Strategic environmental assessment of the proposed marine protected area, Kep Archipelago, Cambodia

Marine Conservation Cambodia
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Seahorse, Cambodia

In Partnership With:

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Acknowledgements

Marine Conservation Cambodia (MCC) has been working on conservation and community livelihoods in collaboration with the Royal Government of Cambodia Fisheries Administration (RGC FiA), local authorities and local communities since 2008. Our Marine Monitoring, Marine Research and socio-demographic programs around Koh Rong and Koh Rong Samloem were used in the creation of the first Marine Fisheries Management Area in Preah Sihanouk Province: we are currently undertaking marine surveys around Kep's 13 islands to monitor the coral reefs, seagrass beds and seahorse populations to assist the Provincial Authorities in the creation of Fisheries Management areas, Cambodia's equivalent to Marine Protected Areas (MPAs).

Close collaboration with the provincial and national FiA, Local government bodies and International Institutions is the key to our success. MCC is a respected and credited leader in conservation and community work in Cambodia. As such, we were requested to set up the first base line surveys for a continued monitoring program and the start-up of a Coral Reef Restoration Pilot Project on the islands off the coast of Kep.

H.E. Som Piseth	Deputy Governor, Kep Province
H.E. Mr. Nao Thuok	Director General of the Fisheries Administration
Mr. Ing Try	Deputy Director General of the Fisheries Administration
Mr. Ouk Vibol	Director of Fisheries Conservation Division
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List of Abbreviations and Acronyms

FiA	Fisheries Administration
MCC	Marine Conservation Cambodia
MPA	Marine Protected Area
RFLP	Regional Fisheries Livelihoods Program
RGC	Royal Government of Cambodia
USD	United States Dollar
SS	Survey Site
HC	Hard Coral
SC	Soft Coral
SG	Sea Grass
SD	Sand
RC	Rock
RKC	Recently Killed Coral
SI	Silt
RB	Rubble
SP	Sponge
AN	Anemone
ZO	Zooanthids
OT	Other
NIA	Nutrient Indicator Algae

Executive summary

The Kep Archipelago has the potential to be a globally significant, productive marine environment, as history shows it is capable of supporting a vast array of species, such as dolphins, endangered dugongs, seahorses, bamboo sharks and countless other species, some of which are unique to the region. Strategic marine management is required to address the issues that are currently destroying vital habitat, significantly reducing biodiversity and contributing to the risk of population collapses. Recognizing the urgent need for action, the Cambodian government requested MCC to conduct a marine environmental assessment of the Kep Archipelago. This paper presents the main findings of the assessment, which has involved coral reef survey studies of Koh Seh, Koh Mak Prang and Koh Angkrong, and a socio-demographic analysis of the island communities of Koh Pou.

Baseline assessments of Koh Seh, Koh Mak Prang and Koh Angkrong were conducted in March 2014. These the islands were selected, as their potential to regenerate into productive, diverse ecosystems is high, and their position within the Kep Archipelago can allow for conservation efforts to have flow-through effects, benefitting surrounding waters. Since MCC has relocated their headquarters to Koh Seh (November 2013) we have been conducting joint enforcement of fishing regulations with the FiA, alleviating the pressures of illegal fishing. Efforts have been focused within a 'triangle' encompassing Koh Seh, Koh Angkrong and Koh Mak Prang. A second series of reef surveys (January 2015) were conducted to assess any improvements in the marine health of the 'triangle'. Such temporal-comparative studies are useful because they monitor population and diversity counts over an extended period of time. This, in turn, can be indicative of how effective any conservative or protective efforts in place are actually being.

Both sets of surveys found the overall health of the islands' reef ecosystems to be relatively poor. This conclusion is based on the observed low abundances and diversity of fish and invertebrates, and the limited complexity of substrates. Comparison between the results from the initial island surveys and the follow up surveys suggest fish populations are already beginning to regenerate. Interestingly, a number of indicator fish species/families were observed in 2015 that were not present during the 2014 surveys. Many of the fishes that were observed in 2015, but not 2014, are larger commonly targeted fish families/species, suggesting relieved fishing pressure has already positively impacted the

diversity of the reefs. Results suggest that the diversity of fishes is particularly increasing at Koh Seh. The structure and substrate complexity of the reefs are overall in fairly poor condition, but healthy sections of reef demonstrate the potential for the area to support diverse sedentary life (e.g. soft and hard corals, anemones, sponges). Given the current substrate cover, the implementation of the MPA encompassing Koh Seh, Koh Angkrong and Koh Mak Prang holds great potential in revitalizing the reef structure, enriching diversity and increasing population densities, as long as protection is enforced. Calculated Jacquard Similarity Index (JSI) values for Koh Seh's demonstrate that its' reefs are in best condition of the three islands. The increase in diversity and population abundance, which is more significant on the east coast, is likely because the MCC headquarters is located on the eastern side of the island, and thus, it receives more thorough protection against illegal fishing. This displays the clear correlation between increased reef health and proper enforcement of fisheries regulations.

MCC has continued to observe and document the use of unsustainable and illegal fishing methods, such as trawling, gill nets and air-supplied fishing. The observed low abundance and diversity of fish demonstrates the negative implications of overfishing. Reef survey results suggest that populations of larger species of carnivorous fishes, such as groupers, snappers and flathead, have been decimated, leaving small fish populations to grow unregulated by predation. Overfishing of these large fish species decreases the reef's diversity, forcing the food web out of balance and decreasing the productivity of the ecosystem. In addition to observing illegal fishing from the island of Koh Seh, or from our dive boat, the destruction from these fishing activities is evident underwater. Scientists and trained survey divers recorded a high amount of pollution from fishing activities, including batteries from crab cages, broken nets, cages and lines, plastics and polystyrene waste. High trawling activity was evidenced by broken coral, uprooted seagrasses and scoured seafloors, as well as high amounts of large suspended particles that are remnants of reef breakage and bottom disturbance. Patrols (fisheries authorities and the MCC patrol team) still catch illegal fishers within the 'triangle' of Koh Seh, Koh Mak Prang, and Koh Angkrong. Many are

Vietnamese trawlers and tube fishermen, who are turning to Cambodian waters since their marine environment has been unsustainably fished, and thus, has declined in productivity (Pomeroy, 2011). Khmer fishers are also caught using illegal fishing gear.

Thus far, MCC has interacted with the local people of Koh Pou. Three visits to the island and numerous conversations aimed to gather the locals' perception on the state of fisheries resources, and to provide an opportunity for locals to voice their concerns about the state of the marine environment. Information on waste management on Koh Pou was also collected, as it is evident that waste is negatively impacting the marine and terrestrial environment, as well as the locals' livelihood.

Given the encouraging results of the reef surveys, MCC recommends the implementation of a Marine Protected Area (MPA), including a no-take zone along Koh Seh's east coast. With the creation of the recommended MPA, species will have the opportunity to repopulate and ultimately contribute to the marine ecosystems' diversity and resilience. With the initial and follow-up survey data as a baseline for comparison, MCC will have the opportunity to monitor the effectiveness of conservation efforts, allowing for management decisions to be informed and the benefits of the MPA to be optimized. If the region were able to support such a diverse and unique array of species, Cambodia, and Kep in particular, would be a highly attractive, economically lucrative marine environment, capable of generating significant revenue.

1 Introduction

Cambodian waters are situated within the South China Sea, a once highly diverse and rich marine environment. The nations bordering the South China Sea are home to 5% of the world's human population (Talaue-McManus, 2000). These populations heavily rely upon the resources and services provided by the marine environment, including seafood production, employment (e.g. fisheries, shipping, tourism) and ecological services (e.g. carbon sequestration; Talaue-McManus, 2000). It is clear that strategic management of the

marine environment is vitally required in order to conserve biodiversity, promote productivity and support local livelihoods (Wheeler *et al.,* 2000).

Cambodia's economy is largely dependent on its coastal and marine sector (Wheeler *et al.,* 2000). This is particularly true for Kep Province. The Kep Archipelago is a series of thirteen islands with fringing coral reefs and seagrass meadows. Marine resources support the island communities, the coastal city of Kep, and other coastal inhabitants. The city of Kep is a popular tourist destination and acts as the entrance point to the Kep Archipelago. The area is famous for its seafood, particularly 'Kep Crab' (blue swimmer crab,). The health and productivity of the region's marine environment is declining, largely due to unsustainable fishing activities resulting in habitat loss and overall ecosystem productivity. Kep provincial government has recognized the need for management actions to focus on the protection and regeneration of marine ecosystems. Coral reef and seagrass ecosystems require particular attention.

Coral reefs are complex, highly productive and biologically diverse ecosystems, composed of a vast diversity of unique life. Worldwide, populations rely on the crucial ecosystem goods and services provided by coral reefs, namely fisheries production, coastal protection, biodiversity, carbon sequestration, and tourism (Conservation International, 2008). An economic analysis of recreational opportunities related to coral reefs in Cambodia's Ream National Park, estimated the present value of the best protection scenario ranged from $21,390 to $699,636 per km^2 of healthy coral reef ecosystem (Conservation International, 2008).

Seagrass meadows are among the most diverse and highly productive coastal ecosystems in the world (Duarte *et al.* 2004). Seagrasses produce huge amounts of biomass out of solar energy, facilitating carbon sequestration and generating crucial habitat for many different species. As primary producers of a complex ecosystem, seagrasses make nutrients available to the marine food web. Animals that rely on seagrass as a direct food source include fishes, dugongs, sea turtles and marine birds. Decaying seagrass also enriches the ocean with detrital food, which provides the foundation for long and complex food chains,

leading to important human food sources. Their complex root systems stabilize sediments, and dense enough meadows act as buffers that decrease wave action during intense storms. Seagrasses serve as 'ecological sentinels', reflecting anthropogenic effects and overall ecological health within coastal ecosystems, making seagrasses ideal for studying large-scale trends (Bjork *et al.* 2008). For instance, the decline in seagrass extent and health in Cambodian waters should be taken as a warning sign, indicating the need for management actions focused on the conservation of seagrass meadows.

Seagrass and coral reef ecosystems are susceptible to a number of anthropogenic influences, including unsustainable fishing activities, pollution, siltation, and nutrient run off. Such threats have negatively impacted the status of Kep's marine environment; consequently, measures to protect and revive seagrass and coral reef ecosystems are urgently required.

Marine Protected Areas (MPA) are internationally recognized as valuable tools for the protection and recovery of species and key habitats in decline, together with the associated ecosystem services (Pauly *et al.,* 2002). In 1970, there were only 118 MPAs globally (Kelleher and Kenchington 1992). By 2008, the number of MPAs had grown to over 5,045 worldwide (Spalding *et al.* 2008). MCC recommends that a MPA be established in the Kep archipelago (Figure 1). The MPA would encompass Koh Seh, Koh Mak Prang and Koh Angkrong, and a portion of Koh Pou (Figure 2), as assessments of these islands' reefs indicate a high potential for recovery. If successful, the MPA would be an important step towards the sustainability of fisheries, and the protection of biodiversity, which is vital to a productive marine environment.

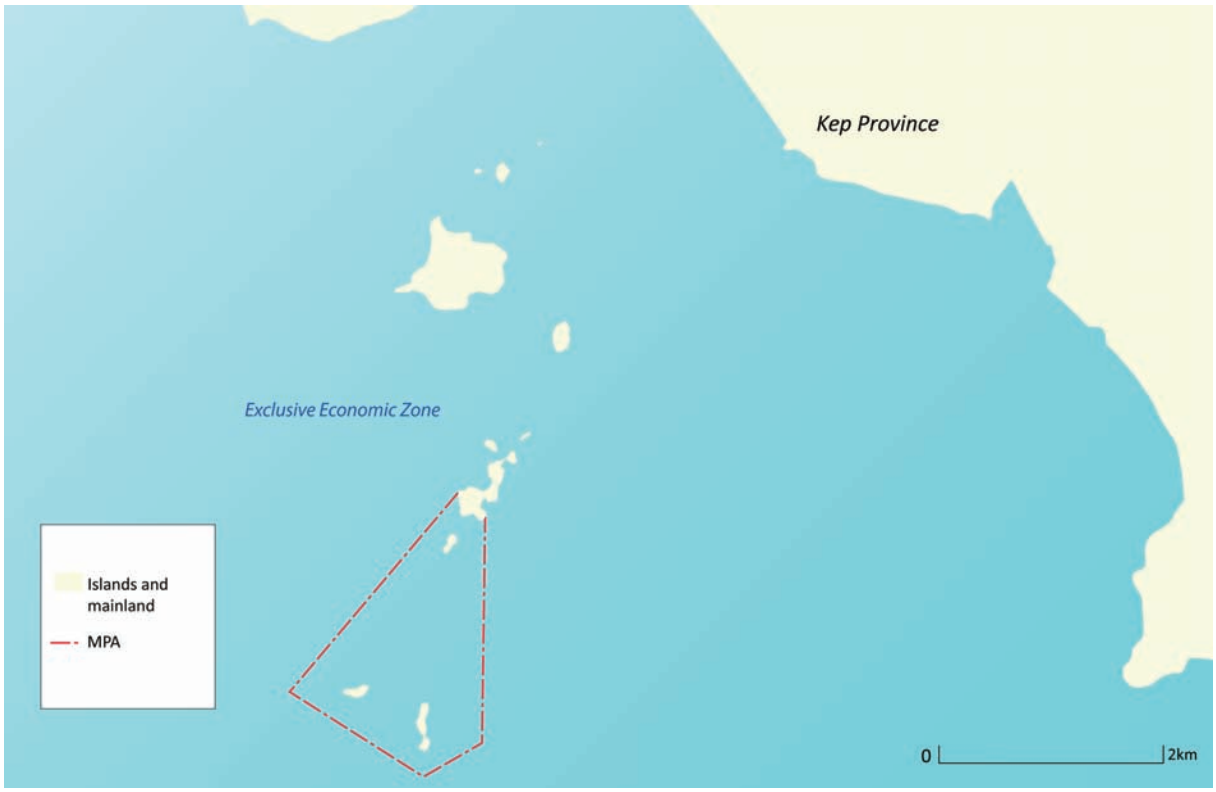

Figure 1: Location of proposed MPA in Kep Archipelago, Cambodia.

