20m depth), and Article 52; prohibition of fishing that damages or

disturbs coral reef or seagrass (FiA 2007) (see Appendix 1 for full article descriptions). Trawling destroys and displaces significant amounts of seagrass, thus removing vital seagrass roots from stabilizing the substratum. The extensive root system of seagrasses helps to hinder sediment re-suspension, store nutrients and oxygenate sediments (Duarte 2002). Trawling gear rips seagrass from the seabed, destabilizing the associated sediment and leading to major ecological problems (Mam 2002). These problems include potential microbial production (Gotner *et al.* 2000), heightened nutrient and contaminant levels, smothering of respiratory and feeding organs, and exposure of anoxic layers (Kaiser *et al.* 2001). This induces a perpetual cycle, whereby eutrophication (heightened nutrients) is correlated with more rapid seagrass decline, which is furthermore exacerbated by sediment re-suspension (Burkholder *et al.* 2007). All these problems also constitute serious threats to the health of coral colonies. Due to the intensification of those stressors over the past years they may, in a near future, prevent their recovery from the seasonal bleaching events happening every year in Kep which would have devastating consequences for the fish stocks, the ecosystem and Kep province in general. Constant disturbance to seagrass habitat greatly restricts its ability to recover, and under such circumstances, population recovery may never occur (Clarke & Kirkman 1989; Preen *et al.* 1997). Persistent trawling in a sandy bottom area (substrate suitable for seagrass growth) constantly disturbs the sea bed, up-heaving it, displacing it and eventually removing the sandy sediment layer, leaving silt and mud (Poiner *et al.* 1989). This remaining muddy sediment is not capable of supporting seagrass resettlement and growth. Safeguarding of coral reefs and seagrass ecosystems from illegal fishing activity, predominantly trawling, is thus vital in preserving and restoring their health and productivity. Protection of seagrass beds will align with prior targets to place 90km^2 of seagrass under sustainable management by 2016 (FiA 2006), and new goals formed in the developing National Plan of Action. Evidently, it is in the best interests of Cambodia's government and other pertinent authorities to protect Cambodia's remaining vulnerable coral reef and seagrass meadows.

In order to mitigate the anthropogenic stresses placed on Cambodia's marine environment (e.g. unsustainable fishing, pollution, etc.), and prepare for the increasing threats of climate change (e.g. sea level rise, increasing storm events, rising water temperatures), management decisions must be carefully calculated and implemented. Management of marine resources for conservation objectives and fishery production is in a

period of global change, with calls for a greater number of 'no-take' marine conservation areas internationally. Zoning of commercial and subsistence fishing methods around the border of these 'no-take' areas, forms a Marine Fisheries Management Area (MFMA). When MFMA regulations are imposed in conjunction with marine fisheries laws, the implementation of such schemes has shown to have positive effects in rebuilding depleted fish stocks (Pauly *et al.* 2002), in turn developing a sustainable and successful fisheries industry.

The government of Kep Province has recognised the increasing pressure being placed on marine resources in the Kep Archipelago, and is taking action to restrict illegal and unsustainable fishing methods by working alongside MCC to implement the second MFMA in Cambodia (MCC 2016). The zoning will encompass Koh Seh, Koh Mak Prang, Koh Angkrong and Koh Pou, and include a series of highly protected 'no-take' conservation zones to be surrounded by small-scale family fishing, multi-use and buffer zones. The conservation zones will include primarily fringing reefs, in addition to some seagrass meadows.

In order to optimize the impact of an MPA/MFMA, multi-level support is needed from government agencies, law enforcers, research groups and all relevant communities (Bustamante 2014). Island villagers are directly linked to the MPA/MFMA's success, as their livelihood immediately depends on the productivity of the marine environment. As local actions will influence the regenerative capacity of the area, widespread awareness regarding the aim and potential of the protection plan is required. Fishers possess valuable local ecological knowledge that can contribute to informed management decisions (Andrew & Evans 2009). Experiences of other MPAs indicate that community involvement can significantly benefit the effectiveness of an MPA/MFMA, as participation in management actions leads to information exchanges, and the development of plans strategically designed to the local condition (Andrew & Evans 2009). The creation of an MPA/MFMA would align with Cambodia's Royal Decree on the Establishment of Fisheries Communities (adopted in 2005), which encourages local small-scale fishers to form community organizations for the purpose of promoting sustainable use of fisheries resources within locally defined areas.

The following report summarizes the results of surveys in the vicinity of Koh Karang and will assist in the implementation of a sustainable MPA and marine conservation program in Kep Province. Consequently, this report will cover:

- The general distribution of coral reefs surrounding Koh Karang.
- The abundance and distribution of reef health indicators such as members of specific fish and invertebrate families, as well as particular substrates.
- The general condition of the reef survey sites in terms of visible impacts (e.g. fishing impacts, storm damage, trash).
- The main issues that require attention within the proposed MPA region.

3 Methodology

3.1 *Survey Sites Location and Selection*

MCC's 2016 coral reef surveys of Koh Karang (10.357375N, 104.319890E), Kep Province, Cambodia were conducted at two sites (refer to figure 1 & appendix 2), spanning over a period of two weeks in July 2016. One site (10.46553N, 104.21593E), the 'fringing reef', was located on the fringing reef west of the Koh Karang. The second site (10.46228, 104.22260E), the 'patch reef', was situated on a patch reef approximately 600 meters south-east of the island. Both reef sites were characterized by shallow depths (<3.5m) and the presence of relatively large coral colonies. The patch reef seems to contain heteroclite rock on which sessile invertebrates have settled and grown. Initial surveys were performed in order to determine where a suitable stretch of reef occurred, which was representative of the island's marine ecosystems. During these surveys, a small patch of seagrass (maximum 800m^2) was discovered near the south-east tip of the island. Additionally, it should be noted that a continuous coral reef habitat encompasses both Koh Karang and its small sister island. All sites were recorded via GPS and can be used in future surveys.

