Serendipity Beach Marine Environmental Assessment, Sihanoukville

Report and Feasibility Assessment for a Coral Reef Rehabilitation Pilot Project

Marine Conservation Cambodia
January 2011

1- Hard Coral cover, Serendipity Beach 2011

In Partnership With:

Report By:

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ABSTRACT

Upon request Marine Conservation Cambodia (MCC) undertook a series of marine surveys that can now also be used as the base line for a continual monitoring program to assess the health of the marine ecosystem in Serendipity Beach area, Sihanoukville, Preah Sihanouk Province. The MCC Research Team surveyed the chosen area on January 19th using the Reef Check methodology and completing results by conducting additional snorkeling surveys on the 20th. Results of this study indicate that hard coral is the dominant substrate (40%), while sand covers 25% and rocks (potentially suitable settling grounds for coral larvae) 19% of the substrate. Anthropogenic impact on coral is low; however, severe signs of overfishing have been observed for both fish and invertebrates. Bleaching did occur in very low intensity yet should be closely monitored. It is clear that the Marine Resources in Serendipity Beach area are under strain and need active protection in order to restore the reefs and increase its potential in attracting eco-tourism. Nevertheless, the overall health and abundance of coral reefs makes it quite a favorable site to set up a Rehabilitation and Conservation Programme.

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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), Sihanoukville ICM Programme, 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. 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 Rehabilitation Pilot Project on Serendipity Beach, Sihanoukville.

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Picture Credits

All pictures were taken by Bonny Krell and Ueli Schmid on January 19th at survey sites.

List of Abbreviations and Acronyms

FAO	Food and Agriculture Organization of the United Nations
FiA	Fisheries Administration
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
KRS	Koh Rong Samloem
MCC	Marine Conservation Cambodia
MPA	Marine Protected Area
RFLP	Regional Fisheries Livelihoods Programme
RGC	Royal Government of Cambodia
USD	United States Dollar

INTRODUCTION

Coral reefs are the so called "rainforest of the sea" as they are the most diverse marine ecosystems presenting a high biodiversity (Knowlton &Jackson, 2008) that provides significant economical goods and services that are critical to human well-being (Conservation International, 2008). Unfortunately coral reefs are threatened by destructive fishing methods and overharvesting, as well as siltation, sewage, agricultural garbage, mining and industrial pollution, coastal development, global warming and tourism-associated damages (Kim et al, 2004; GCRMN, 2004; Knowlton & Jackson, 2008). The loss of coral reef ecosystems inevitably leads to the decline in abundance and diversity of reef fish and plants through the loss of structural heterogeneity (Jones et. Al, 2004: Bruno & Selig, 2007).

Cambodia's economy is largely dependent on this Coastal and Marine sector (Wheeleret.al, 2000). A wide variety of economic valuation studies have been made on coral reefs and related systems around the world, with a focus on ecosystem goods and services namely tourism, fisheries, coastal protection, biodiversity and carbon sequestration. An economic analysis of Ream National Park in Cambodia, focusing on recreational activities opportunities related to coral reef, 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).

Sihanoukville is one of the most popular tourist spots in Cambodia, along with Siem Reap and Phnom Penh. Its coastline and islands bordered and surrounded by coral reefs support local tourism by attracting an increasing number of eco-tourists willing to discover these spectacular marine environments. However, there too, this precious resource is in jeopardy due to the accumulation of the destructive factors mentioned above.

In response to these concerns and as part of its Integrated Coastal Management Programme and Beach Zoning Plan, Sihanoukville decided to double the efforts on Marine Conservation. As such, an area located within Serendipity Beach was selected as being a potential site for a Coral Reef Rehabilitation Pilot Project with the aim of attracting eco-tourism (**Figure 1**).

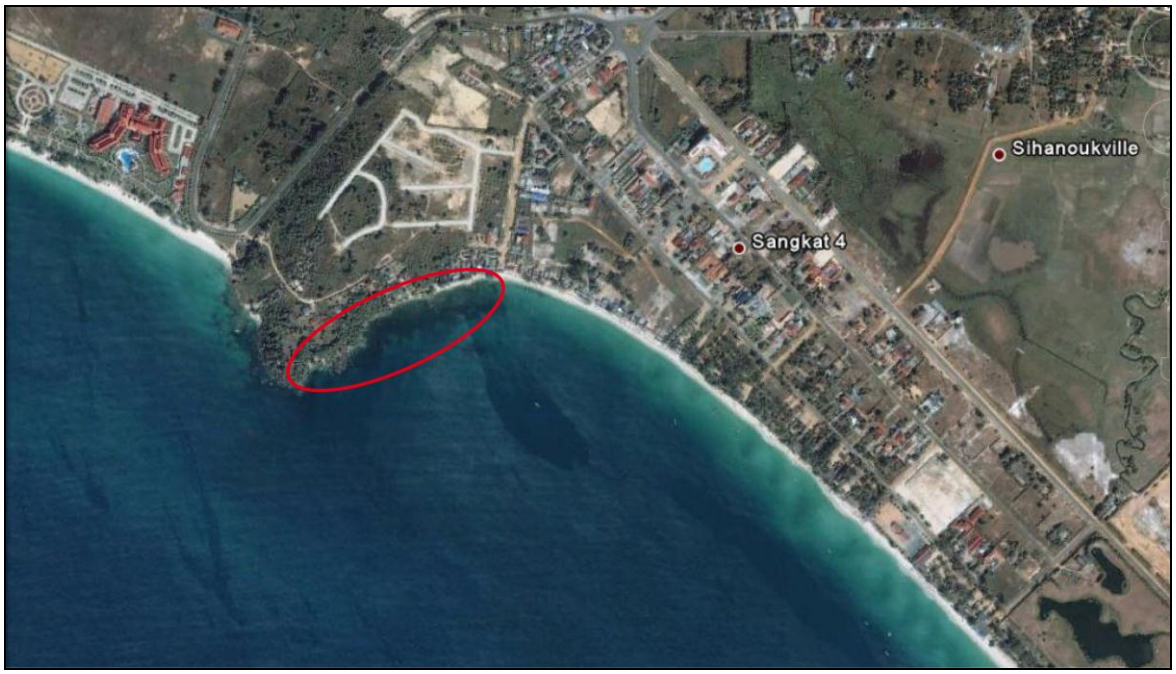


Figure 1 - Area of Serendipity Beach chosen to be surveyed (Google Earth).

From a terrestrial point of view, the area presents as many opportunities as challenges for such a project: highly touristic area, resource use conflicts (fishing and recreational activities), unstable environmental quality (sewage issues from tourist facilities located on the beach)… From a marine point of view, very little was already known which justified the need for a marine environmental assessment. Therefore, this study aims at:

- Determining the general distribution of coral reefs on a chosen area of Serendipity Beach and to conduct baseline quantitative surveys on the abundance and distribution of reef health indicators such as fish and invertebrates.

- Determining the general condition of the coral reefs in terms of visible impacts.

- Identifying the main issues to be addressed in order to design a Coral Reef Renovation and Conservation Plan for the area and optimize its management; this will ultimately lead to the development of a sustainable eco-tourism attraction focusing on snorkeling opportunities.

I. METHODOLOGY

Standard Reef Check monitoring was applied for the survey sites at Serendipity beach in order to assess the abundance, diversity and composition of selected fish and invertebrate 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

Figure 2 - Location of Survey Sites. Darker areas suggest the presence of rocks and/or coral reefs. The recently built pier is not visible as the satellite imagery was recorded in 2007 (Google Earth)

For this study, 2 complete survey transects of 100 m were chosen within the coral reef area on Serendipity beach (**Photo 2 and 3**). The starting point of both Transects was almost the same,

exclusively the transect orientation changed (**Figure 2**). Four 20-meter (m) transects were laid parallel to the coastline (for each transect direction). The segments were separated by a gap of 5 m. In these 5 m gaps, no data was recorded; this helps ensure independence for each 20 m section, which is necessary for reliable statistical analysis. This was done in order to get a complete overview of the area. As the Transects were so close, they were analyzed as 1 Survey site only. Therefore, 1 transects of 200 meters was studied with eight 20-m transects. The recorded data has been transferred to standard data forms.

Of note is the fact that after the surveys, as it seemed that algal abundance was increasing closer to the pier, it was decided to analyze another site (Site 3) closer to the pier. As the water was so shallow that it was only possible to snorkel, only the substrate was surveyed to record the variation of density of algae.

2 - Setting up transects

3 – Recording substrate cover.

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.

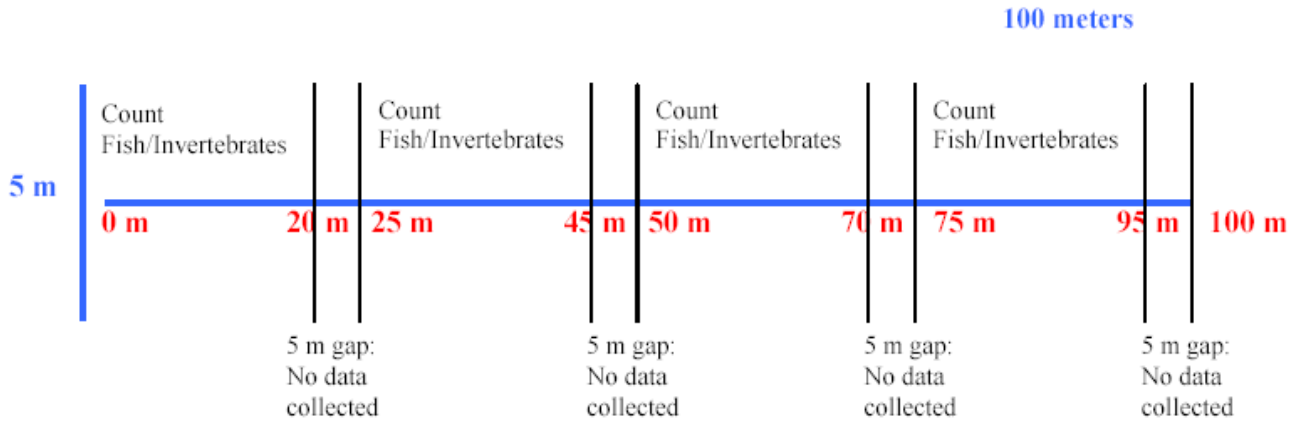


Figure 3 - Fish and invertebrate belt transect count method (in Hodgson et al, 2006)

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.

