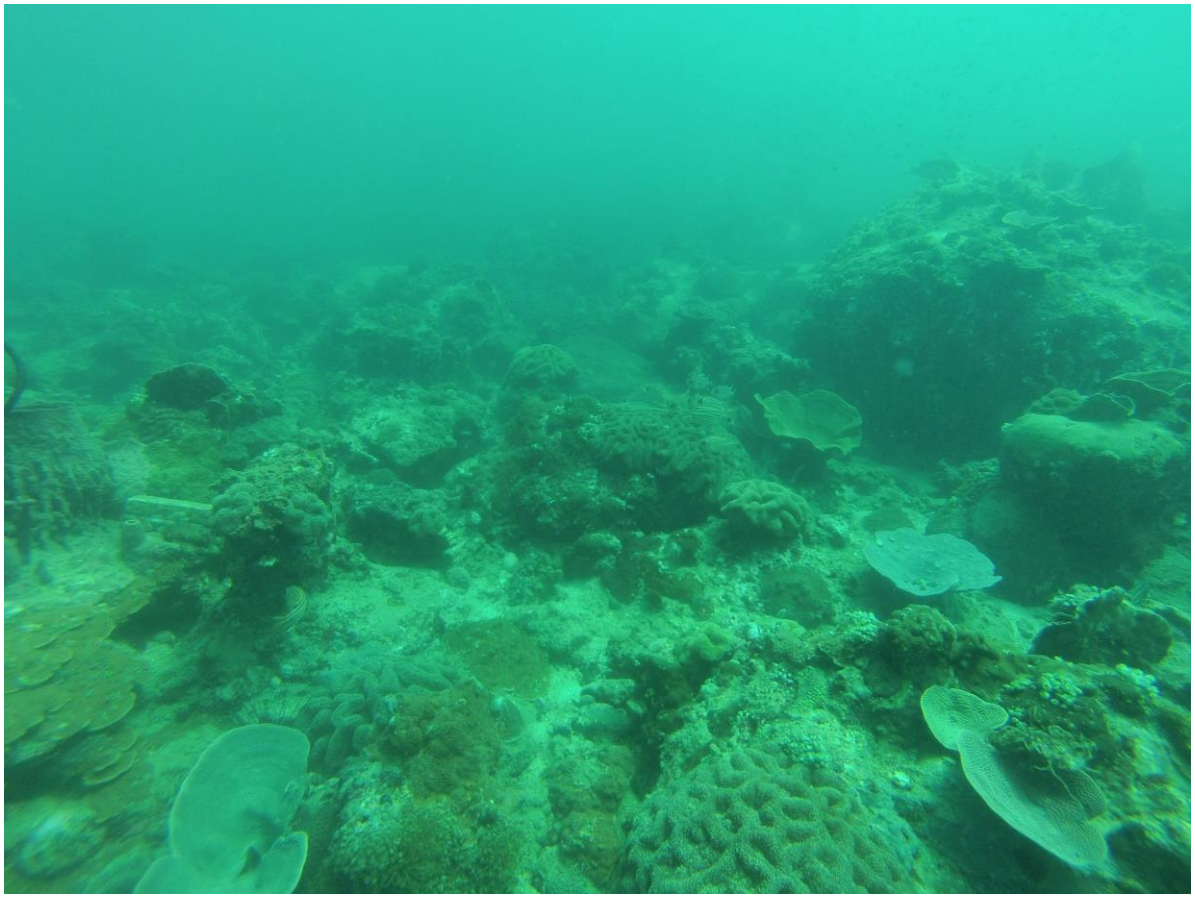
Koh Rong Samloem Marine Environmental Assessment,

Preah Sihanouk Province, Cambodia



Marine Conservation Cambodia
August 2013

1- Anemone, Koh Rong Samloem 2013

In Partnership With:

Report By:

Paul Ferber – Managing Director and Project Founder, MCC
Daniel Grainger – BSc(Ecology), Marine Research Team, MCC
Alexandra Barlow – BEnvSc(Hons), Conservation Manager
Emma Robertson – BEnvSc(MarineSc), Conservation Co-ordinator

ABSTRACT

In 2011, upon request Marine Conservation Cambodia (MCC) undertook 43 marine surveys that served as the base line for a continual monitoring program to assess the health of the coral reef ecosystem surrounding Koh Rong Samloem, Preah Sihanouk Province. This study, in 2013, revisited the same 43 survey sites in order to obtain data that would allow a comparative analysis to take place. This comparative study allowed MCC to gain information on how the ecosystem is recovering with the removal of unsustainable fishing practices, and thus, the continued effectiveness of the No Take Zone (NTZ) and Community Fishing Area (CFA) put in place in 2 years before the initial baseline surveys. The Research Team surveyed the chosen areas from June to August 2013 using the Reef Check methodology. Results of this study indicate that live reef cover (total area covered by hard coral, soft coral, nutrient indicator algae and sponge) has improved substantially, with 29 survey sites experiencing a significant increase. Overall, fish (P=0.043, p=0.05) and invertebrate counts were also found to have significantly increased. However, the signs of anthropogenic impact (general trash, fishing trash, anchor damage, dynamite damage) have all increased. Although levels of coral bleaching have remained at a relatively low level, yet should be closely monitored. It is evident from this study that the coral reef ecosystem of Koh Rong Samloem is slowly recovering. However, for this positive trend to continue it is crucial that active protection, stricter enforcement, and monitoring of the reefs continue.

Marine Conservation Cambodia
Koh Rong Samloem Village, Koh Rong Samloem
Mittapheap District, Sihanoukville
CAMBODIA
info@marineconservationcambodia.org

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 and Marine Research programs around Koh Rong and Koh Rong Samloem are now well underway: we are currently undertaking marine surveys around Koh Rong Samloem to monitor the Seahorse populations and the coral reefs to assist the FiA in the creation of Fisheries Management areas, Cambodia's equivalent to Marine Protected Areas (MPAs).

Close collaboration with the FiA, Coastal Provinces' representatives and International Institutions such as the FAO Regional Fisheries Livelihoods Programme (RFLP) proved that MCC is now respected and credited as a leader in conservation and community work in Cambodia. MCC is now expanding their conservation efforts further down the Southern coast of Cambodia to include the islands off the coast of Kep.

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
Paul Ferber	Managing Director and Project Founder, MCC
Alexandra Barlow	BEnvSc(Hons), Conservation Manager
Emma Robertson	BEnvSc(MarineSc), Conservation Co-ordinator
Daniel Grainger	BSc(Ecology), Marine Research Team, MCC

Research Team

Alexandra Barlow
Amelia Bartlem
Emma Cookson
Molly Dalidae
Erika Delemarre
Kerwin Fleurial
Kori Hague
Sophie Lyon-Smith
Ruud Nederpelt
Alex O'Grady
Gal Peleg
Emma Robertson
Eli Romm
Mark Saunders
Maren Toor
Eveline Vekemans

Boat Crew

Mr. Rowe
Mr. Bo
Mr. Han

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Cover – Substrate cover at a survey site around Koh Rong Samloem

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Pictures were taken by Emma Robertson at survey sites during this study.

List of Abbreviations and Acronyms

CFA	Community Fishing Area
FiA	Fisheries Administration
MCC	Marine Conservation Cambodia
MPA	Marine Protected Area
NTZ	No Take Zone
RFLP	Regional Fisheries Livelihoods Programme
RGC	Royal Government of Cambodia
USD	United States Dollar

INTRODUCTION

Coral reefs are highly productive and biologically diverse ecosystems, composed of a large variety of plant, invertebrate, and vertebrate species (Humann and DeLoach 2002). As such, these environments are rich in resources which provide many individuals with their primary sources of income and employment (Conservation International 2008; McManus 1997). However, the life-history of many of these genera makes the marine ecosystems they comprise highly susceptible to overexploitation (Jennings et al. 1999; Denney et al. 2002). Unsustainable harvesting, or overexploitation, is the international most significant threat to marine habitats (Jackson et al. 2001). As coral reefs are the most diverse marine ecosystem and provide humans with significant social activity and economic revenue; they are among the most at risk of the coastal ecosystems (Mascia, 2003; Conservation International 2008). In particular, developing nations are often at a higher risk of depleting their natural marine resources due to; a lack of implemented policies to protect these environments, a lack of funding or support of conservation efforts, destructive fishing methods and agricultural run-off (Kim et al. 2004).

The way in which marine ecosystems are exploited threatens both the biodiversity of the habitats and livelihoods of coastal communities. Increasing demand on coastal habitats due to growing global populations and shifts in socio-economic dynamics makes it vital to introduce measures to sustainably use these ecosystems. Therefore, in order to ensure the existence of marine habitats and fortify anthropogenic income, it is crucial to raise awareness of the need to introduce methods that evaluate and assess their condition (Conservation International, 2008).

Cambodia is a rapidly developing nation in the Gulf of Thailand, with 435 kilometers of coastline circumventing 69 islands. Much of this coastline consists of coral reef, seagrass beds and mangrove habitats (Touch 1995). The local coastal communities rely on the marine sector for food, raw materials, climate regulation, mitigation of extreme natural events, waste treatment and marine tourism such as diving and snorkeling (Bryant et al. 1998). However, characteristic of developing nations, these coastal ecosystems are at risk of being unsustainably exploited.

