Koh Angkrong Marine Environmental Assessment, Kep Province, Cambodia

Marine Conservation Cambodia

January 2015

Seahorse, Cambodia

In Partnership With:

Report By:

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I. Abstract

Upon request Marine Conservation Cambodia (MCC) has been undertaking a series of marine surveys to assess the health of the marine ecosystems of Koh Angkrong, Koh Seh and Koh Mak Prang, Kep Province. This is the second in the series of reports on Koh Angkrong. This report, using the first as the base line of this continual monitoring program, will begin to draw comparisons between the initial and present data. The MCC Research Team surveyed the pre-determined sites during January using the globally recognized Reef Check International methodology. The results of this study indicate that hard coral is the dominant substrate of the reef ecosystem surrounding Koh Angkrong (30%) while rock and sand (potentially suitable settling grounds for coral larvae) were the next most abundant (24% and 17% respectively). Anthropogenic impact on coral is low; however, severe signs of overfishing have been observed for both fish and invertebrates. Coral bleaching was observed and will continue to be closely monitored, helping to gauge the threats of climate change in the Gulf of Thailand. Given the observed improvements, the implementation of a properly managed MPA with active enforcement is anticipated to enhance Koh Angkrong's marine ecosystems, promoting the resilience and productivity of the region's marine life.

II. Acknowledgements

Marine Conservation Cambodia (MCC) has been working towards environmental conservation and securing community livelihoods in collaboration with the Royal Government of Cambodia Fisheries Administration (RGC FiA), local authorities and local communities since 2008. Our marine monitoring, marine research and socio-demographic programs around Koh Rong and Koh Rong Samloem supported the creation of the first Marine Fisheries Management Area in Preah Sihanouk Province: we are currently undertaking marine surveys around Kep's thirteen 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. To date, we have conducted the second set of reef surveys, which demonstrate the success of enforced fisheries management and great potential of the Coral Reef Restoration Project.

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H.E. 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
Mr. Sar Sorin	Director Kampot & Kep Fisheries Cantonement
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VI. 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

1 Introduction

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

The South China Sea, within which Cambodian waters are situated, is a diverse marine environment with highly valuable coral reefs, sea grass beds and mangrove ecosystems. The nations bordering the South China Sea are home to 5% of the world's human population (Talaue-McManus, 2000). These populations heavily rely upon the resources and services provided by the marine environment, including seafood production, employment (e.g. fisheries, shipping, tourism) and numerous ecological services. Anthropogenic impacts, including sedimentation, nutrient runoff, overfishing, physical damage by boats and waste pollution, are resulting in habitat loss and decreased biodiversity in Cambodia's marine environment (van-Bochove *et al.* 2011), as well as elsewhere in the South China Sea. Healthy marine ecosystems are vital to the region's economies and natural environment, and thus, proper management is urgently required to address the anthropogenic impacts that are stressing the marine environment. It is clear that careful management and protection of Cambodia's marine environment is vital to sustain the livelihoods of the region's people (van-Bochove *et al.* 2011).

Coral reefs are complex, highly productive and biologically diverse ecosystems. These environments are susceptible to a number of anthropogenic impacts, such as destructive fishing activities (e.g. overfishing, trawling, anchoring, dynamite, poison, long-lines, small mesh nets etc.), nutrient loading (e.g. untreated waste input, runoff from agricultural fields), and pollution (Pauly *et al.* 2002). Not only do these anthropogenic activities decrease the biodiversity of the system, they negatively alter the coral reef structure, altering habitat that is vital to many marine species, including commercially important fisheries species (van-Bochove *et al.* 2011).

Seagrass meadows are among the most diverse and highly productive coastal ecosystems in the world (Duarte *et al.* 2004). Seagrasses play an important role in the general health of the surrounding sea, and function as a habitat for many different species due to their ability to produce a huge amount of biomass out of solar energy. They are the primary producers of a complex web and provide shelter and nourishment to many species and juvenile fish. There are a few species that make use of seagrass habitats as direct food sources, such as fish, 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 (Bjork *et al.* 2008). 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). The decline in seagrass extent and health in Cambodian waters should be taken as a warning sign, indicating the need for management actions aimed at decreasing anthropogenic stressors and preserving remaining seagrass meadows.

Cambodia's economy is largely dependent on its coastal and marine sector (Wheeler et.al, 2000), and thus, on its coral reefs and sea grass ecosystems. In addition to providing valuable ecological services (e.g. carbon sequestration, nutrient cycling, habitat, sediment stabilization), seagrasses support commercially important fisheries species and present the potential for acquisition of money from carbon credits. Coral reefs contribute to Cambodia's economy by providing ecosystem services that are essential to the fisheries industry, and by drawing tourists to the region. For instance, an economic valuation analysis of Ream National Park in Cambodia focused on the recreational opportunities related to coral reefs, estimated the present value (10% discount, 20 years) of the best protection scenario between $21,390 to $699,636 per km^2 of healthy coral reef (Conservation International, 2008).

There has been major exploitation of marine resources in neighboring Vietnam, with employment in marine fisheries being the highest in the South Central area (11.3%). Along its 3260km coast, resources have been fished down to 5-30% of their unexploited levels (Pomeroy, 2011). This major decline in their marine resources is driving the spread of illegal Vietnamese fishers into Cambodian waters.

In order to mitigate the anthropogenic stresses placed on Cambodia's marine environment (e.g. unsustainable fishing, pollution, etc.), and prepare for the increasing threats of climate change (e.g. sea level rise, increase in storm events, warming water temperatures), management decisions must be carefully calculated. Management of marine resources for biodiversity objectives and fishery production is in a period of global change, with calls for greater use of areas with marine protected areas (MPAs) where zoning is utilized to manage activities within the MPA (Botsford *et al.* 2008). Marine protected areas, including no-take areas, combined with strong enforcement of strategically designed fishing regulations in waters surrounding the MPA, have been shown to have positive effects in rebuilding depleted fish stocks (Pauly *et al.* 2002).

Embracing the concept of a MPA, the government of Kep Province is taking action to restrict unsustainable fishing methods, and has expressed its support for the implementation of a MPA encompassing Koh Seh, Koh Mak Prang and Koh Angkrong. This will involve a coral reef rehabilitation project, including a no-take zone on the eastern side of Koh Seh. MCC conducted baseline studies in 2014 and comparative studies in 2015 around the islands to evaluate the current state of Kep's marine environment. The following report summarizes the findings of MCC's marine environmental assessment of Koh Angkrong (Figure 1). Consequently, this report will cover:

- The general distribution of coral reefs surrounding Koh Angkrong.

- The abundance and distribution of reef health indicators, such as fish and invertebrates.
- The general condition of the reef survey sites in terms of visible impacts (e.g. boat damage, dynamite destruction, trash).
- The main issues that require attention within the proposed MPA.

This report present the findings of the second set of reef surveys conducted by MCC to assess the health of Koh Angkrong (Figure 1) in order to provide in-depth information on the marine environments of all islands within Kep Province. These reports will assist in building a sustainable marine conservation program for Kep Province.