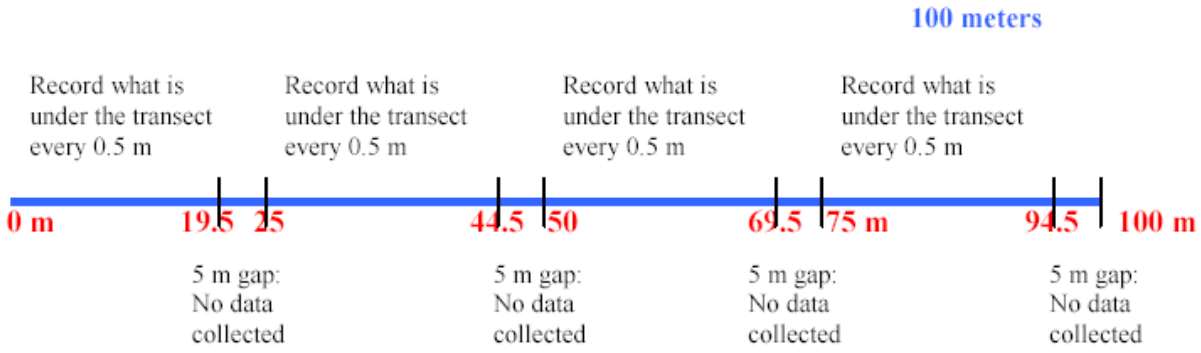


Figure 4 - Point intercept transect count method to determine benthic cover (in Hodgson et al, 2006).

Again, the site closest to the pier was so shallow that only substrate was surveyed to record the variation of density of nutrient indicator algae. This was necessary as it seemed during the first transects that algal abundance was increasing closer to the pier.

c. Data entry and analysis

The total cover composition on Serendipity Beach was estimated by the average composition of all 20-m transects.

Coral damage was noted in an empirically way by qualifying it within four levels of damage: 0- none, 1- low, 2- medium and 3- high. The damage was then estimated as the mean of the 8 surveyed transects.

Bleaching was estimated for coral population and colony. The mean percentage of the surveyed transects was calculated by the average bleaching of corals.

For the fish and invertebrate transect, the mean number of individuals per square meter and the mean composition of indicator fish has been calculated.

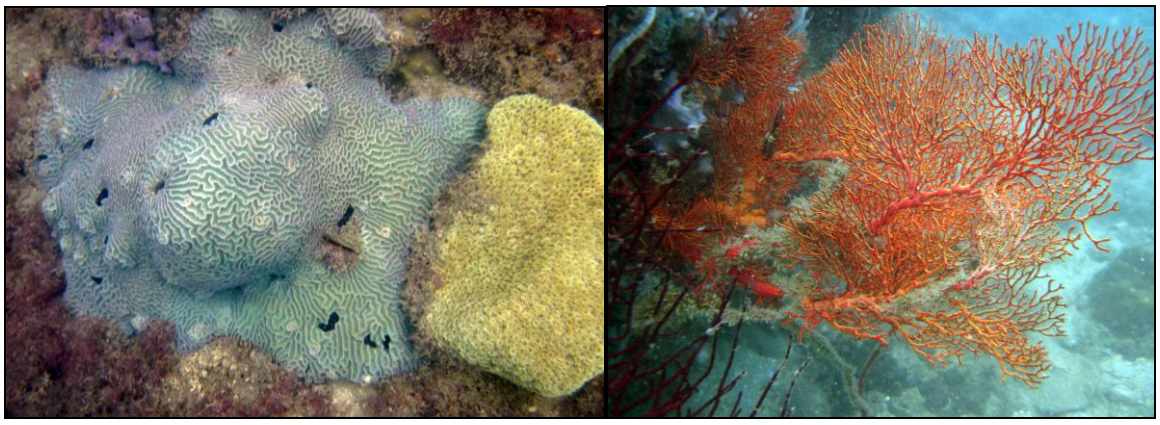
The Percentage Algae cover, along the coastline of Serendipity Beach, was calculated per transect. This was done to get an overview of its abundance evolution along the coast.

II. RESULTS

The results from these surveys are shown in a graphical format, and they aim to provide a picture of Serendipity Beach coral reef status.

a. Substrate Composition

The dominant substrate cover encountered on surveys was coral (**Figure 5**). The average hard coral cover within the area to be protected, was found to be 35 % (**Photo 4**). Hard coral cover is an indicator of general reef health because they are reef builders, and it is recognized that reef fish diversity is directly related to it. The next most abundant substrates were sand with coverage of 26 % and rock with an average cover of 21 %. Rock constitutes an important part of reefs as it provides settling ground for coral larvae. No recently killed coral has been found. An average cover of nutrient indicator algae of 7 % and 8 % of *Sargassum* sp. cover has been noticed. This leads to the conclusion that there are sign of eutrophication in this area. This is to be expected as there are many sewage pipelines on this beach. Cover of sponges and soft corals was generally low (< 1 %).



4 –Hard Coral cover and Sea Fan

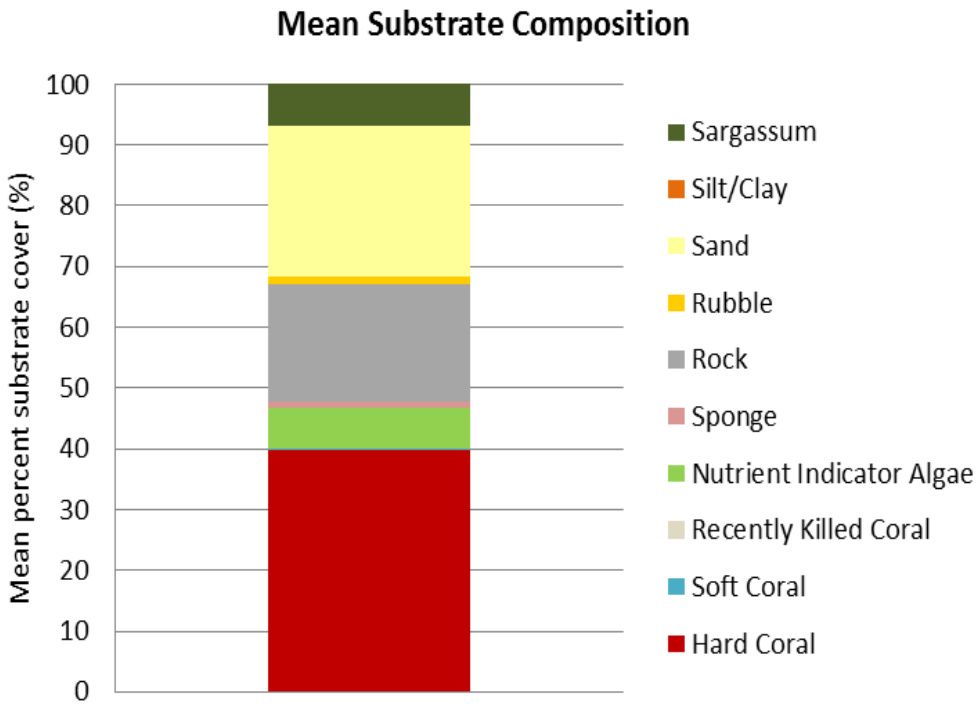


Figure 5 - Mean composition of substrate cover at the three surveyed sites

Figure 6 shows the density of algal coverage recorded along the coastline of Serendipity Beach within three transects, i.e. in total 240 meters were investigated. Nearly along the entire transect a certain percentage of algal, either only *Padina* sp. or only *Sargassum* sp. or both together were detected. Especially within the shallowest area (S3T1 – S3T4) the algal coverage was relatively high, i.e. denstities of *Sargassum* reached a peak of a mean percentage of more than 18 % (**Photo 5**). Furthermore, algal coverage, especially *Sargassum* sp. showed a second somewhat smaller peak of 12 % within the last 40 meters (S2T2 – S2T4). In general, at 9 out of 12 segments investigated substrate was covered by nutrient indicator algae.

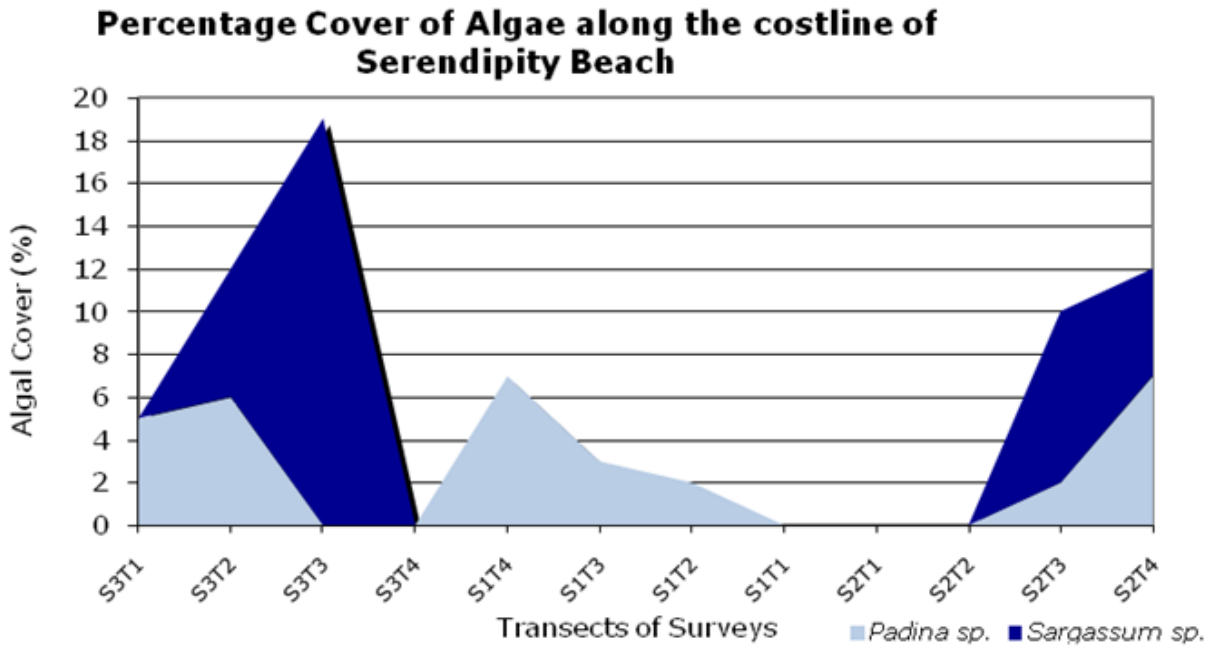
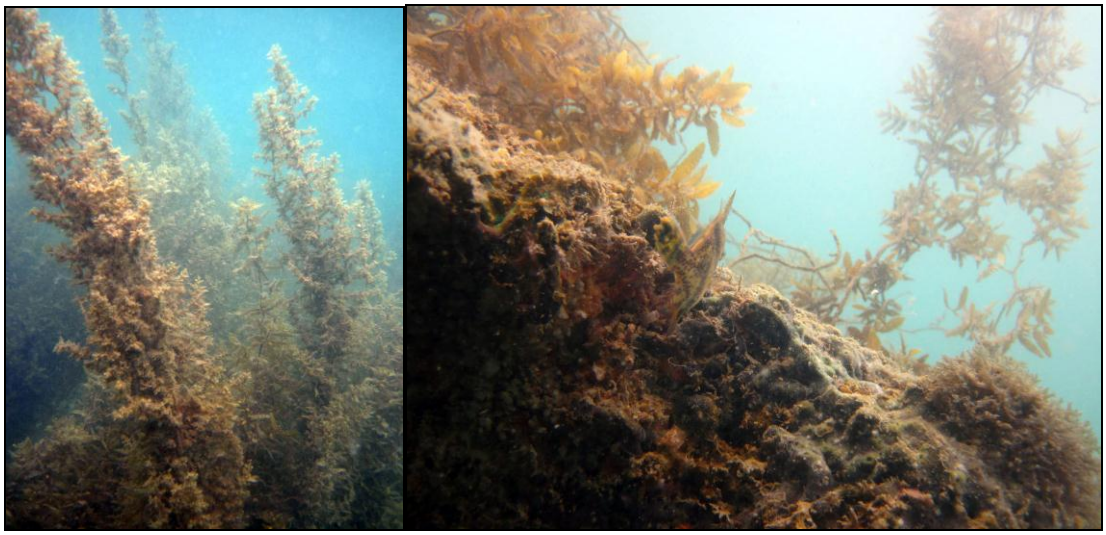