Coral reefs and other marine habitats in the region are at risk from Cambodian, Vietnamese and Thai boats using unsustainable fishing methods which deplete marine species populations below sustainable population recruitment levels and destroy and fragment habitat (Kim et al. 2004). Unsustainable fishing techniques include dynamite and cyanide fishing, inshore benthic trawling, air supplied fishing and shell collection, and ghost netting (MCC 2011). It is important to note that traditional, sustainable fishing methods, such as collapsible crab trapping, line fishing off a paddle boat and traditional line fishing are techniques employed by local fishers also take place. However, these occur at a level which allows populations to recruit sequential generations and persist in the area. A collective effort by local and foreign parties, spearheaded by Marine Conservation Cambodia (MCC), has been working to conserve the marine ecosystems surrounding the southwest coast of Cambodia.

In February, March and April of 2011, MCC began a series of surveys over forty-nine sites aimed at assessing the health of the coral reef systems surrounding Koh Rong Samleom. By assessing the same sites in later years, a temporal pattern of habitat change can be identified. Temporal studies of this nature are integral to the understanding of ecosystem functioning and response to anthropogenic activity (Vincent 1996). Firstly, they assess the condition of the area, and then examine the effectiveness of any protective measures and changes within the surveyed habitat composition by comparing the different datasets collected over time (GCRMN, 2004).

The current study revisited the same forty-nine sites as in 2011 and carried out the same assessment. This paper takes the baseline data collected in 2011 and compares the site condition (species and substrate composition) to 2013. The 2011 study aimed to:

- Determine the general distribution and condition of coral reefs around Koh Koun and Koh Rong Samleom, and to conduct baseline quantitative surveys on the abundance and distribution of reef health indicators such as fish and invertebrate
- To identify sites for future monitoring programs
- To identify areas with high biodiversity and healthy coral reefs for the purpose of sustainable fisheries management, marine conservation and the creation of a Marine Fisheries Management Area (MFMA) and associated Zonal Management Plan aiming at developing the area as a sustainable eco-tourism destination.

As of 2008, a three hundred meter No Take Zone (NTZ) has been installed around the islands, encompassing the area in a Community Fishing Area (CFA). It is stipulated that no unsustainable fishing activity can occur within the area. Moreover, anti-trawling blocks were dropped in target areas to prevent trawling. These areas are enforced with patrols initially carried out by MCC (in 2009-2011), and now controlled by the Fishieries Association of Cambodia (FiA) as of 2012.

The 2011 survey concluded that the hard coral in the CFA was generally in good health, theoretically providing habitat to support a healthy coral reef ecosystem (MCC 2011; Kim et al. 2004). Furthermore, the relatively high presence of rock at many of the sites provides solid foundation for coral recruitment. This is due to the fact that rock acts as settling surface for coral larvae, and subsequently is the anchor for hard and soft coral and sponge growth, providing the habitat for fish and invertebrate species to inhabit (Kim et al. 2004). Despite this, low fish and invertebrate numbers and diversity in 2011 indicated severe overfishing, and anchor damage at a number of the healthier sites indicated tour dive boats severely damaging and fragmenting the habitats (MCC 2011). There were signs of minor sedimentation, coral disease and coral bleaching. As such, as an entire ecosystem, the coral reefs within the Koh Kon and Koh Rong Samleom CFA were in relatively poor condition in 2011.

The combined effects of reduced anthropogenic activity (due to the NTZ), and the foundation of relatively healthy coral and rock to support population growth predicts an increase in live coral cover over the forty-nine sites between 2011 and 2013. Moreover, an increase in fish and invertebrate species diversity and population numbers is predicted due to reduced fishing pressure and a habitat of improving quality.

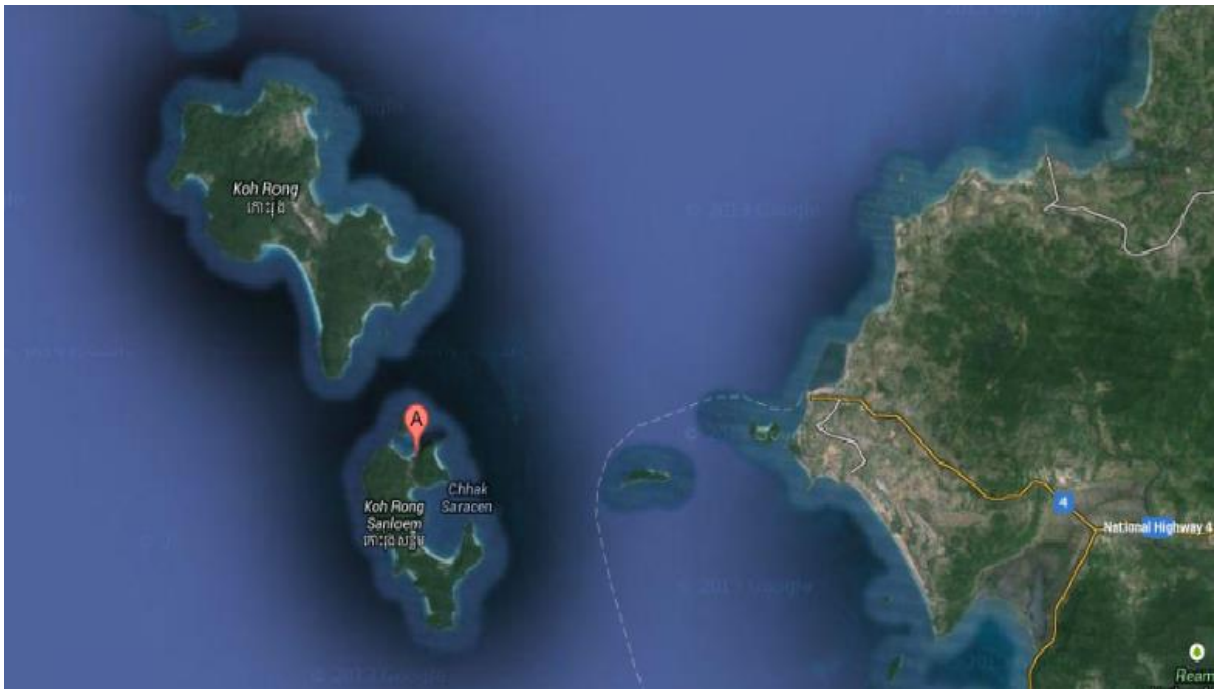


Figure 1 – Location of Koh Rong Samloem on the Southern coast of Cambodia (Google Earth 2013).

METHODOLOGY

Standard Reef Check monitoring was applied for the survey sites surrounding Koh Rong Samloem in order to assess the abundance, diversity and composition of selected fish, invertebrate and plant species. This methodology was used because it provides rapid assessment of coral reef condition and health. Furthermore, since the methodology is based on pre-defined criteria and descriptors, reliability is better assured.

a. Location of survey sites and reasons for their selection

Location of survey sites around Koh Rong Samloem and Koh Koun

Figure 2 - Location of survey sites surrounding Koh Rong Samloem and Koh Koun (Google Earth 2013).

In 2011, 49 sites were chosen using a random GPS generation method of the plots surrounding Koh Rong Samleom and Koh Koun islands. For this study, these sites were revisited and a Reef Check survey was conducted at each. However, the Koh Koun sites were emitted from the study due to missing data from 2011 and no surveys were conducted at sites

28, 29 and 30 due to dangerous weather conditions. As such, these sites have been omitted from the current study as they cannot be used for temporal comparison.
Each survey was laid parallel to the coastline (for each transect direction) and was 100m in length with four 20-meter (m) segments. The segments were separated by a gap of 5 m. In these 5 m gaps, no data was recorded to help ensure independence for each 20 m section, which is necessary for reliable statistical analysis.

b. Type of data collected at each survey site / transect

An overall description of each site was recorded. This included: Basic information, natural and anthropogenic impact, historical facts, and degree of protection enforcement. Based on their effectiveness as indicators of overall reef health, certain target species have been chosen by Reef Check. A history of overfishing, aquarium collection, nutrient pollution and sedimentation can all be indicated by these species. More specifically, the Reef Check methodology designates three different transects: fish belts transect, an invertebrate belt transect, and a substrate line transect (Figure 3 and 4).

In order to complete the fish belt transect, divers recorded fish in an area 2.5m on each side of the transect and 5m above. Since fish get easily disturbed by divers the fish belt transect was completed first. In order to record an accurate assessment of the fish population, this portion of the survey was conducted by swimming slowly along the transect, counting the indicator families and species.

The same four 5m wide and 20m long segments were used for the invertebrate belt transect. The divers executed this portion of the survey by swimming slowly in an S-shape pattern on each side of the transect counting the indicator invertebrates. To reassure accurate results, surveyors looked into holes, burrows and cavities.