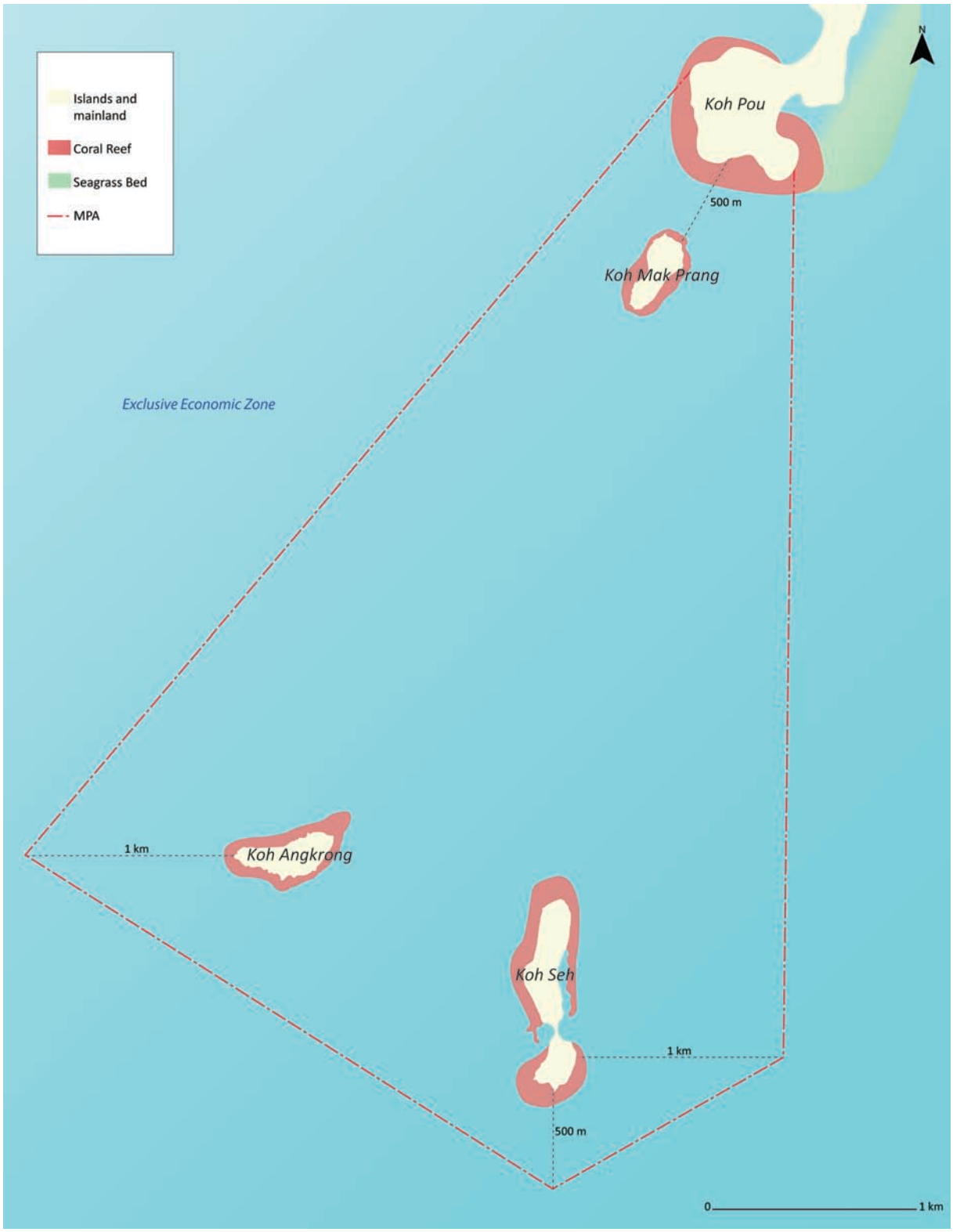

Figure 2: Dimensions of proposed MPA encompassing Koh Seh, Koh Angkrong and Koh Mak Prang, Kep Archipelago, within Cambodia's exclusive economic zone.

In order to optimize the impact of an MPA, 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's success, as their livelihood immediately depends on the productivity of the marine environment. As local actions will influence the regenerative capacity of the MPA, widespread awareness regarding the aim and potential of the MPA is required. Fishermen possess valuable local ecological knowledge that can contribute to informed management decisions (Andrew and Evans, 2009). Experiences of other MPAs indicate that community involvement can significantly benefit the effectiveness of an MPA, as participation in management actions leads to information exchanges, and the development of plans strategically designed to the local condition (Andrew and Evans, 2009). The creation of an MPA 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 (FiA, 2005).

In support of the proposed MPA, MCC has conducted baseline survey studies assessing the three islands' reefs in March 2014, followed by a second set of comparative survey studies in January 2015. Community interviews conducted on Koh Pou have provided valuable insight into the issues that are threatening the health of the marine environment, and decreasing the security of local livelihoods.

The following report summarizes the main findings of MCC's research in the Kep Archipelago, discusses the main issues requiring attention, and presents potential considerations and approaches that promote marine conservation and long-term sustainability of fisheries.

2 Methodology

The following section describes the methodology of the overall assessment of the three islands. For the readers' ease, the applied methodology previously detailed in the individual reports of Koh Seh, Koh Mak Prang and Koh Angkrong is included in Appendix 7.1.

2.1 Data Analysis

Data was analyzed for each island individually, as described in the Appendix 7.2.

2.1.1 Jacquard Similarity Index

The Jacquard Similarity Index (JSI) was calculated for pairwise comparison of the three islands to give an estimate of the similarity in diversity. All fish and invertebrate species that were recorded in the 2014 and 2015 survey sets were utilized to perform the calculation, as shown in Table 1.

Table 1. Formula and parameters for calculating the Jacquard Similarity Index.

J =c / a + b - c
a = # sp. island a
b = # sp. island b
c = # sp. observed on a and b

2.2 Assessment of Island Communities' Challenges and Perceptions

Thus far, MCC has interacted with the local people of Koh Pou (Figure 3). Three visits to the island and numerous conversations aimed to gather the locals' perception on the state of fisheries resources, and to provide an opportunity for locals to voice their concerns about the state of the marine environment. Information on waste management on Koh Pou was also collected, as it is evident that waste is negatively impacting the marine and terrestrial environment, as well as the locals' livelihood. MCC teams, consisting of at least one Khmer speaking MCC staff member and international staff/volunteers, interviewed fishermen individually. A copy of the interview questionnaire is included in Section 7.1.4. Interviews generally lasted over an hour. After the visit, completed questionnaires were reviewed, entered into electronic versions, and discussed. Each team provided a summary of

their interview to the other teams, facilitating discussion and clarification of points if needed.

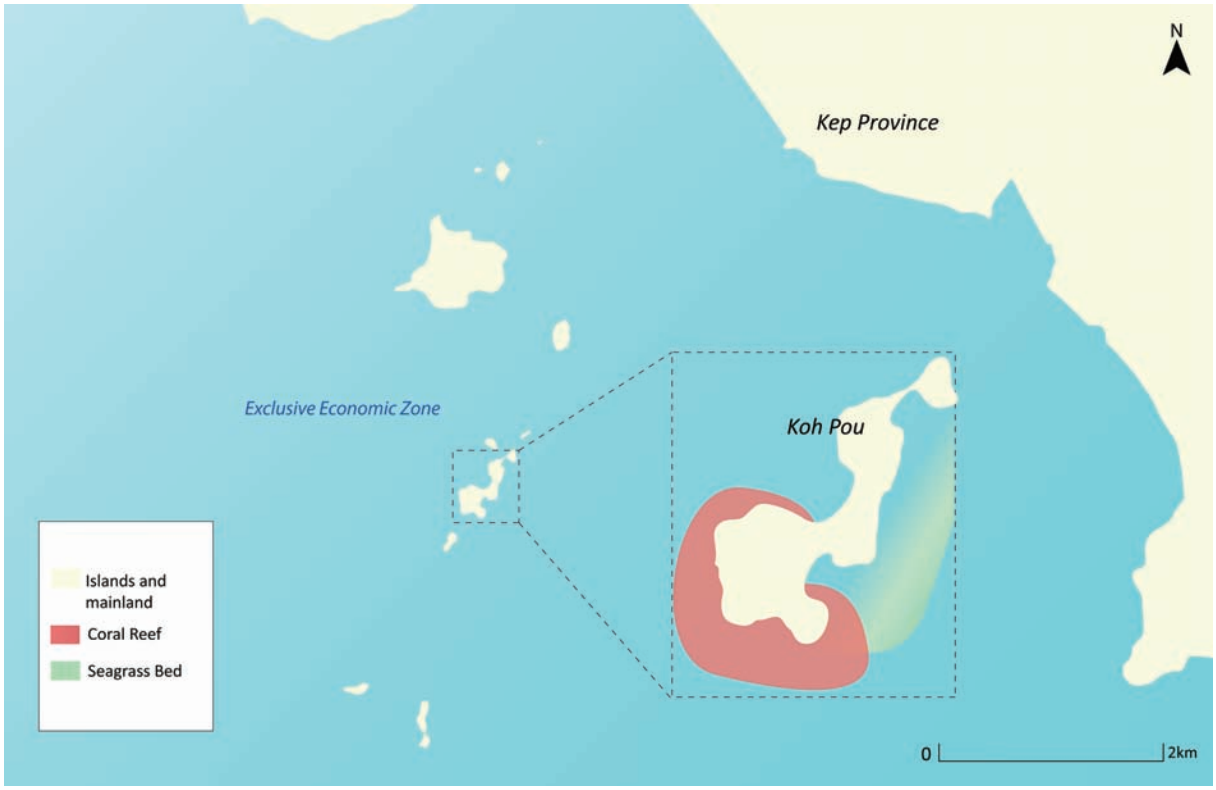

Figure 3: Location of Koh Pou in the Kep Archipeligo, Cambodia

2.3 Project Limitations

During the reef survey period, the MCC team was confronted with several limitations that influenced the data collection process. Such project limitations included:

Weather: Strong winds and/or heavy rain resulting in high-energy condition limited the opportunities to perform survey dives. Waves and strong currents mainly caused by wind, made it dangerous for divers to be in the shallow reef area where there are sharp corals and a high occurrence of sea urchins. In December 2014, very frequent strong winds forced the MCC team to stop surveying for several weeks.

Visibility: Wind and rain also resulted in a decrease of visibility due to particles being suspended in open water by the force of waves or water streaming into the sea. During the survey dives, divers must be able to spot and recognize fish, before they hide or swim out of sight. Bad visibilities made it hard, or in some cases impossible, to conduct survey dives. Trawling destructs the seafloor, uprooting seagrass, breaking the coral reef structure, and disturbing sediments, which causes large suspended particles to significantly decrease the visibility in the day(s) following the trawling event. A high occurrence of trawling in the waters near Koh Seh, Koh Mak Prang and Koh Angkrong caused a decrease in visibility that was often so intense that data collection was not possible.

Sources of Error: In addition to the aforementioned project limitations, errors in the data collection process occurred. Firstly, survey teams counted zoanthids as hard corals on the 2014 surveys of Koh Seh and Koh Mak Prang; zoanthids are now being recorded as "other substrate" since zoanthids are classified as an independent family. Because of the incorrect classification during the 2014 surveys, we could not make comparisons between the substrate data from the initial and second set of surveys of Koh Seh and Koh Mak Prang.

Another source of error was that the survey site locations differed slightly between the two survey sets (March 2014 and January 2015) of Koh Seh and Koh Angkrong. This was due to a lack of GPS marks or visible references to define the beginning and the end of each survey site. Most of the survey sites are similar, but distances from the end of one survey site to the beginning of the next differ, causing an increase of conducted surveys around Koh Angkrong.

Limited Replicates: The reef check methodology recommends that data collection be conducted within the same survey site in replicates to allow for a more accurate representation of the abundance and diversity of marine life. This is to reduce the impact of outliers, meaning, for instance, that if a big school of fish is observed, the data from that survey indicates there is a high abundance of the schooling fish when in fact, the average abundance is likely less; replicates of the survey will provide the opportunity to collect more

counts, allowing for a more accurate average abundance to be determined. MCC only conducted two replicates of each site, since reef surveys were required around the entirety of the islands and are time consuming. This compromise allowed us to perform an overall assessment of the status of the reefs surrounding Koh Seh, Koh Mak Prang and Koh Ach Krong. In the future, MCC will select permanent survey lines adjacent to each island, allowing for more frequent monitoring, and thus, enough replicates to formulate strong conclusions about the abundance and diversity of the reefs. With the data collected during March 2014 and January 2015, and data from the permanent survey sites, the improvement in reef health can be monitored, and our understanding of the area's marine environment can be enhanced.