Figure 6 - Coverage of algae, Padina sp. and Sargassum sp., along the coastline.

The transect order was established beginning close to the pier and moving away from it. The "S" refers to the SURVEY of a 100 m transect, and the "T" to the 20 m TRANSECT within the 100 m transect



5- *Sargassum sp.* cover

b. Anthropogenic impact on coral reefs

In general, the impact on corals due to anthropogenic activities was evaluated to be *low*. As **Figure 7** indicates, the highest mean degree of coral damage was provoked by general trash reaching a mean degree of 1.125 in the empirical evaluation. Some degree of damage through boat and anchoring was observed. Fish nets were only observed in a very low abundance. Impacts resulting from dynamite fishing or other damages could not be recorded.

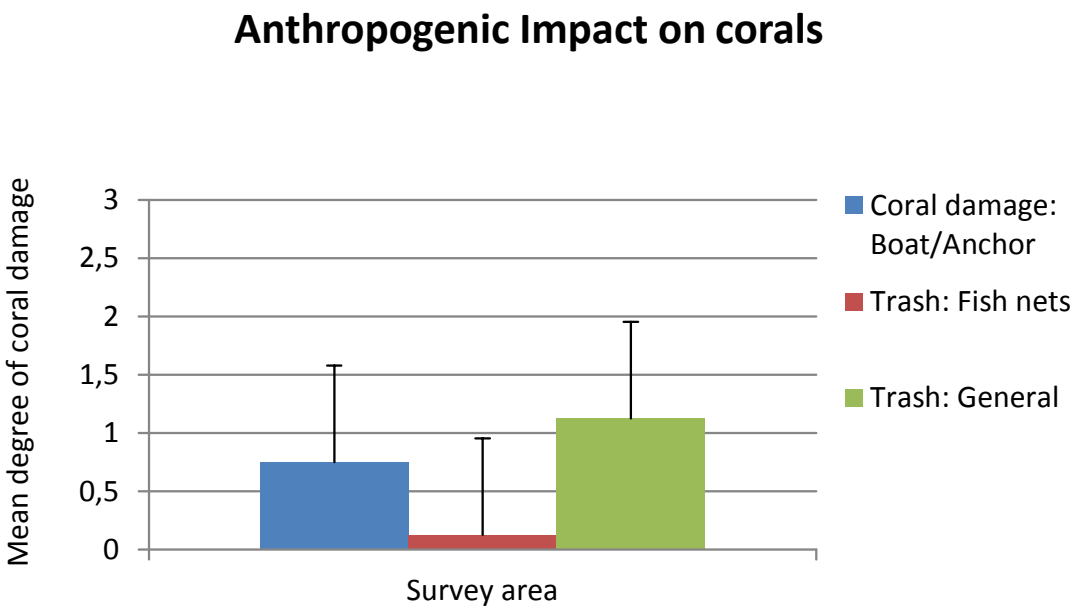


Figure 7 - Mean degree of anthropogenic damage to corals at surveyed sites.

Neither impacts of dynamite fishing nor any other damage were detected.

c. Bleaching impact on coral reefs

Coral populations are slightly affected by coral bleaching reaching on average of 7 % (**Figure 8**). That means that the majority, more than 90 % of the coral populations located within the area to be protected, seem to be generally in good condition and health.

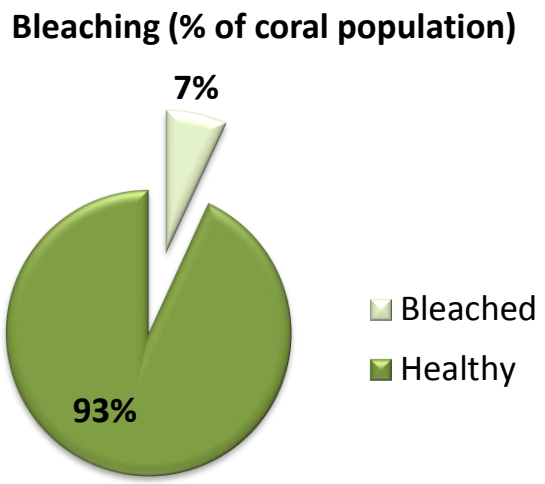


Figure 8 - Mean percentage of coral population affected by bleaching

The results of the study of bleaching affected corals showed that generally the degree of bleaching parts within the colonies was quite low. Colonies experienced on average a 12 % damage through coral bleaching (**Figure 9**).

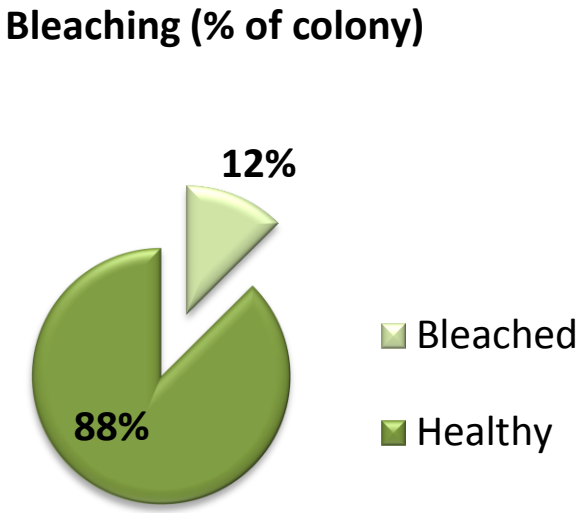


Figure 9 - Mean percentage of coral colony affected by coral bleaching

d. Fish Survey

Figure 10 illustrates the fish composition of the indicator species/families observed at Study site. In general, the diversity was quite low as only four indicator species/families, namely Snapper (Lutjanidae), Butterflyfish (Chaetodontidae), Grouper (Serranidae) and Sweetlips (Haemulidae) were recorded. Snapper contributed the most to the composition observed at the study area, followed by the family of Butterflyfish and Grouper (total length of 30-40 cm). Individuals of Sweetlips were found contributing less to the present fish composition.

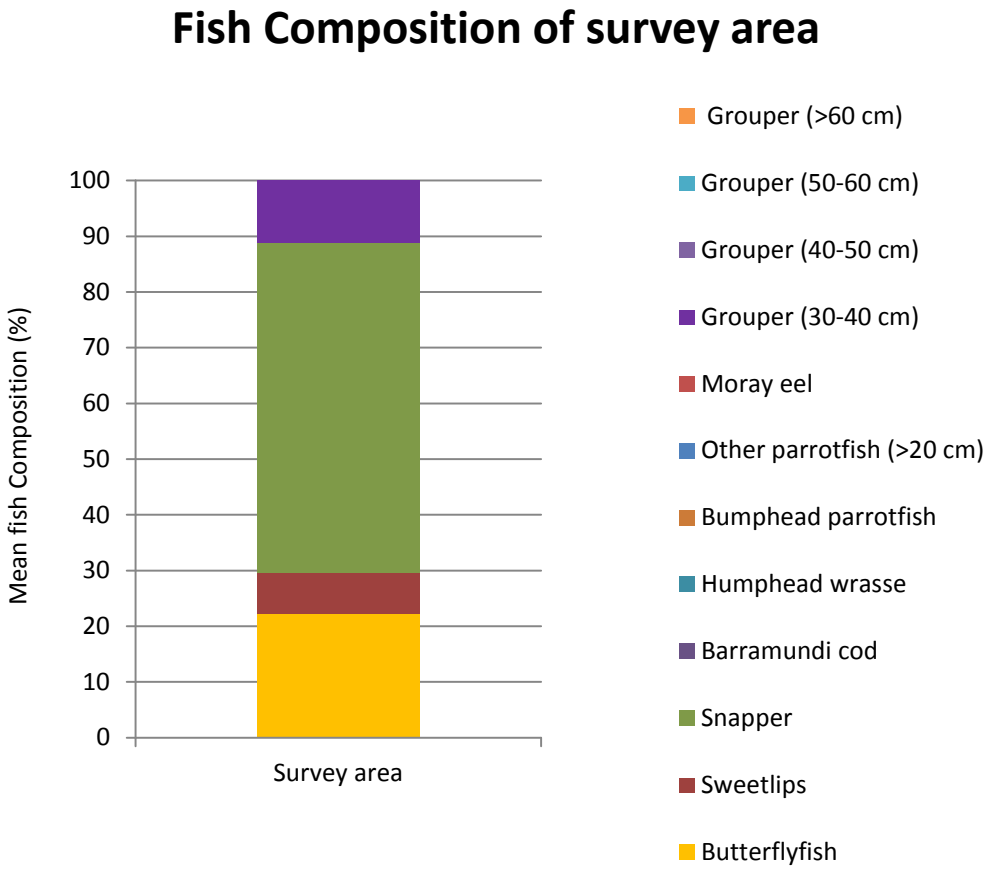


Figure 10 - Mean percentage of each indicator fish species/family recorded at surveyed area

Figure 11 demonstrates the mean abundances of the indicator fish families observed at the entire survey site.