One of the goals of MCC's reef surveys is to determine the level and consequences of human-induced impacts on coral reefs, which is aligned with the recommendations of Reef Check International (Hodgson *et al.* 2006). Koh Karang coral reef survey sites were chosen based upon varying levels of anthropogenic impact, as well as incorporating environmental and topographical variation. This method allows for effective management action in response to comparable changes in and between the health of Koh Karang's coral reef ecosystems, as well as unveiling how environmental and topographical alterations affect them..

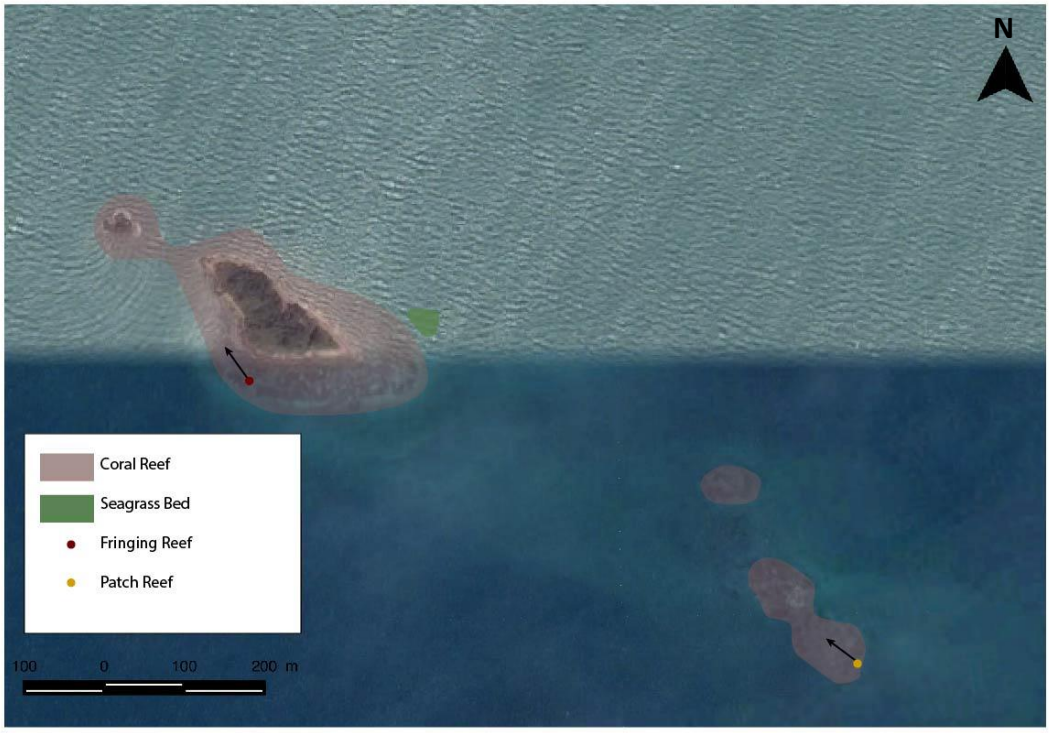

Figure 1: Map depicting MCC's survey sites and direction, in addition to the coral reef and seagrass habitat distribution of Koh Karang, Kep Province, Cambodia (refer to Appendix 2 for a full-page version).

3.2 *Data Collection*

3.2.1 Coral reef survey methodology

Field data collection followed the procedures of Reef Check International (Hodgson *et al.* 2006). Before carrying out each survey, a checklist of general site conditions was completed. This included environmental parameters (temperature, visibility, current direction/strength), evident natural and anthropogenic impacts, known historical facts, and the degree of protection/law enforcement. Within both survey sites a 100m transect line was laid along the reef, targeting areas of high coral cover (known-bias survey). Data was collected along four 20m segments of the transect, with a 5m gap between each. For fish and invertebrate surveys, a 5m height (above line) by 5m width belt transect was used relative to the line (refer to figure 2). Substrate surveys were carried out as a line transect, logging substrate data every 0.5m (refer to figure 3).

The Reef Check methodology shows particular focus on the abundance of coral reef organisms that best reflect the condition of the ecosystem, i.e. indicator species. Indicator species are those used to monitor environmental changes, assess the efficacy of management,

and provide warning signals for impending ecological shifts (Siddig *et al.* 2016). Selection of these species was based on their economic and ecological value, in addition to their sensitivity to human impacts. MCC has adapted the species surveyed within the Reef Check methodology to include regional indicators, in addition to the global indicators already present. These indicators include a broad spectrum of fish, invertebrates and substrates that reflect the impacts of human activities such as overfishing, destructive fishing and pollution. Some reef survey categories include individual species, while others include any species belonging to a certain family (Hodgson *et al.* 2006).

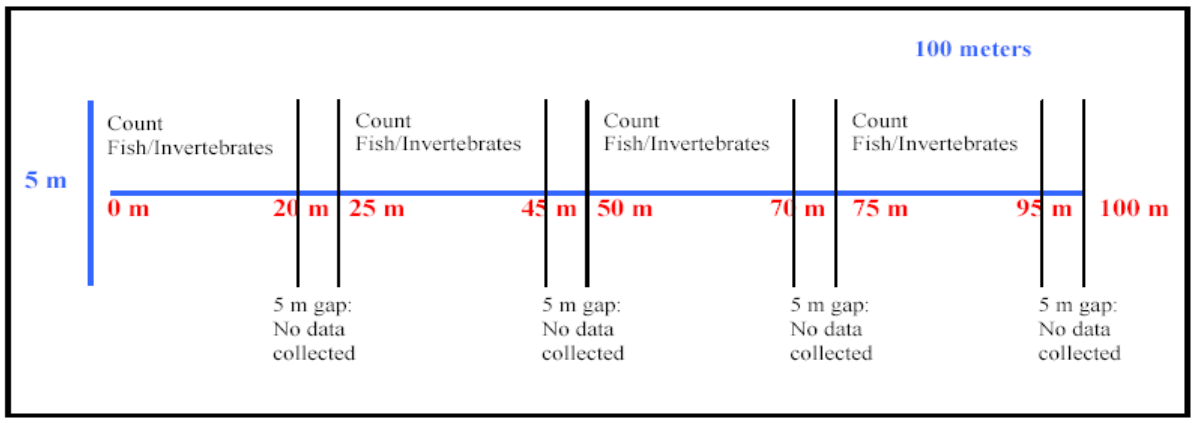

Figure 2: Reef Check fish and invertebrate belt transect reef survey method.