3 Results

3.1 Fish Survey Results

Fish surveys have been conducted on the three islands of Koh Seh, Koh Mak Prang and Koh Angkrong in 2014 and 2015, as described in **Error! Reference source not found.** 6.1. The comparisons of the results for each island are shown in Figure 4, Figure 5 and Figure 6 respectively. One of the dominate species of all three islands was the sergeant fish (Figure 7), which showed constant counts across years for Koh Mak Prang, a slight increase for Koh Seh, and a drop from the exceptionally high count (almost 75 counts per survey) for Koh Angkrong, to an average similar to that of the other two islands in 2015. For Koh Seh, cardinal fish were found to be another dominant species that showed an increased number of average counts per survey site. Interestingly, a number of species were observed in 2015 that were not present during the 2014 surveys of Koh Seh, including monocle bream, sweetlips, soapfish, lizardfish/sandperch and box fish (Figure 4). Around Koh Mak Prang, some species counts increased, whilst other decreased from 2014 to 2015; most of the decreases were moderate (around or less than 1 count); a prominent increase in cardinal fish was recorded (Figure 5). Similar to Koh Seh, previously undetected species were

observed during the 2015 surveys of Koh Mak, including moray eels, filefish and blennies. During the surveys of Koh Angkrong, however, the average counts of most species decreased. The number of rabbit fish did increase, and trevally, a previously unobserved species, was seen during the 2015 surveys of Koh Angkrong.

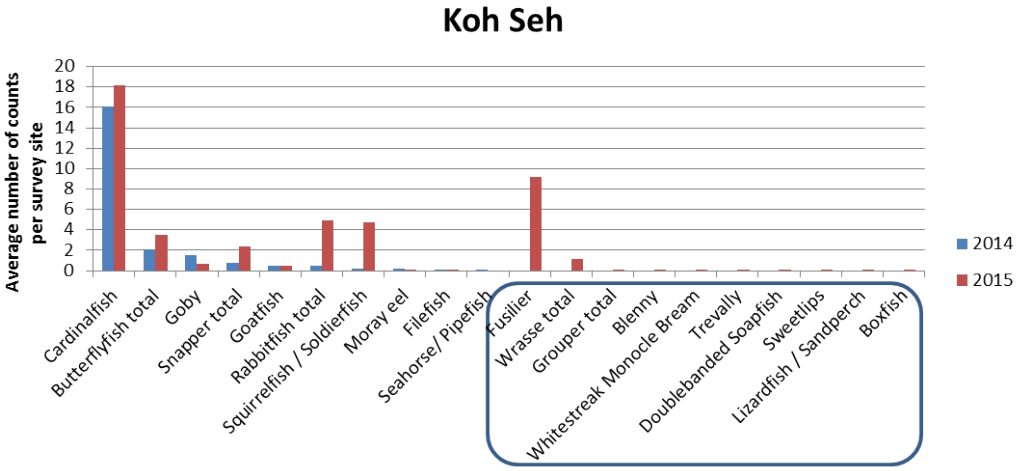

Figure 4: Average number of counts (mean abundance) surveyed at Koh Seh (2014 and 2015). The circled species were observed in the 2015 surveys, but not in the initial surveys in 2014.

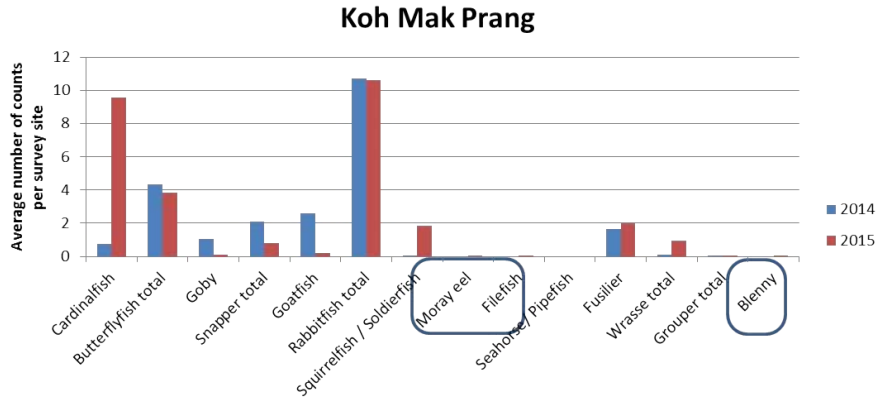

Figure 5: Average number of counts (mean abundance) for fish surveyed at Koh Mak Prang (2014 and 2015). The circled species were observed in the 2015 surveys, but not in the initial surveys in 2014.

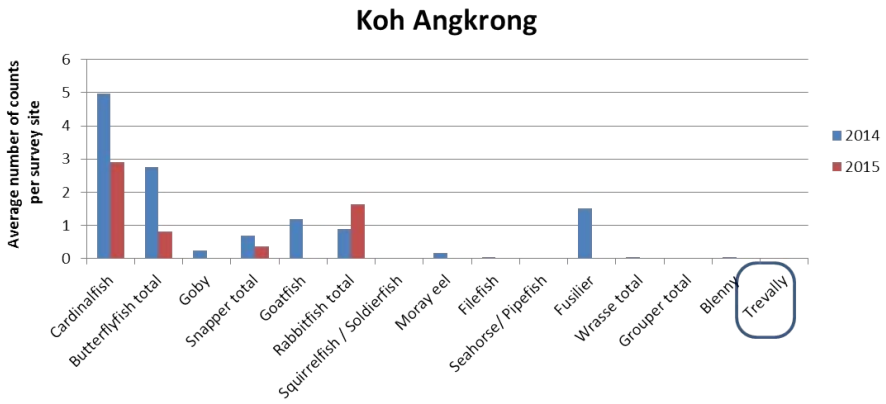

Figure 6: Average number of counts (mean abundance) for fish surveyed in 2014 and 2015 at Koh Angkrong. The circled species was observed in the 2015 surveys, but not in the initial surveys in 2014.

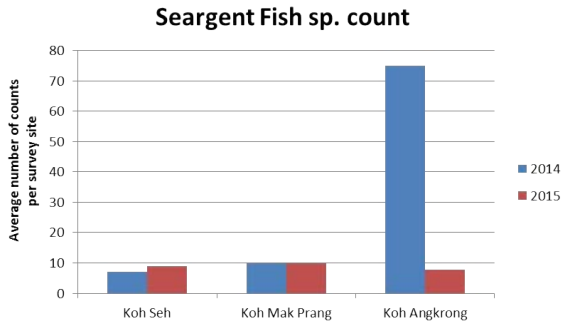

Figure 7: Average number of counts (mean abundance) of sergeant fish surveyed at Koh Seh, Koh Mak Prang and Koh Angkrong in 2014 and 2015.

3.2 Invertebrate Survey Results

The initial surveys of indicator invertebrate species showed that, as of March 2014, the reefs of all three islands were dominated by synaptic sea cucumbers and diadema sea urchins (Figure 8). The 2015 survey results indicated a decrease in diadema sea urchins and synaptic cucumbers at all three islands, except for at Koh Mak Prang (Figure 8). With a decrease in diadema urchins and synaptic sea cucumbers, the results of the 2015 surveys show a more even spread of invertebrate mean abundances. This suggests that the islands are becoming less dominated by a few species, and thus, the biodiversity around the islands is seemingly increasing.

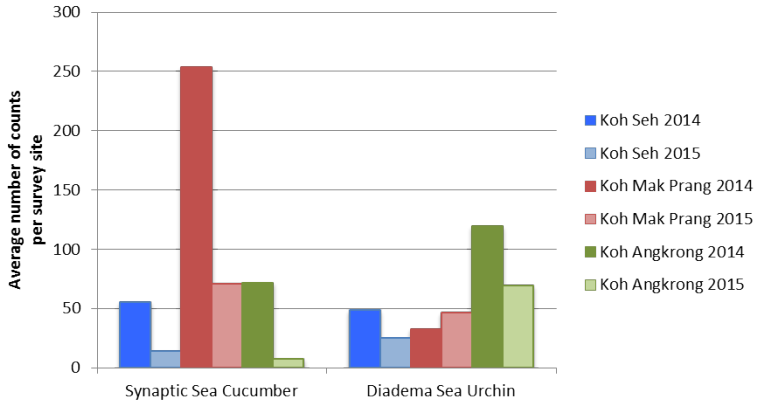

Figure 8: Average number of counts (mean abundance) for the two most abundant invertebrate species recorded at Koh Seh, Koh Mak Prang and Koh Angkrang during 2014 and 2015 surveys.

Many of the other indicator invertebrate species experienced an apparent increase in abundance (Figure 9) from the initial surveys to the second series of surveys of Koh Seh. Only counts of pencil urchins and collector urchins decreased significantly (Figure 9), suggesting the urchins are no longer dominating the benthic (seafloor) environment. Feather stars and greenfish were not present during the 2014 surveys, but were observed in the 2015 surveys of Koh Seh (Figure 9), increasing the apparent diversity of invertebrates.

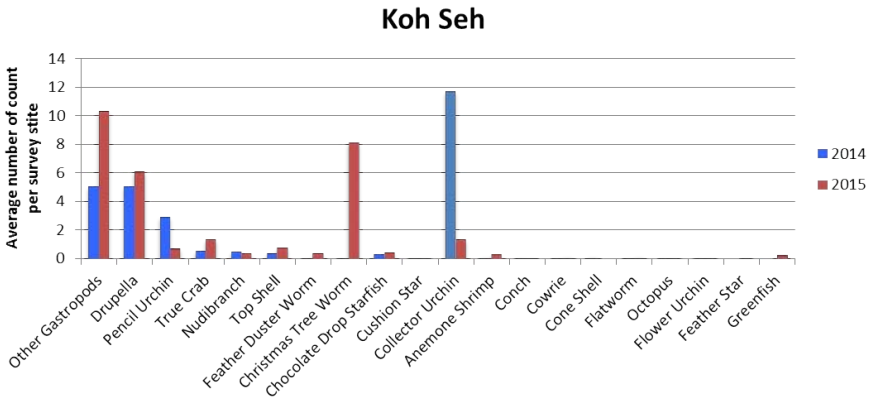

Figure 9: Average number of counts (mean abundance) for indicator invertebrates recorded on surveys of Koh Seh (2014 and 2015).

Surveys of Koh Mak Prang recorded more invertebrate species in 2015 than in 2014, with the most notably increases in drupella, feather duster worms, true crabs and Christmas

tree worms (Figure 10). Additionally, six new species were recorded, including the cone shell, flatworm, flower urchin, cuttlefish, basketstar and greenfish (Figure 10).

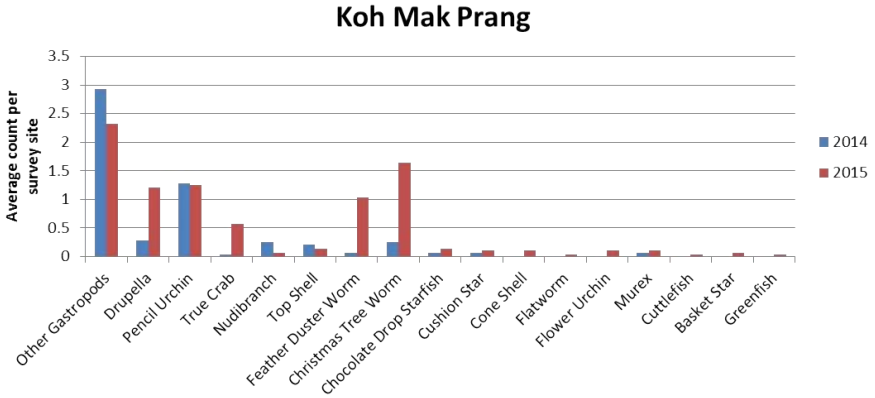

Figure 10: Comparison of average number of counts for indicator invertebrate species between 2014 and 2015 on survey sites on Koh Mak Prang.

There was a general trend of decreased mean abundances for invertebrates surveyed at Koh Angkrong in 2015, as compared to the 2014 survey results (Figure 11). There were notable declines in the amount of drupella, Christmas tree worms and other gastropods (Figure 11), making the counts more even across species. Flatworms and flower urchins were not seen during the 2014 set of surveys, but were observed in 2015 (Figure 11).

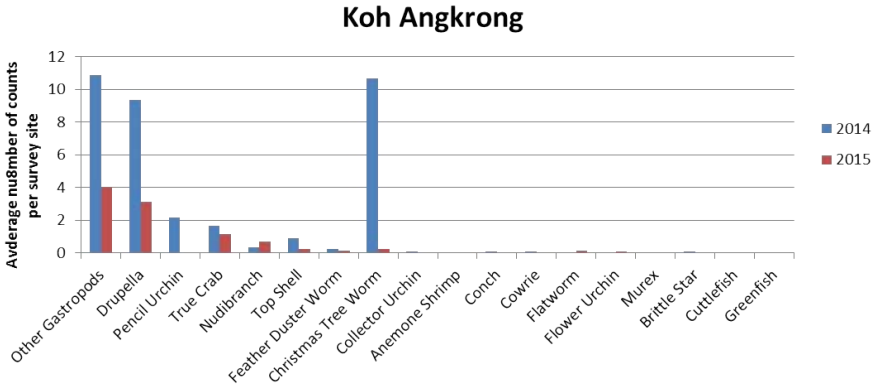

Figure 11: Comparison of average number of counts for indicator invertebrate species between 2014 and 2015 on survey sites at Koh Angkrong.