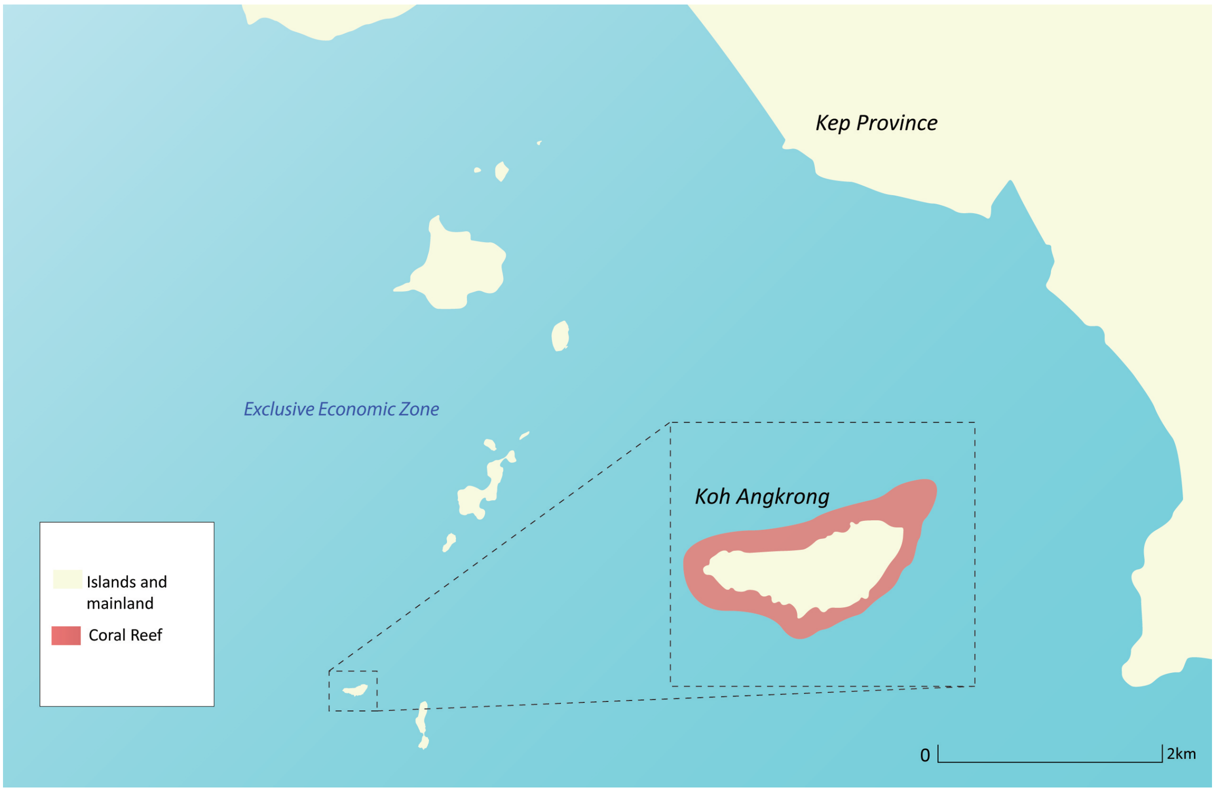

Figure 1: Location of Koh Angkrong

2 Methodology

2.1 Survey Sites Location and Selection

To create a complete overview of the island, nine survey sites encompassing the island were selected (Figure 2). A reef survey was conducted at each designated site, for each survey, a 100 m length transect line was laid parallel to the coastline (Figure 3 and Figure 4). Four 20 m segments of the transect line were surveyed, each one separated by a gap of 5 m where no data was recorded. This helps ensure independence for each 20 m section, which increases the statistical reliability of the data collected.

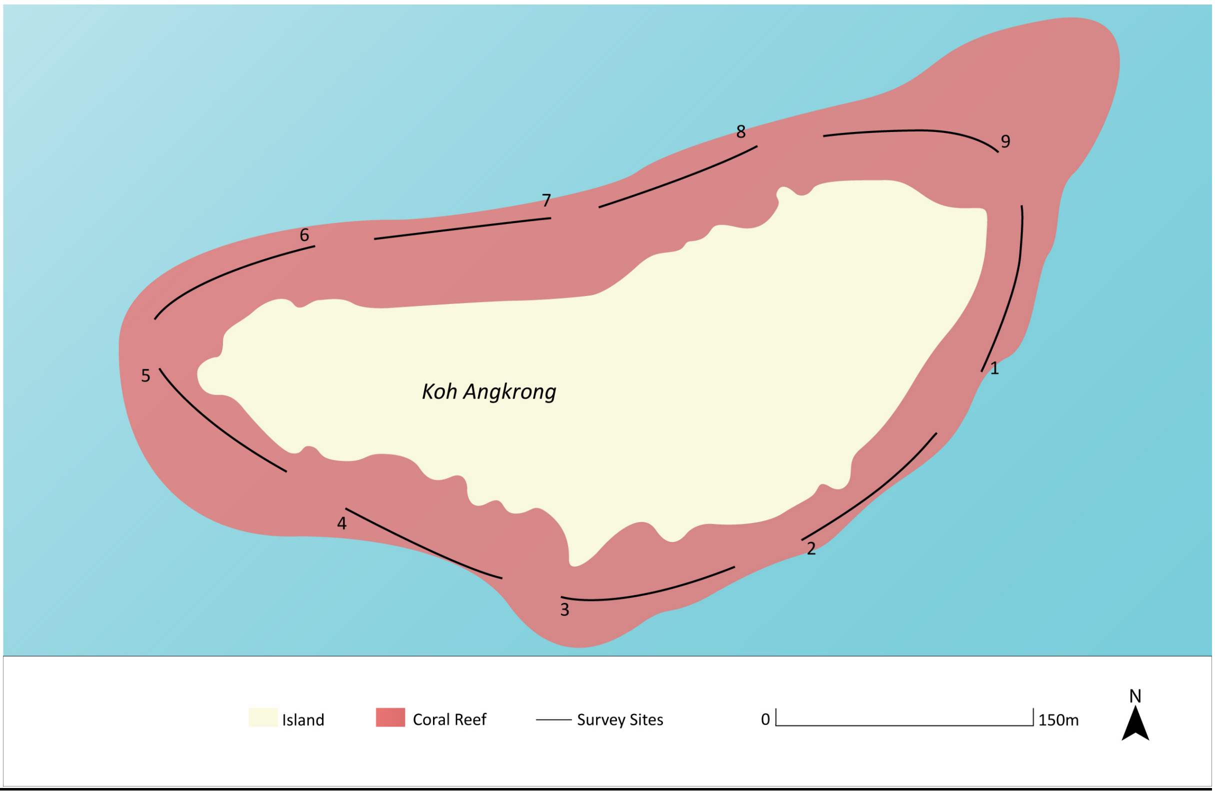

Figure 2: Location of the nine survey sites situated around Koh Angkrong

2.2 Data Collection

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).

MCC survey teams collect 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

The applied methodology was used in the 2014 and 2015 surveys and will be subsequently replicated in future surveys.

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 3 and Figure 4).

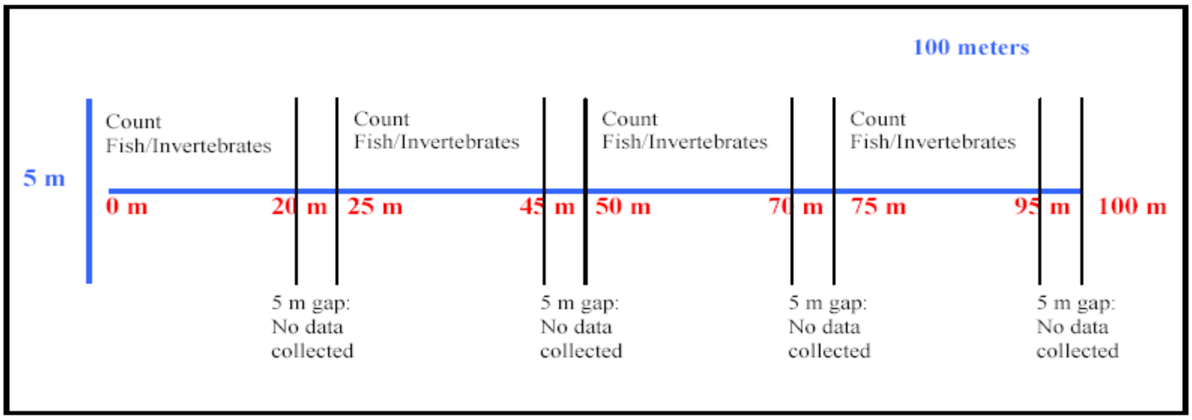

Figure 3: Fish and invertebrate belt transect count method

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 3). Invertebrates were then counted on the same segments. Substrate was recorded every 0.5m within the four 20m segments along the transect line (Figure 4).