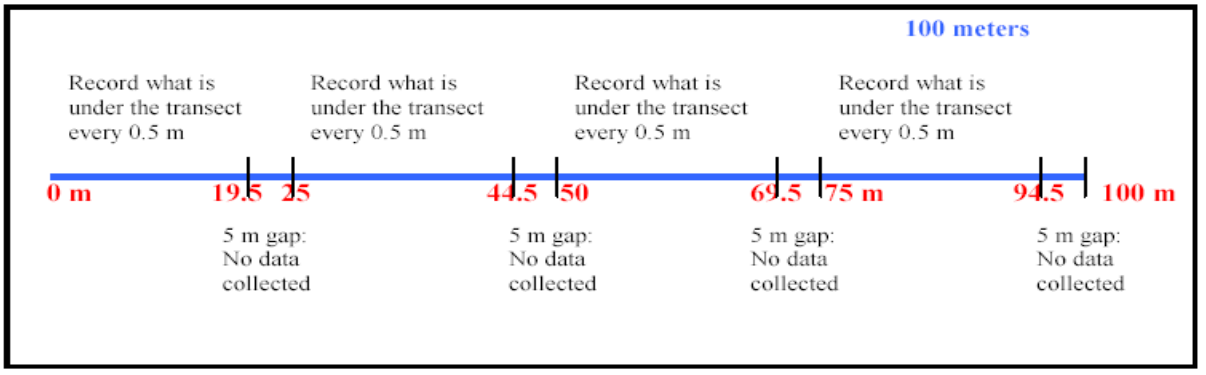

Figure 3: Reef Check substrate line transect reef survey method.

3.2.2 Impact assessment

For both surveys sites, trained reef surveyors recorded any observable impacts from anthropogenic activities or natural events. Data was logged within the 20m segments described previously.

Coral damage, trash and bleaching

Coral bleaching was recorded by estimating the percentage of the bleached coral within the population, and the percentage of bleaching in the observed bleached coral colony.

The amount of coral damage from anchors, fishing and storms was recorded. Coral damage was ranked via four levels: 0 = none, 1 = low, 2 = medium and 3 = high.

The presence of trash was documented, specifically plastics, rice bags, fishing nets, broken traps and lines. Quantity of rubbish was based on four levels; 0 = none, 1 = one piece, 2 = two to four pieces and 3 = five or more pieces.

Coral disease and predation

Currently, the study of coral disease is in its infancy and those who devote their time and expertise to it are virtually 'learning as they go along' (Raymundo et al. 2008). In order to gain knowledge regarding the impacts of coral ailments on reefs in Kep Province, trained surveyors have and are recording the incidence of coral disease as a new component of reef surveys in 2016. An additional reason for undertaking this impact assessment, is a desire to contribute to the development of coral disease knowledge amongst the scientific community. Both the percentage of the entire coral population and the percentage of the individual coral colony suffering ailment were noted.

Coral predation was another new impact assessment recorded in 2016. Similar to coral damage, predation was categorized into four levels of damage: 0 = none, 1 = low, 2 = medium and 3 = high.

3.3 *Data Analysis*

The abundance of fish and invertebrates was calculated from the mean number of individuals per 20 metre segment (p/s) averaged across all three replicates of each site. The mean percentage of substrate coverage, coral bleaching and disease was determined via averaging the three replicates within each site. Likewise, the mean rank of coral damage, predation and trash prevalence was determined by averaging the three replicates of each site. Two-tailed t-tests were utilized via Microsoft Excel to contrast all measures between the fringing reef and patch reef survey sites.

4 Results

4.1 *Fish Survey Results*

MCC's 2016 coral reef surveys of Koh Karang indicated that the fringing and patch reef did not differ vastly in fish species abundance (refer to figures 4 & 5). Both reefs contained relatively a dense mean population of rabbitfish (29 & 43.6 per 20m segment – p/s), which consisted predominately of the java species (18.8 & 41.2 p/s). On average, sergeant fish species were also comparatively abundant (19.8 & 9.6 p/s), with cardinal fish (6.4 & 6.7 p/s), snapper (5.5 & 3.9 p/s) and butterflyfish (2.5 & 6 p/s) to a lesser extent (refer to figure 4).

MCC's data revealed that sweeper (18.3 vs. 1.5 p/s; p=0.05) and butterflyfish (6 vs. 2.5 p/s; p=0.02) occurred at a significantly greater number in Koh Karang's patch reef. In contrast to this, other snapper species not recorded explicitly (0.3 vs. 0.0 p/s; p=0.02) showed a higher density in the fringing reef.