Figure 12 shows target invertebrate species that were not recorded during the 2014 surveys, but were observed during the 2015 surveys. This data indicates the return of the

greenfish, basket star, feather star, and cuttlefish to the area, suggesting conservation efforts are already benefitting the marine ecosystems by enhancing the biodiversity of the three islands' marine ecosystems. The increased diversity was particularly apparent at Koh Seh, where more surveys (20/survey set) were conducted compared to the other islands (9/survey set), and a greater degree of protection was possible (MCC's headquarters is located on Koh Seh).

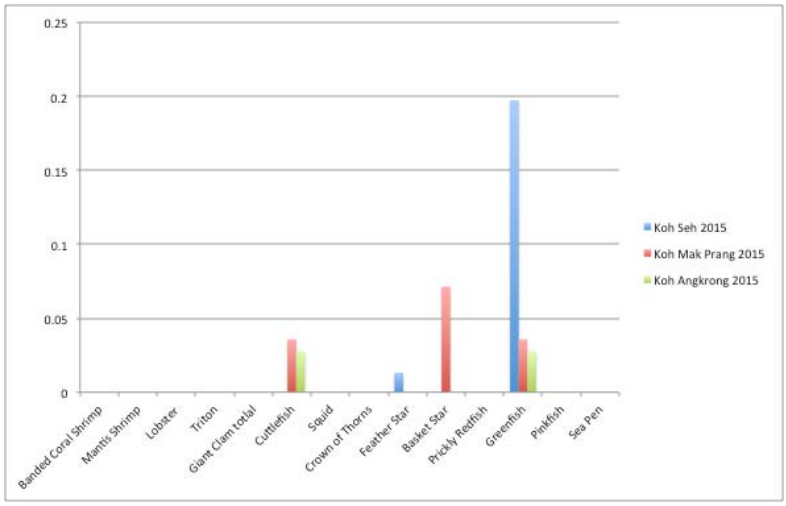

Figure 12: Indicator invertebrates recorded in 2015, but not detected in 2014 surveys of Koh Seh, Koh Mak Prang and Koh Angkrong.

3.3 Substrate Survey Results

The mean percentages of substrate types for each island are displayed in Figure 13. Since the 2014 set of surveys, there has been a decrease in sponge (SP) and an increase in soft corals (SC) at all three islands. Silt (SI) coverage (recorded when greater than 1 cm in depth) decreased at Koh Mak Prang, increased at Koh Angkrong, and was never observed at Koh Seh. There has also been an increase in NIA for Koh Angkrong from 2.77% to 5.42%. Sand (SD) and rock (RC) have decreased across all three islands, and other (OT) and hard coral (HC) have decreased at Koh Angkrong and Koh Mak Prang. OT and HC for Koh Seh cannot be compared, as data collected in 2014 was found to be invalid (zoanthids were misclassified) and was therefore disregarded. The 2015 data is valid, so will serve as a baseline to compare with data collected in future surveys.

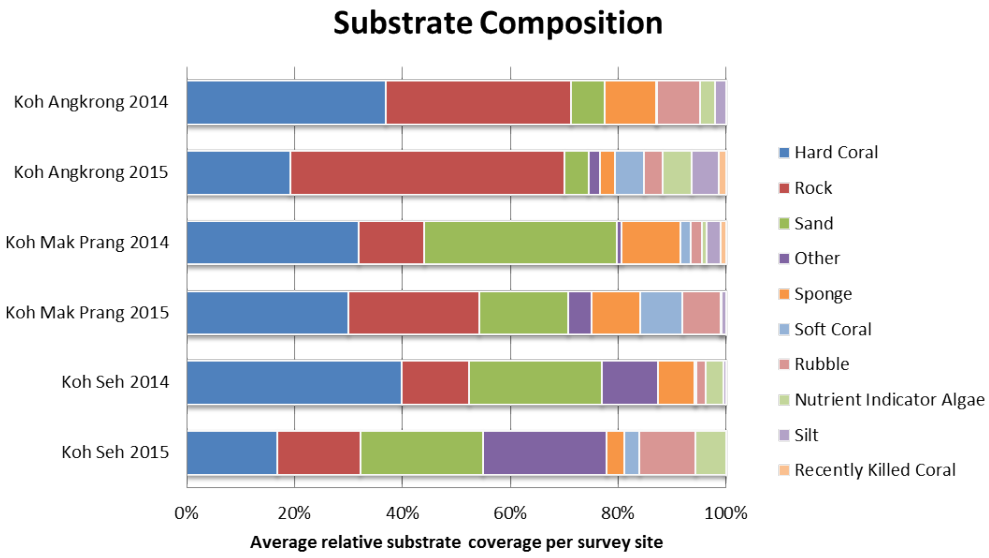

Figure 13: Comparison of area occupied by different substrates on the surveyed sites on Koh Seh, Koh Mak Prang and Koh Angkrang from 2014 and 2015.

3.4 Jacquard Similarity Index

The Jacquard Similarity Index (JSI) was calculated for pairwise comparison of the three islands' fish and invertebrate diversity. The calculated JSIs for both 2014 and 2015 survey sets indicate that more species were observed on surveys of Koh Seh than on surveys of Koh Mak Prang or Koh Angkrong (Table 2). This suggests that there is a greater diversity of fish and invertebrate species on Koh Seh, compared to the other two islands. Koh Angkrong and Koh Mak Prang have a higher similarity index than either island has with Koh Seh.

Table 2: Jacquard Similarity Index for pairwise comparison between fish and invertebrate species recorded at Koh Seh, Koh Mak Prang and Koh Angkrang during the 2014 and 2015 sets of surveys.

	Koh Seh	**Koh Mak Prang**	**Koh Angkrong**
Koh Seh	1	0.57	0.66
Koh Mak Prang	0.64	1	0.59
Koh Angkrong	0.47	0.57	1

2014
2015

3.5 Summarized Results of Community Interviews

Nine fishermen on Koh Pou were interviewed regarding the socio-demographics, fishing practices, waste management and concerns of their village. The fishermen all relied on crab trap-fishing for income, primarily of blue swimmer crabs. Each fisherman, except one that worked as a crewmember, owned a long-tail fishing boat and employs 3 to 5 people (employees and family members). On average, each boat owner had 2000 crab traps, although some of the fishermen reported that as many as 200 traps per month are lost to illegal trawling gears that destroy the traps and/or trap markers. All of the interviewed fishermen agreed that they caught the most during rainy season (20-120kg/trip) and the least during dry season (5-20kg/trip), mainly consisting of blue swimmer crabs.

Six fishermen noted that their catch numbers and the size of their catch have notably declined in recent years. They felt the reason for the decreased catch was the illegal trawling and overfishing in the area. One of the fisherman mentioned changing weather (climate change), particularly an increase in winds, as another possible reason for catch declines. It was reported that at least 10kg of crabs per day is needed to cover the expenses of operating one long-tail boat with 3 employees. It was estimated that 150 people have moved to the island in the last decade, many of whom are seeking better fishing conditions.

When asked about marine ecosystems and how their health influences the crab fishery, responses were quite variable, and indicated that some of the fishermen know about the importance of healthy sea grass, coral reef and mangroves, while others know very little. Those who demonstrated a general understanding, acknowledged that the coral reef and sea grass ecosystems in the area have been under constant decline; they thought that this was due to illegal and destructive fishing practices, particularly trawling. Mangroves in the area were thought to be in decent condition because illegal fishing practices do not directly impact the mangroves. Most fishermen recognized that it is important to conserve habitats, including coral reefs, mangrove and seagrass beds in order to sustain crab populations; however, it was reported that illegal fishing practices were destroying these habitats.

All nine fishermen reported that they frequently (as much as daily/nightly) witness illegal or destructive fishing practices in the Koh Pou area, including pair-trawling, electric trawling, supplied air fishing, small mesh size nets, and the use of toxins or 'medicines' to catch fish. Vietnamese fishermen were largely blamed. There was unanimous concern about these fishing practices, and that the current law-enforcement was not enough to stop the destruction. One fishermen admitted that they gave a small portion of their catch to marine police each time the police helped them, but could not afford to continue to do this every time there is a conflict with illegal fishers. When action against illegal trawlers has been taken, physical altercations have arisen; the trawling boats have rammed smaller crab fishing boats, fights have broken out and gear has been robbed. Locals seemed supportive of MCC's patrolling, and many reported their willingness to assist (e.g. call MCC when they see illegal fishing practices).

When asked about aquaculture and crab banks, three of the eight crab boat captains had an understanding of these practices and their potential benefits. Some had heard about a crab bank in Kep that collects pregnant crabs to raise and release the juveniles. There was a lot of interest in aquaculture and crab banks; seven interviewees stated they would be willing to work in an aquaculture facility; and six would be willing to leave the island for work in aquaculture, as long as it would generate an income equal to, or greater than what they earn fishing. Only one fisherman said he would prefer to keep fishing because he enjoys that part of his life, although he still expressed an interest to learn about aquaculture. It was generally conveyed that implementing an aquaculture facility on Koh Pou would be very challenging because of limited financial resources and the lack of knowledge about aquaculture. Concerns were raised that an aquaculture facility would be a government owned operation that would not present much opportunity for local involvement. A lot of misconceptions about marine ecosystems were apparent, and some of the fishermen admitted to having never seen the coral reefs or seagrasses. When asked about their interest in learning more and seeing the marine environment, interviewees responded positively and showed an interest in snorkeling.

During the visits to Koh Pou, it was clearly evident that there is an urgent need for better waste management on the island. Seven of the fishermen expressed a concern about the amount of garbage and the lack of waste management options, while others thought it was normal to have so much garbage present. Interviews indicated that each family burns their waste; however, there is so much waste that washes onto the beaches, and general trash that is littered around the island, adequate waste management seems impossible without proper infrastructure. Sometimes metals, batteries and plastic recyclables are separated, but there is neither a local waste mill on the island, nor a transportation system to the mainland so dumping batteries and metal into the sea is common. Apparently there were public garbage bins in the past, but they broke and were never replaced. When asked about any composting system for organic wastes, two fishermen responded that they use food waste on coconut trees, but most felt that composting did not make sense due to the absence of fresh water available for growing food. Concerns about human health issues related to the unsanitary island conditions were expressed. Most of the fishermen seemed eager to be involved in any future projects aimed at addressing the waste issues, although some mentioned the limitation of time, as most of their time is taken by fishing. It was thought that most of the islanders would like to help with the waste problem, but without a designated leader/authority in charge of waste management, no one would instigate action, and widespread participation would be difficult. Interviews indicated that single use batteries are used for the crab traps, ranging from 2 boxes (24 batteries) to 7 boxes (84 batteries) per boat per week. Once spent, the batteries are generally thrown into the sea, or, as reported by one fisherman, collected and dumped in garbage bins on the mainland. It was generally known that batteries require proper disposal, but without appropriate infrastructure, this is not possible.

As a final question, fishermen were asked what changes they would make to address the issues that most concern them if they had unlimited power. Almost all of the fishermen answered that they would stop illegal fishing in the area because it is having such negative impacts on their livelihood.

4 Discussion

4.1 Discussion of Reef Survey Results

Similar to the baseline assessments of Koh Seh, Koh Mak Prang and Koh Angkrong (March 2014), the second series of reef surveys (January 2015) found the overall health of the islands' reef ecosystems to be relatively poor. This conclusion is based on the observed low abundances and diversity of fish and invertebrates, and the limited complexity of substrates, which emphasizes the need to continue conservation efforts in the area. There were, however, indications that the reefs are already responding positively to the conservation efforts. It is, thus, anticipated that conditions will continue to improve with time, as species with longer lag times have the chance to recover. Lag time refers to the period of time required for a population to recover and begin to regenerate once enforcement of fisheries regulations has alleviated the stress of overexploitation and habitat degradation. Species that are slow growing and have vulnerable reproductive behavior tend to have longer lag times. With the creation of the recommended MPA, such species will have the opportunity to repopulate, reducing the risk of extinction, and ultimately contributing to the ecosystem's diversity and resilience.

Comparison between the results from the initial island surveys and the recent follow up surveys suggest fish populations are beginning to regenerate. All three islands showed a high abundance of small, crevice dwelling species (i.e. sergeant fish, cardinal fish). Interestingly, a number of indicator fish species/families were observed in 2015 that were not present during the 2014 surveys. Koh Seh surveys recorded 10 new indicator fishes, while Koh Mak Prang and Koh Angkrong surveys only detected 3 and 1 new indicator fishes, respectively. These results suggest that the diversity of fishes is particularly increasing at Koh Seh. Many of the fishes that were observed in 2015, but not 2014, are larger commonly targeted fish families/species, suggesting relieved fishing pressure is already positively impacting the diversity of the reefs. The increase in diversity is likely because Koh Seh is

receiving strict protection from illegal fishing activities, since the MCC headquarters is located on the eastern side of the island. The correlation between more enforced fishing regulations and increases in diversity is further supported through a comparison of Koh Seh's east cost with the southwest coast. These two areas, defined as Zone A and Zone B respectively, were distinguished because Zone A is most monitored by MCC, while Zone B is out of view so fishing activities still occur on occasion.

The initial surveys of indicator invertebrate species showed that, as of March 2014, the reefs of all three islands were dominated by synaptic sea cucumbers and diadema sea urchins. The 2015 survey results indicated a decrease in diadema sea urchins and synaptic sea cucumbers at Koh Seh and Koh Angkrong. Surveys of Koh Mak Prang showed a significant decrease in synaptic sea cucumbers, which were extremely prominent in the 2014 surveys, but the mean abundance of diadema sea urchins increased slightly. These decreases in dominant invertebrates suggests a more even spread of invertebrate mean abundances, which signifies the reefs are not as off-balanced as they once were. The biodiversity around the islands is seemingly increasing in response, as many invertebrate indicators that were not observed in the initial series of surveys (2014), were recorded in the follow-up surveys (2015). It is hoped that, with time and protection, invertebrate populations will continue to recover, adding to the reefs' biodiversity and overall productivity.