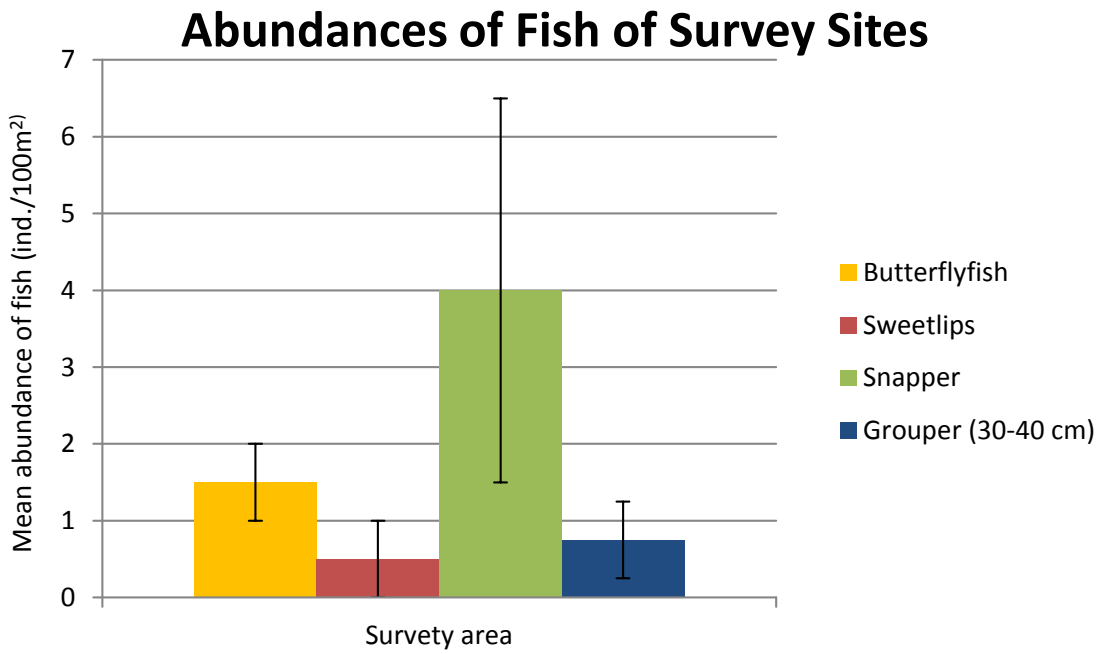


Figure 11 - Mean abundances (ind./100 m²) of the different indicator species/families at study site.

Figure shows only the observed fish families. Error bars indicate standard error.

e. Invertebrate Survey

Figure 12 illustrates the mean abundance of invertebrate indicator species. There were only *Diadema* sp. urchins; no other invertebrates have been recorded on either survey site.

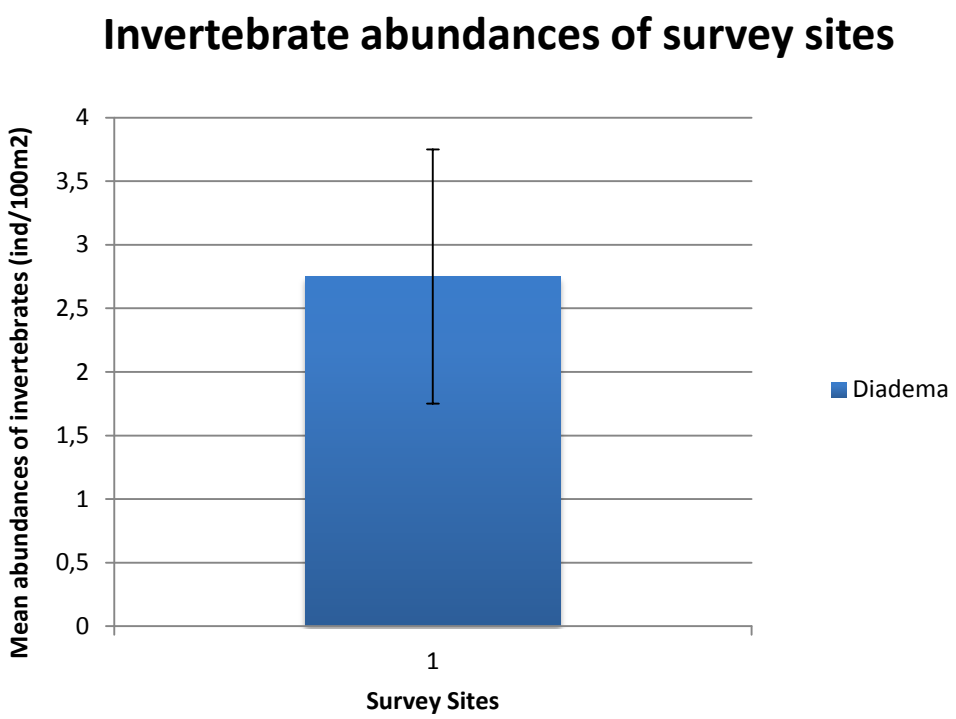


Figure 12 - Mean abundances (ind./100 m²) of Diadema urchins.

Figure shows only the Diadema urchins as no other invertebrates were found. Error bars indicate standard error

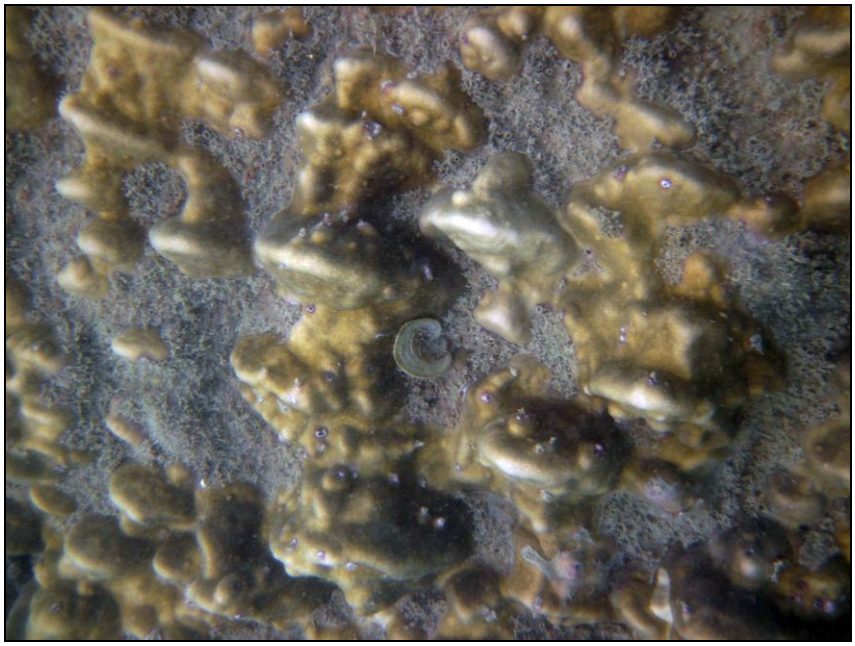
A complete list of species observed during the survey is included in this report (**Annex 1**).

III. DISCUSSIONS

In general, the health condition of corals at Serendipity Beach was much better than expected, despite the adverse environmental conditions present at the site. However, observations show that:

- A considerable amount of nutrient indicator algae was found. This is an indication of eutrophication, i.e. nutrient enriched environment. This was expected due to the sewage pipes from the restaurants that lead directly into the water.

- A representative amount of sediments covering coral population was observed. This might result from suspended sediments most likely due to trawling fishing methods. If not controlled, sedimentation can cause a severe problem as corals may get suffocated by the amount of sediment covering them.



6 - Hard Coral covered by sedimentation

- Bleaching has been found in low percentage but, it should be closely monitored to allow management practices if necessary.

- The low number of fish abundances and their small size are signs of severe overfishing.

- The near absence of invertebrates shows that these organisms are also suffering from a high overfishing rate. This is particularly important for Diadema sea urchins as they are algal-grazing: they play an important role in keeping the reefs clean of algae, especially when there are few herbivorous fish around to fulfill this role.

IV. RESOURCE USE CONFLICT

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

a. Fishing

A relatively important fishing activity was observed in the surveyed area.

- Squid fishing was observed, using lines with lures thrown from the shore. The catches seemed of very small size thus indicating overfishing (absence of adult specimen). Throwing lures and line fishing in general can hardly be compatible with diving and snorkeling activities in such a small area. As an example, one of the lines thrown from the shore landed on one of our team member while doing a snorkeling survey. Fortunately, the lure got tangled in his equipment and not in the snorkeler's skin.

- Subsistence net fishing was recorded, one individual using a short, small mesh net from the shoreline, beating the water to scare fish into the net.

- Several individuals were seen spearfishing and shell collecting using metal sticks. These activities are highly destructive to both coral reefs and targeted species. It is suspected to be the reason why almost no invertebrates and bigger size fish could be recorded during the surveys. This is an issue to be urgently addressed.

b. Motorized activities

Jet-skis operating at full speed, very close to the shore, were observed, as well as a few fishing boats (longtails) operating quite close to our diving team. The presence of such motorized activities within or close to a protected –snorkeling- area could lead to both environmental (anchoring on the reef, pollution, noise) and safety issues: boats, especially

speed boats and jet-skis, are a real threat to divers (but also swimmers and snorkelers) as they cannot see them surfacing when driving at full speed.

V. RECOMMENDATIONS

a. Notes on ICM

"Coral reefs are vital to the well-being of millions people and their conservation plays a major role in achieving Integrated Coastal Management. Coral reef managers and government officials trying to save their valuable national resources need management-related information on coral reefs. Ecological economic decision support models can play a critical role in the development of effective ICZM for the protection and restoration of coral reef." (MOU Chile/OEA, 2008).

As pioneer city in ICM, Sihanoukville has the capacity and ability to focus its effort on rehabilitation and conserving its marine environment. By doing this, it will be able to promote its best management practices for coral reefs and related ecosystems and attract a significant number of "eco-tourists"; developing the eco-tourism market is an opportunity for Sihanoukville to insure a continuous flow of high-end tourism and sustainable revenues for the Province.

b. Projected tourism-related environmental impacts

Tourism impacts on the environment could be dramatic if not managed properly. Many tourism-related issues can currently be observed near Serendipity area and further impacts can be projected if no management actions are taken.