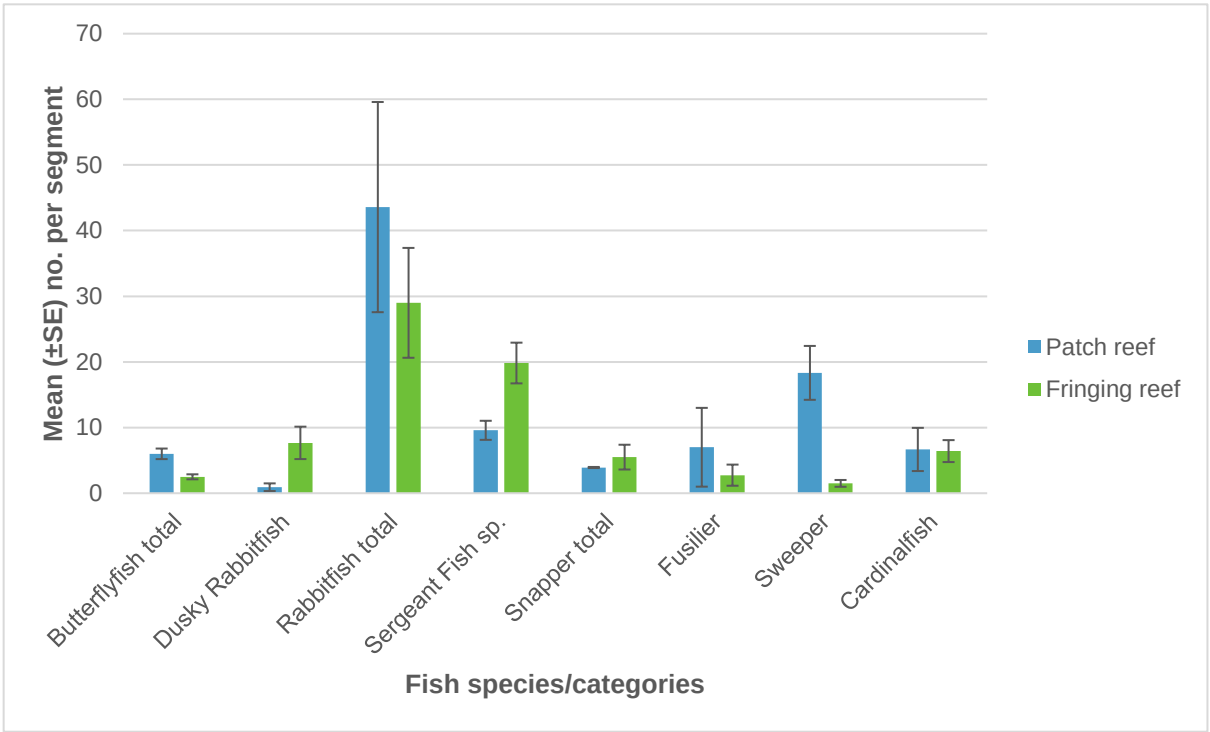

Figure 4: Mean (±SE) number of fish species/categories counted per 20 metre segment within the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

A small number of variations in fish present on each reef were logged during surveys by MCC (refer to figure 5). Gold-spotted sweetlips, double-banded soapfish, boxfish and a species of snapper were only noted in the fringing reef. In opposition to this, toadfish, filefish and pufferfish were only surveyed in the patch reef.

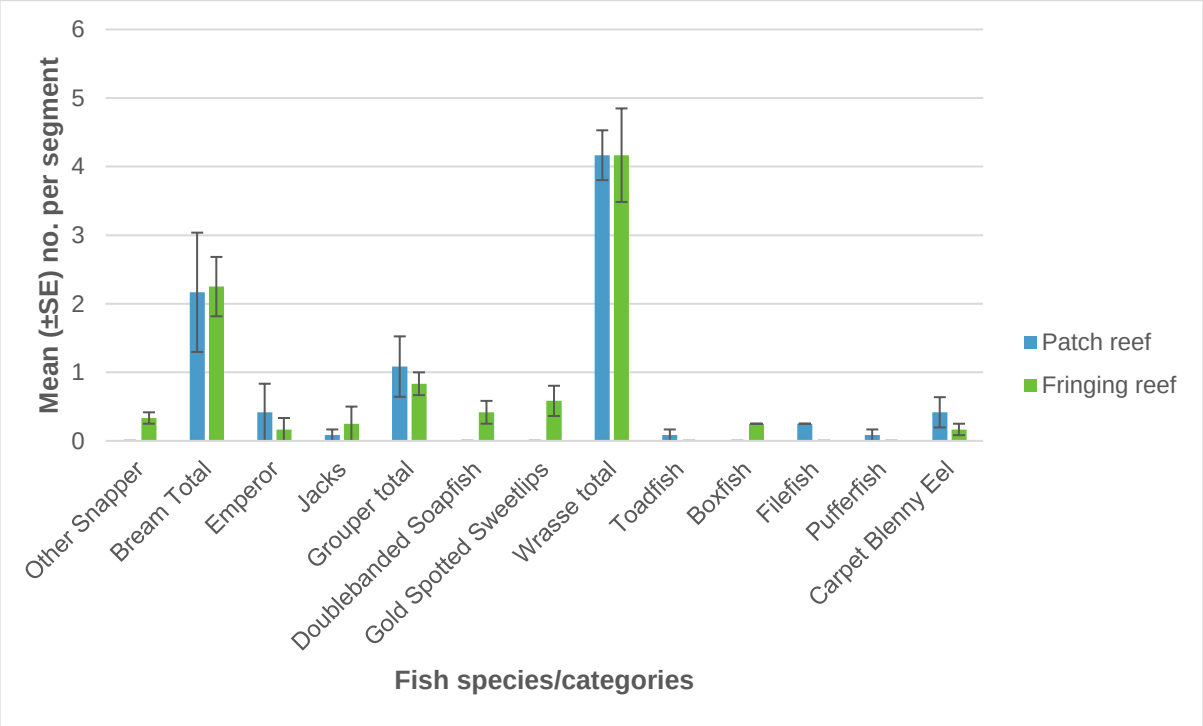

Figure 5: Mean (±SE) number of fish species/categories counted per 20 metre segment within the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

4.2 *Invertebrate Survey Results*

MCC's 2016 coral reef surveys of Koh Karang determined that the fringing and patch reefs were both dominated by a small number of invertebrate species (refer to figure 6). These include *Diadema* urchins (90.7 & 181.7 p/s), Christmas tree worms (49.7 & 93.4 p/s), boring bivalves (24.7 & 51.9 p/s) and feather duster worms (19.4 & 39.9 p/s).