Despite the conclusion that the structure and substrate complexity of the reefs are in fairly poor condition overall, healthy sections of reef that have experienced low levels of damage from destructive fishing techniques demonstrate the potential for the area to support diverse sedentary life (e.g. soft and hard corals, anemones, sponges). Substrate complexity is highly beneficial within a reef ecosystem because the various structures provide specific habitats that are vital to particular species. The living substrates, such as corals and anemones, can also be crucial to the survival of certain species because of symbiotic relationships; for instance, anemones and anemone shrimp have evolved to live together in an association that has benefits for both participants; in some symbiotic relationships, the participants have evolved a dependence on one another, and thus, one

cannot survive without the other. Healthy reef ecosystems are full of instances of such delicate interdependencies.

Rock and hard corals were found to be the dominant substrate types of Koh Mak Prang and Koh Angkrong. Sand and 'other' were the most common substrate recorded during the 2015 surveys of Koh Seh, although rock and hard coral were almost as abundant. Much of Koh Seh's substrate classified as 'other' is zoanthids, which are growing on rocks and remnant coral structures. The high presence of hard coral and rock surfaces indicate the high potential for improvement of the reef health; hard coral offers a solid substrate where other species can colonize; hard coral provides habitat for fish and invertebrate species; and rocks support coral reproduction by providing suitable surfaces for coral larvae to settle. Given the current substrate cover, the implementation of the MPA encompassing Koh Seh, Koh Angkrong and Koh Mak Prang holds great potential in revitalizing the reef structure, as long as protection is enforced.

Calculated Jacquard Similarity Index (JSI) values indicated that survey results (2014 and 2015) from Koh Mak Prang and Koh Angkrong are the most similar to one another in terms of diversity and spread in abundance. Koh Seh's calculated JSI values demonstrate that its' reefs are in best condition of the three islands. Again, this displays the correlation between increased reef health and proper enforcement of fisheries regulations, as Koh Seh has received the most effective protection to date.

Given the encouraging results of the reef surveys, MCC recommends the implementation of a Marine Protected Area (MPA), including a no-take zone along Koh Seh's east coast (Zone A). With the initial and follow-up survey data as a baseline for comparison, MCC will have the opportunity to monitor the effectiveness of conservation efforts, allowing for management decisions to be informed and the benefits of the MPA to be optimized.

4.2 Environmental Threats

4.2.1 Unsustainable Fishing

The observed low abundance and diversity of fish demonstrates the negative implications of overfishing. Reef survey results suggest that populations of larger species of carnivorous fishes, such as groupers, snappers and flathead, have been decimated, leaving small fish populations to grow unregulated by predation. Overfishing of these large fish species decreases the reef's diversity, forcing the food web out of balance and decreasing the productivity of the ecosystem. Fishing poses the greatest threat to slow growing fish species with vulnerable reproductive behavior, and is most detrimental when larger individuals, who have the greatest reproductive potential, are targeted.

MCC has continued to observe and document the use of unsustainable and illegal fishing methods, such as trawling, gill nets and air-supplied fishing. In addition to observing illegal fishing from the island of Koh Seh, or from our dive boat, the destruction from these fishing activities is evident underwater. Scientists and trained survey divers recorded a high amount of pollution from fishing activities, including batteries from crab cages, broken nets, cages and lines, plastics and polystyrene waste. High trawling activity was evidenced by broken coral, uprooted seagrasses and scoured seafloors, as well as high amounts of large suspended particles that are remnants of reef breakage and bottom disturbance. Even when trawling was not evident in the immediate area, a high level of large suspended particles was observed on many of the surveys; this indicates the trawling activities are negatively impacting a much greater area than just the sites where the trawl nets are deployed. Because high levels of large suspended particles decrease light levels and smother corals, seagrasses and other marine life, trawling activities must be stopped within the proposed Marine Protected Area, as well as in the surrounding area. Boat anchor damage was also apparent, indicating the need for markers to show boat operators the location of the reef and other fragile marine components. Another solution to anchor damage would be the installation of permanent mooring blocks where boat operators could attach boats, instead of using anchors.

Patrols (fisheries authorities and the MCC patrol team) still catch illegal fishers within the 'triangle' of Koh Seh, Koh Mak Prang, and Koh Angkrong. Many are Vietnamese trawlers and air-supplied tube fishermen, who are turning to Cambodian waters since their marine environment has been unsustainably fished, and thus, has declined in productivity (Pomeroy, 2011). Khmer fishers are also caught using illegal fishing gear.

Due to the fragility and complexity of the reef and seagrass ecosystems, recovery can only occur if the area is relieved of unsustainable fishing pressures, and therefore, such practices should be addressed immediately. Continued enforcement and demarcations of the conservation area will serve to prevent unsustainable fishing activities. If unsustainable fishing continues, further declines in the health of Kep's marine ecosystems will result, leading to crashes in commercial fisheries stocks and detrimental decreases in biodiversity.

4.2.2 Trophic Imbalances

Trophic levels are used as indicators of fisheries impacts (Pauly et al., 2002). Seagrass beds and coral reefs are primary producers and the basis of two highly productive ecosystems providing structure, shelter and nourishment for a huge array of species of invertebrates, molluscs and juvenile and adult fish. Without these substrates at the base of the chain, the web cannot begin and likewise removal of organisms at the top of the chain results in top-down ecosystem collapse. From the bottom to the top and all in between, everything in an ecosystem plays a specific role in retaining the trophic balance. If any part of the chain is removed, trophic levels shift which result in a trophic cascade and in turn ecosystem collapse. The sea urchin *Diadema antillarum* plays a significant role in the delicate balance of this system.

Described as a 'key herbivorous species', this sea urchin plays an important role in determining the structure and function of coral reef ecosystem (Tuya *et al.,* 2004). *D. antillarum* is both beneficial and harmful and must be present in optimal densities for greatest benefit. A low abundance like in the west Atlantic results in algae (which would be grazed by *D. antillarum*) covering reefs, suffocating coral and reducing space and sunlight for coral growth. In contrast, a high abundance of *D. antillarum (*like we see here), in the east

Atlantic resulted in overgrazed ecosystems and in turn ecosystem collapse. This urchin has been extensively involved in ecology studies as it is directly implicated in the phase shifts of the major components of the live reef structure (Tuya *et al*., 2005). There have been numerous studies in relation to high abundances of *D. antillarum.* Low abundance and biomass of top predatory fish seem to be related to high densities of sea urchins (Tuya *et al*., 2004).

Our results in 2014 show an absence of large macro invertebrate-eating predatory fish, a dramatic abundance of *D. antillarum* as well a low fish species richness. Triggerfish, jacks and porcupine-fish are all *D. antillarum* predators and were completely absent in 2014 surveys on all three islands. It is a positive sign that there was a slight increase in sightings in 2015 at Koh Seh revealing an increase in species richness and biodiversity in the area. There has been little to no illegal fishing on Koh Seh (east) and this is most likely the main factor for the increase. This shows that if an MPA were implemented, the population of *D. antillarum* predators would make a recovery and therefore control *D. antillarum* populations. In correlation to this, there has been a drop of almost half of the *D. antillarum* recorded here than in 2014. Having more large predatory fish back on the reef is most likely the main cause of this decline in *D. antillarum* population.

Overgrazing by *D. antillarum* has been shown to be detrimental to reef ecosystems in different parts of the world such as Kenya, the Canarian Archipelago and the east Atlantic Ocean. Due to loss of predators leading to hyper abundances of D. antillarum in the Atlantic, reefs have been replaced with stark barren space (Tuya *et al.*, 2004). 'Urchin barren' areas are considered as a "global phenomenon mediated by overexploitation of inshore resources" (Tuya *et al.*, 2005). A similar trophic imbalance has been recorded in the Canarian Archipelago by (Tuya *et al.,* 2004) who concluded that this cascade is "at least partially related to over-fishing of large macroinvertebrate-eating fish" and in Kenya *D. antillarum* reduced growth rate to almost zero and prevented accumulation of coralline algae as an important coral substrate and therefore 'reduced reef stability, growth and resilience' (O' Leary *et al.,* 2010).

Unsustainable fishing leads to decreased diversity of fish groups on the reef resulting in less valuable ecosystems with fewer resources being generated for society (Tuya *et al.,* 2005). Species-rich areas are known to thrive while low diversity areas do not and ecosystem growth ceases. Our results show that this delicate balance of *D. antillarum* population is not being achieved on the reefs surveyed and has resulted in a top-down trophic cascade, although an MPA would rectify this, as we are beginning to see already on Koh Seh.

4.2.3 Coral Bleaching

Coral bleaching is another issue requiring attention. Bleaching occurs when the coral undergoes stress and expels the zooxanthellae, which are tiny photosynthetic organisms that live together with the coral. Without the zooxanthellae, many corals are unable to acquire the nutrients from the sun that are needed for reef building and survival. High temperatures, low light levels, high turbidity (number of particles per unit water volume) and pollution are stressors that cause corals to expel their zooxanthellae. While the initial and subsequent survey sets recorded small amounts of coral bleaching, monitoring is required to ensure increases in coral bleaching are observed and thus, can be properly managed. Data from the second survey showed a decrease in recently killed coral, which could be due to a number of factors, including a decrease in siltation, slightly lower water temperatures (seasonal change), and a decrease in destructive anthropogenic activities (anchor damage, dynamite, trawling, etc.). Divers from MCC have noticed an increase in bleached corals during the summer months (seasonal highs), which is likely enhanced due to global warming causing sea surface temperatures to rise. Given the stress placed on corals from temperature increases, which cannot be managed and will likely continue to increase as global warming advances, a focus should be placed on mitigating the stresses to corals that can be controlled (e.g. pollution, siltation).

4.2.4 Siltation

Siltation is another major threat to the recovery and rehabilitation of the area. Siltation can smother coral by depriving the coral of light and nutrients, which inhibits coral

growth and prevents future coral larvae settlement and reproduction. Blankets of sediment can also encourage the growth of disease-causing bacterium. The initial and subsequent surveys of Koh Mak Prang observed sediments covering coral populations, which was most likely due to mainland run-off, high-energy wave action or fishing activities, particularly trawling. Efforts aimed at mitigating siltation are needed; this could involve improved management of coastal erosion, increased efforts to conserve and promote stabilizing seagrass meadows, and enforcement against trawlers and other destructive fishing practices.

4.3 Marine Protected Areas

4.3.1 Potential Outcomes

Given the effectiveness of properly managed MPAs elsewhere, and the notable increase in reef health observed in the 'triangle' since MCC's efforts commenced, the following outcomes are anticipated to result within the proposed MPA:

- increased biodiversity, notably fish and invertebrate species diversity
- greater abundances of fish, invertebrates and other marine life
- improved coral health and diversity, enhancing the productivity of the reef
- increased extent, density and general health of seagrass beds
- return of marine mammals, such as dolphins and dugongs
- increased knowledge of the area's marine ecosystems, contributing to the information available to inform sustainable resource management in the area

In order for these outcomes to be realized, it is vital that fisheries regulations be enforced, particularly with regards to illegal trawlers, tube fishers and foreign fishers. If achieved, the benefits of the MPA would contribute to the persistence of sustainable fisheries in the greater Kep area, as the habitat and productivity conserved within the MPA would have flow through effects into surrounding ecosystems (e.g. exporting juveniles or

adults to help sustain the fishery outside the MPA; Pauly *et al.,* 2002). For instance, the environmentally and economically crucial habitat of seagrass would be protected and propagated, benefiting global carbon cycling and ensuring habitat for numerous marine species, such as the economically significant blue swimmer crab (*Portonus pelagicus*). In time, there would even be potential for numerous large endangered marine species, such as dugongs, to return to the region. Pods of dolphins have already been sighted within the 'triangle' of the proposed MPA on multiple occasions by MCC. Ultimately the implementation of the proposed MPA in the Kep archipelago would be an important step towards the sustainability of fisheries, and the protection of biodiversity, which is essential to a productive marine environment.

The MPA could attract more tourists to the Kep area. Tourism is the largest global industry, and coral reefs surrounding tropical islands are one of the most desirable destinations (Hodgson *et al.* 2006). In one year, over twenty million SCUBA divers travel to explore coral reefs. With proper implementation, particularly enforcement of illegal fishing, a single km^2 of protected coral reef can bring in three million American dollars ($ 3 000 000) in tourism, compared to a potential fifteen thousand American dollars ($15 000) generated in fisheries production (Hodgson *et al.* 2006).

In order for the economic benefits of tourism to be long lasting, threats of unsustainable tourist development and activities must be managed. Increased tourism holds the potential for boat damage, pollution and unintentional damage caused to the corals by incompetent or careless snorkelers, swimmers or divers. Strategies to mitigate these threats might include the use of buoy stations, reef demarcations, and educational information regarding responsible marine resource use. Any proposed eco-tourist establishments should undergo environmental assessments that will highlight potential negative impacts, and suggest strategic alternatives that can reduce the identified threats of development. Many architects and others in the building trade are specializing in environmentally friendly buildings, and thus, could be utilized to provide input into the development of a sustainable eco-tourism scene in the Kep archipelago. Based on the observations and opinions of MCC's

international staff and volunteers, there is an apparent trend of increasing environmentalism and support for eco-tourist ventures; thus, with healthy marine life and sustainable development, Kep could become a trendy destination for tourists. With sustainable development (i.e. potential negative environmental impacts of tourism are managed), tourism has the potential to significantly contribute to Cambodia's economy over a long term.