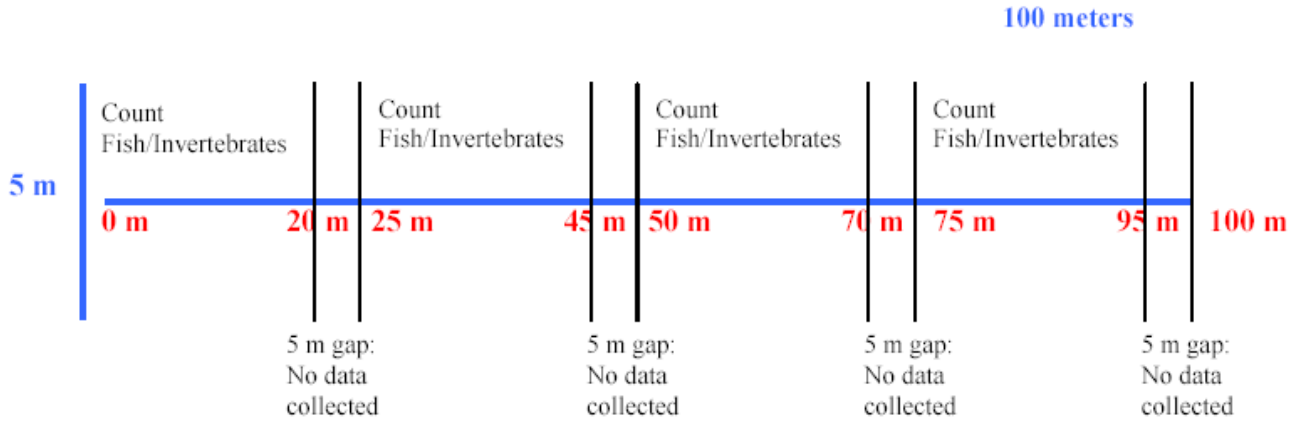


Figure 3 - Fish and invertebrate belt transect count method (in Hodgson et al, 2006)

This transect was used again to conduct the substrate line transect. In a 0.5m interval along the tape, points were sampled to determine the substrate of the reef. The benthic categories used in this assessment included: hard coral, soft coral, recently killed coral, nutrient indicator algae, sponge, rock, rubble, sand, silt/clay and other. Moreover, coral bleaching, anchor damage, dynamite damage, general damage and trash were also estimated along the transect line by the surveyors.

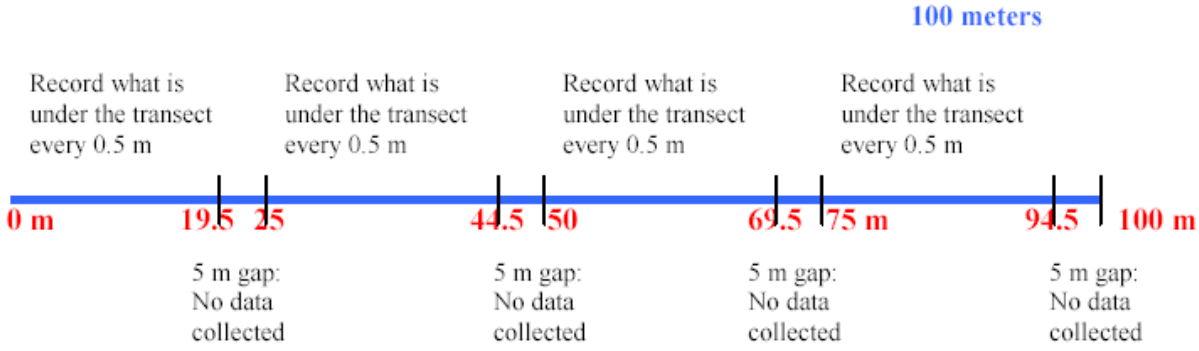


Figure 4 - Point intercept transect count method to determine benthic cover (in Hodgson et al, 2006).

c. Data entry and analysis

Data was recorded and stored in Microsoft Excel template acquired from the Reef Check website (www.reefcheck.org). As with the 2011 study, mean substrate cover was calculated as

a percent for each site. Hard coral, soft coral, nutrient indicator algae and sponge were assessed as 'live reef cover', and temporal comparisons between 2011 and 2013 were made. Fish and invertebrate species were analyzed as average population counts for the entire CFA and at each individual site.

Human impacts were both individually and cumulatively analyzed, to give a thorough picture of the continued anthropogenic activity within the CFA.

Data sets were tested for significant difference between the years using student paired-t tests conducted in Microsoft Excel.

II. RESULTS

The results from these surveys are shown in a graphical format, and they aim to provide a picture of changes in the coral reef health status of Koh Rong Samloem between 2011 and 2013.

a. Substrate Composition

Entire substrate cover for all sites is shown in Figure 5. At twenty nine of the survey sites, live reef cover (the total area covered by hard coral, soft coral, nutrient indicator algae and sponge) increased; six sites experienced a decrease (Figures 6 and 7). Of those that increased, site 28 experienced the largest live reef growth with a 52% increase. Nine other sites increased at least 30% live reef growth. Site 34 showed the largest reduction in live reef cover by 32%. This change in live reef cover between 2011 and 2013 is statistically significant (P=0.001, p=0.05).

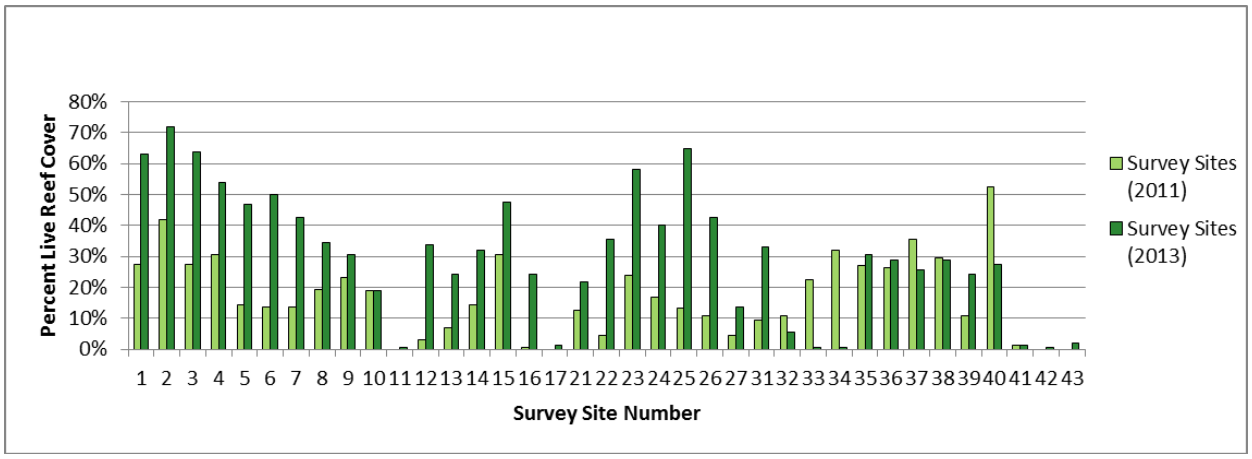


Figure 5 Percent live substrate coverage of sites for 2011 versus 2013. There was no live reef recorded at sites 18, 19 and 20 and as such these have been omitted.

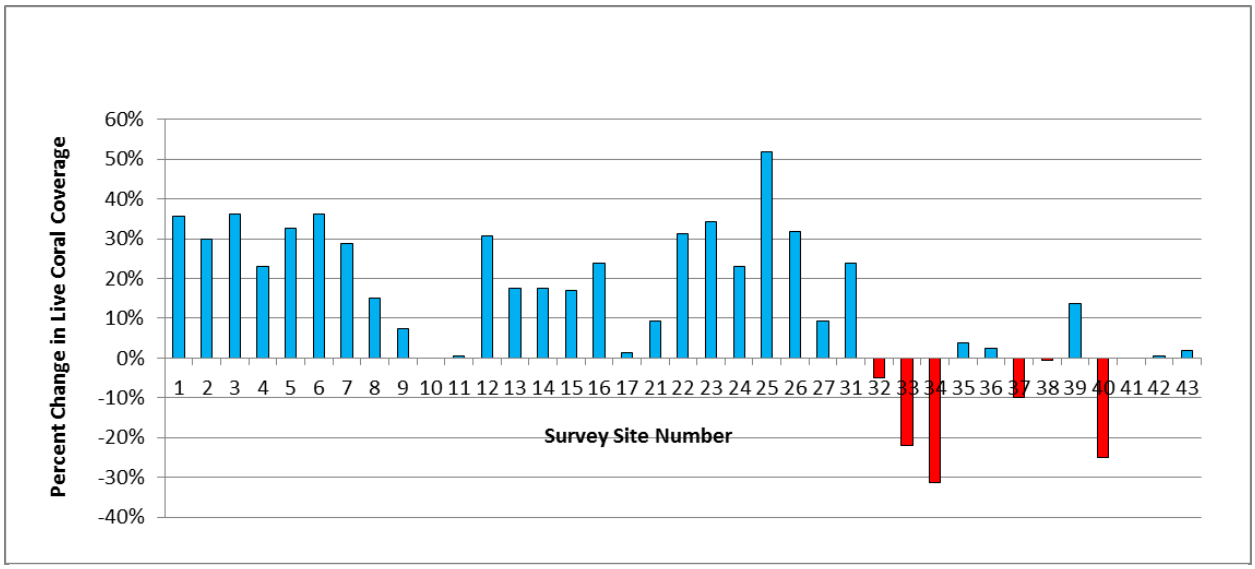


Figure 6 Percent change in live substrate coverage from 2011 to 2013. There was no live reef recorded at sites 18, 19 and 20 and as such these have been omitted.