- Terrestrial runoff

Logging, soil compaction and surface sealing reduce infiltration and increase run-off of sediment and nutrients. Direct detrimental effects on the growth and survival of hard coral colonies, coral reproduction and recruitment as well as organisms that interact with coral populations of terrestrial runoff have been already witnessed in other parts of the world such as the Great Barrier Reef in Australia. (D.Williams, M. Furnas, 2002).

➔ *Minimized surface sealing, infrastructures adapted to tourism demand, moderate logging and reforestation should be considered as a way to limit the impact of tourism development on the area and more generally to Sihanoukville Coastal Environment and ensure a continual tourist flow on a long-term scale.*

- Waste management issues

Development of hotels and resorts on the beach front have brought the issue of waste discharge and its impacts on marine life, starting with the death of coral reef that will be followed by a decline in marine species. In most cases, sewage plants do not exist, are broken, improperly maintained, incorrectly operated, or simply overwhelmed by the volume of wastes they are required to treat. Rich in nutrients such as nitrogen, phosphorus and ammonia, treated sewage is suspected of fueling the growth of algae that smother reefs. Chemical from sewer pipes and coastal runoff are harming coral reefs. Studies show that corals near sewage pipes and inlets, where urban and agricultural runoff flows into the ocean, showed harmful changes in levels of molecules associated with the ability to heal wound. Without any healthy coral reefs to observe, visitation volume will eventually decrease.

➔ *"Hotels and resorts around the world are now adopting environmental management systems as a means of improving resource use efficiency, reducing operating costs, increasing staff involvement and guest awareness, and obtaining international recognition in the travel and tourism marketplace" (B. Meade, J Pringle, 2001).*

In order to avoid such issues as irresponsible dumping and waste discharge, development plans shall include waste discharge regulation. Waste management is a fundamental condition to sustainable tourism and an essential part of Integrated Coastal Management.

- Carrying capacity of the area

As the number of snorkelers increase in the area, there is a risk of an open access system that may lead to reef deterioration through the impact of high levels of tourism usage. Damage to coral reefs from careless snorkelers (as well as divers and swimmers), pollution and other ecosystem impacts from recreational vessels, are among the range of tourism effects documented in MPAs worldwide. Controlling these impacts can be as important an element of managing a Coral Reef Rehabilitation and Conservation Area. A potential key to such management lies in assessing the number of tourists that an MPA can support sustainably: its carrying capacity (B. Barr, 2004).

In some areas such as in the Shark Reef Marine Reserve (SRMR) in Fiji, the dive operator limits the number of divers it takes to the SRMR to fewer than 20 per day. Thus, the number of divers is intentionally limited by the capacity of the dive operator to bring divers to Shark Reef and offer them an exclusive diving experience.

➔ *Following the creation of a Coral Reef Rehabilitation and Conservation Area, visitation volumes are expected to start at a low level, time for the reef to recover from previous damages and become attractive again. However, as tourism is expected to increase rapidly, assessing the carrying capacity of the protected area will have to be seriously considered in the next years. Most surrounding countries have a system in place to rotate or limit diving at certain times of year and in areas of specific scientific interests.*

c. 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". Zoning Plans define what activities can occur in which areas and allow protecting the marine environment as well as avoiding potential resource-use conflicts.

To prevent any resource use conflict and in order achieve Coral Reef Rehabilitation and Conservation in an effective way, the Serendipity Coral Reef Rehabilitation Pilot 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 mooring, within the area. Proper demarcation would be needed in order to avoid any confusion and/or conflicts between users.

A strict implementation of a Zoning Plan is necessary in order to secure vital social and economic benefits including tourism and recreational activities, but also commercial activities and fishing. Concerning a "Rehabilitation" or "Conservation" Zone, specific regulations, especially fishing restrictions, will have to be firmly enforced in order to restore and increase the attractiveness of the area, enhance tourism satisfaction and secure self-sustaining revenues.

d. Visiting the Reefs

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

ICM and the creation of MPAs have 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 Sihanoukville 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 per day to access and use the area for snorkeling, or even kayaking -glass bottom kayak-) could be designed for a Coral Reef Rehabilitation Pilot Project in Serendipity area and help to optimize the management of the area by financing:

- 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.
- An Artificial Reef Rehabilitation project.
- A Waste Management project, etc.

A study conducted in May 2010 by our team 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 beach 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 13**).

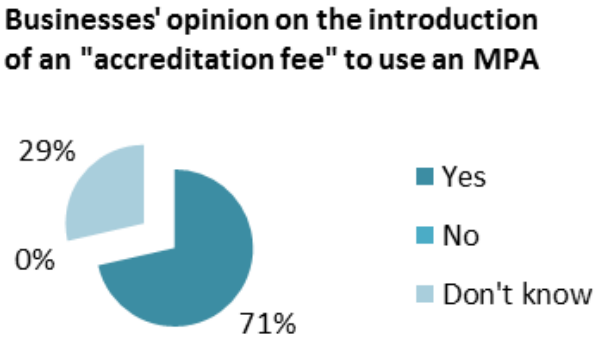
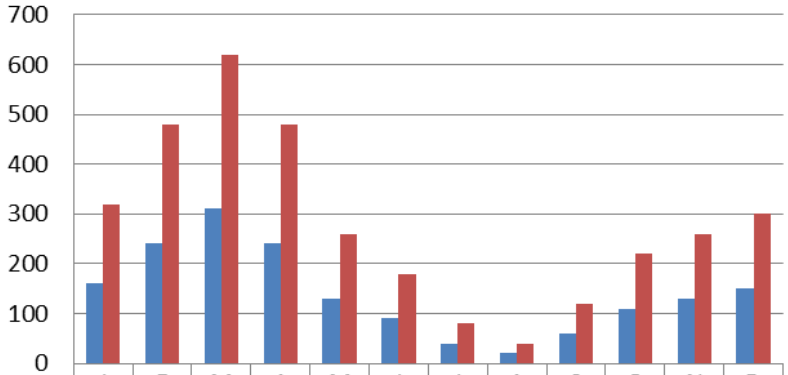


Figure 13 - Businesses' willingness to be charged an accreditation fee to use an MPA

- 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 14 and 15**).

Estimation of revenue generated through a 2 USD "snorkeling" fee in the year following the creation of the Coral Reef Restoration Area

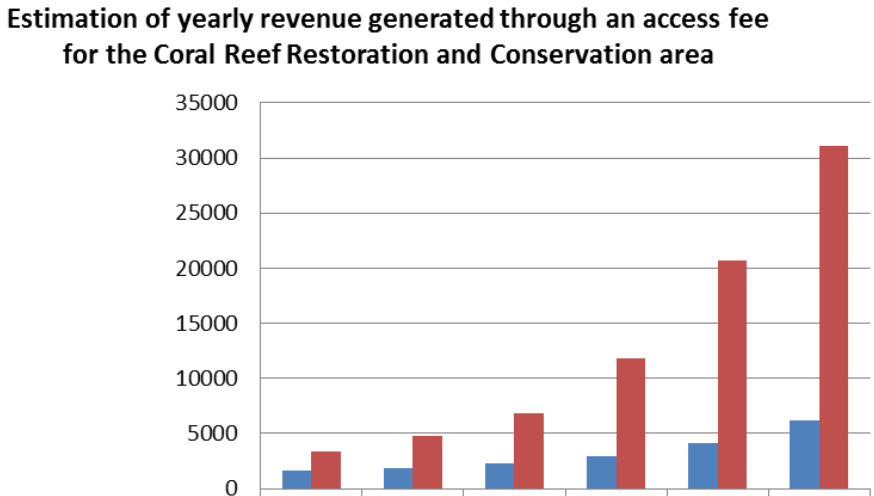


	J	F	M	A	M	J	J	A	S	O	N	D
Monthly estimation of visitation volumes	160	240	310	240	130	90	40	20	60	110	130	150
Monthly income generated through a 2 USD fee	320	480	620	480	260	180	80	40	120	220	260	300

Figure 14 – 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 15 takes into account an increase in the "quality" of the area, making it 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 15 – 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 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, emphasize should be put on public awareness and education. Strict snorkeling 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 Serendipity area (**Annex 4**).

e. Continued Monitoring

Continued Monitoring of the Coral Reef of the area is necessary to measure to effectiveness of protection. Underwater surveys such as the one presented in this document should 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 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.

In order to evaluate the effectiveness of protection measures, a chosen "control site", located outside of the Rehabilitation Area, should also be closely monitored. This would allow determining whether the increase or decrease of the overall health of coral reefs located within the protected area is related to the introduction of protection measures or to other external factors.

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.

An existing Conservation Project around the island Koh Rong Samloem, closely monitored by our team since 2008, would be an interesting point of comparison to evaluate the effectiveness of protection between the two sites and share experiences in order to optimize the management and enhance the eco-tourism potential of MPAs in Cambodia.

GENERAL CONCLUSION

The study presented in this document aims at demonstrating the feasibility of the creation of Coral Reef Rehabilitation and Conservation Area in Serendipity Beach area, Sihanoukville.

The results of the underwater survey allowed us determining the general distribution of coral reefs and main marine 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 general health condition of the coral reef was good but threatened by various factors, especially overfishing and waste discharge, which make the area perfectly suitable for a Rehabilitation Project. Although physical damages such as anchoring were observed as being low, signs of pollution from sewage water and serious overfishing were recorded. Thus, the area will be able to recover naturally only if appropriate management actions are taken to reduce anthropogenic stress.

In this case, management actions should involve the insertion of the Protected Area into a proper Zoning Plan, including on-site demarcations and focusing particularly on fishing restrictions and waste management. The results of the management actions should be closely and regularly monitored, with comparisons to other protected/unprotected sites, in order to evaluate and optimize the management plan.

Coral Reefs are economically valuable as they provide a great variety of goods and services. Worldwide, "tourism and recreation account for USD 9.6 billion of the total USD 29.8 billion global net benefit of [healthy] coral reefs" (Conservation International, 2008). 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, the set-up of a TUF program would significantly subsidize the protection of the coastline and marine environment.

Serendipity area surely presents a significant number of qualities, along with fundamental challenges, that makes it a perfect candidate for the creation of a Coral Reef Rehabilitation Pilot Project. With an effective management plan and cooperation between stakeholders, this area could become a model of best management practices, enhance eco-tourism in Sihanoukville and help developing national marine eco-tourism market to support local and national economies.