4.3.2 Management Considerations

The effectiveness of a MPA necessitates collaborative effort between different stakeholders, principally the relevant authorities, scientists, resource harvesters and users (Bustamante, 2014). Ecosystem-based management approaches, which involve the consideration of all relevant ecosystem components requiring monitoring and management, are considered to be the best tactic for conservation and sustainable resource extraction (Andrew and Evans, 2009; Beaumont *et al.,* 2007).

Monitoring the health of environmental indicators, such as coral reefs and seagrass meadows, can provide vital insight that can inform management decisions. Conservationists and marine scientists are required to assess the environment and offer advice to the relevant authorities responsible for the formulation of policies and management plans to address the threats to the environment. In turn, authorities responsible for enforcing these policies must be persistent, thorough and consistent in ensuring the MPA remains free of detrimental anthropogenic activity. Additionally, knowledge gained through scientific research must be conveyed to the resource harvesters and users. Although the ecological principle of MPA success is very straightforward, actually imposing and achieving a true MPA is, in practice, far more difficult (Bustamante, 2014).

One of the major tasks facing fisheries management and MPA formation lies in managing the loss of livelihood to the fisherfolk (McManus 1997), in Kep's case, any fishers utilizing illegal fishing gear. This requires a comprehensive approach, "considering marketing, job training, gender equity, child labour, environmental impacts of new industries and effects on quality of life" (McManus 1997). MCC researchers are currently

investigating designs for low-cost, semi-intensive aquaculture systems for blue swimmer crabs, as a potential alternative income source for local fishermen (see Section 6.3) Aquaculture has the potential to reduce the need for artisanal fishermen to seek work on trawling boats out of desperation. For instance, personal communications have revealed that some crewmembers of trawling boats used to be crab trap fishermen, but could not afford to keep replacing their crab traps that were repeatedly destroyed by trawling boats; thus, work on a trawling boat seemed like the only economically viable option. One fisherman interviewed reported losing an average of 400 of his 2000 crab traps to trawlers every 3 months.

Communicating with the local communities, and explaining the necessity of the MPA to the persistence of any marine-based livelihood, is vital if the project is to go ahead without creating resentment and subsequent backlash. The expected increased fish density and diversity both inside and outside the MPA is ultimately beneficial to the fishermen, as it will provide future fishing potential outside the MPA. If this is effectively communicated to local fishing villages, the communities that depend on the area's marine resources will support the MPA. Their support may come in many forms, such as following fisheries regulations more strictly, switching to more sustainable practices, and reporting illegal fishing activities to the MPA's regulatory enforcers.

Another vital aspect of an MPA is the assurance of the dedication of security personnel in honestly and effectively enforcing the policies and preventing restricted activity in the area. Given that MCC's headquarters are located on Koh Seh, the MCC Patrol Team is in a strategic position to assist in enforcing fishing regulations within the MPA, particularly around Koh Seh.

Costs associated with the establishment and maintenance of an MPA are relatively minimal, only requiring the employment of patrol teams and the fuel required to enforce the area. The associated costs could be handled with the introduction of a TUF (Tourism based User Fee). Previous research has shown that tourists visiting Cambodia would generally

support the implementation of a TUF to support the formation of MPAs, and are willing to pay a fee of up to four USD for entry to such an area (MCC 2013).

The elements contributing to the success of a MPA are related to ecological conditions, better governance, local community involvement, and improved communication and training (Bustamante, 2014). In order to achieve the multi-sector collaboration that is necessary to optimize the impact of the MPA, cooperation between government agencies, relevant communities, and non-government organizations, a framework for decision-making is required (Bustamante, 2014). This multi-sector involvement will allow for the development of a management plan for the MPA, which will be realistic to implement since all parties had input into the design of the plan. The development of such management plans takes time, but experience has shown that integrated management processes generate long-lasting, effective results (Bustamante, 2014). If the 'triangle' MPA around Koh Seh, Koh Angkrong and Koh Mak Prang were created, MCC would be willing to contribute to the development of an integrated management plan for the MPA.

5 Conclusion

This study demonstrates the feasibility and urgent need for a zoned fisheries management area, including no-take zones, and enforced regulations on fishing activities around Koh Seh, Koh Angkrong and Koh Mak Prang. This 'triangle' Marine Protected Area encompassing the three islands requires a surrounding buffer zone, where sustainable fishing methods (i.e. crab traps) are permitted, but regulated. As the positive impacts of integrated fisheries management within this area becomes apparent, the sustainable practices will hopefully extend beyond the defined zones.

The results of the underwater surveys of Koh Seh, Koh Mak Prang and Koh Angkrong allowed us to determine the general distribution of coral reefs and sea grass habitats in the chosen area, as well as the abundance and distribution of reef health indicators, such as fish and invertebrates. Results showed that the overall health of the marine environment is low, however, characteristics of the surveyed islands (e.g. suitable settling grounds for coral

larvae; reef diversity increased in only 10 months of enforcement against illegal fishing activities) indicate the potential for the coral reef and seagrass ecosystems to rejuvenate if protected. Anthropogenic stresses, particularly unsustainable fishing practices and pollution, are evidently causing serious damage to the coral reef and seagrass ecosystems of Kep Province. The recovery of the region's marine environment will only be possible if appropriate management actions are taken to reduce such anthropogenic stresses, and to manage marine resources to promote sustainability.

The established MCC headquarters on Koh Seh provides a basis for marine research and conservation to build upon. By drawing on the skill sets of international staff and volunteers, as well as the knowledge of the Khmer staff, MCC is in the position to support the development of a collaborative and productive marine management strategy for the Kep archipelago.

The level of degradation recorded on the marine ecosystems surrounding Koh Seh, Koh Mak Prang and Koh Angkrong are similar to the degradation observed when MCC first started rehabilitation and conservation work on the coral reefs of Koh Rong Samloem. Monitoring surveys conducted around Koh Rong Samloem, Koh Rong and Koh Koun, recorded a dramatic improvement in marine health during the 6-year conservation program that MCC implemented. Increased substrate cover and coral structure complexity, a greater abundance and diversity of indicator fish and invertebrate species, and an increase in larger sized fish were all evident. The increased reef health benefitted local fishing communities, and attracted more tourism, particularly SCUBA divers, to the region.

The National Action Plan for Coral Reef and Seagrass Management in Cambodia (2006-2015) includes a target that aims to have at least 8.4 km² of coral reefs and 90 km² of seagrass "under some form of sustainable management by 2016" (MAFF 2006). The proposed MPA in the Kep archipelago would significantly contribute to achieving this target, as the MPA would encompass many fringing coral reefs and seagrass beds.

Hopefully, the current positive momentum driving environmental awareness and protection in Kep province continues to grow. The adoption of the proposed MPA would be

a crucial step towards achieving goals of sustainable marine resource use and environmental protection. This is an exciting time for Kep and Cambodia, as further marine research and conservation has the potential to lead to the recovery of a unique, once vibrant, marine environment, rich in biodiversity and plentiful in resources.

6 Future Plans and Considerations

6.1 Rationale and Logistics of Continued Reef Monitoring

A major goal of any coral reef monitoring program is to provide the data required for management to be informed, and thus, more effective. The main purpose of MCC's reef monitoring is to assist resource managers (government, fisheries, etc.) to make informed decisions by providing crucial information regarding the status of Kep's marine environment. Data of this area is virtually inexistent due to a lack of technical, economical and logistical resources MCC's surveys the marine ecosystems of Koh Seh, Koh Mak Prang and Koh Angkrong, which were requested by the government, provide a novel overview of the current status of the marine environment in Kep province.

It is fundamental to consider how the data could be used to inform decision-making and resource use. Many Marine Protected Areas (MPAs) elsewhere have demonstrated the importance of monitoring the influence of management decisions in order to optimize conservation efforts. Marine monitoring will provide insight into the effectiveness of marine management actions, will help indicate what ecosystem components require more protection, and will determine anthropogenic influences that are continuing to negatively impact the marine environment.

To detect more detailed changes in the status of the reefs, more precise data is needed. To attain more precision, more replicate surveys, at fewer, but more precise sites (pre-determined and marked using GPS) will be performed subsequently. Ideally, a long-term marine management plan will be designed to utilize the results from marine monitoring and assessments, and to ensure multi-level (local communities, fisheries

authorities, provincial and federal government agencies) support of sustainable resource use and management actions.

A number of issues must be considered when using reef survey protocol for long-term monitoring. The most important are taxonomic specificity (classification of species), temporal and spatial replication. Each location has specific needs and resources that require a custom design. MCC Research Team uses an adaptation of the globally recognized Reef Check methodology, integrated into a more site-specific approach. The core methods include four spatial replicates along a 100 m transect line. These four replicates are sufficient to capture variability within one site, and achieve a robust sample of the marine health along the transect line (Reef Check 2006). Research has indicated that monitoring at the genus or even family level provides similar information than if much more costly and time-consuming species level data was collected (Clarke and Warwick, 1997); given the limited resources of MCC, a low taxonomic specificity (typically family level) was utilized for this study. Published evidence from detailed studies has shown that reliable data can be collected, not only scientists, but also by trained volunteers (Harding et al. 2002), therefore, MCC is confident about the accuracy of collected data. It should be noted that if broad-level problems within the marine ecosystems are detected, monitoring efforts could be increased and become more specific in an effort to determine the reasons behind the changes and better understand how to remediate the damage.

Now that a baseline has been established for Koh Seh, Koh Mak Prang and Koh Angkrong, subsequent reef monitoring will involve multiple replicates of fewer transect lines at different times of the year. A useful benchmark for sampling is 3 sites per 1km area. This type of survey is called stratified random sampling because you are choosing the zone where the random sample is taken. An advantage of random sampling is that the data from a number of randomly placed transects may provide a more representative picture of the whole reef area than data from a few permanent transects and it avoids bias of the person choosing a site. But this only works when sufficient replicate transects are conducted to account for spatial variation on the reef such that these can be differentiated from the

temporal differences that you are primarily interested in. Recent studies indicate that three to five replicate (full) surveys are sufficient to achieve a stable picture of conditions at individual reefs (Myerset al., submitted). If reef surveys are repeated at quarterly intervals, they can then act as an early warning system for major anthropogenic changes such as bleaching, blast or poison fishing, overfishing, eutrophication and sedimentation

After the implementation of the MPA around Koh Seh, Koh Mak Prang and Koh Angkrong a useful approach will be to use a sampling design that includes sites inside and outside of the future Marine Protected Area (MPA). With sufficient surveys (3 to 5 outside and 3 to 5 inside), it will be possible to show how effective the protected area is and to distinguish if reef health improves over time. If improvement in reef health can be shown, this may serve as a valuable case study of a successful MPA and help coral reef managers replicate this effort elsewhere.

MCC plans to continue the assessment of the Kep's marine environment, with a focus on areas that have high potentials for recovery and future productivity, mainly the proposed MPA. MCC would be willing to contribute to the development of an integrated management plan for the MPA, which is recommended to ensure the benefits of the MPA are fully realized.

6.2 Community Involvement

Following the ongoing collaboration between MCC and the Koh Pou fishermen it was determined that there is a common interest in implementing a crab bank system around the island. The crab bank system is a form of community-based management aimed at increasing species population to promote the sustainability of the fishery. This is achieved by allowing caught gravid females to release their zoea before being marketed. Females could be kept in the ocean within a net until eggs are released, or in an aquaculture system that would subsequently culture the larvae through to adulthood. Further discussions and investigations are required to ensure any issues with implanting such a plan are highlighted in advance.

Interviews conducted with fishermen in the community have revealed that they have practical knowledge of the reef gained through vast fishing experience. There is an opportunity to combine this knowledge with scientific information, which will enable a more holistic view of the marine system's status. MCC can offer discussions and presentations aimed at equipping fishermen with knowledge of their influence on the reef ecosystems. This would be beneficial to both parties, as the fisherman depend heavily on the health of the reef in order to maintain their livelihoods, and their cooperation will support efforts to improve local marine health. Local knowledge empowers communities, enabling them to participate in reef conservation contributing to reef health. Based on community interviews we anticipate participation from fishermen on Koh Pou. Interviews have revealed that unsustainable fishing practices and pollution are the major contributing factors to the destruction of the coral reef and it is clear that the communities need to be involved in order to establish a long lasting solution to both issues. Further community collaboration with MCC is planned (See Section 6.3 and 6.4).

6.3 Aquaculture

MCC is currently investigating the potential of culturing the blue swimmer crab (*Portunus pelagicus*). The blue swimmer crab is vital in sustaining local livelihoods, and to Kep's growing tourism industry. As such, attention must be drawn to the consequences that unsustainable fishing and anthropogenic activity could have for the blue swimmer crab and its trophic role in the Kep marine ecosystem.

To date, a pilot project on Koh Seh has involved the construction of a low-cost, open semi-intensive aquaculture system for blue swimmer crabs. The aquaculture system is built on a hill site; hence seawater is pumped up to fill storage tanks, which then supply the system with water throughout the day. This design is advantageous because the water pump does not need to run all day long. By using gravity to exchange the water in the actual crabs and larvae tanks, energy is saved. The aeration system is built to run with one of two options; an electric powered system with an air pump; and a non-electric system that uses

cylinders of compressed air (i.e. SCUBA tanks) to aerate the water when power is not available. The system also includes a water filter, a water flow aeration slope, three crab tanks for adults that have reached sexual maturity, and four tanks for different stages of larvae. Depending on the larval stage, phytoplankton or zooplanktons are required as a food source. Adult crabs are fed with trash fish.