Average substrate cover over the entire survey area did not change significantly between the two years (Fig. 1.4, P=0.49, p=0.05). However, all living reef categories increased. Non-living substrate cover generally decreased; rock cover reduced from 26% to 24%, rubble cover reduced from 11% to 2% and sand cover reduced from 43% to 37%.

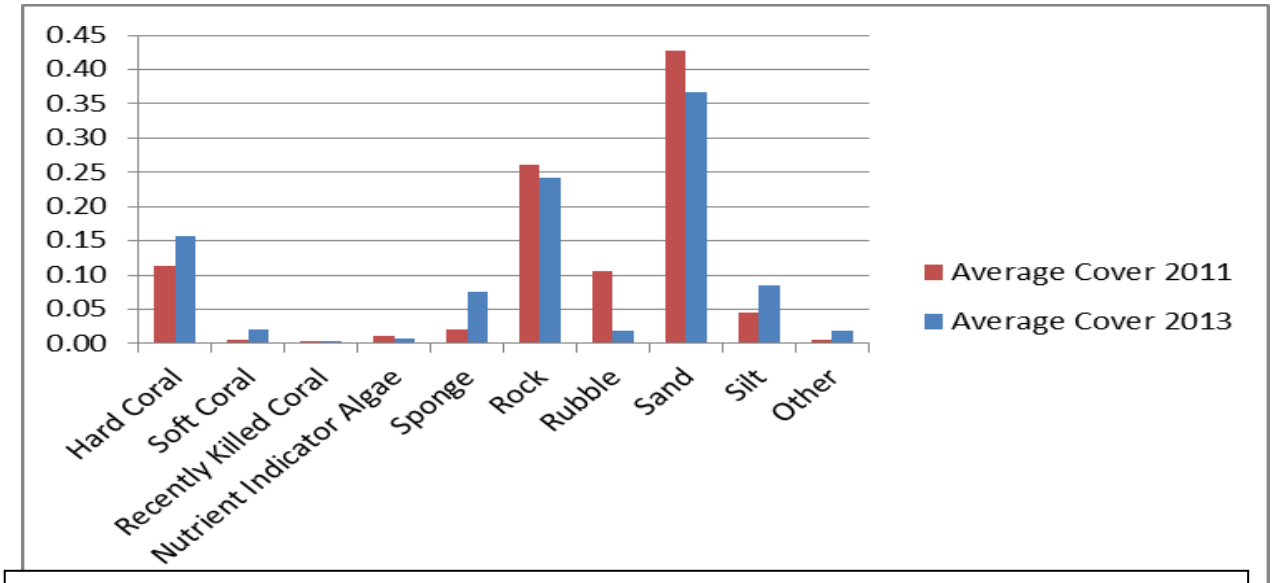


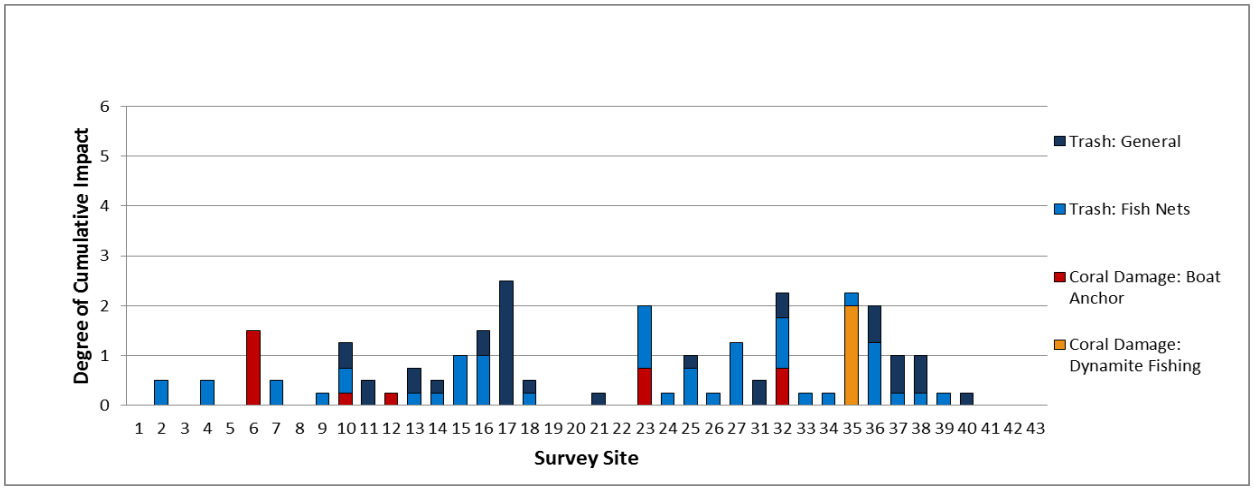
Figure 7 Comparison of average substrate cover over all survey sites in 2011 and 2013

b. Anthropogenic impact on coral reefs

In 2011, trash was the most significant human impact observed over the survey area, being found at twenty eight of the sites, however never affecting any single site more than 2.5 (site 17, Figure 8). Those sites being affected most were 17, 32 and 36, having ratings of 2.5, 1.8 and 2 respectively. In 2013, trash remained the most common human impact on the reefs. It was found at thirty of the sites, in far higher amounts than in 2011. Sites 9, 14, 15, 24 and 27 were the most severely polluted having ratings of 5.5, 5.8, 5.8, 5 and 5 respectively. With the exception of sites 18, 21, 33 and 34, all sites experienced an increase in both general trash and fishing trash.

In 2011, site 35 was the only site damaged by dynamite fishing; in 2013, sites 14, 15 and 24 were damaged, although only minimally (0.2, 0.2 and 1.7 respectively).

Five sites were damaged by boat anchors in 2011 (6, 10, 12, 23 and 32). In 2013, this number has increased to fifteen, with sites 10 and 32 being the only sites to be damaged in both years. Sites 1, 12 and 13 were most affected by anchoring, with 2.5, 2.3 and 2.5 respectively.



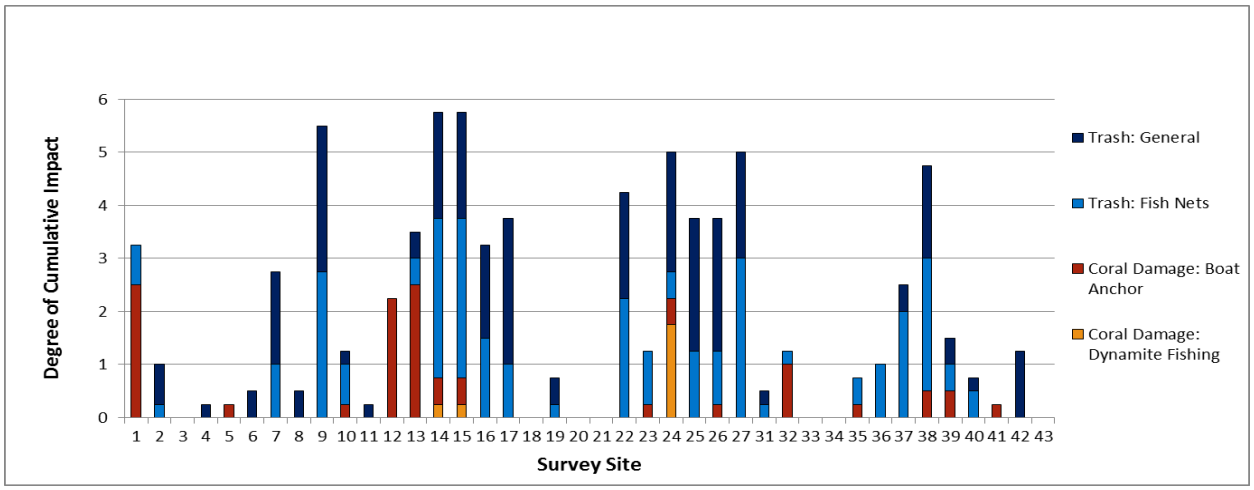


Figure 8 Comparison of human impacts (general trash, fishing net trash, boat anchor damage to coral and dynamite fishing damage to coral) at surveyed sites between 2011 (top) and 2013 (bottom)

Ten of the sites surveyed showed a decrease in human impacts from 2011 to 2013 (Figure 9). Twenty three sites showed an increase in the cumulative human impact. Of these, six sites were completely unaffected in 2011 however were polluted (to one extent or another) in 2013. Sites 9, 14 and 15 experienced the greatest increase in pollution, increasing by at least 400%. Pollution levels were significantly higher in 2013 than in 2011 (P=0.001, p=0.05).