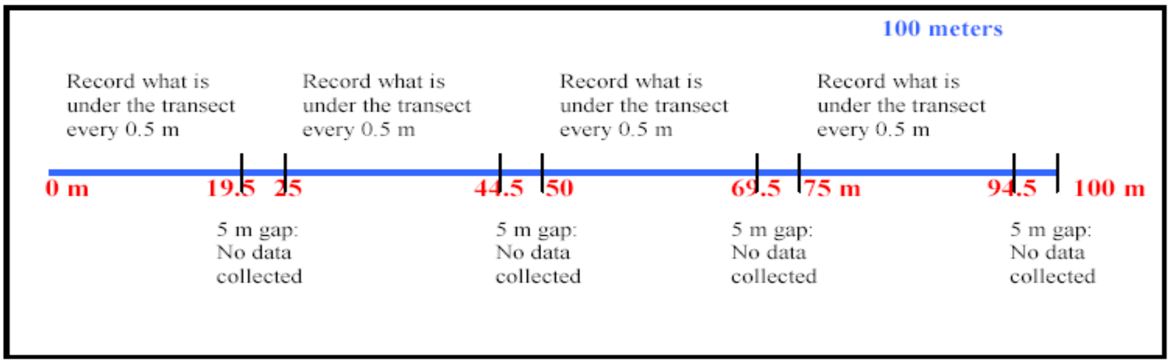

Figure 4: Point intercept transect count method to determine benthic cover

2.3 Observed External Impacts

For each of the nine 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.

2.4 Data Analysis

Data collected by divers was transcribed electronically following each survey. Upon completion, the data was graphed and compared with the results from the initial surveys of the island. The mean abundance of fish and invertebrates was calculated from the mean number of individuals per square meter. Statistical t-tests compared fish and invertebrate mean abundances from the initial 2014 survey with the January 2015 survey. F-tests were performed on the data sets of each species to determine whether variances are equal or unequal. Paired two-tailed t-tests were used for data sets with equal variances, and standard t-tests were used for data sets with unequal variances.

The substrate composition of Koh Angkrong was estimated by the average composition of the 20-m segments along the nineteen surveyed transect lines. The found average substrate composition was compared to the initial survey findings using a t-test analysis. F-tests were performed on the data sets of each substrate type to determine whether variances were equal or unequal. Paired two-tail t-tests were used for data sets with equal variances, and standard t-tests were used for data sets with unequal variances.

Coral damage is categorized into four levels of damage: 0- none, 1- low, 2- medium and 3- high. The overall damage was estimated as the mean of the nine surveyed transect lines. Coral bleaching was described by estimating the percentage of bleaching within the coral population and percentage within the coral colony.

3 Results

3.1 Fish Survey Results

The fish species with the highest mean abundance were the sergeant fish (7,7), cardinal fish (2.9) and java rabbitfish (1.6; Figure 5). All other recorded fish species were observed in relatively low abundance (Figure 6) and species diversity was considerably low, which is similar to the 2014 results. It is important to note that the fish families present were observed to be of a small body size, with no large individuals of any family observed at the seven survey sites. The high abundance of cardinal fish, which are small fish with fast reproductive rates, can be attributed to the lack of fishing pressure on this species, and the high abundance of diadema urchins in the area. Cardinal fish are often associated with seagrass and the long-spine sea urchin Diadema, using the sea urchins' spines for protection.

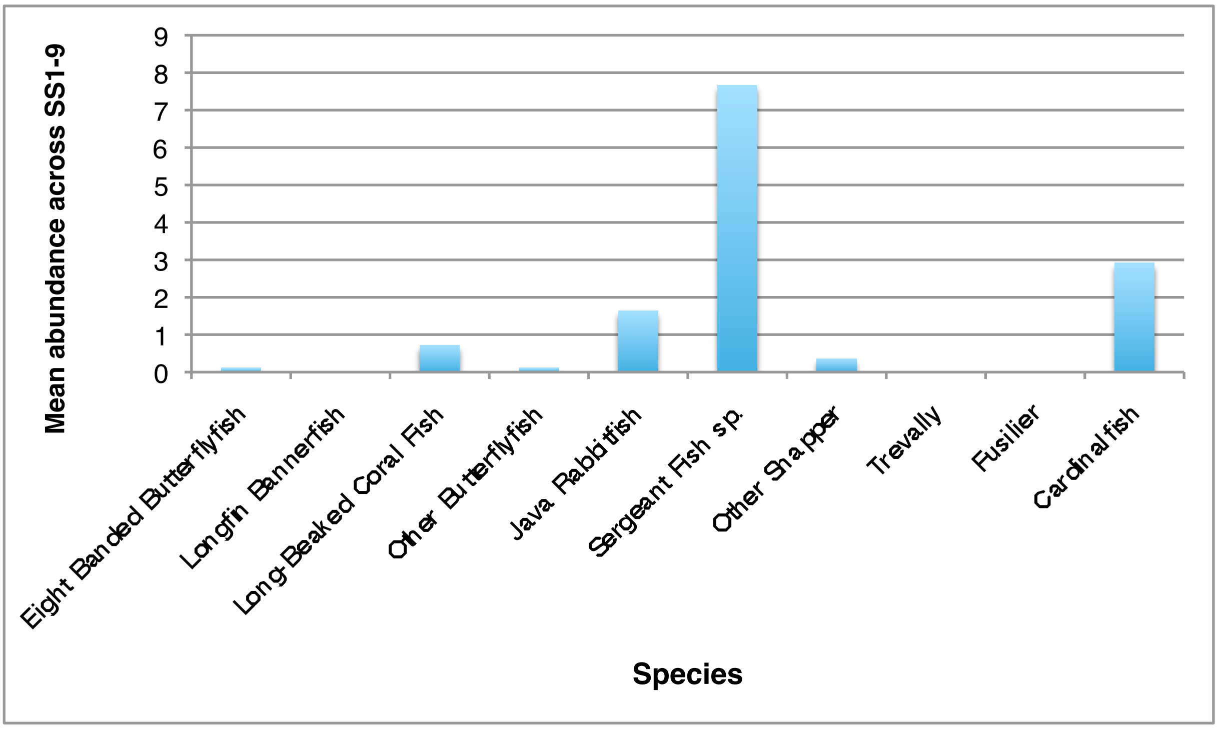

Figure 5: Mean abundances of target species across SS1-9 of Koh Angkrong (2015).

Comparisons of fish abundances in 2014 and 2015 (Figure 6 and Figure 7) depict a decrease in most species. This result can be attributed to the lack of replication within the study; when the number of surveys is limited, as is this case for this study, observing one school of fish can distort the results. Thus, we believe that the slight decrease (note scale) in the mean abundance of most fish species (Figure 6 and Figure 7) is due to a lack of replication, and not an actual decline in fish populations.