Once the test facility is operating efficiently on Koh Seh, the aquaculture system can be presented to the local communities and potentially replicated. Some of the fishermen from Koh Pou have already expressed an interest in aquaculture and told MCC they would be keen to learn more as our research develops. We believe that an aquaculture facility on Koh Pou, or any other island in the Kep Archipelago would be feasible since the required materials are low in cost and readily available, and the training necessary to operate such a system is achievable. This would provide local fishermen with an opportunity to culture blue swimmer crabs as an alternative income source to fishing. If successful, fishermen would have a more reliable source of income, and fishing pressures on the marine environment would be lessened (Hishamunda et al., 2009).

6.4 Waste Management

Due to a lack of human and financial resources, there is no coordinated waste management system in place for communities, such as those residing on Koh Pou. Solutions to meet the island's needs cannot be addressed by simply introducing or upgrading existing technology. It is vital to also implement a program that helps train and educate the local communities, in order to ensure that they are able to manage their waste in the future. Any solution models must be thoroughly analyzed prior to implementation in order to properly understand the resources and finances required for success.

There is a large amount of domestic waste on many of the islands in the Kep Archipelago. This poses a huge threat to the marine environmental, and also to island inhabitants. The community has no sustainable way to handle their household garbage and the waste that washes ashore daily. Currently waste is disposed of by burning everything

including plastics, cans, food containers, organic food waste, bottles and printed papers. This releases toxic fumes into the atmosphere, causing both environmental and health related problems, both locally and globally.

Burning of plastics releases toxic emissions, such as dioxins and styrene gas. Dioxins are a very toxic chemical to humans as they are carcinogenic and a hormone disruptor. They do not bio-degrade, so therefore, settle on crops and water, where they enter into the food chain and accumulate in body fat over time. Mothers can pass dioxins to their babies via the placenta, therefore this chemical can affect generations.

Burning polystyrene polymers, such as foam cups, meat trays, egg containers, yogurt and deli containers, releases styrene in the atmosphere. Styrene gas is readily absorbed through the skin and lungs. At high levels, styrene vapor can damage the eyes and mucous membranes. Long term exposure to styrene can affect the central nervous system, causing headaches, fatigue, weakness, and depression.

Small scale burning of waste is an extremely inefficient method of disposal and causes high levels of smoke emissions. Setting up a small, cost effective incinerator with a filtration system could be a more suitable solution to burning waste material on the island. Another unfortunate aspect of burning is the loss of reusable resources that could have been separated, collected and reused. Materials such as plastics, glass and tires could be treated and produced into new products. Organic food waste could be turned into compost which could be used for growing vegetables.

As previously discussed, solutions to the waste issues on Koh Pou cannot be successful without community involvement. It is essential that the inhabitants of Koh Pou are able to take responsibility for managing any implemented projects around waste handling. Examples of solutions involving the community could be families taking shifts in garbage collection, or one or two people being paid to carry out a specific job.

Before any long term solutions can be implemented on Koh Pou, it essential that a large-scale cleanup take place in order to prevent the already sizeable issue from worsening. Currently, waste is present in large quantities spread all over the island and MCC urgently

require manpower, tools and support in order to prepare the island for longer-term solutions for waste management. Interviewed fishermen agreed that waste was an issue, and expressed their desire to participate in an organized island clean up, if MCC organized one. This will have to be planned with the fishermen's schedule in mind, as many mentioned their desire to help, but their limited free time.

Inspiration and ideas for sustainable waste management can be gained from other successful, well-documented projects around the world. Such initiatives have other beneficial side effects, such as business opportunities and job creation. This would align with Kep's 'Keep Kep Clean' initiative, which has led to Kep receiving national recognition for its successful pollution control. Additionally, a healthier environment leads to a healthier population, and improved health gives increased opportunities for education and employment productivity, thus benefiting Cambodia on many levels. Proper waste management will improve environmental and human health, as well as enhance Kep's image as a beautiful, coastal tourist destination. MCC is dedicated to finding sustainable waste management solutions to help improve the livelihoods of local communities, the environment and the local marine life.

7 Appendix

7.1 Methodology

The utilized reef survey methodology was designed to assess the health of coral reefs and is quite different from other monitoring protocols. We particularly focus on the abundance of particular coral reef organisms that best reflect the condition of the ecosystem. Selection of these indicator organisms was based on their economic and ecological value and their sensitivity to human impacts. The methodology has been adapted to include global, as well as many regional indicator organisms serving as specific measures of human impacts on coral reefs. These indicators include a broad spectrum of fish, invertebrates and plants that reflect the impacts of human activities such as fishing, collection or pollution. Some reef survey categories include individual species, while others include any species belonging to a certain family (Hodgson *et al.* 2006).

7.1.1 Location of survey sites

Figure 14 shows the reef survey transect locations for the 2015 study of Koh Seh, Koh Mak Prang and Koh Angkrong.

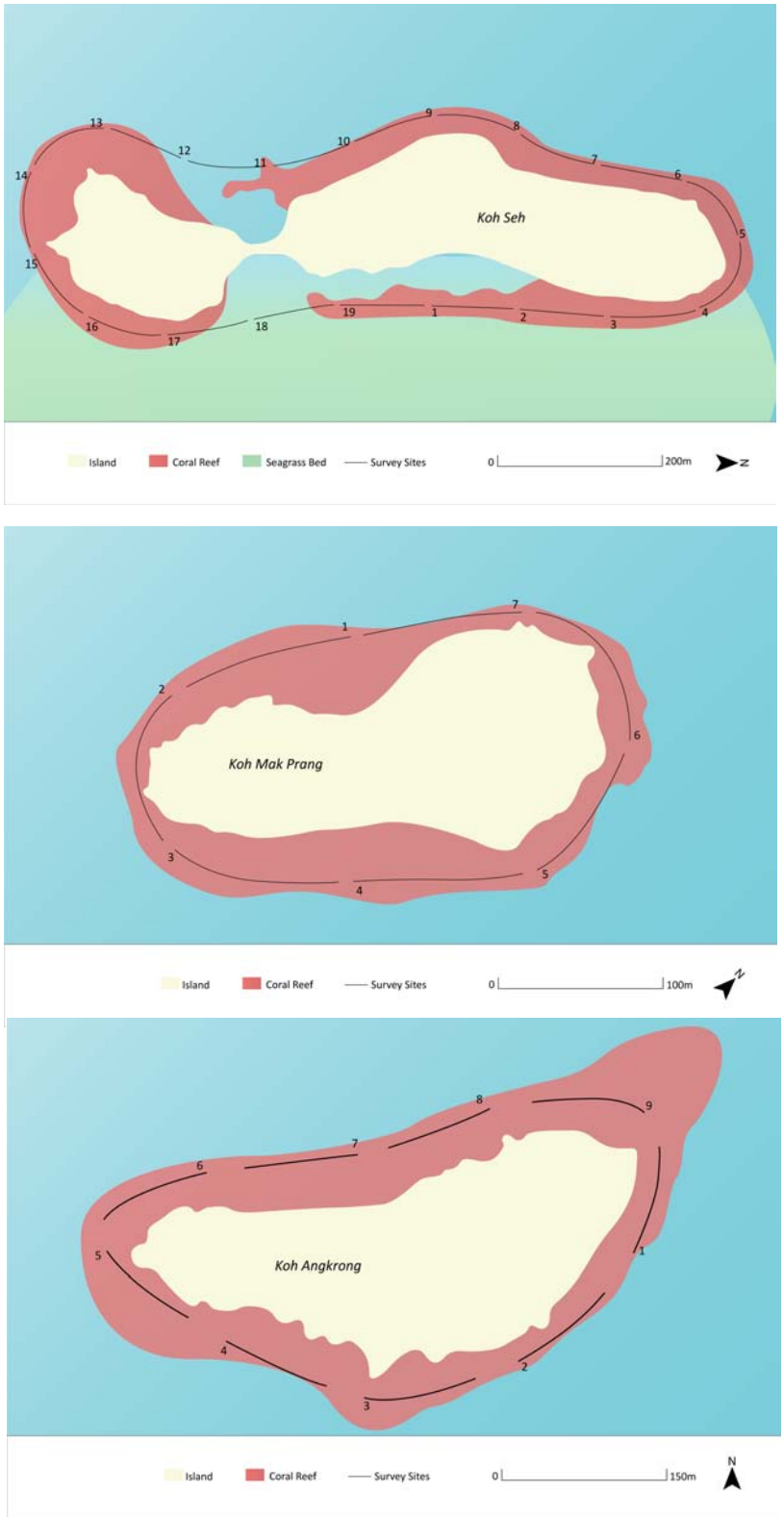

Figure 14. Map showing the reef survey transect locations for the 2015 study of Koh Seh, Koh Mak Prang and Koh Angkrong.

7.1.2 Data Collection

MCC survey teams collected four types of data:

1) A description of each reef site based on over 30 measures of environmental and socio-economic conditions and ratings of human impacts
2) A measure of the percentage of the seabed covered by different substrate types
3) Invertebrate counts
4) Fish counts

A checklist of general site conditions was completed for each survey. This included environmental parameters (temperature, visibility, current direction/strength), evident natural and anthropogenic impacts, known historical facts, and the degree of protection enforcement. MCC also includes important socio-economic parameters in the survey: Extent of Human Impacts/Distribution/Ecological importance and Information Content (e.g. desirability and high demand for an organism involves a high likelihood of human impact, thus the absence of these organisms indicates overfishing).

More specifically, the MCC survey methodology designates three different transects: fish belt transect, invertebrate belt transect, and a substrate line transect (Figure 15 and Figure 16). Fish were recorded along four 20m segments of the transect line, including fish within 2.5m of the line and 5m above the line (Figure 15). Invertebrates were then counted on the same segments. Substrate was recorded every 0.5m within the four 20m segments along the transect line (Figure 16).

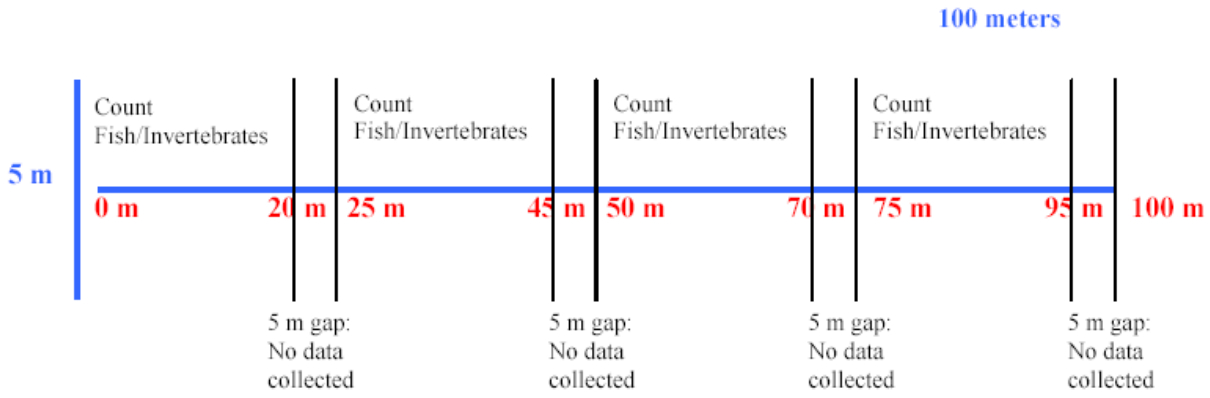

Figure 15. Fish and invertebrate belt transect count method.

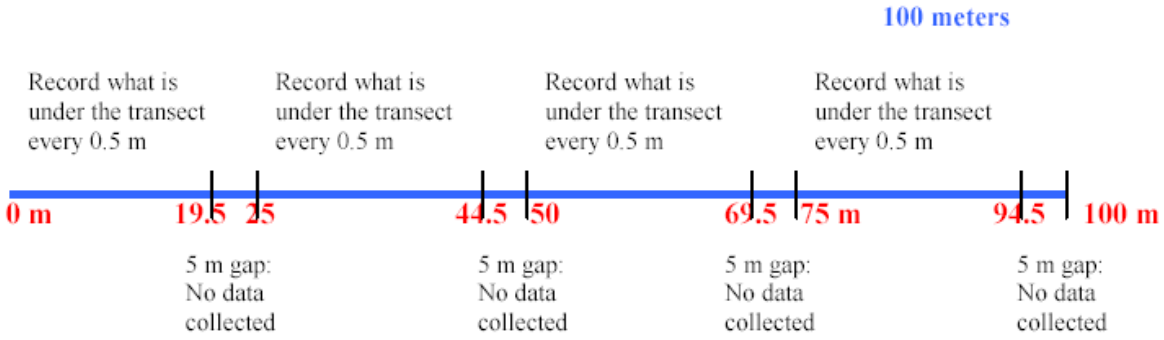

Figure 16. Point intercept transect count method to determine benthic cover.

7.1.3 Observed External Impacts

For each of the seven surveys, scientists/ trained reef surveyors took notes on any observable impacts from anthropogenic activities or natural pressures. The amount of coral damage from boats, anchors and from trawlers was recorded. In addition to large swaths of destructed reef and uprooted seagrasses, trawling was evidenced by high amounts of large suspended particles that are remnants of reef breakage and bottom disturbance. The presence of trash was documented, specifically plastics, rice bags, fishing nets, broken traps and lines. 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. High levels of silt (>1cm coverage), which prevent coral and seagrass regrowth, were recorded in high proportion at certain locations. Coral damage from high-intensity storm

events was not observed during these surveys, but will be recorded if it is present in future surveys, as well as any coral disease.