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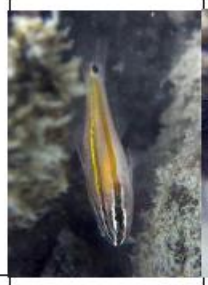
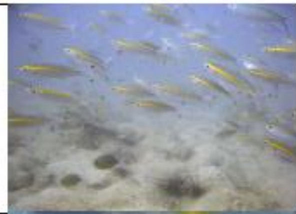
ANNEX 1 – Species (vertebrates and invertebrates) observed during the survey around Serendipity Beach

Order	Family	Species	Common Name	Photo Location	Picture	Reference
Perciformes	Apogonidae	Apogon cavitiensis	Caviti Cardinalfish	Koh Rong		Ref. 1 & 2
Perciformes	Apogonidae	Apogon endekataenia	Sixstripe Cardinalfish	Koh Rong		Ref. 1 & 2
Perciformes	Caesionidae	Caesio cuning	Redbelly yellowtail fusilier	Koh Rung Samleom		Ref. 1 & 2
Perciformes	Caesionidae	Caesio teres	Blue & Yellow fusilier	Koh Rong		Ref. 1 & 2

Perciformes	Caesionidae	Pterocaesio tessellata	Narrowstripe fusilier	Koh Rong		Ref. 1 & 2
Perciformes	Caesionidae	Pterocaesio tile	Bluestreak fusilier	Koh Rong		Ref. 1 & 2
Perciformes	Carangidae	Gnathanodon speciosus	Golden trevally	Koh Koun		Ref. 1 & 2
Perciformes	Chaetodontidae	Chaetodon octofasciatus	Eight-Banded Butterflyfish	Koh Rong		Ref. 1 & 2
Perciformes	Chaetodontidae	Chelmon rostratus	Long-Beaked Coralfish	Koh Rong		Ref. 1 & 2

Rajiformes	Dasyatidae	Himantura imbricata	Scaly whipray	Koh Koun		Ref 3
Rajiformes	Dasyatidae	Taeniura lymma	Blue-spotted Ribbontail Ray	Koh Koun		Ref. 1 & 2
Perciformes	Gerreidae	Gerres oyena	Blacktip Silver Biddy	Koh Rung Samleom		Ref. 1 & 2
Perciformes	Gobiidae	Cryptocentrus cinctus	Banded Shrimpgoby	Koh Rong		
Perciformes	Gobiidae	Cryptocentrus leptocephalus	Pink-Spotted Shrimpgoby	Koh Rong		Ref. 1 & 2

Perciformes	Gobiidae	Cryptocentrus sp.	Bluespot shrimpgoby	Koh Rong		Ref. 1 & 2
Perciformes	Gobiidae	Gobius melanopus	Pink-speckled shrimpgoby			Courtesy of FishBase.org
Perciformes	Gobiidae	Valenciennea immaculata	Immaculate goby	Koh Rung Samleom		Ref. 1 & 2
Gobiesociformes	Gobiesocidae	Diademichthys lineatus	Urchin Clingfish			Ref. 1 & 2
Perciformes	Haemulidae	Diagramma pictum	Silver sweetlips	Koh Rong		Ref. 1 & 2

Perciformes	Haemulidae	Plectorhinchus chaetodonoides	Many Spotted Sweetlips	Koh Rong		Ref. 1 & 2
Beryciformes	Holocentridae	Myripristis murdjan	Pinecone soldierfish	Picture From www.Fishbase.org		Courtesy of FishBase.org
Beryciformes	Holocentridae	Sargocentron rubrum	Redcoat squirrelfish	Koh Rong		Ref 1 & 2
Perciformes	Labridae	Cheilinus chlorourus		Koh Rung Samleom		Ref 3
Perciformes	Labridae	Halichoeres chloropterus	Pastel-Green Wrasse	Koh Rong		Ref. 1 & 2

Perciformes	Labridae	Halichoeres hortulanus	Checkerboard wrasse	Koh Rung Samleom		Ref 1 & 2
Perciformes	Labridae	Halichoeres leucurus	Chain-Lined Wrasse	Koh Rong		Ref. 1 & 2
Perciformes	Labridae	Labroides dimidiatus	Bluestreak Cleaner Wrasse	Condor Reef		Ref. 1 & 2
Perciformes	Lutjanidae	Lutjanus argentimaculatus	Mangrove red snapper	Koh Rung Samleom		Ref 1 & 2
Perciformes	Lutjanidae	Lutjanus decussatus	Checkered snapper			Ref 1 & 2

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Perciformes	Lutjanidae	Lutjanus fuscescens		Koh Rong		Ref 1 & 2
Perciformes	Lutjanidae	Lutjanus fulviflamma	Dory snapper	Picture From www.Fishbase.org		Ref 1 & 2
Perciformes	Lutjanidae	Lutjanus vitta	Brownstripe snapper	Koh Rung Samleom		Ref. 1 & 2
Tetraodontiformes	Monacanthidae	Monacanthus chinensis	Fan-bellied leatherjacket	Koh koun		Ref. 1 & 2
Tetraodontiformes	Monacanthidae	Pseudomonacanthus macrurus	Strapweed Filefish			Courtesy of FishBase.org

Perciformes	Monodactylidae	Monodactylus argenteus	Diamond Fish	Koh Rong		Ref. 1 & 2
Mugiliformes	Mugilidae	Crenimugil crenilabis	Fringelip mullet	Koh Rong		Ref. 1 & 2
Perciformes	Mullidae	Upeneus tragula	Freckled goatfish	Koh Rung Samleom		
Perciformes	Nemipteridae	Pentapodus paradiseus	Paradise whiptail	Koh Rung Samleom		Ref 1 & 2
Perciformes	Nemipteridae	Scolopsis bilineatus	Bridled Monocle Bream	Koh Rung Samleom		Ref 1 & 2

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Perciformes	Nemipteridae	Scolopsis ciliatus	Whitestreak Monocle Bream	Koh Rung Samleom		Ref 1 & 2
Perciformes	Nemipteridae	Scolopsis margaritifer	Pearly Monocle Bream	Koh Rung Samleom		Ref 1 & 2
Perciformes	Nemipteridae	Scolopsis vosmeri	Whitecheek monocle bream	Koh Rong		Ref 1 & 2
Perciformes	Pempheridae	Pempheris sp.	Sweeper	Koh Rong		Ref 1 & 2
Perciformes	Pinguipedidae	Parapercis millipunctata	Spotted sandperch	Koh Rung Samleom		Ref. 1 & 2

Perciformes	Pomacanthidae	Abudefduf bengalensis	Bengal Sergeant	Koh Rong		Ref 1 & 2
	Pomacentridae	Abudefduf sexfasciatus	Scissortail sergeant	Koh Rung Samleom		Ref 1 & 2
Perciformes	Pomacentridae	Amphiprion perideraion	Pink Anemonefish	Condor Reef		Ref 1 & 2
Perciformes	Pomacentridae	Cheiloprion labiatus	Big-lip damsel	Picture From www.Fishbase.org		Ref 1 & 2
Perciformes	Pomacentridae	Dascyllus reticulatus	Reticulated Dascyllus	Koh Rung Samleom		

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Perciformes	Pomacentridae	Chromis ternatensis	Ternate Chromis	Koh Rong		Ref 1 & 2
Perciformes	Pomacentridae	Pomacentrus simsiang	Blueback Damsel	koh Rong		Ref 1 & 2
Perciformes	Scaridae	Scarus ghobban	Blue-barred parrotfish			Courtesy of FiA Cambodia
Perciformes	Scaridae	Scarus prasiognathos	Greencheeck parrotfish			Courtesy of FiA Cambodia
Scorpaeniformes	Scorpaenidae	Scorpaenopsis Venosa	Raggy Scorpionfish	Koh Rong		Ref 1 & 2
Perciformes	Serranidae	Cephalopholis boenak	Chocolate Grouper	Koh Rung Samleom		Ref 1 & 2

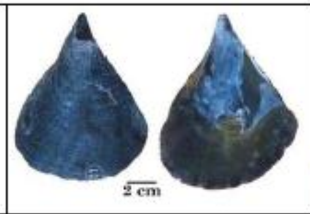
Perciformes	Serranidae	Cephalopholis formosa	Bluelined grouper			Courtesy of FiA Cambodia
Perciformes	Serranidae	Cephalopholis sonnerati	Tomato grouper			Courtesy of FiA Cambodia
Perciformes	Serranidae	Diploprion bifasciatum	Doublebanded Soapfish	Koh Tas		Ref 1 & 2
Perciformes	Serranidae	Epinephelus bleekeri	Duskytail grouper	Koh Rung Samleom		Ref 1 & 2
Perciformes	Serranidae	Epinephelus macrospilos	Snubnose Grouper	Koh Rung Samleom		Ref 1 & 2
Perciformes	Serranidae	Epinephelus merra	Honeycomb Grouper	Koh Rung Samleom		Ref 1 & 2

Perciformes	Serranidae	Epinephelus quoyanus	Longfin grouper	Koh Rung Samleom		Ref 1 & 2
Perciformes	Siganidae	Siganus guttatus	Golden Rabbitfish	Koh Rong		Ref 1 & 2
Perciformes	Siganidae	Siganus javus	Java Rabbitfish	Koh Rong		Ref 1 & 2
Perciformes	Siganidae	Siganus virgatus	Virgate Rabbitfish			Courtesy of FiA Cambodia
Syngnathiformes	Syngnathidae	Hippichthys cyanospilus	Estuary Pipefish			Ref 1 & 2
Echinodermata						

Asteroidea	Oreasteridae	Culcita novaeguineae	Cushion star			
Crinoidea	Comasteridae	Comanthus alternans	White feather star			
Echinoidea	Diadematidae	Astropyga radiata				
Echinoidea	Diadematidae	Diadema savignyi	Savigny's sea urchin			
Echinoidea	Echinometridae	Anthocidaris crissipinina				

Holothuroidea	Holothuriidae	Holothuria leucospilota	Stained sea cucumber			
Holothuroidea	Synaptidae	Euapta godeffroyi	Godeffroy's sea cucumber			
Holothuroidea	Synaptidae	Euapta sp.				
Mollusca						
Veneroida	Tridacnidae	Tridacana gigas	Giant clam			Courtesy of FiA Cambodia
Arcoida	Arcidae	Arca ventricosa				

Ostreoida	Gryphaeidae	Hyotissa hyotis		Giant oxocomb oyster	
Ostreoida	Pectinidae	Pendum spondyloideum		Coral scallop	
Ostreoida	Spondylidae	Spondylus sp.			
Ostreoida	Spondylidae	Spondylus sp.			
Pteroidea	Malleidae	Malleus albus		White hammer oyster	

	Pinnidae	Atrina vexillum	Flag pen shell			Courtesy of FiA Cambodia
Octopoda	Octopodidae	Octopus sp.				Courtesy of FiA Cambodia
Sepiida	Sepiidae	Sepia latimanus	Broadclub cuttlefish			
Patellogastropoda	Nacellidae	Cellana radiata	Indo-pacific limpet			Courtesy of FiA Cambodia
Nudibranchia	Chromodorididae	Chromodoris geometrica	Geometric chromodoris			

Nudibranchia	Discodorididae	Jorunna funebris	Funeral jorunna			
Nudibranchia	Phyllidiidae	Phyllidia pustulosa				
Nudibranchia	Phyllidiidae	Phyllidia sp.				
Archaeogastropoda	Trochidae	Tectus niloticus	Commercial trochus			
Archaeogastropoda	Turbinidae	Turbo brunneus	Burnt turban			

Mesogastropoda	Cassidae	Phalium bisulcatum	Sophia's bonnet			
Mesogastropoda	Cassidae	Phalium glaucum				
Arthropoda						
Decapoda	Portunidae	Portunus pelagicus	Flower crab			
Decapoda	Majidae	Camposcia sp.				
Lepadiformes	Lepadidae	Lepas sp.				
Cnidaria						

					
Antipatharia	Antipathidae	Antipathes sp.			
Alcyonacea	Ellisellidae	Ellisella sp.			
Alcyonacea	Ellisellidae	Ellisella sp.			
Alcyonacea	Alcyoniidae	Sarcophyton sp.			