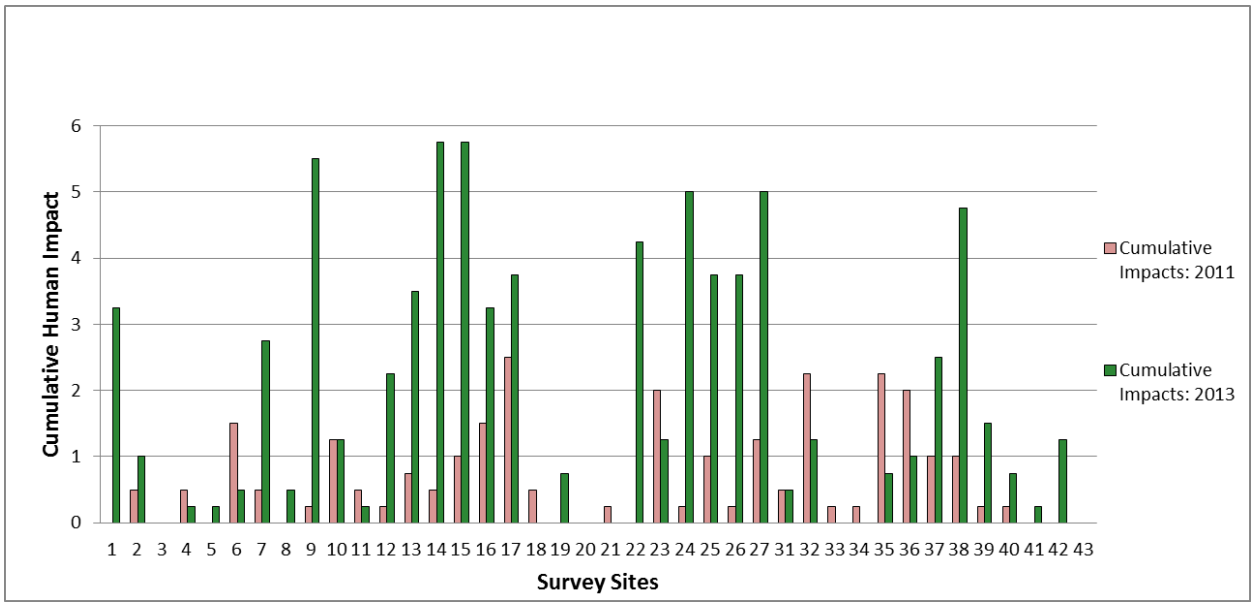


Figure 9. Total observed human impact at sites in 2011 versus 2013.

c. Bleaching impact on coral reefs

Across both years, coral bleaching was present at twelve of the forty survey sites (Figure 10). Eight sites were newly bleached in 2013, although to minimal levels (sites 2, 5, 14, 15, 16 and 25). Six sites decreased in percent bleached, site 23 experienced the largest reduction from 17% to 2%. Sites 3, 7 and 10 were the most severely bleached in 2013, at 22%, 17% and 18% respectively.

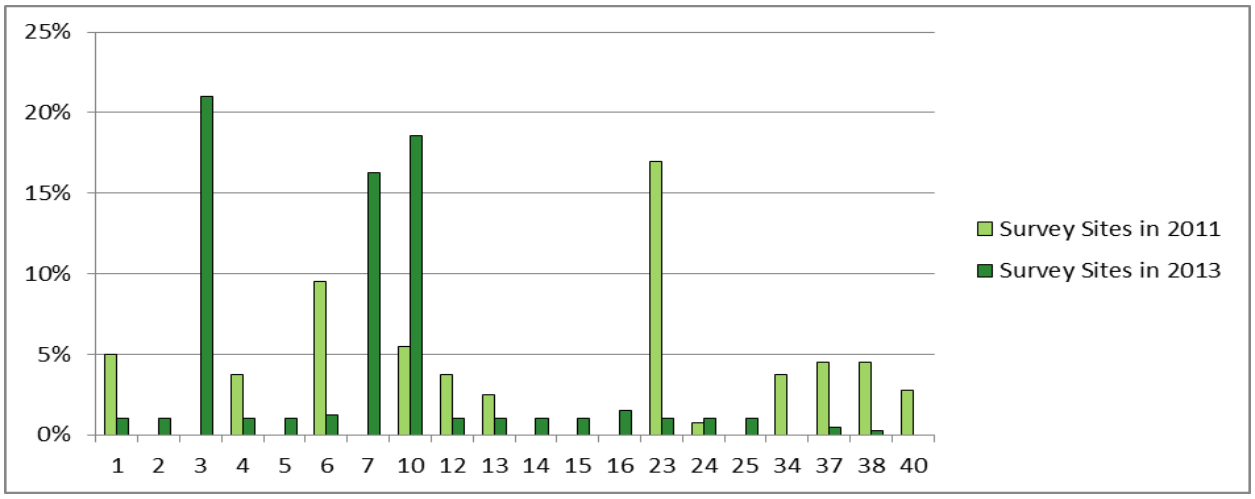


Figure 20 Percent of coral bleached in 2011 compared to 2013. Survey sites with zero bleaching for both years have been omitted.

d. Fish Survey

From 2011 to 2013 there has been a significant increase in the overall number of fish recorded at the survey sites (P=0.043, p=0.05). This increase was recorded at twenty five of the forty sites surveyed (Figure 11), with sites 15, 22, 24, 25 and 32 showing the greatest growth in fish populations. Eight sites were found to have less fish in 2013 than in 2011, of which site 4 experienced the most drastic reduction (200 to 30). Five sites had no fish in either year.

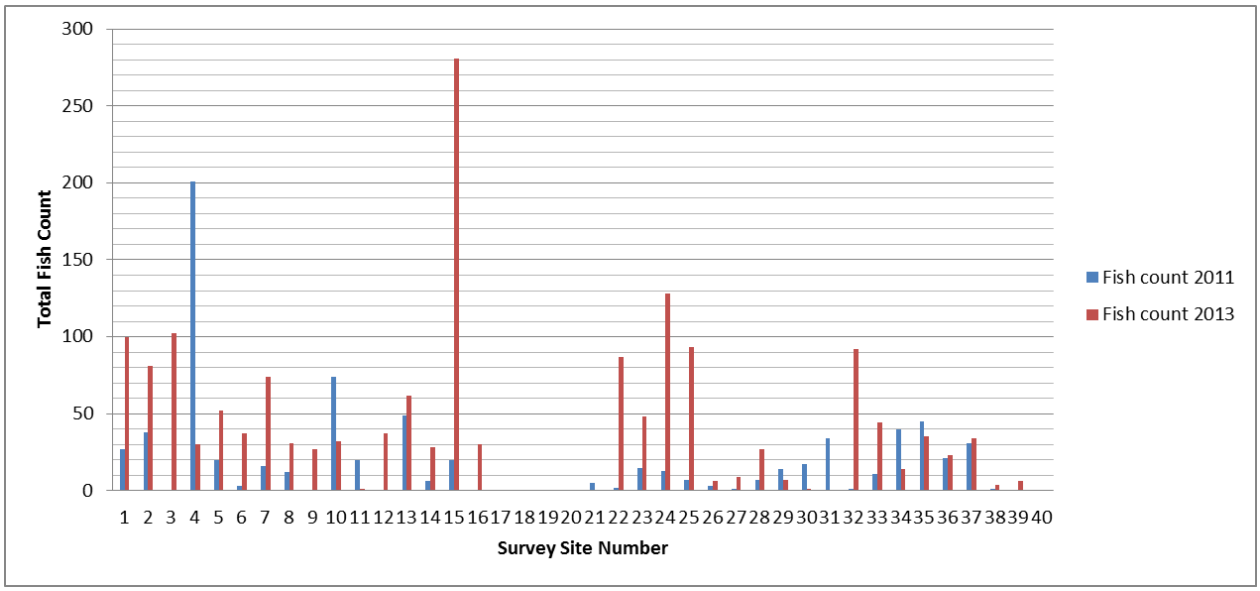


Figure 11. Total number of fish counted at survey sites in 2011 and 2013.

e. Invertebrate Survey

Eighteen of the survey sites had lower invertebrate counts in 2013 than in 2011 (Figure 12). Twelve sites saw an increase in invertebrates. Despite this, there was an overall increase in the invertebrate count between the two years.

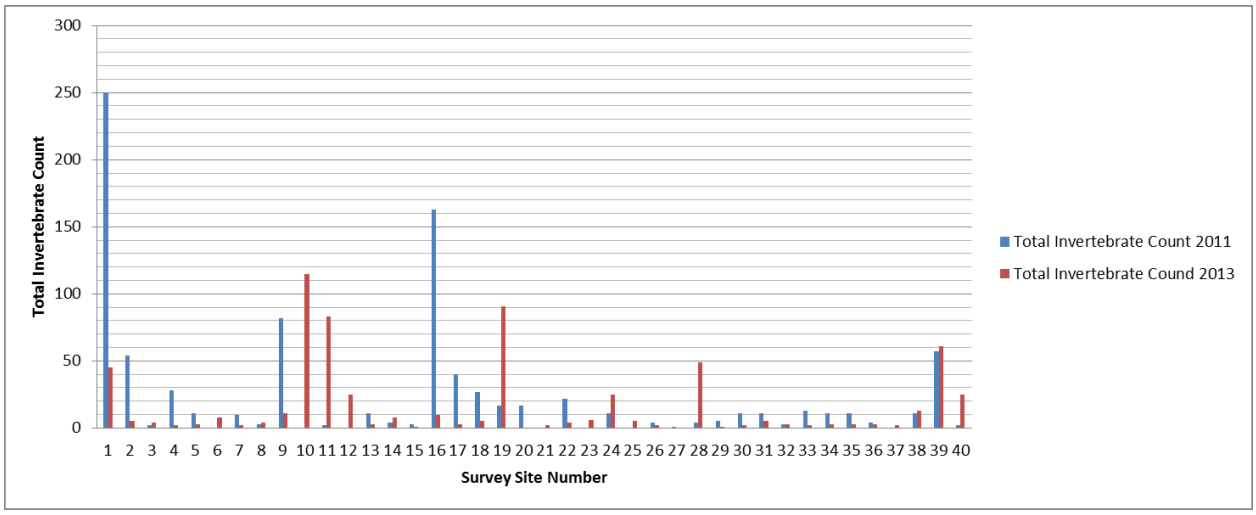


Figure 12. Total number of invertebrates counted at survey sites in 2011 and 2013.

f. Relationship Between Substrate Composition and Fish Count

There was a significant, weakly positive correlation between percent change in live reef cover and difference in fish counts between the two years ($P=0.028$, $p=0.05$, $R^2=0.0977$, Figure 13). There was no significant relationship between invertebrate populations and substrate cover ($P=0.13$, $p=0.05$), and invertebrate and fish counts were also independent of one another ($P=0.25$, $p=0.05$).