7.1.4 Community Interview Questionnaire

7.2 Additional Background Information

7.2.1 Illegal Fishing Practices

The following fishing practices are illegal in Kep province and are highly destructive, causing devastating and long term impacts to marine life and habitats.

Trawling is practiced by both Vietnamese and Khmer vessels around the waters of Kep province. Due to it unselective nature, by-catch is exceedingly high, with many fish being discarded back into the ocean (Kumar & Deepthi 2006). Trawling is highly destructive to large areas of the seabed, which contains habitat and breeding grounds for a plethora of species. Seagrass beds are particularly susceptible to disturbance, as trawling completely uproots the plants and disrupts sediment composition (Jones 1992; Thrush et. al. 2002). Clearing sections of the seabed decreases the area available for marine species to live and thrive in. Additionally, trawling causes sediment disruption, which can smother seagrass beds and coral reefs miles away (Roberts 2012). All trawling activities in Kep are illegal under Article 51 in the Fisheries Law on in-shore trawling (i.e. less than 20m).

Electro-fishing is a particularly crude, yet highly efficient, gear. A net dragged from the back of the boat, similar in style to a trawling net, is rigged with chains attached to batteries, producing an underwater electrical current. Reportedly, yields can be between 30-40 kg/day (Viner et al. 2006). Fish that are not collected by fishermen may be released, however many do not survive. Those that do survive may experience electro-fishing injury and may subsequently suffer short-term, long-term, or lifetime handicaps that affect their behavior, health, growth, or reproduction. Significant numbers of surviving but adversely affected fish may ultimately impact community structure, population size, quality of the

fishery resource and management strategies. (Snyder 2003, Panek & Densmore 2011). As both the catches and residual impacts are great, electro-fishing is listed as illegal under Cambodian Law.

7.2.2 Unsustainable Fishing Techniques

There are a number of highly unselective and unsustainable fishing practices in Cambodian waters. Listed below are the most commonly used fishing techniques in Kep province. They are listed in order of the severity and impact that they have on the Kep marine ecosystem.

Supplied air fishing enables fishermen to stay underwater for a prolonged period of time, allowing them to easily target species like sea cucumbers, molluscs, seahorses, bivalves and other invertebrates in large numbers. This mass, targeted removal of invertebrates can disrupt the food chain and easily begin a trophic cascade. The removal of algal grazing invertebrates (such as molluscs, murex, conch and turbo shells) on this scale dramatically reduces the grazing pressure they exert on algae (Duffy et al. 2003). As a result, algae populations exhibit a dramatic increase, which reduces water quality (decreases light availability), disrupts nutrient balances, and smothering corals, seagrasses and other life (Folke et al 2004).

Gill netting is used to catch fish that swim through a net and become entangled by their gills, fins and spines. Larger mesh sizes allow for the escape of larger marine species, targeting only certain smaller species; however mesh sizes are usually too small to allow escape and are therefore highly unselective. When left overnight or unattended, larger species such as turtles, sharks and marine mammals are easily entangled and drowned in the nets. A recent study on gill net fisheries found that bycatch from gill netting is high across all species groups (ISSF 2014). The small mesh sizes are used in order to extract both juvenile fish and larger adults, however this removes juveniles before they have a chance to mature and reproduce (Jones 1983). Early removal of juveniles from a population results in a disturbed-breeding population, which has the potential to lead to the extinction or

reduction of the local population (Bescheta and Ripple 2009). .

Seine fishing is practised globally, using a net that is hung vertically in the water, with buoys to keep the top edge afloat and weights to sink the bottom edge. This allows the net to stretch in the water, surrounding fish species. The net is closed in a circle and pulled in, which results in any sort of marine life being caught. Like gill netting, seine fishing can easily lead to overfishing, particularly if the mesh size of the fishing net is not regulated (Jones 1983). In Kep, very small mesh sizes of less than 1cm² have been observed. This size of net removes fish of all ages and sizes, greatly disrupting the breeding potential of the population. However, close regulation of mesh size, twine strength, as well as net length and depth can help to reduce bycatch of non-target species, potentially making seine fishing a sustainable fishing method for local fisheries.

Push-nets involve using nets to "scoop" marine species out of the water, usually along or just above the sea floor in relatively shallow estuarine areas, mangrove creeks, shallow bays and littoral areas (Silvestre et al. 1987). Traditionally, a "bag net" connected to poles is pushed forward through the water by hand, targeting shrimp, crabs and fish. The efficiency of this traditional equipment has increased by using motors rather than manpower (Silvestre et al. 1987, Nagalaksana 1987). This change allows fishermen to fish farther from the shore with a larger net. Push nets are non-selective and it is believed that motorized push-net fishing boats are causing the deterioration of marine animal resources and the coastal ecology in shallow, near-shore areas, such as the Kep archipelago (Pramokchutima & Vadhanakul 1987).

7.2.3 Sustainable and Recommended Fishing Techniques

It must be remembered that whilst many fishing practices, such as those listed above, are highly detrimental to a region, there are some sustainable methods that can propagate species recruitment via the controlled harvesting of target predator species. These non-destructive fishing gears can provide economic revenue for local fishermen with minimal impact on the environment.

The use of crab traps and octopus shelling are considered sustainable methods of fishing. With the correct trap design, crab traps can target crabs of a particular size and therefore age class (DEH 2006). This also applies for octopus shell traps, whereby fishermen use shells to mimic the octopus's nest to lure them into the trap. Octopus shell traps are often strung out on a line, the beginning of which is marked by a floating flag or buoy. Small scale, sustainable fishing of this nature can be beneficial to other species in a rejuvenating environment. For example, the mitigated harvesting of predator species such as the crab and octopus from Kep's waters slightly reduces predation pressure upon fish and other invertebrates species, allowing populations to recruit at a slightly elevated yet stable level, whilst ensuring the fishery catches of local fishermen. Additionally, local fishing villages can be engaged in the building of crab traps, providing economic revenue by producing and repairing the cages. Another benefit to crab trapping and octopus shelling is the minimal impact that they have on the habitat. As mentioned above, trawling, gill netting, seine fishing and push netting drag the ocean floor, tearing up the sediment and seabed. The Kep archipelago has perfect environmental conditions for seagrass, which is a delicate and vital habitat. The seagrass plays a pivotal role in the developmental stages of many species found in the Kep region (Short 1983). Crab trapping and octopus shelling methods do not contribute to the destruction of the seabed and are therefore less damaging to seagrass. Although crab trapping and octopus shelling are considered to have minimal impacts on the environment, it is important to keep in mind that these fishing methods must be controlled and monitored to prevent overfishing, as overfishing of these predators can lead to a breakdown in the trophic system.

7.2.4 Seagrass Ecosystems

Primary production rates of healthy seagrass habitats are remarkably high. Therefore, they supply food for many different species, either by direct grazing or the utilization of the detritus, produced from decaying seagrass material (Zieman 1982). Due to the provision of primary food and the three-dimensional space created in the water column by the seagrass, it functions as habitat for many different species, including fish,

invertebrates, and even mammals (dugongs, dolphins). Many species are dependent on the shelter and camouflage provided by seagrass, such as seahorses and pipefish. Also, seagrass beds are a crucial habitat for the larval stage of the blue swimmer crab, which is one of the most important food resources for Cambodia's coastal and island communities. Juvenile fish of various species migrate from the inshore mangrove habitats to seagrass beds, which provide refuge and food before they migrating offshore to deeper waters (Philips 1985). Due to the various interactions of seagrass meadows with surrounding ecosystems, monitoring of seagrass habitats provides insight into the overall coastal ecosystem health, allowing for mitigation of stressors and identification of ecological trends (Duarte *et al.* 2014). By conducting seagrass surveys in the future, MCC will gather information about the general health of surrounding ecosystems.

By reducing the water motion within the leaf canopy, and securing the substrate with its root systems, seagrasses improve water quality and stabilize sediments, protecting surrounding reef structures from siltation (Zieman 1982). Organic material, which is contained in the sediment as well, binds a remarkably high amount of carbon dioxide, a process known as carbon sequestration. Declining seagrass abundance is a global trend that is highly concerning, as the carbon normally sequestered in seagrass meadows is contributing to the already high level of carbon dioxide in the atmosphere. Conservative estimates indicate that current global seagrass loss rates could account for the release up to 299 teragrams of carbon per year, contributing greatly to greenhouse and climate change. (Fourqurean 2012) As it has been shown that disturbances can lead to permanent loss of seagrass ecosystems (Short 1996), it is vital that this resource receive management and conservation attention.

Trawling nets, used by illegal fishers in seagrass beds leads to major ecological problems. Disturbance caused by trawling and siltation uniformly uproot seagrass and disturb the associated sediment (Mam 2002). Constant disturbance to seagrass habitat greatly restricts its ability to recover, and under such circumstances, population recovery can take years (Clarke & Kirkman 1989; Preen et al.in press). 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). The remaining silt and mud sediment is not capable of supporting seagrass growth.

This coastal degradation is analogous with persistent, extensive deforestation and the resultant removal of topsoil; once all the trees are removed from an area, over time, rain and wind remove the nutritional soil from the area, making the area incapable of supporting tree growth. Currently, in Kep, large quantities of this dislodged seagrass are washed ashore, a second severe environmental impact of trawling. Once the seagrass is uprooted and deposited on the shore, it begins to decompose. The decaying organic matter produces toxic chemicals such as hydrogen sulphide and ammonia; such toxins are highly lethal to benthic marine animals (Islam & Tanaka 2004), and their deposition compromises water quality.

7.2.5 Blue Swimmer Crabs

The blue swimmer crab (*Portunus pelagicus*) is harvested in the Kep archipelago for consumption and sale. As such, attention must be drawn to the consequences that unsustainable fishing and anthropogenic activity could have for the blue swimmer crab and its trophic role in the Kep marine ecosystem. The loss of blue swimmer crabs would directly affect Kep's growing tourism industry.

Blue Swimmer Crabs have a vast geographic distribution throughout the Indo-Pacific (DEH 2006). They inhabit coastal and estuarine waters, occupying sandy, muddy, or algal and seagrass habitats. Larger marine species such as turtles, sharks, rays and large fish prey on this crab, whereas the crabs themselves are bottom feeding scavengers and carnivores, targeting primarily invertebrate algal grazers and filter feeders. As has been discussed, the trophic role of the blue swimmer crab relative to the Kep marine environment could be at risk if unsustainable fishing gears continue to operate in the region. However, the overexploited marine resources are making aquaculture facilities an important economic

income and a decrease of the fishing pressure of the wild stock (Ababouch & Karunasagar, 2013). Kep is particularly well known for its "Kep Crab", attracting tourists which leads to indirect spending in Kep province. This species are highly fecund; fast growing, early to reach sexual maturity with females laying up to 2 million eggs per batch (DEH 2006). Because of this, the blue swimmer crabs is a good target species to grow in aquaculture facilities.

Predation on this species plays a major role in keeping the population numbers in balance with the marine environment. If released from predation pressure, this highly fecund species could have catastrophic consequences on the associated ecosystem via trophic cascading. In other words, decline or omission of predators from the environment would allow the crab population to go unchecked, which in turn would contribute to the decline in the crab's food and an ultimate imbalance or collapse in the marine ecosystem. It is, therefore, extremely important that the status of blue swimmer crab populations be monitored, and fisheries be managed to promote sustainability and ensure the species survives and maintains a healthy population.

7.2.6 Marine Mammals In Kep's Waters

Until very recently (within the past eight years), the Kep archipelago was found to support a number of large, endangered marine species such as dugongs (Dugong dugong), potentially five different turtle species (Chelloni spp.) and up to ten different species of dolphin (Delphinidae spp.) (Beasely et al. 2007). In particular, the marine mammal species diversity and population in the region was thought to be of global significance (Beasley et al. 2007). Compared to Vietnamese and Thai survey records, the 2007 survey of Cambodian waters revealed far higher marine mammal diversity in Cambodian territory. In Thai waters, there were almost no marine mammal encounters.

Over the past five years, however, the populations of these charismatic and attractive species around Kep have been greatly reduced due to unsustainable fishing techniques. Marine mammal species such as dugongs and dolphins require healthy environments to support them. The depletion of water and habitat quality through unsustainable fishing

methods and by-catch of marine mammals due to unselective fishing gears are main causes for the loss of marine mammals from an ecosystem. The marine habitat in the Kep region is no longer capable of supporting large, apex predator species. One paper noted that it is a truly dire situation, outlining measures that could have been taken in order to protect and conserve the globally unique populations of marine mammals in Kep and the greater Cambodian waters (Beasley et al. 2007). However, such measures were not taken and only seven years after this survey, current sightings and by-catch numbers of marine mammals have plummeted to almost insignificant levels. Nonetheless, recent sightings of dolphins off Koh Seh (directly within the proposed MPA area) are signs that the ecosystem is already responding to a recent reduction in fishing pressure.

The dugong feeds preferentially on particular seagrass species, mainly *Halophila ovalis* or *Halophila uninervis* (Aragones *et al.* 2006). Therefore, if the seagrass in Kep is able to re-establish, it is far more likely that dugongs would return to the area. The situation is the same with the dolphin species. Dolphins are apex predators, occupying the highest point on the marine food chain; in other words, healthy adult dolphins have no predators (Matich *et al.* 2010). All dolphin species depend on an abundance of healthy fish to support their growth, development and breeding. Therefore, if large fish are able to return to the Kep archipelago, dolphins will surely follow.

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