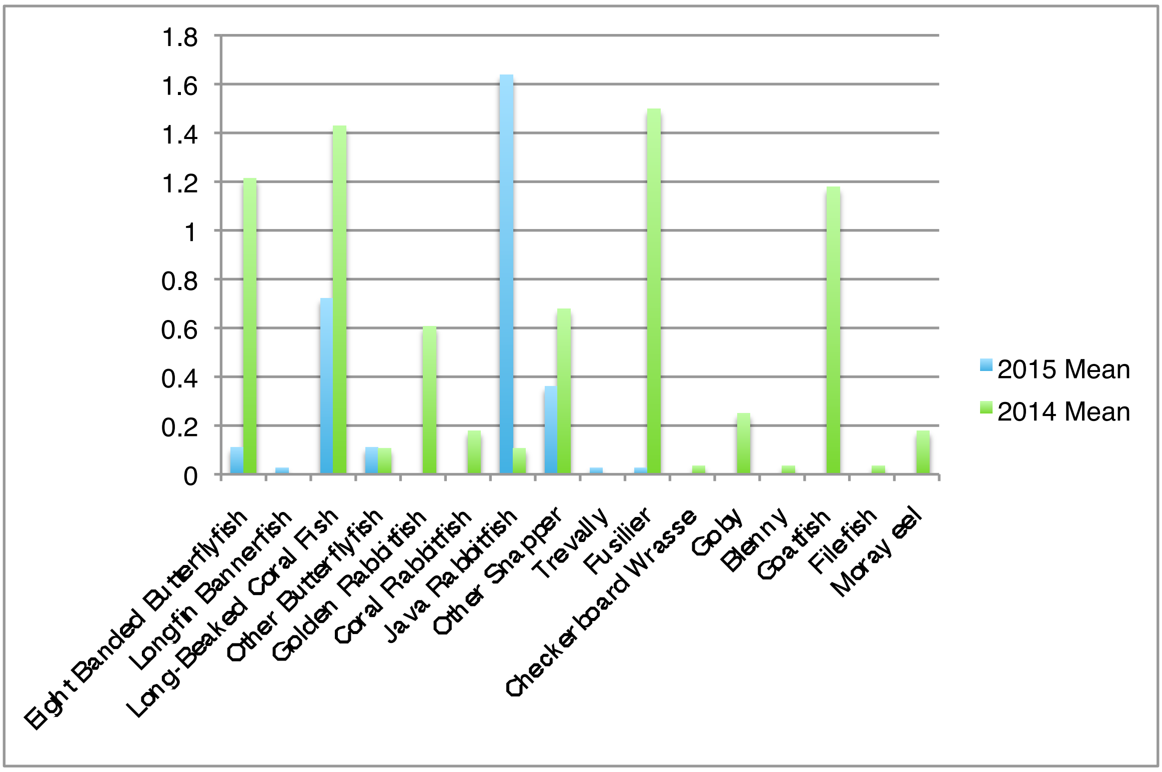

Figure 6: Comparison between 2015 and 2014 of mean abundance of majority of target fish species (excluding cardinal fish and sergeant fish, which are shown in figure 7) across SS1-9 of Koh Angkrong.

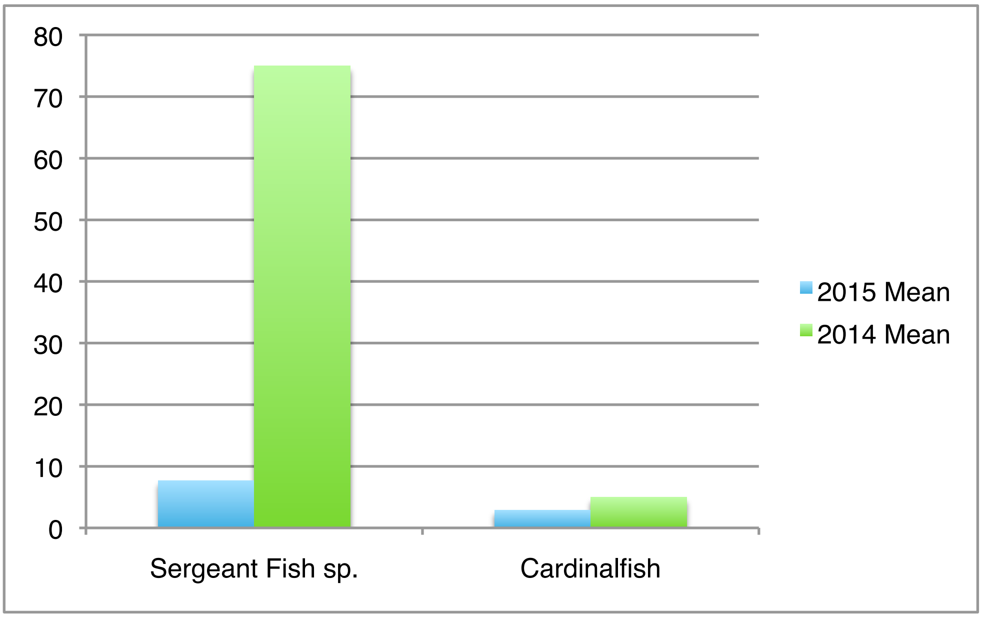

Figure 7: Comparison between 2015 and 2014 of mean abundance of sergeant fish and cardinal fish across SS1-9 of Koh Angkrong.

3.2 Invertebrate Survey Results

This study demonstrates that the overall diversity and the abundance of many invertebrates are particularly low in the marine environment of Koh Angkrong (Figure 8 and 9). This indicates that the reef ecosystem is in poor health and is unable to sustain a high diversity and number of invertebrates, which are essential to the overall functioning and productivity of the reef ecosystem. The two most abundant invertebrates were synaptic sea cucumbers and diadema urchins (Figure 9). Such a high abundance of diadema urchins indicates nutrient imbalances (eutrophication) that are causing abnormally high algal cover, which stimulate urchin growth, but inhibit other invertebrates and smothers corals.