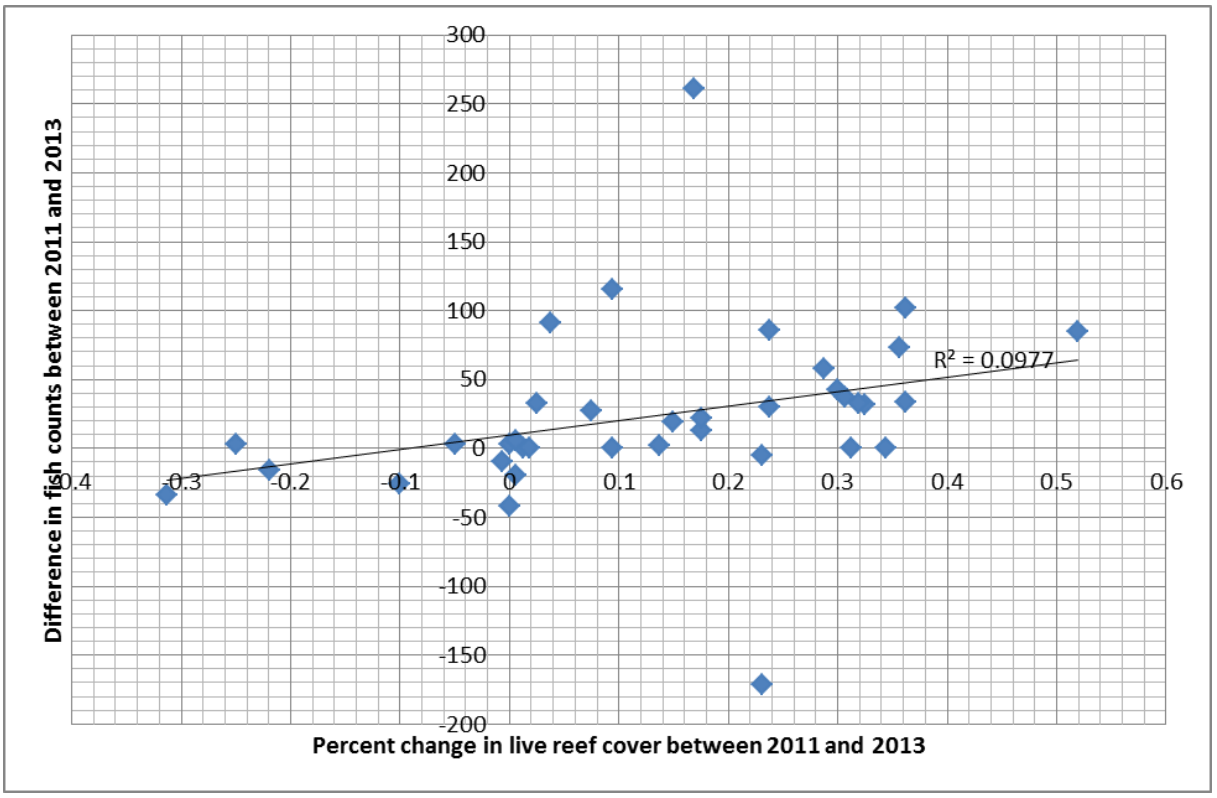


Figure 13. Percent change in live reef cover (hard coral, soft coral, nutrient indicator algae and sponge) compared to the difference in fish count, for each survey site, between 2011 and 2013.

III. DISCUSSION

The many functions of coral reefs make them integral to coastal ecosystem functioning (Wilkinson 2004). As they house a diverse range of species and are often highly aesthetically pleasing, they are often susceptible to unsustainable anthropogenic use (Mascia 2003). In developing nations, unsustainable fishing methods and misuse by tourist companies pose significant threats to the health of coral reefs (Joseph and Valencia 1983). In this study, we aimed to assess the effect that a No Take Zone (NTZ) is having on the health and quality of the reefs and coastal marine habitat surrounding Koh Koun and Koh Rong Samleom. This is part of a series of surveys to be conducted every two years, monitoring species counts and diversity over forty sites surrounding the islands. The current study compares the first two survey sets; the first conducted in January, Feburary and March of 2011, the second in June, July and August 2013.

The first, thus baseline, set of surveys conducted in 2011 showed a marine habitat in relatively poor condition, with low species diversity and population counts (MCC 2011). This initial survey set was conducted two years after the implementation of the NTZ, and as such preliminarily showed that the marine habitat and populations were slow to respond to the release of human disturbance. However, slow species and population recruitment is expected in marine habitats, as these ecosystems have intricate species composition and slow initial recruitment rates (Jackson et al. 2001). The relatively high presence of hard coral and rock in 2011 indicated potential for coral reef expansion within the survey area (Kim et al 2004). As such, the continued relief from destructive anthropogenic activity at the survey sites would have the greatest effect on species recruitment in the area. It must be remembered, that although unsustainable fishing techniques are banned in accordance with the NTZ, the area is still sustainably harvested by fishermen and tour/dive boats still operate on the sites and evidence of occasional illegal activity is still observed.

The second series of surveys collected in 2013 has given valuable comparison data, which provides insight into how the survey area is initially responding to restricted human activity. Highly simplified, coral reef composition largely revolves around rock and sand acting as anchors for live substrate and invertebrate species, which in turn provides the habitat for other invertebrate and vertebrate life (McClanahan and Graham 2005). The reef ecosystems

discussed in the current study are currently rejuvenating; five years after the implementation of the NTZ, there are signs pointing to its effectiveness. The significant increase in live reef cover over twenty nine of the sites from 2011 to 2013 clearly shows that hard coral, soft coral, sponge and 'other' substrate cover has begun to respond to the absence of destructive fishing techniques. Also, this increase in live reef cover explains the reduction in rock substrate in the study area, as rock acts as a settling ground for coral larvae, which hatches and grows on the underlying rock (Harvell et al. 2007). The significant increase in average fish abundance, and an increase in the overall invertebrate count, suggests that fish and invertebrate species are beginning to respond to both the improved habitat and the release from unsustainable human activity. As various species have different life history strategies, they will recruit in an area in different patterns (organisms may reach sexual maturity at different ages, have different feeding strategies, produce offspring at different rates and have different home ranges, to name but a few aspects of organismal life-history) (Sale 2008).

The significant correlation shown in the current study between difference in fish count and change in live reef cover between 2011 and 2013 hints at this fluctuation in community structure. All sites (except one) that saw a decrease in fish counts saw a decrease in live reef cover; likewise, an increase in live reef cover correlated with an increase in fish counts. The causal factor in this relationship would be the fluctuation in live reef cover, supporting the various amounts of fish population recruitment. As such, it is firstly imperative to protect or establish habitat in order to conserve an ecosystem. With continued restriction of human activity within the survey area, we can hope to continue to observe these increases in reef health and quality.

As the survey area continues to be sustainably harvested, the recruitment of fish species is an encouraging trend, not only for the reef ecosystem persistence, but also for the local community which largely depends on subsistence fishing for their livelihood. If the local reef systems within the CFA are able to begin to regenerate in the face of sustainable fishing methods, it can be suggested that these systems will continue to be able to be harvested, providing it is done so in a sustainable manner. However, there are clear signs that undesirable human activities are still occurring within the NTZ.

The current effectiveness of the NTZ cannot be disputed in the face of the significant increases in marine life in the general survey area. However, when looking at the human

impacts at the survey sites, there appears to be a pattern whereby clusters of sites are disproportionately affected relative to others. The presence of boat anchor damage at fifteen of the sites in 2013 (as opposed to five in 2011) clearly shows an increase in human activity at these sites. As the NTZ has no influence on tour and dive boat operations, it is possible that growing amounts of dive and snorkel tourism is accountable for this increase in anchor damage; the three sites which experience the most substantial anchoring damage are particularly popular dive sites.