Scleractinia	Acroporidae	Acropora sp.			
Scleractinia	Acroporidae	Acropora sp.			
Scleractinia	Caryophyllidae	Euphyllia sp.			
Scleractinia	Caryophyllidae	Euphyllia sp.			
Scleractinia	Caryophyllidae	Euphyllia sp.			

					
Scleractinia	Dendrophylliidae	Turbinaria peltata			
Scleractinia	Dendrophylliidae	Turbinaria sp.			
Scleractinia	Dendrophylliidae	Turbinaria sp.			
Scleractinia	Dendrophylliidae	Turbinaria sp.			
Scleractinia	Euphyllidae	Physogyra sp.			

					
Physogyra sp.	Physogyra sp.	Echinopora sp.	Favia sp.	Goniastrea sp.	
Euphyllidae	Euphyllidae	Faviidae	Faviidae	Faviidae	
Scleractinia	Scleractinia	Scleractinia	Scleractinia	Scleractinia	

Scleractinia	Fungiidae	Fungia moluccensis				
Scleractinia	Fungiidae	Fungia sp.				
Scleractinia	Fungiidae	Fungia sp.				
Scleractinia	Fungiidae	Herpolitha limax				
Scleractinia	Mussidae	Lobophyllia corymbosa				

Scleractinia	Mussidae	Mussidae sp.			
Scleractinia	Pectiniidae	Echinophyllia sp.			
Scleractinia	Poritidae	Alveopora sp.			
Scleractinia	Poritidae	Goniopora sp.			
Scleractinia	Poritidae	Goniopora sp.			

Scleractinia	Poritidae	Porites sp.				
Scleractinia	Poritidae	Porites sp.				
Scleractinia	Poritidae	Porites sp.				
Zoantharia						

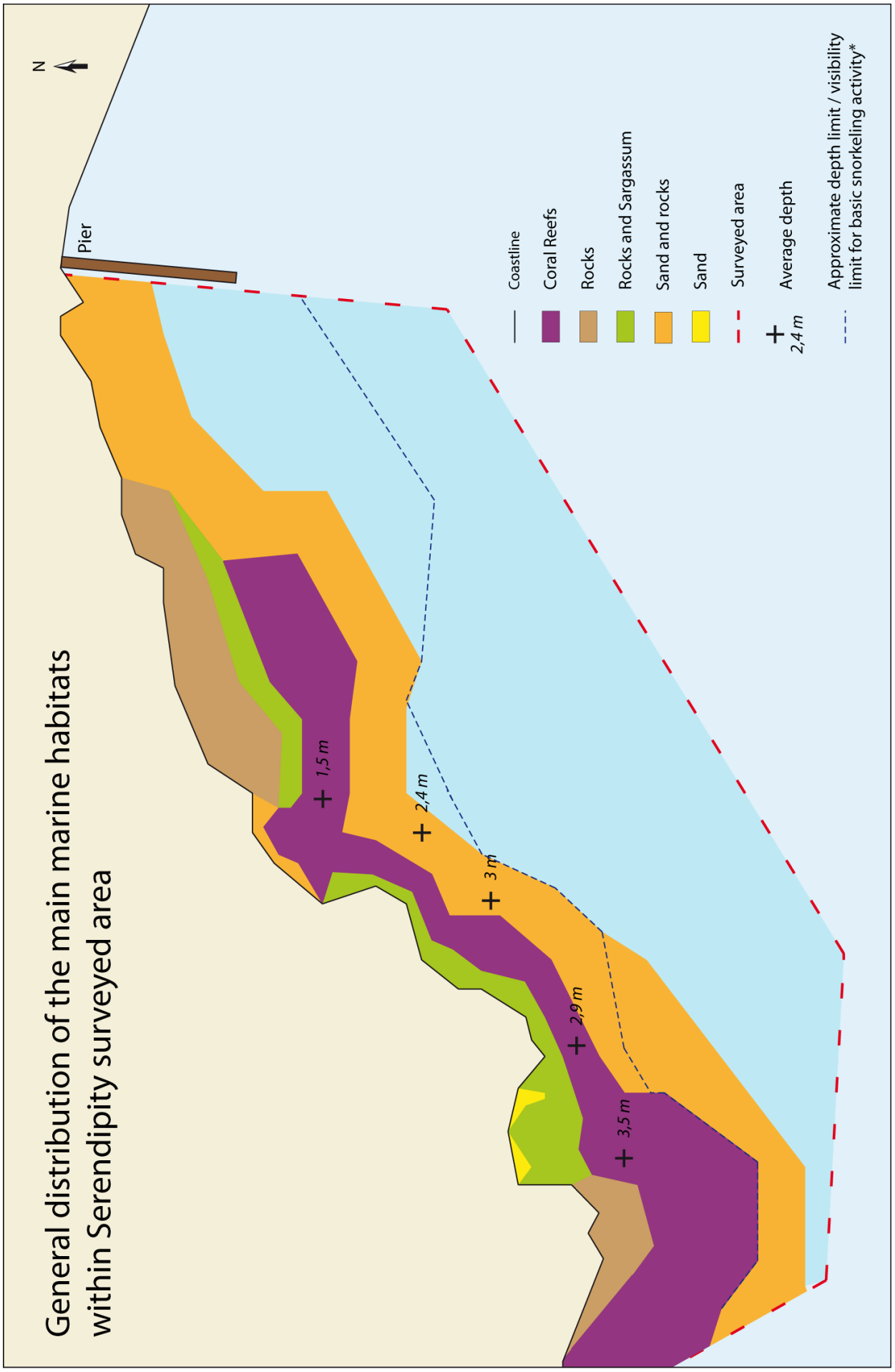
Zoantharia						

Reference 1: Reef Fish Identification Tropical Pacific "Gerald Allen, Roger Steene, Paul Humann & Ned Deloach
Reference 2: World Atals of Marine Fishes "Rudie H Kuiter & Helmut Debelius
Reference 3: Field Guide to the Marine Living Resources in Cambodia "FIA"

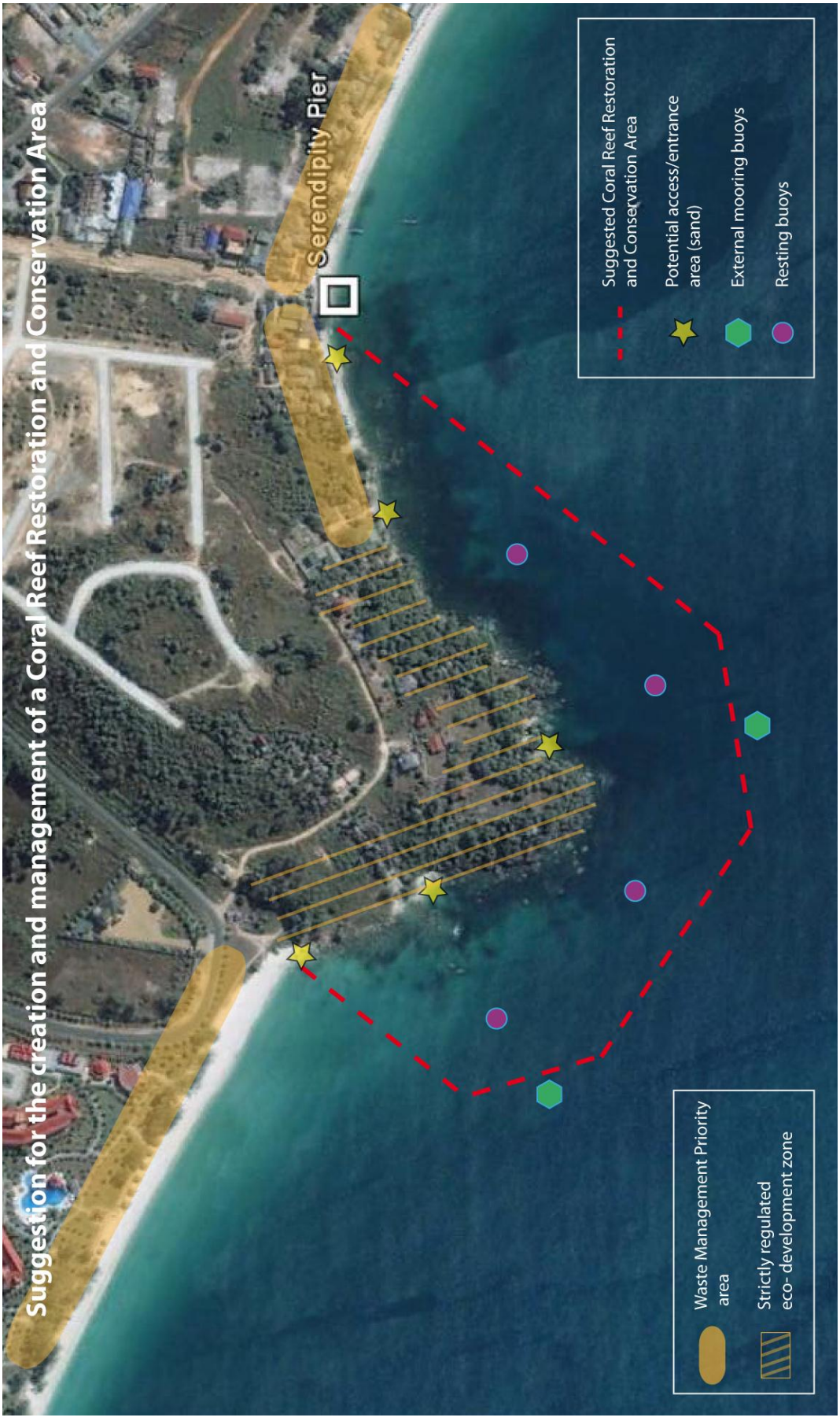
Annex 2 – Sketch map of habitat distribution in the surveyed area

Note: In a context of increasing demand for eco-tourism, overcrowding of the area should be anticipated and regulated. Here, the suggested Protected Area is relatively small; yet, coral reefs have been observed outside of this area, following the coastline. Thus, the protected area could be easily extended westwards in order to create a decent-sized marine eco-tourism zone and increase its capacity of charge (**Annex 3**).