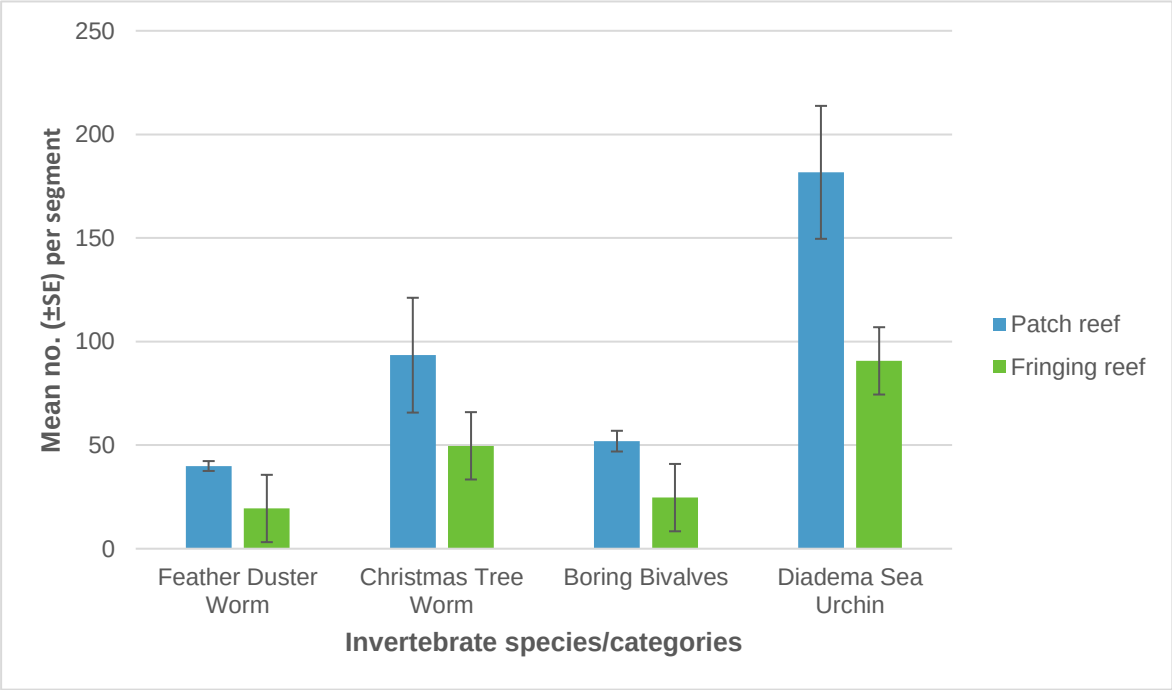

Figure 6: Mean (±SE) number of invertebrate species/categories counted per 20 metre segment within the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

No conclusive differences in invertebrate abundance were unveiled between the two reefs as a result of MCC's surveys. Nevertheless, a number of variations in species richness were noted (refer to figure 7). Gastropod species, including *Trochus* and others not explicitly recorded in their own category (chiefly *Turbo* species), were only surveyed within the fringing reef. In contrast, cowrie, pencil urchins and collector urchins were only documented in the patch reef.

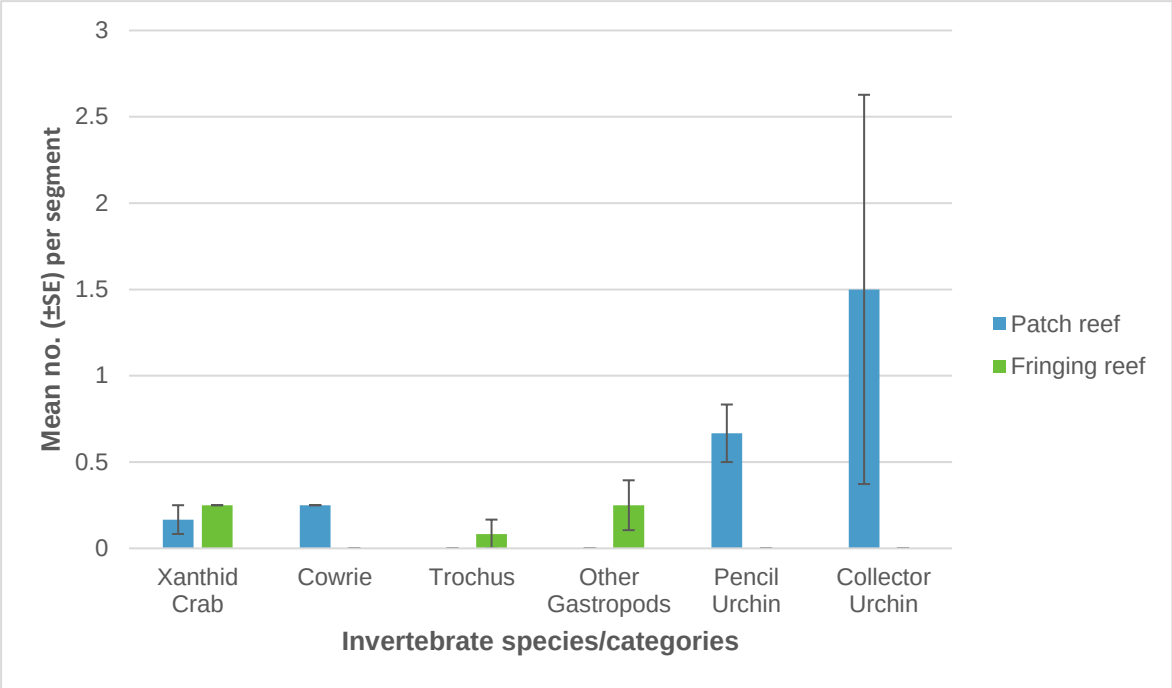

Figure 7: Mean (±SE) number of invertebrate species/categories counted per 20 metre segment within the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