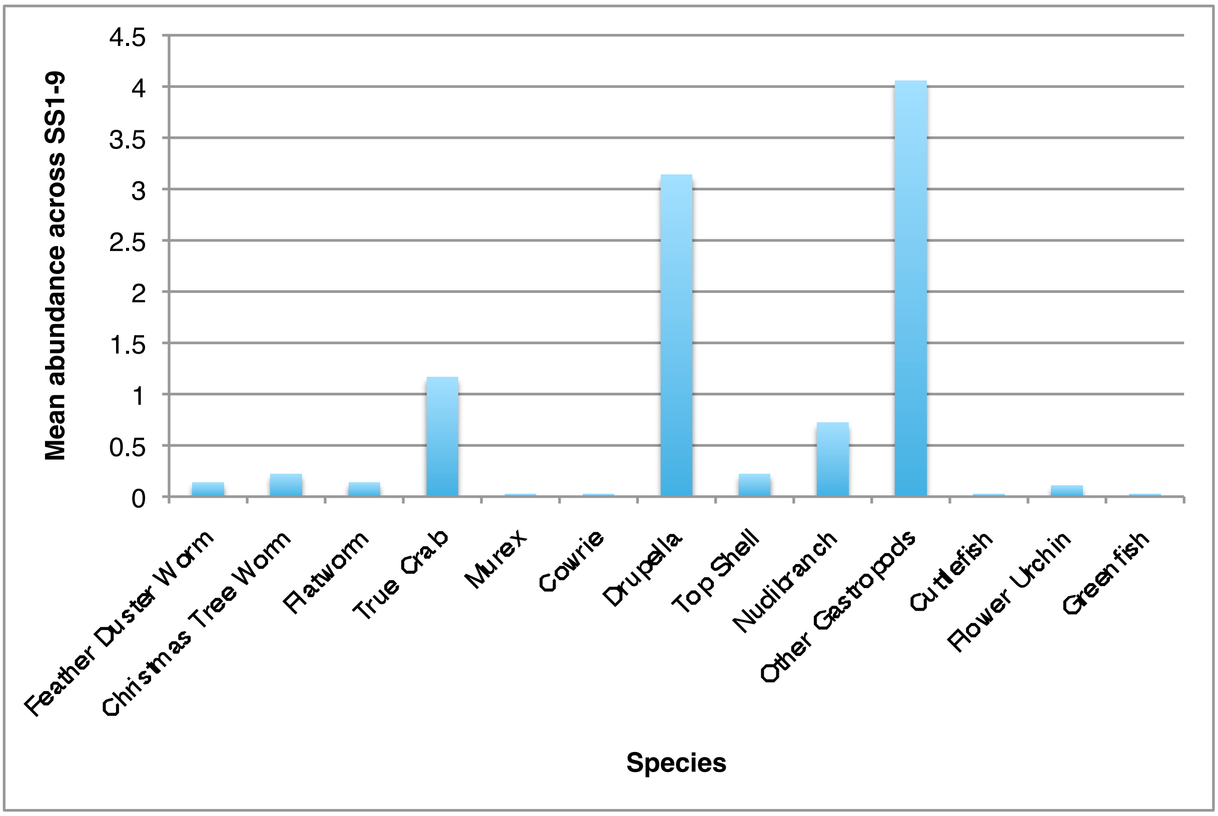

Figure 8: Mean abundance of invertebrates (excluding synaptic sea cucumber and diadema sea urchin, which are shown in Figure 9) across SS1-9 of Koh Angkrong.

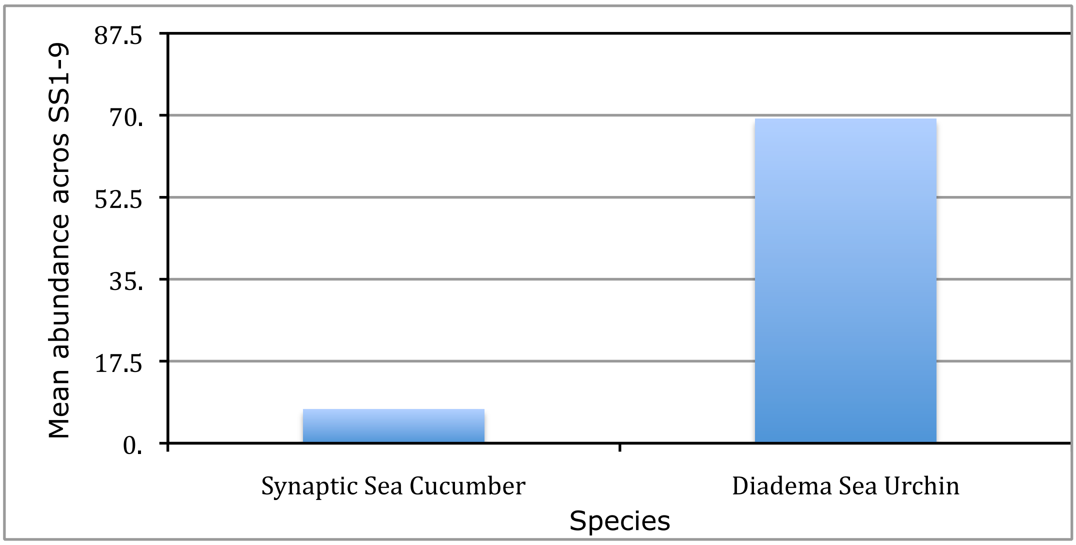

Figure 9: Mean abundance of invertebrates synaptic sea cucumber and diadema sea urchin across SS1-9 of Koh Angkrong in 2015

A comparison between the mean abundances of invertebrates observed in 2014 with 2015 results indicates slight declines in some species (Figure 10 and Figure 11); however, similar to the fish results, we attribute this to a lack of survey replicates and not the actual decline of invertebrates.

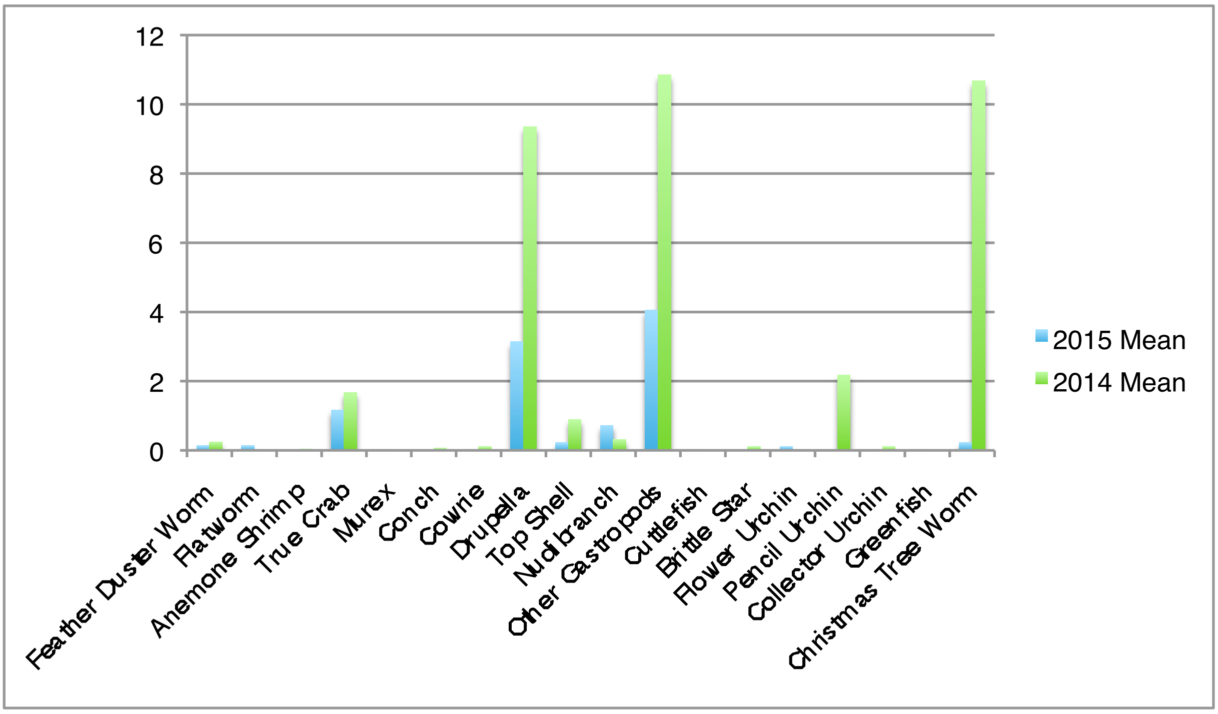

Figure 10: Comparison between 2015 and 2014 of mean abundance of majority of target invertebrates (excluding synaptic sea cucumber and diadema sea urchin, which are shown in Figure 11) across SS1-9 of Koh Angkrong