The other twelve sites that had anchor damage are not used by dive operators. They are scattered around the southwest and southerly coast of KRS, which despite being within the NTZ, is less frequently patrolled relative to the northern part of the island. This provides an opportunity for illegal fishing boats to exploit the reefs. In 2011, only one site showed signs of dynamite damage, site 35. Site 35 was amongst those which showed the least increase in live reef cover between the two survey sets (only 2%), and showed a decrease in fish between the two years. Comparatively, three sites in 2013 had dynamite damage, (albeit minimal damage) yet all showed medium levels of live coral recruitment. Moreover, despite being dynamite damaged, sites 15 and 24 were amongst those which increased most in total fish count. This could be explained by these sites being in relatively good condition in 2011, providing a precursor environment for the ecosystem to recruit faster than other areas. It is, however, more likely that during our surveys, anchor damage was mistaken for dynamite damage; dynamite fishing notoriously annihilates coral and fishes in an area, and as such it is not expected to see an improvement in reef health despite new dynamite damage at various sites. Consequent surveys (the next of which is to be conducted in 2015) will clarify these discrepancies, as we would expect to see a reduction in reef health in the presence of dynamite damage.

The fact that pollution levels were significantly higher in 2013 indicates an increase in anthropogenic activity in the entire region. Twenty six of the survey sites showed an increase in fishing trash, such as lines and nets. This would suggest an increase in fishing activity in the area since the 2011 surveys. It is possible that as larger fishing vessels are now restricted from using unsustainable fishing methods, traditional line fishing occurs more frequently within the NTZ. The increased presence of general trash at the surveys sites could be attributed to an increase in smaller vessels visiting the area, but also by a growing number of

people living in and visiting the region. Trash is easily transported large distances by currents and winds, and it is likely that much of the trash found at the survey sites did not originate there.

When comparing figures 9 (cumulative human impacts at all sites), 10 (substrate cover in 2013) and 11 (total fish count between the years), there is a visible trend between the relative health of the site and human impact. It is expected that fishermen would exploit the areas with highest fish counts, as would dive tours want to dive at the most entertaining sites. The improvement in reef health between 2011 and 2013 clearly signify that the reduction in unsustainable fishing is having positive effects on the reefs surrounding Koh Rong Samleom, however continued monitoring and possible quota restrictions on dive operations could further aid the growth of the reefs in the area. For the reef to continue to improve, measures need to be taken to reduce the amount of pollution in the area. Pollution restricts live cover growth, and poses severe threats to fish and other species. One method to reduce this impact is to actively clean sites; however this only momentarily solves the problem. A far more practical and effective approach is to raise awareness within the coastal human communities regarding effective and sustainable rubbish disposal.

As the region improves in marine quality, there is potential for it to be targeted as a fishing destination. Continued patrolling to deter unsustainable fishing, and even introducing quotas on sustainable catch quantities, will encourage further improvements in the marine habitat quality. The next set of surveys, set for 2015, will potentially show further live reef cover increase, higher fish and invertebrate populations, and hopefully an increase in species diversity. We could expect to continue to see a correlation between substrate quality and fish populations, and perhaps see new relationships between invertebrate population balances relative to fish and substrate. Indeed, in healthy and fully functioning reef systems, community structure is regulated by relative predator-prey abundance cycles, or trophic cascades. Continued protection of the survey area and analysis of species abundance could indeed lead to studies of the relative strategies that regulate population abundance and recruitment rates.

As reef health improves, it would perhaps be prudent to widen the scope of the species documented, in order to give an increasingly accurate portrayal of how different species occur and persist in an area. The 2013 surveys did in fact take a wider species scope than the 2011.

This data has been omitted from the current study as there can be no comparison done with it; in the 2015 survey set and report, this data will be used. It must be remembered that discrepancies in data recording during these surveys is inevitable. The Reef Check methodology does standardize and provide an effective tool for reef assessment, however individual surveyor capability and conditions on any particular dive must be considered. The collection of these two data sets (2011 and 2013) recruited a number of different teams of five core individuals to carry out the surveys. These surveyors were all trained to a standard which ensures the highest possible identification and count accuracy, however variables such as water visibility, diver attention and individual discretion will vary between sites and individuals, and will undoubtedly have some influence on our results.

Temporal comparisons of this nature are imperative to the understanding of human environment relations (Pajaro et al. 1998). By employing internationally standardized, robust and efficient survey techniques such as the 'Reef Check methodology' used in this study, scientific non-governmental and grassroots organizations can monitor marine habitat overtime and aid the implementation of No Take Zones and Marine Protected Areas (Roberts and Hawkins 2000).

IV. RESOURCE USE CONFLICT

The relationship between recreational users (snorkelers, tourist fishers, etc.) and professional/livelihood fishermen, competing for use of the same space, could rapidly deteriorate if appropriate measures are not taken.

a. Fishing

The following fishing activity was observed in the surveyed area.

- Around the South side of the island, a number of Thai basket boats were observed anchored off the coast. A number of baskets were observed fishing close to the shore in shallow areas with fishing nets with small mesh size.

- Khmer trawlers were also seen at almost every survey site, however their numbers increased the further away the survey site was from the M'Pei Bei community.

- Some tradition Khmer fishing boats (longtails) were also observed fishing with gill nets with small mesh size.

- Around one of the survey sites (which is frequently visited by tour operators) a group of 3 men were observed spear fishing, which is strictly prohibited under the CFA.

Illegal and destructive fishing has been highlighted by these surveys and must be addressed for continued the rehabilitation of the coral reef ecosystem surrounding Koh Rong Samloem.

b. Motorized activities

Traditional fishing boats (longtails) were observed operating quite close to all 3 study sites. The presence of such boats within or close to these areas could lead to environmental (anchoring on the reef, pollution, noise) issues.

V. RECOMMENDATIONS

a. Zoning

A "zonation" is a spatial or temporal allocation of specific uses and activities to well-defined areas within a larger area. Nowadays, many Marine Protected Areas (MPAs) with zonation schemes are called "marine parks".

To prevent any resource use conflict and in order achieve Coral Reef Restoration and Conservation in an effective way, a Coral Reef Restoration Site should be included within a wider Marine/Beach Zoning Plan. This plan would emphasize on restricting and regulating fishing practices and motorized activities (professional and recreational) including limited and designated mooring, within the area.

b. Visiting the Reefs

i. Financing Conservation: Tourism-Based User Fees (TUFs)

The creation of MPAs has been the worldwide policy response to the increasing pressure of tourism development over marine resources, especially coral reefs. However, funding is the main issue to accomplish conservation objectives. With an increasing flow of tourists visiting Koh Rong Samloem and its surrounding islands every year, the set-up of a TUF program would significantly subsidize the environmental protection of the coast line. A simple small-scale TUF program (e.g.: 2 USD per person to access and use the area could be designed and help to optimize the management.
To create sustainable financing for Sihanoukville's marine conservation efforts:

- The installation of mooring and demarcation buoys.
- The surveillance, monitoring and fees collection mechanism.

- The design of an education program and education materials to increase environmental awareness among the local users and visitors. This could also be done by creating a Cambodian Marine Environment Resource Center/Library opened to the public.
- Artificial Reef Rehabilitation
- Waste Management.

A study conducted in May 2010 by MCC focused on Tourists' opinion concerning the introduction of the TUF to access a Marine Protected Area (MPA) (M. Skopal, P. Ferber, S. Fairclough, 2010).

The results of the surveys were as follow:

- An overwhelming 93 percent of visitors surveyed think that popular coral reefs and dive sites should be legally established as MPA through a government ordinance to help protect/improve the management of these areas.

- 74 percent of visitors surveyed think that "users", such as tourists and visitors, should be charged a "fee" if they are allowed to use an MPA, such as for scuba-diving.

- 93 percent think that the private sector (such as local resorts and dive operators) should do more to help protect/improve the coastal environment in the area.

- 86 percent think that an "accreditation fee" should be charged to allow a business, like a dive or boat operator, to use an MPA.

- 14 percent of visitors surveyed said that they would be willing to pay between 1 and 2 USD (United States Dollars) per person per diving trip, while 44 percent said they would pay between 2 and 4 USD and 42 percent said they would be willing to pay more than 4 USD.

The Private Sector, that is to say businesses located along the coast that would get benefit from the creation of a protected area in term of visitation volume, could also be involved in contributing to the management costs of the area. A similar study focusing this time on businesses and available in the same report, was conducted in May 2010. The results show that:

- 71 percent of surveyed businesses agreed on the introduction of an "accreditation fee" that would be charged to allow a business (dive or boat operator) to use an MPA, whereas 29 percent had no opinion (Figure 14).

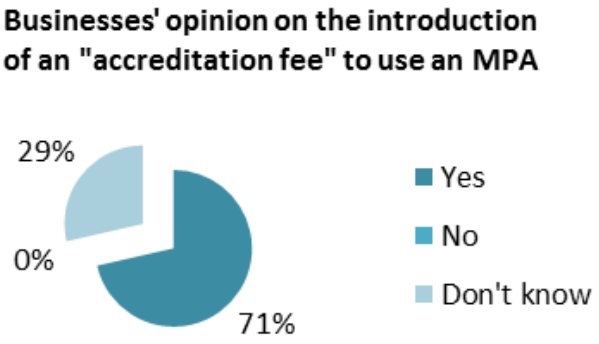


Figure 14 - Businesses' willingness to be charged an accreditation fee to use an MPA

- Finally, 72 percent of surveyed businesses agreed on the idea of charging a fee to allow boats that enter an MPA to use a MAP mooring buoy or land within the MPA, while 21 percent disagreed and 7 percent had no opinion.