4.3 *Substrate Survey Results*

The 2016 Koh Karang coral reef surveys undertaken by MCC denoted that both the fringing and patch reef structure consisted primarily of live hard coral (refer to figure 8). Following hard coral (57.1% & 56.7%), rock (22.7% & 13.1%) and sponge (13.1% & 17.1%) displayed a moderate average cover in these reefs. All additional substrate types recorded were present at relatively low levels (≤5.6%).

A small number of significant differences were produced from MCC's substrate data. The patch reef was found to contain a conclusively greater coverage of soft coral (4.6% vs. 0.4%; p=0.05). Conversely, rock (22.7% vs. 13.1%; p=0.04) and zoanthids (0.8% vs. 0.0%; p=0.02) composed a significantly larger proportion of the fringing reef's structure.

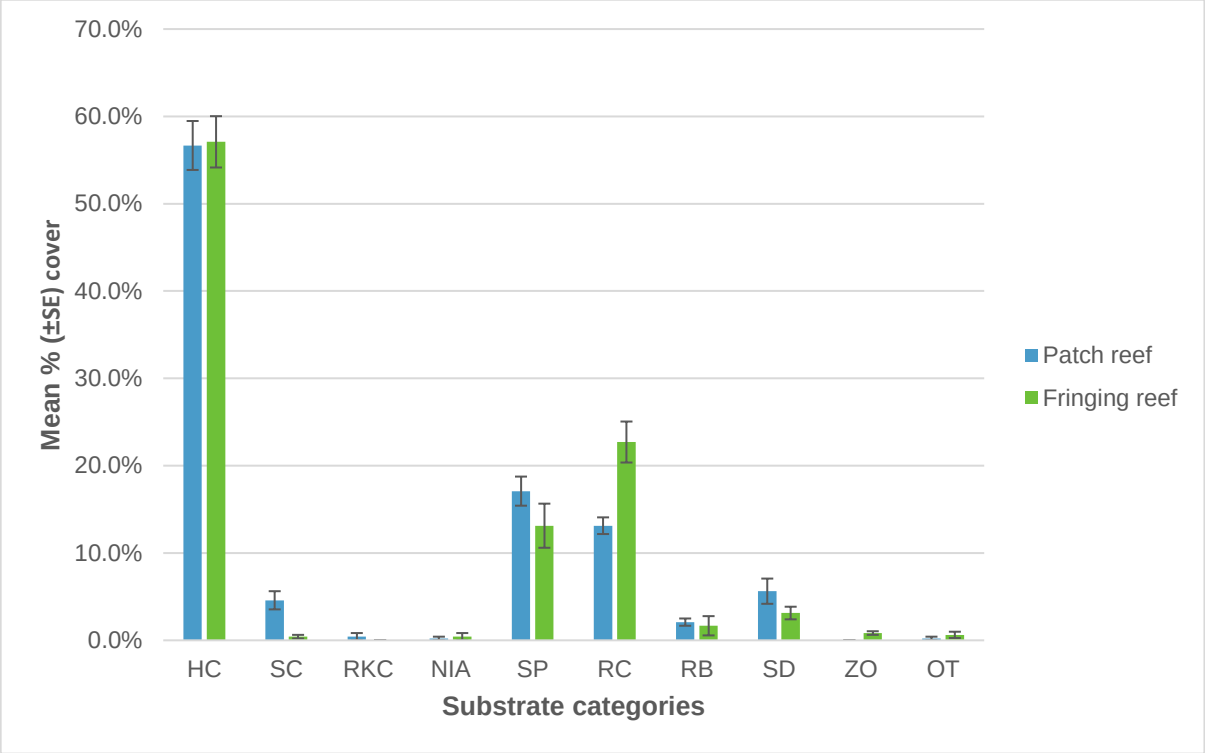

Figure 8: Mean % (±SE) of substrate coverage within the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

4.4 *Impact assessment:*

Data from MCC's 2016 coral reef surveys of the fringing and patch reef sites at Koh Karang, indicated that a noteworthy mean incidence of bleaching and disease occurred here (refer to figures 9 & 10). On average, bleaching was recorded on moderate levels within coral colonies (27.7% & 15.8%) and throughout the coral population at each site (28% & 15.4%) (refer to figure 9).