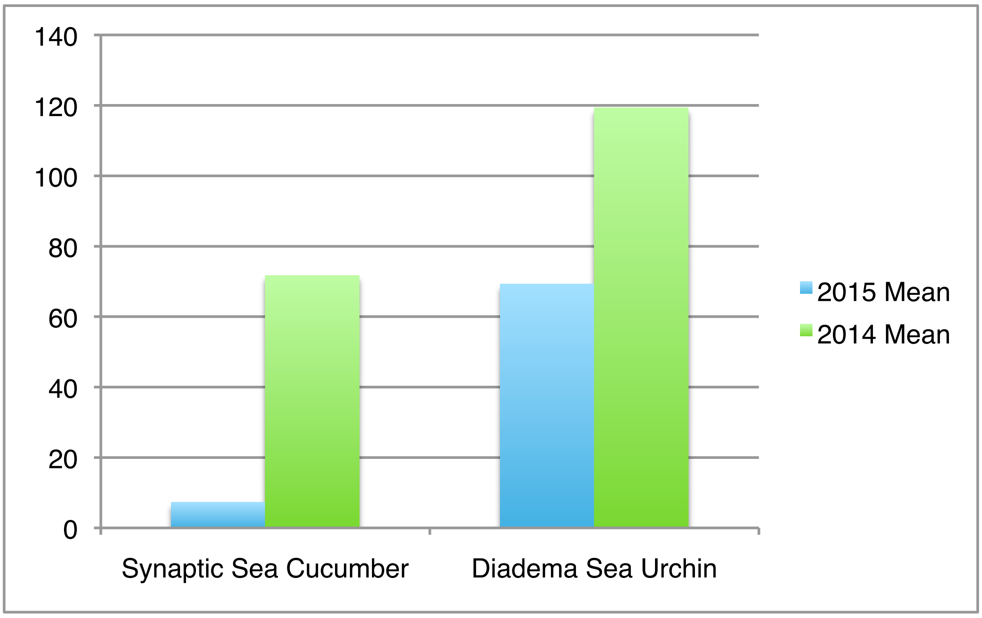

Figure 11: Comparison between 2015 and 2014 mean abundances of synaptic sea cucumber and diadema sea urchin across SS1-9 of Koh Angkrong

3.3 Substrate Survey Results

The most dominant substrate cover across the seven survey sites was rock (Figure 12 and Figure 13). The hard coral cover across all survey sites was found to be the second most prominent substrate (19.17%; Figure 12), with the highest percentage (30%) of hard coral found at survey site 4 (Figure 13). As they are reef builders, hard coral cover is an indicator of general reef health and contributes to reef diversity. It should be mention, in regard to the mean percentage of substrate coverage, that the discrepancy between 2014 and 2015 (Figure 14) is due to the transect line positioning and the lack of replication within the study. It does not reflect a drastic reduction in hard coral cover around the island.

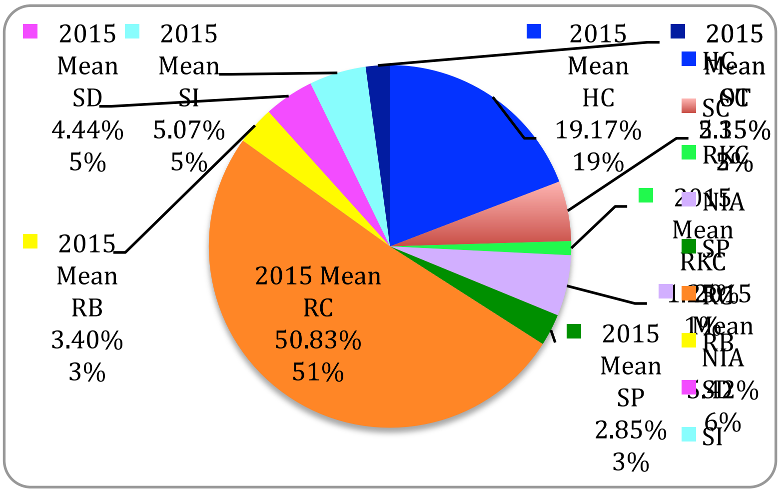

Figure 12: Average percentage of substrate coverage at Koh Angkrong January 2015

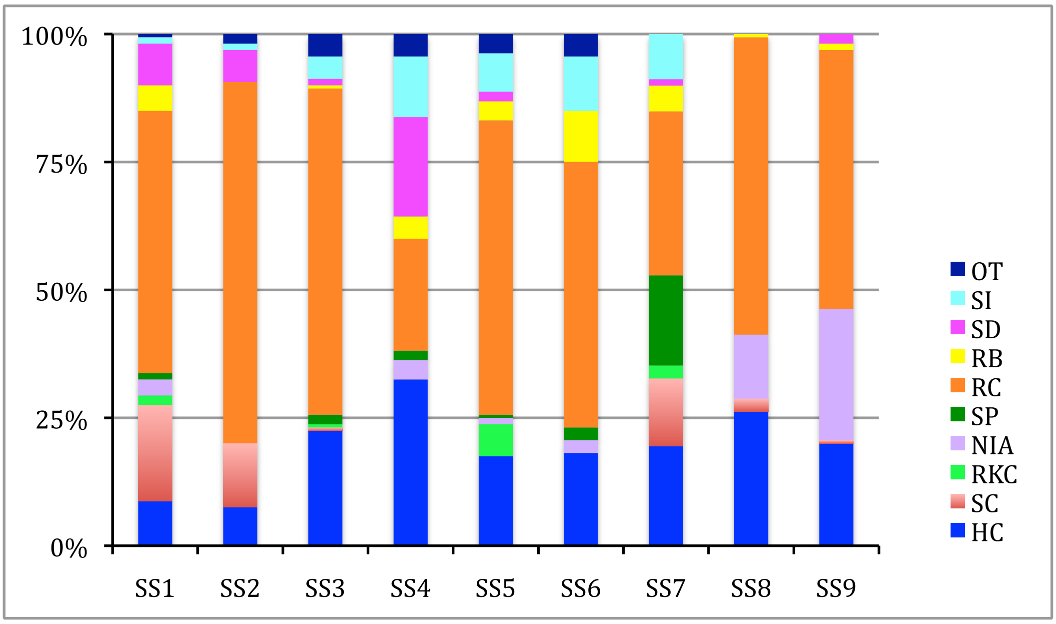

Figure 13: Composition of substrate cover at each of the 9 survey sites of Koh Angkrong, January 2015

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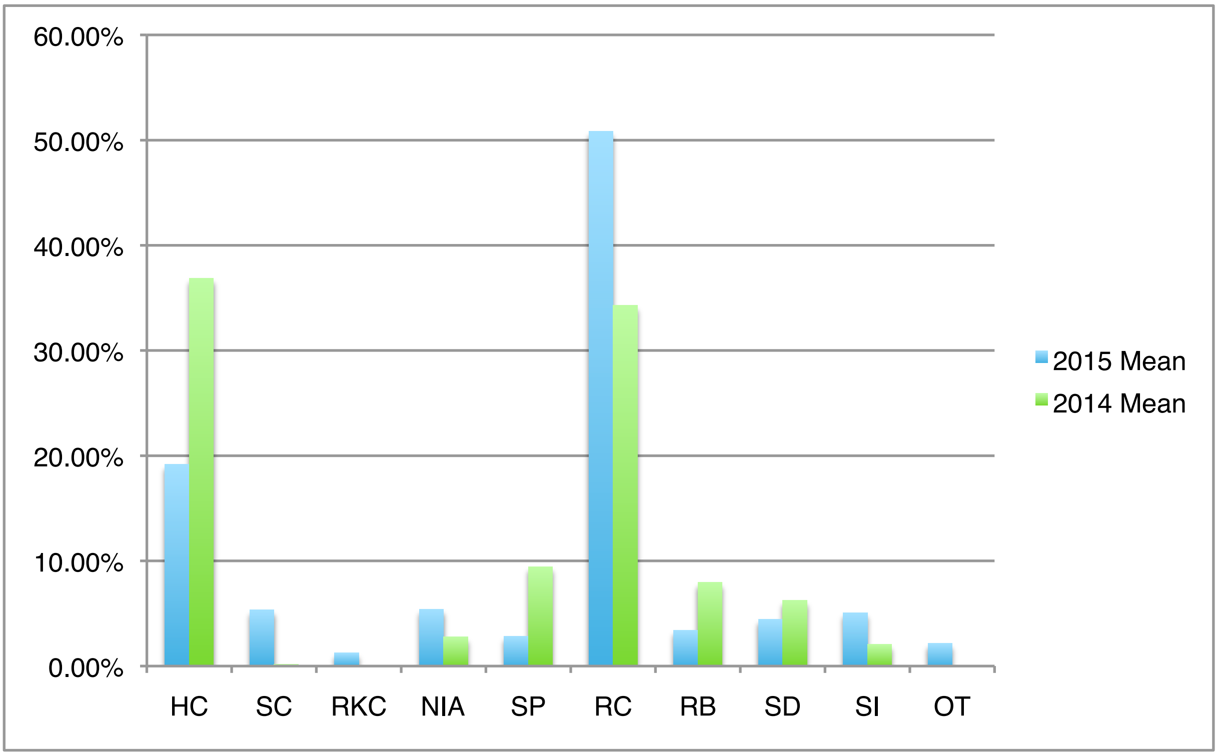