With proper data on tourism volumes, it would be possible to estimate the average monthly/yearly revenue that could be generated through a tourism-based fee or "access fee" to the protected area. Nevertheless, it is possible to establish scenarios based on general trend in tourism and taking into account an ongoing improvement of the global health of the protected area thus an increase in its potential of attracting tourism (Figure 15 and 16).

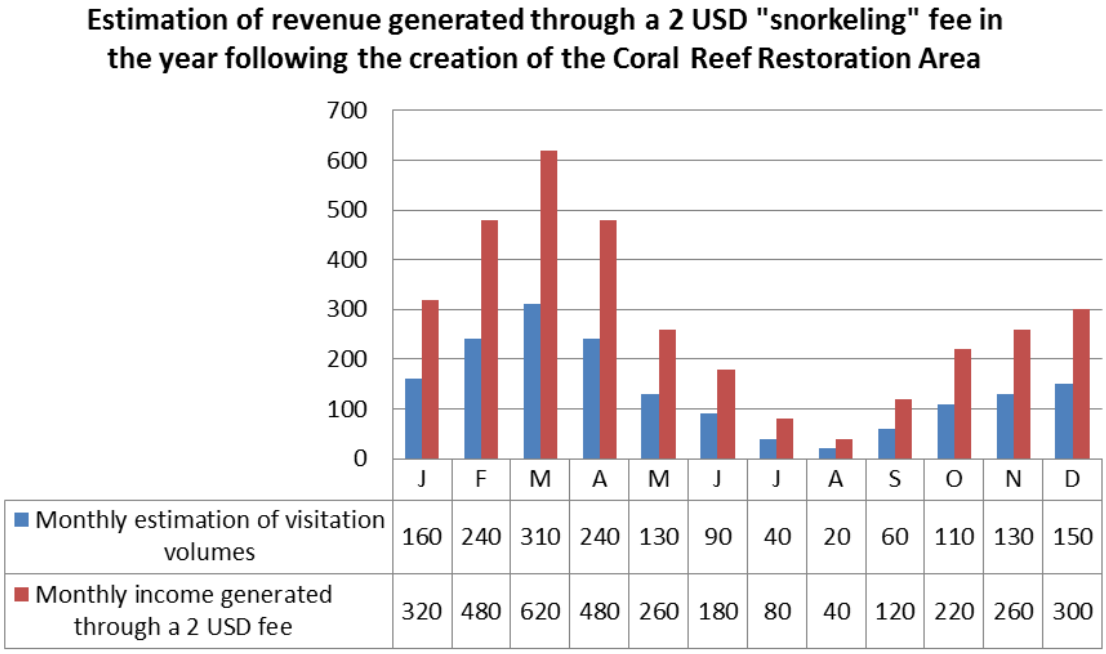
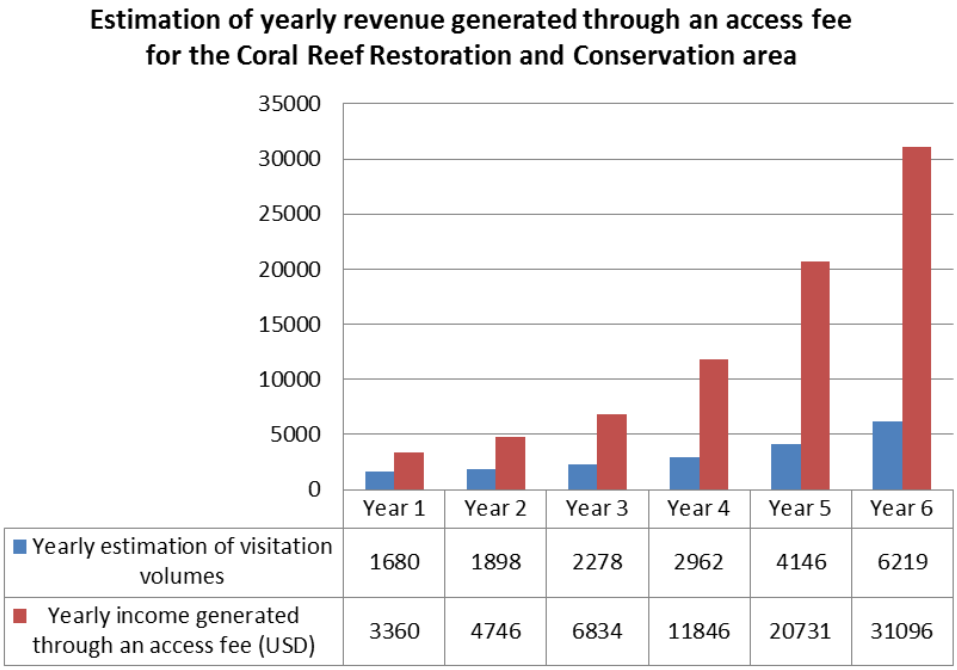


Figure 15 – Possible revenues that could be generated through a 2 USD fee/person to get access to the protected area on the first year. This figure tries to take into account high and low season visitation volumes. Note that these numbers are not accurate as there is no data available concerning this particular area.

Figure 18 takes into account an increase in the "quality" of the area, making in more attractive to tourism, along with a global increase in general tourism. Tourism in the area increases from 13% (Year 2) to 20% (Year 3), 30% (Year 4), 40% (Year 5) and 50% (Year 6).
In the best case scenario, the health of the Coral Reef will improve, allowing an increase of the access fee from 2 USD (Year 1) to 2,5 USD (Year 2), 3 USD (Year 3), 4 USD (Year 4) and 5 USD (Year 5 and 6).

Again, these numbers should be seriously evaluated to allow a correct estimation of visitation volumes and incomes generated through a tourism-based user fee. Figure 14 and 15 aim at demonstrating the feasibility of the introduction of TUF and its potential in generating incomes that could then be put back into the management of the area.



	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Yearly estimation of visitation volumes	1680	1898	2278	2962	4146	6219
Yearly income generated through an access fee (USD)	3360	4746	6834	11846	20731	31096

Figure 16 – Estimation of yearly revenue generated through the access fee.

ii. Protecting the Reefs and Resources: Code of Conduct

As tourism increases, concern will grow about the impact of snorkeling/diving on such a small size protected area. Indeed, most common recreational snorkelers do not measure the impact of their visits on the reefs and the damage they can cause by simply kicking their fins on the coral.

As part of a Pilot Management Plan for the area, emphasis should be put on public awareness and education. Strict snorkeling/diving rules should be advertised, explained and applied; this could be done in several ways such as displaying banners, posters or distributing brochures along with the entrance ticket fee. Public awareness is an important measure to be addressed as it also helps to promote the site as a best management practice area, which will eventually attract an increasing number of eco-tourists.

Code of Conduct for snorkelers is a worldwide, widespread practice allowing protected the reef from the afflux of visitors. This could be easily applied to the Sihanoukville area.

c. Continued Monitoring

Continued Monitoring of the coral reef of the area is necessary to measure the effectiveness of protection. Underwater surveys such as the one presented in this document should continue to be undertaken on a regular basis with the compiled results made available to Government Officials and used to optimize the management of the area. Survey results, such as these, showing an improvement in the overall health of the area should also be made available to a wider public in order to insure people's understanding of strict environmental management measures and promote the area as a best eco-management practices site.

Visitor volumes should also be carefully monitored in order to assess the impacts of their visit on the reef and anticipate potential damages related to the overcrowding of the area.

GENERAL CONCLUSION

The aim of this study was to revisit the sites around Koh Rong Samloem that were first surveyed in 2011, in order to collect a second set of survey data that would allow comparisons to be made. These comparisons allowed conclusions to be made in relation to the condition of substrate cover, the abundance and diversity of fish and invertebrates, and the level of anthropogenic impact observed.

In 2011, results from the initial baseline study indicated that the general health of the coral reef ecosystem surrounding Koh Rong Samloem was quite low due to the historical, and sometimes current, use of unsustainable fishing practices.

The results of this study, two years later, with continued monitoring and patrols demonstrates an ecosystem that is slowly recovering. Overall reef health has improved dramatically, with significant evidence of increased live reef cover, a greater abundance and diversity of target fish, and a greater overall abundance of invertebrate species.

To ensure the continual improvement of the health of the ecosystem, future management actions should involve the implementation of a stricter Zoning Plan, including a Marine Protected Area and on-site demarcations. This Zoning Plan should have a strong focus on fishing restrictions, waste management and education. The results of these management actions should be closely and regularly monitored, with comparisons to other protected/unprotected sites, in order to evaluate and optimize the management plan.

When discussing the future management of this area thought must also be given to the economic aspects. As development in reef areas increases, the amount of recreational users of these areas also increases. Healthy coral reefs provide a number of goods and services that generate a large amount of income for the local and national economy (Conservational International 2008; Gomez 1997).

The creation of a Protected Area represents a certain cost related to its maintenance and management and funding could rapidly be seen as a main issue. However, this could be addressed effectively by the introduction of a Tourism-Based User Fee that would allow access to the area. Studies show that most tourists are willing to pay for conservation; with an increasing flow of tourists visiting Sihanoukville every year (with subsequent island visits),

the set-up of a TUF program would significantly subsidize the protection of the coastline and marine environment.

Overall, if these recommendations are put in place, the improved health of the marine ecosystem surrounding Koh Rong Samloem (and other nearby islands) should increase tourism to the islands as tourists are increasingly seeking out these protected, eco-tourism locations.

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