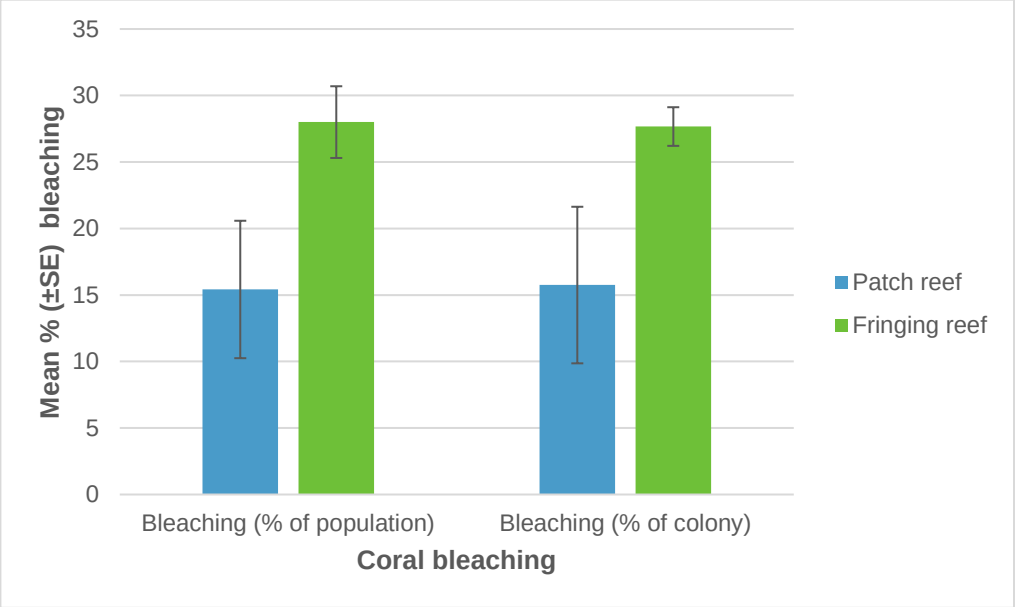

Figure 9: Mean % (±SE) of bleaching within coral colonies and throughout the coral population at the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

Coral disease was noted in a significantly greater percentage of colonies in the fringing reef relative to the patch reef (26.7% vs. 15.4%; p=0.04) (refer to figure 10). Coral ailments also affected a comparatively larger proportion of individual colonies within the fringing reef site (28.1% vs. 14.6%), however this result was narrowly non-significant (p=0.06).

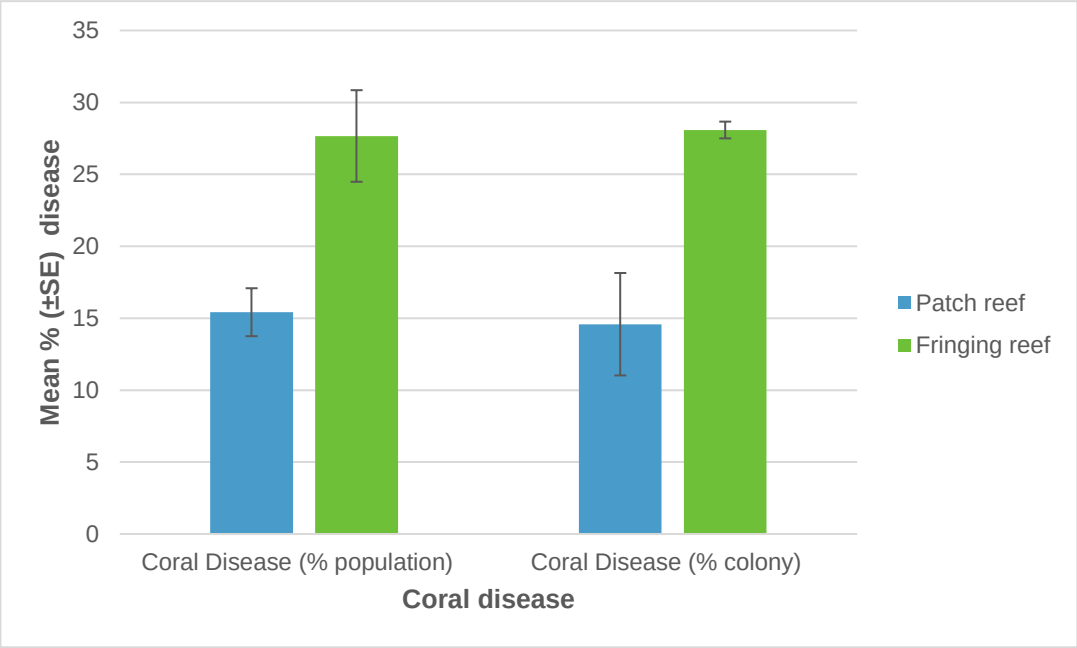

Figure 10: Mean % (±SE) of disease within coral colonies and throughout the coral population at the patch reef (n=3) and fringing reef (n=3) during MCC's 2016 coral reef surveys of Koh Karang.

5 Discussion

MCC's 2016 coral reef surveys of Koh Karang, Kep Province, Cambodia, unveiled data indicative of two coral reefs that are moderately degraded, yet hold the potential for recovery. The fish biodiversity and abundance was low, however a moderate-high coverage of live coral is an encouraging sign. Positively, the fringing and patch reefs contained a relatively high population of rabbitfish and sergeant fish, both of which are important grazers and thus assist in regulating algal abundance. This, in conjunction with a low presence of predatory fish (mainly grouper, fusilier, snapper and jack species), supports top-down and bottom-up mechanisms to help ensure trophic stability. This is vital in ensuring that the various the trophic levels, for instance producers (algae and seagrass), herbivores, mesopredators and predators, remain at population numbers necessary for ecosystem stability.

The small number of differences in fish species noted between the fringing and patch reef may symbolize real alterations in the species composition of the two sites. Comparatively less abundant species within Kep Province were recorded by MCC, such as boxfish (fringing reef) and pufferfish (patch reef). This gives hope as to the potential for population recovery of these vulnerable species, however this is hinged upon greater enforcement of Cambodian fisheries law within Koh Karang's marine environment. Despite the occurrence of these fish, many functionally important marine species are still seemingly missing from Koh Karang, including dugongs, turtles, sharks, parrotfish and numerous others. The return of these significant marine animals is a long-term goal for Koh Karang, and may require several years of habitat restoration and fisheries law enforcement.

The invertebrate diversity of Koh Karang was determined through MCC's data to be low, with a small number of species dominating both reefs. The densely populated invertebrates on both reefs included *Diadema* urchins, Christmas tree worms, boring bivalves and feather duster worms. A number of key invertebrate species were not surveyed or observed by MCC, such as giant clam, commercial sea cucumber and lobster, as well as numerous others.