Figure 14: Comparison between 2015 and 2014 of mean percentage of substrate coverage across SS1-9 of Koh Angkrong

3.4 T-test Results

T-test results are included in the appendix (see section 7.1). The lack of replicates in this study allows outliers to skew the results of the t-test, so it is not valid to formulate conclusions based on the t-test results. In future studies, it will be possible to perform more replicates, and the Mann-Whitney statistical analysis will be used to limit the effects of outliers, allowing for statistical significances to be utilized in conclusion formation.

4 Discussion

Similar to the baseline assessment of Koh Angkrong's reef ecosystem conducted in March 2014, this follow-up study found the overall health of the marine environment 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 immediately conserve and rehabilitate this area. The low abundance and diversity may be due to the continued presence of bottom trawl gears and other unsustainable fishing gears, as well as the lag time in species recovery after habitat restoration has begun. 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. Again, MCC recommends the adoption and implementation of a Marine Protected Area, with management plans for protection, conservation, and monitoring to mitigate the negative impacts of past and present unsustainable actions.

Despite the conclusion that Koh Angkrong's marine ecosystem health and structure is poor, the high presence of hard coral and rock surfaces indicate the potential for improving the reef health is high; 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 Marine Protected Area encompassing Koh Angkrong holds great potential in revitalizing the reef ecosystem as long as protection is enforced.

The recent survey data demonstrates evidence of overfishing through a low abundance and diversity of fish, similar to what was observed in March 2014 surveys. Fishing often targets larger species of carnivorous fishes, such as groupers, snappers and flathead. Overfishing of larger fish species decreases the richness of fish species and families; leaves only the smaller, juvenile individuals from the species remaining; and poses the greatest threat to fish species with vulnerable reproductive behavior. The fish data from the initial and subsequent surveys at Koh Angkrong reveal small sizes among all observed fish species. The most popular species for human food consumption (e.g. groupers and snappers) were seen in small quantities and were recorded as being less than 10cm in body size; the small body size could either be a result of the larger fish being more easily caught, or that the population is evolving to grow to a smaller maximum size in order to decrease their risk of being caught. Other fish species observed were those that are naturally small in size and reside under ledges and crevices. Commercial fishing targets these fish families and species less due to their small size and hard-to-access habitat.

The study findings demonstrate a low abundance and diversity of invertebrates in the marine environment of Koh Angkrong. Overfishing is likely responsible for the limited prevalence of invertebrates in this area. Invertebrates are often fished in high numbers, as they are utilized for food (e.g. blue swimmer crab, sea cucumber) and other commercial uses, such as jewelry and tourist souvenirs. The low abundance and diversity of invertebrates is concerning because these species play an important role in coral reef ecosystems. A low abundance and diversity of invertebrates can lead to a number of issues, such as disruption of nutrient cycling, imbalances in the food web, and ultimately, decreased biodiversity. For example, many invertebrates consume algae, which is an important function in keeping the coral and algae in equilibrium. The lack of these invertebrates can trigger a surge in algal production that smothers corals, blocking their light and disrupting their ability to collect nutrients, resulting in nutrient imbalances in the ecosystem. This problem is compounded in ecosystems where there are few herbivorous fish to feed on algae in the absence of invertebrates. Measures to protect and rehabilitate invertebrate populations are required in order to safeguard the overall health of the reef, and to ensure that economically significant invertebrate species (e.g. blue swimmer crabs) survive and are plentiful enough to provide fishing jobs and food for Cambodians.

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 illegal fishing sightings from the island of Koh Angkrong, or from our dive boat, the destruction from these fishing activities is evident underwater. Scientists and trained survey divers recorded a high amount of trash from fishing and other human activities, including batteries from surface markers, 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.

Sedimentation is another major threat to the recovery and rehabilitation of the area. Sedimentation 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 Angkrong observed sediments covering coral populations, which was most likely due to mainland run-off or fishing activities, particularly trawling. Efforts aimed at mitigating sedimentation are needed; this could involve enforcing laws restricting trawling in shallow areas, improved management of coastal erosion, and increased efforts to conserve and promote stabilizing seagrass meadows.

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 surveys of Koh Angkrong 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 an increase in recently killed coral, which could be due to a number of factors, including increased sedimentation, slightly higher water temperatures (seasonal change), or that the transects surveyed in 2014 happened to have less apparent damage from destructive fishing compared to the transect lines selected during the 2015 surveys. 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, a focus should be placed on mitigating the stresses to corals that can be controlled (e.g. pollution).

Not only are the reef ecosystems suffering from human influence, seagrass beds are also dramatically declining in extent and health. Much of the damage inflicted by anthropogenic activities results from unsustainable fishing methods, particularly trawling nets since they uproot seagrasses, destroying entire meadows. Eutrophication (excess nutrient input causing harmful algal blooms) and pollution also lead to major damages in seagrass ecosystems. Trophic imbalances, often resulting from fishing pressure, also compromise the health of seagrass ecosystems; an absence of predators that target seagrass grazers can lead to an overabundance of grazers, which in turn leads to detrimental overgrazing of the seagrass meadow.

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 pipepish. 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). 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 sedimentation (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.

Due to the fragility and complexity of the region's marine ecosystems, recovery can only occur if the area is relieved of unsustainable fishing pressures, and therefore, such practices should be addressed immediately. 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.

5 Conclusion

The study presented in this document aims at demonstrating the feasibility and urgent need for a zoned fisheries management area, including a marine protected area (MPA) encompassing Koh Mak Prang, Koh Seh and Koh Ang Krong. Sustainable fishing activities (i.e. crab trap fishing) will be permitted within this 'triangle' MPA, aside from in the no-take zone along Koh Seh's east coast. As the positive impacts of conservation and integrated fisheries management within this area become apparent, the sustainable practices will hopefully extend beyond the defined zones.

The results of the underwater surveys 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 coral reefs and seagrass beds are threatened by various factors, especially unsustainable fishing practices. Although physical damages such as anchoring were observed as being low, signs of pollution and serious overfishing were recorded. Thus, the area will be able to recover naturally only if appropriate management actions are taken to reduce anthropogenic stresses.

With the implementation of the proposed MPA, and continued enforcement of fishing regulations, Koh Angkrong's coral reef and seagrass ecosystems have the potential to recover from decades of anthropogenic stresses (fishing pressure, pollution), and regenerate into diverse and productive marine environments.