* «Basic snorkeling activity» refers to an average depth limit of 5 meters which most inexperienced and/ or occasional snorkelers will not go past. This definition also takes into account the visibility factor as it has been observed that the visibility was poor once past an average of 4 meters depth. However, this tendency should be verified according to the tides and current weather on site and might be reduced by restricting trawling activities operating near the area.


General distribution of the main marine habitats
within Serendipity surveyed area
N
Pier
Coastline
Coral Reefs
Rocks
Rocks and Sargassum
Sand and rocks
Sand
Surveyed area
Average depth
Approximate depth limit / visibility
limit for basic snorkeling activity*
1,5 m
2,4 m
3 m
2,9 m
3,5 m
2,4 m

Annex 3 – Suggestion for the creation and management of a Coral Reef Rehabilitation and Conservation area



Annex 4 - Examples of Code of Conduct taken from Dominican Republic and Turks & Caicos Islands.

BUENAS PRACTICAS AMBIENTALES

SNORKELING

Los arrecifes de coral están entre los ecosistemas mas espectaculares del mundo, y el snorkeling es una excelente forma de explorarlos. A medida que los arrecifes de coral enfrentan un futuro cada vez mas incierto, las personas que practican snorkeling y otros visitantes en los arrecifes de coral pueden jugar un papel muy importante en la protección de estos frágiles ecosistemas. Sigue estas simples recomendaciones y te convertirás en un snorkeler "amigable de los corales".

ANTES DE DISPONERTE A EXPLORAR LOS ARRECIFES

- Para tus vacaciones, escoge un hotel o resort ambientalmente amigable; uno que practique la conservación de energía, que recicle, y que trate las aguas negras y desechos sólidos en forma responsable.
- Paga cuotas de usuario o haz una donación cuando visites parques coralinos y otras áreas de conservación marina.
- Asiste a los mejores cursos de snorkeling que puedas tomar.
- Practica tus destrezas para hacer snorkel lejos del arrecife.
- Asegúrate de que tu equipo se ajusta apropiadamente a tu cuerpo antes de que salgas a hacer snorkeling cerca de los corales, ya que puede ser muy difícil de ajustarlo dentro del agua.
- Si no te sientes seguro o eres un snorkeler sin experiencia, considera utilizar un chaleco para snorkeler y de esa forma mejorar tu flotabilidad.
- Aprende todo lo que puedas acerca de los arrecifes de coral; son ambientes fascinantes y frágiles.

EN EL AGUA

- Nunca toques los corales; aun el contacto mas leve puede dañarlos, y también algunos corales pueden causarte heridas.
- Selecciona cuidadosamente los puntos de entrada y salida para evitar dañar a áreas de arrecife de coral.
- Mantén una distancia cómoda al arrecife de coral.
- Sabe donde están tus aletas todo el tiempo y procura no levantar arena.
- Mantente horizontal mientras estas cerca o sobre el arrecife de coral.
- Aprende a nadar sin usar tus brazos.
- Muévete lenta y deliberadamente dentro del agua. Relájate mientras nadas y toma tu tiempo.
- Recuerda: ¡Mira y no toques!

El Snorkeling de manera amistosa ayudara a proteger directamente a los arrecifes coralinos y a promover la concientizacion sobre los mismos.

Asegúrese de informarse localmente de las normas y legislaciones ya que pueden diferir de estas medidas generales.

SNORKELING

Simply the best in the world and it's conveniently located directly in front of the resort on the Bight Reef in Princess Alexandra National Park.

Just step off the pristine white powder beach into a warm, clear, turquoise heaven. Your senses will be overcome with a rainbow of colors. You will see many species of tropical fish and coral, sea turtles, dolphins, crabs, lobsters, eels, manta rays and more.

Please help us to preserve this irreplaceable National Treasure by following these simple rules of reef preservation:

1. Corals are living animals. Avoid kicking up sand on them. Please do not touch, stand on or break off coral. They will die!

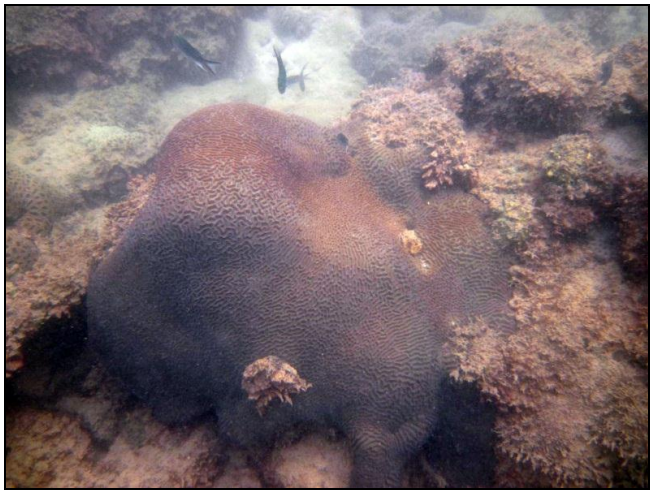
2. Please do not take anything out of the water. The smallest shell can be home for a tiny sea creature.

3. Please do not feed the fish. Artificial food can kill fish and upset the reef ecosystem.

4. Please remain outside the roped buoy area and enjoy the snorkel trail placed around the perimeter of the reef by the National Trust.

Please note that National Parks Service wardens patrol the reef. They have the power to fine or arrest you should you not follow regulations.

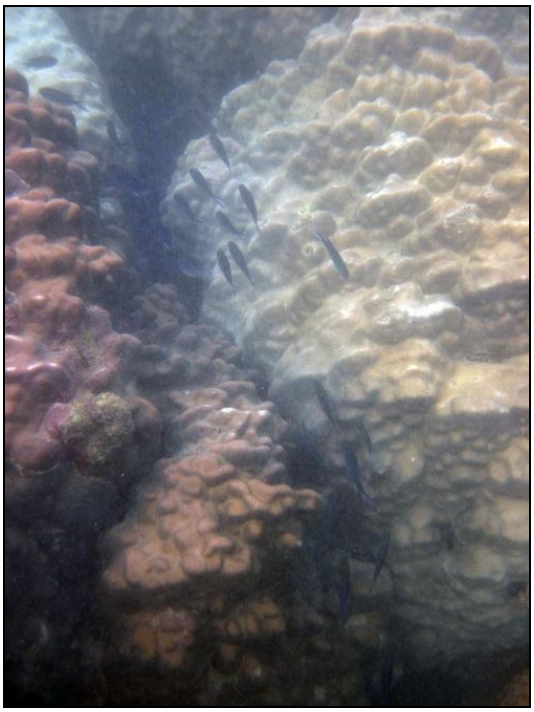
Annex 5 – Selected pictures from January 19th surveys



Faviidae

Porites sp.

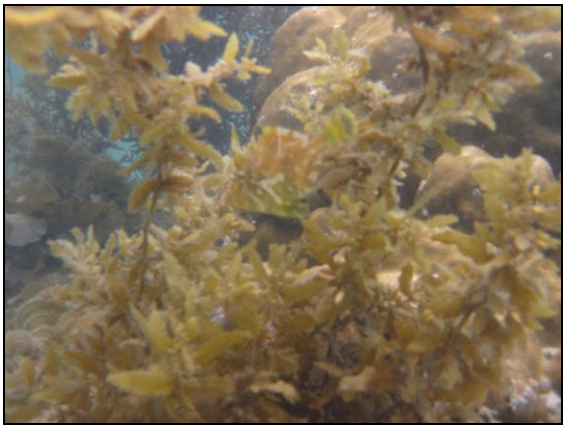
Echinophyllia sp.



Porites sp.

Favites sp, *Euphyllia sp*.

Algie

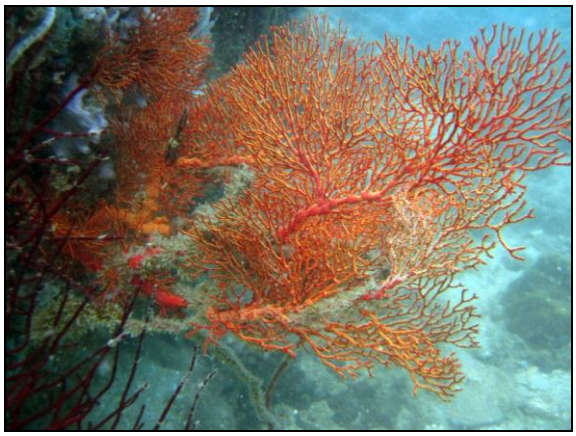


Sargassum sp.

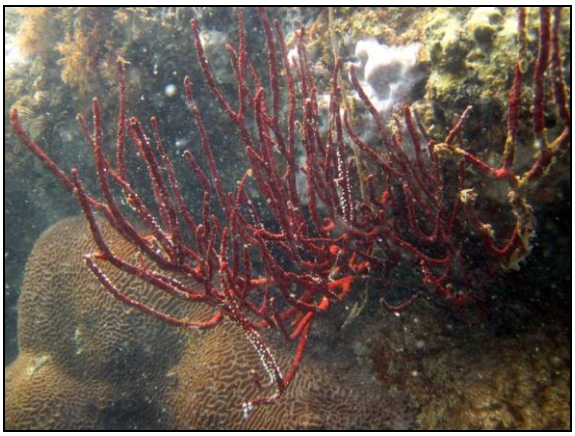
Sabellidae sp. (Tube Worm)

Xestospongia sp. (Barrel Sponge)

Turbinaria decurrens



Sea Fan



Ellisella sp;

Turbinnaria sp. behind algie

Padina sp.