MCC's reef surveys found both the fringing and patch reef contained a moderate-high coverage of hard coral. Considerable research in the Indo-Pacific region has found correlative increases in fish biodiversity and abundance, with coral cover and coral species richness

(Komyakova *et al.* 2013). This is especially true for the abundance of Chaetodontidae (butterflyfish and coralfish) and Scaridae (parrotfish) species found in this region yet absent from Koh Karang, both of which feed upon dead or living coral structure. Furthermore, juveniles of many fish species prefer to settle near live coral (Komyakova *et al.* 2013). Both these findings reinforce the potential for fish populations to regenerate in the impacted reefs of Koh Karang. In order for this potential to be reached, the coral population of the fringing reef and patch reef need to be monitored carefully, especially in light of MCC's impact assessment results. Bleaching was exhibited on a moderate level within both reefs. Coral bleaching impairs coral growth, calcification, overall lifespan and reproduction of corals, as well as resulting in declines of coral cover and species richness (Ostrander *et al.* 2000; Loya *et al.* 2001). The rejuvenation or demise of coral colonies following bleaching events at Koh Karang need be evaluated regularly in order to avoid these adverse impacts.

Coral disease incidence appeared to be moderate-high within coral colonies and throughout the coral population of both reef sites. The Coral Disease Working Group of the Global Environmental Facility Coral Reef Targeted-Research Program (2007) quotes various papers estimating the 2002 – 2006 regional average disease prevalence of Australia, Palau, East Africa (5%), the Philippines (8%), in addition to the Caribbean and Yucatan peninsula (up to 20%). Based on these statistics, the fringing reef coral colonies (28.1%) and population (27.7%) showed markedly high disease prevalence. Despite being significantly lower, disease incidence in the patch reef coral colonies (14.6%) and population (15.4%) was also above average. These concerning levels of disease are with high probability due to anthropogenic stressors, for instance destructive fishing, waste and pollution, sedimentation and negligent discarding and misuse of fishing gear/trash. Coral ailments need be monitored carefully in order to prevent potential outbreaks that could result in widespread coral mortality, thus ensuing highly adverse ecosystem effects.

Despite its currently degraded status, Koh Karang's marine bioregion could plausibly develop into a thriving and productive area through concerted conservation effort. The most vital aspect of this is protection against illegal and destructive fishing techniques, predominately trawling. Fish and shrimp trawling frequently damages coral communities in Southeast Asia (McManus 1997) and the Kep Archipelago. Trawling nets indiscriminately catch fish, invertebrates and habitat (seagrass, sponges, coral etc.), resulting in sometimes higher

than 80% by-catch and extensive ecosystem harm (MCC 2016). By intensely disturbing the sea-bed, trawling can cause microbial production (Gotner *et al.* 2000), heightened nutrient and contaminant levels, smothering of respiratory and feeding organs, and exposure of anoxic layers (Kaiser *et al.* 2001). Furthermore, the nutrients and sediment released can contribute significantly to coral mortality (Szmant 2002).

MCC surveyors witnessed numerous trawling and fishing vessels within close proximity to Koh Karang. Trawling sediment frequently clouded the water, hindering visibility and thus MCC's ability to survey the coral reefs. Discarded fishing gear was littered throughout both survey sites, entangling and smothering marine organisms. Regulation of fishing and the expulsion of illegal fishing techniques are necessities in facilitating ecosystem restoration of Koh Karang.

MCC strongly endorses the implementation of the Marine Protected Area (MPA) for Koh Karang proposed by Knai Bang Chat. The current state of the marine ecosystems within the locality of the island are not unsuitable for tourist activities, however large room for improvement remains. Based on MCC's previous experience in marine environment restoration, two years of conservation effort and fisheries law enforcement may be required to produce considerable enlargements in fish biodiversity and abundance. Implementation will also need to consider the livelihood of local fishers who depend on the marine ecosystems of Koh Karang. Fishers are the main beneficiary of these protected areas due to the higher catch and economic benefits that they are extremely likely to reap in the near future following implementation. Nevertheless, the spread of information and regulations involved in the MPA is essential to ensuring collaboration and cooperation with fishing communities. MCC suggests the integration of regulated fishing zones with Knai Bang Chat's projected MPA, together forming a scheme strongly resembling a Marine Fisheries Management Area (MFMA). MCC has already proposed a stage 1 MFMA scheme for the Kep Archipelago. By founding multiple MFMA/MPA's within Kep Province, connectivity of larvae will with high likelihood ensue between these protected regions. The significance of this would be bolstered marine species populations and enhanced ecosystem resilience. The habitat regeneration arisen through protected area management will very likely increase marine species biodiversity, thus improving ecosystem function, services and productivity. This two-fold MPA/MFMA

implementation is exceedingly recommended by MCC, as it will form a significant step in returning Kep Province waters to their previous thriving state.

6 References

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Appendix 1:

Full article description based upon the Kingdom of Cambodia's Law on Fisheries (FiA 2007):

Chapter 9 – Marine Fishery Exploitation:

Article 49:

Trawling in the inshore fishing areas shall be forbidden, except for the permission from the Minister of Agriculture, Forestry and Fisheries at the request of the FiA to conduct scientific and technical research.

Article 52:

Shall be prohibited:

1 – Fishing or any form of exploitation, which damages or disturbs the growth of seagrass or coral reef.

2 – Collecting, buying, selling, transporting or stocking of corals.

3 – Making port calls and anchoring in a coral reef area.

4 – Destroying seagrass or coral by other activities.

All of the above activities mentioned in points 1, 2 and 3, may be undertaken only when permission if given from the Minister of Agriculture, Forestry and Fisheries.

Appendix 2:

Map depicting MCC's survey sites and direction, in addition to the coral reef and seagrass habitat distribution of Koh Karang, Kep Province, Cambodia.