Effective conservation and restoration of the proposed MPA's reef and seagrass ecosystems will produce highly valuable environmental and economic benefits. With an efficient integrated management plan, and cooperation between involved parties, the Kep

Archipelago could become an emulated model of sustainable marine resource management and conservation.

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7 Appendix

7.1 T-test Results and T-test Results

The following tables show the F-Test and T-Test results. Note that the difference between 2014 and 2015 results is significant if the P-Value (result of T-test) is less than 0.005.

FISH	F-test	Variance	T-test
Eight Banded Butterflyfish	1.26881E-05	unequal variance	0.157124466
Longfin Bannerfish	N/A	N/A	N/A
Long-Beaked Coral Fish	0.415801815	unequal variance	0.044311028
Other Butterflyfish	0.291273269	unequal variance	0.964249859
Butterflyfish total	0.00346963	unequal variance	0.053994149
Angelfish	N/A	N/A	N/A
Spadefish	N/A	N/A	N/A
Golden Rabbitfish	N/A	N/A	N/A
Coral Rabbitfish	N/A	N/A	N/A
Virgate Rabitfish	N/A	N/A	N/A
Java Rabbitfish	2.59204E-06	unequal variance	0.125163255
Vermiculated Rabbitfish	N/A	N/A	N/A
Rabbitfish total	0.191213567	unequal variance	0.495660844
Sergeant Fish sp.	1.80736E-06	unequal variance	0.058685463
Anemone Fish sp.	N/A	N/A	N/A

Checkered Snapper	N/A	N/A	N/A
Red Snapper	N/A	N/A	N/A
Blackteil Snapper	N/A	N/A	N/A
Other Snapper	0.014683668	unequal variance	0.272983464
Snapper total	0.014683668	unequal variance	0.272983464
Bridled Monocle Bream	N/A	N/A	N/A
Whitestreak Monocle Bream	N/A	N/A	N/A
Emperor	N/A	N/A	N/A
Trevally	N/A	N/A	N/A
Great Barracuda	N/A	N/A	N/A
Yellowtail Barracuda	N/A	N/A	N/A
Fusilier	3.5717E-12	unequal variance	0.364310547
Barramundi Cod	N/A	N/A	N/A
Blue-Lined Grouper	N/A	N/A	N/A
Chocolate Grouper	N/A	N/A	N/A
Peacock Grouper	N/A	N/A	N/A
Honeycomb Grouper	N/A	N/A	N/A
Square-Tail Grouper	N/A	N/A	N/A
Other Grouper	N/A	N/A	N/A
Grouper 0-10cm	N/A	N/A	N/A
Grouper 10-20cm	N/A	N/A	N/A
Grouper 20-30cm	N/A	N/A	N/A
Grouper 30-40 cm	N/A	N/A	N/A
Grouper 40-50 cm	N/A	N/A	N/A
Grouper >50 cm	N/A	N/A	N/A
Grouper total	N/A	N/A	N/A
Doublebanded Soapfish	N/A	N/A	N/A

Sweetlips	N/A	N/A	N/A
Bumphead parrotfish	N/A	N/A	N/A
Other Parrotfish	N/A	N/A	N/A
Parrotfish 0-10cm	N/A	N/A	N/A
Parrotfish 10-20cm	N/A	N/A	N/A
Parrotfish 20-30cm	N/A	N/A	N/A
Parrotfish 30-40 cm	N/A	N/A	N/A
Parrotfish 40-50 cm	N/A	N/A	N/A
Parrotfish >50 cm	N/A	N/A	N/A
Parrotfish total	N/A	N/A	N/A
Humphead wrasse	N/A	N/A	N/A
Red-Breasted Wrasse	N/A	N/A	N/A
Crescent Wrasse	N/A	N/A	N/A
Tripletail Wrasse	N/A	N/A	N/A
Checkerboard Wrasse	N/A	N/A	N/A
Wrasse total	N/A	N/A	N/A
Squirrelfish / Soldierfish	N/A	N/A	N/A
Cardinalfish	0.346081508	unequal variance	0.366252469
Lizardfish / Sandperch	N/A	N/A	N/A
Goby	N/A	N/A	N/A
Blenny	N/A	N/A	N/A
Scorpionfish	N/A	N/A	N/A
Boxfish	N/A	N/A	N/A
Goatfish	N/A	N/A	N/A
Sweepers	N/A	N/A	N/A
Triggerfish	N/A	N/A	N/A
Filefish	N/A	N/A	N/A
Pufferfish	N/A	N/A	N/A

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Porcupinefish	N/A	N/A	N/A
Moray eel	N/A	N/A	N/A
Bamboo Shark	N/A	N/A	N/A
Blue-Spotted Ribbontail Ray	N/A	N/A	N/A

INVERTS	**F-Test**	**Variance**	**T-Test**
Feather Duster Worm	0.177925285	unequal variance	0.652383853
Christmas Tree Worm	4.73605E-12	unequal variance	0.084684946
Flatworm	N/A	N/A	N/A
Banded Coral Shrimp	N/A	N/A	N/A
Mantis Shrimp	N/A	N/A	N/A
Anemone Shrimp	N/A	N/A	N/A
Lobster	N/A	N/A	N/A
True Crab	0.229671052	unequal variance	0.591276471
Murex	N/A	N/A	N/A
Conch	N/A	N/A	N/A
Cowrie	0.029862761	unequal variance	0.347771527
Triton	N/A	N/A	N/A
Cone Shell	N/A	N/A	N/A
Drupella	0.841973795	unequal variance	0.027355762
Top Shell	0.000611166	unequal variance	0.166872931
Nudibranch	0.004849141	unequal variance	0.293585892
Other Gastropods	0.036618371	unequal variance	0.082022559

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Giant Clam 0-10 cm	N/A	N/A	N/A
Giant Clam 10-20 cm	N/A	N/A	N/A
Giant Clam 20-30 cm	N/A	N/A	N/A
Giant Clam 30-40 cm	N/A	N/A	N/A
Giant Clam 40-50 cm	N/A	N/A	N/A
Giant Clam 40-50 cm	N/A	N/A	N/A
Giant Clam >50 cm	N/A	N/A	N/A
Giant Clam total	N/A	N/A	N/A
Octopus	N/A	N/A	N/A
Cuttlefish	N/A	N/A	N/A
Squid	N/A	N/A	N/A
Crown of Thorns	N/A	N/A	N/A
Chocolate Drop Starfish	N/A	N/A	N/A
Cushion Star	N/A	N/A	N/A
Brittle Star	N/A	N/A	N/A
Feather Star	N/A	N/A	N/A
Basket Star	N/A	N/A	N/A
Flower Urchin	N/A	N/A	N/A
Diadema Sea Urchin	0.022175906	unequal variance	0.126920893
Pencil Urchin	N/A	N/A	N/A
Collector Urchin	N/A	N/A	N/A
Prickly Redfish	N/A	N/A	N/A
Greenfish	N/A	N/A	N/A
Pinkfish	N/A	N/A	N/A
Synaptic Sea Cucumber	8.90269E-05	unequal variance	0.129424764
Sea Pen	N/A	N/A	N/A

Substrate	F-Test	Variance	T-Test
HC	0.312387721	unequal variance	0.005572237
SC	8.69694E-08	unequal variance	0.067384447
RKC	N/A	N/A	N/A
NIA	0.329759928	unequal variance	0.468082218
SP	0.950233462	unequal variance	0.035755627
RC	0.33868877	unequal variance	0.021187512
RB	0.148320562	unequal variance	0.085832007
SD	0.611812962	unequal variance	0.532398292
SI	0.210697635	unequal variance	0.133608001
OT	N/A	N/A	N/A