Marine Biodiversity Assessment

Kampot, Cambodia

Baseline Survey of Seagrass Beds, Coral Reefs and Dolphins

September 2020

Executive Summary

Important tropical ecosystems in Kampot province are highly threatened by coastal and industrial developments as well as illegal fishing pressures, which destroy habitat and overexploit marine species. In November 2019, Wild Earth Allies (WEA; Cambodia), cooperated with the Conservation Department of the Cambodian Fisheries Administration (FiA), Fishery Administration Cantonment (FiAC), Marine Conservation Cambodia (MCC) and Prek Thnot Community Fishery to conduct baseline ecological assessments to survey an area threatened by industrial development, land reclamation and illegal fishing. Ecological surveys in the form of seagrass, coral and marine mammal assessments were conducted within a proposed Marine Fisheries Management Area (MFMA) in Kampot province. Specifically, assessments were undertaken in proposed permanent and seasonal no-take zones in Prek Thnot and Trapaing Ropov community fishery areas within the broader MFMA. The purpose of the assessments was to contribute towards forming baseline datasets on the distribution and composition of seagrass and coral reef habitats, and to formally acknowledge marine mammal presence in the province. These baselines form the foundation of preliminary ecological assessments within the area and have established a benchmark for conducting periodic biodiversity monitoring in Kampot's proposed MFMA. Following this initial report by WEA and MCC on the state of seagrass and coral reef ecosystems in the MFMA, a conservation strategy is being developed and should be implemented soon. The strategy involves the creation of an 8,486-hectare MFMA, in combination with the deployment of artificial reef structures, the use of community management techniques and the enforcement of fisheries regulations. The overall goal of this conservation strategy is to reduce illegal fishing activities, protect and encourage the regeneration of marine life, and ensure the sustainability of local fisher livelihoods and their communities.

The establishment of the MFMA, in combination with other conservation tools, is expected to create the foundations required for the recovery and regeneration of degraded marine ecosystems in Kampot. This conservation strategy provides mitigation against a multitude of threats and will effectively reduce the habitat destruction caused by illegal bottom trawling and other major anthropogenic stressors. The proposed conservation strategy has been designed to protect entire ecosystems and their services by including ecosystem-based management techniques that will provide wider environmental, social and economic benefits to the region. Subsequent monitoring and research will be conducted by MCC, WEA, FiA, and FiAC inside the Kampot MFMA in order to assess the effectiveness of conservation efforts over time.

Acknowledgements

Wild Earth Allies Cambodia and Marine Conservation Cambodia would like to acknowledge the Conservation Department of the Fisheries Administration, Fisheries Administration Cantonment in Kampot province and Prek Thnot Community Fishery for their help in undertaking this survey and for their dedication to protecting Cambodia's marine environment for the benefit of wildlife, habitats and people.

Special thanks to the following people:
H.E. Eng Cheasan, Director General of the Fisheries Administration
H.E. Pil Kosal, Deputy of Governor, Kampot province
Mr. Ouk Vibol, Director of Conservation Department of Fisheries Administration
Mr. Chan Rith, Director of Department of Agriculture, Fishery and Forestry, Kampot province
Mr. Sar Sorin, Director of Fisheries Administration Cantonment, Kampot province

Research Team

Survey Data Collection Team:

Fisheries Administration:

Mrs. Sok Sota and Ouk Sam Orl

Wild Earth Allies (WEA):

Miss Kelly Hogan and Miss Leng Phalla

Marine Conservation Cambodia

Mr. Amick Haissoune, Miss. Lucy Coals, Miss. Amy Jones, Miss Alissa Boehm, Miss Sarah Tubbs, Mr. Tanguy Freneat, Miss Delphine Duplain, Miss Evie Croxford, Miss Henriette Loose and Miss Anna Charnock.

Prek Thnot Community Fishery

Mr. Ouk Sovanrith

Mr. Moe Chouch

Report by:

WEA and MCC

Edited by:

Kelly Hogan and Leng Phalla

Contributors to the Report:

Authors**:** Lucy Coals, Amy Jones, Amick Haissoune and Alex Reid

TABLE OF CONTENTS

1. Introduction

1.1. Introduction: The Marine Environment

Cambodia's 435-km coastline harbours coral reef, seagrass, and mangrove habitats that are rich in biodiversity and include threatened wildlife and species of economic importance (Kim et al., 2004). Marine and inland fisheries are important economic contributors to the domestic market in Cambodia and provide approximately 80% of animal protein to the population. The industry is crucial for the food security and income of the country's poorest people (MAFF, 2011). It has been reported that marine fisheries land an average of 120,500 tonnes of commercial catch per annum, accounting for 20% of total fisheries production (PIC, 2017).

The marine environment in Kampot province is particularly valuable, comprising one-third of Cambodia's coral reefs (Rizvi and Singer, 2011) and the largest seagrass meadows along mainland Southeast Asia (Mangroves for the Future, 2013). In Kampot, coral reefs, seagrass meadows and bivalve beds occupy much of the shallow seafloor (Huang *et al*., 2015). The area once contained large mangrove forests that contributed 9% of Cambodia's mangroves. However, significant deforestation has reduced the extent of these forests throughout the region (Rizvi and Singer, 2011). The coastal region of Kampot also hosts important megafauna that are threatened with extinction, including the green sea turtle (*Chelonia mydas;* Pilcher, 2006), Irrawaddy dolphin (*Orcaella brevirostris*) and dugong (*Dugong dugon*; Tubbs *et al*., 2019).

Coastal marine ecosystems support social, economic and ecological processes and provide myriad ecosystem services. Seagrasses play important ecological roles in coastal ecosystem networks by cycling carbon, phosphorus and nitrogen; helping to regulate water quality; and creating habitat (Unsworth *et al*., 2008; Nordlund *et al*., 2017). They are also important to wider ecosystem connectiveness and support coastal food webs, productivity and biodiversity (Unsworth and Cullen, 2010; Sigman and Hain, 2012; Nordlund *et al*., 2017). Likewise, bivalve beds perform important roles in regulating water quality as shellfish filter nutrients, sediment and phytoplankton from the water column (Coen *et al*., 2007; Ostroumov, 2005; Grabowski and Peterson, 2007). Management of water quality is most effective when bivalve biomass is high and water depth is shallow, such as the water depth in the Kampot (Grabowski and Peterson, 2007).

Mangrove forests act as important nurseries for coral reef and seagrass-dwelling fish species, helping to increase fish abundance and diversity on coral reefs and seagrass meadows (Lee *et al*., 2014). Mangroves can also improve the likelihood of coral reef recovery following disturbance (Unsworth *et al*., 2008; Olds *et al*., 2013). Habitat connectivity between mangroves, corals and seagrasses improves fish nursery function by increasing availability of shelter and food provision

(Unsworth *et al*., 2008). Intact mangrove forests and seagrass meadows also protect coastlines from natural hazards like storms and erosion. Therefore, protecting and expanding connectivity between marine habitats is essential for supporting productive fisheries and resilient coastlines.

Kampot's marine habitats have become increasingly exploited and degraded by illegal fishing and incompatible coastal development, threatening ecosystem function, coastal resilience and fisheries. To mitigate against these threats, we now have an opportunity to establish an 8,486-hectare Marine Fisheries Management Area (MFMA) in Kampot Province (Figure 1). This report details the current state of seagrass and coral reef ecosystems in proposed permanent and seasonal 'no-take' zones and confirms presence of dolphins within the MFMA.

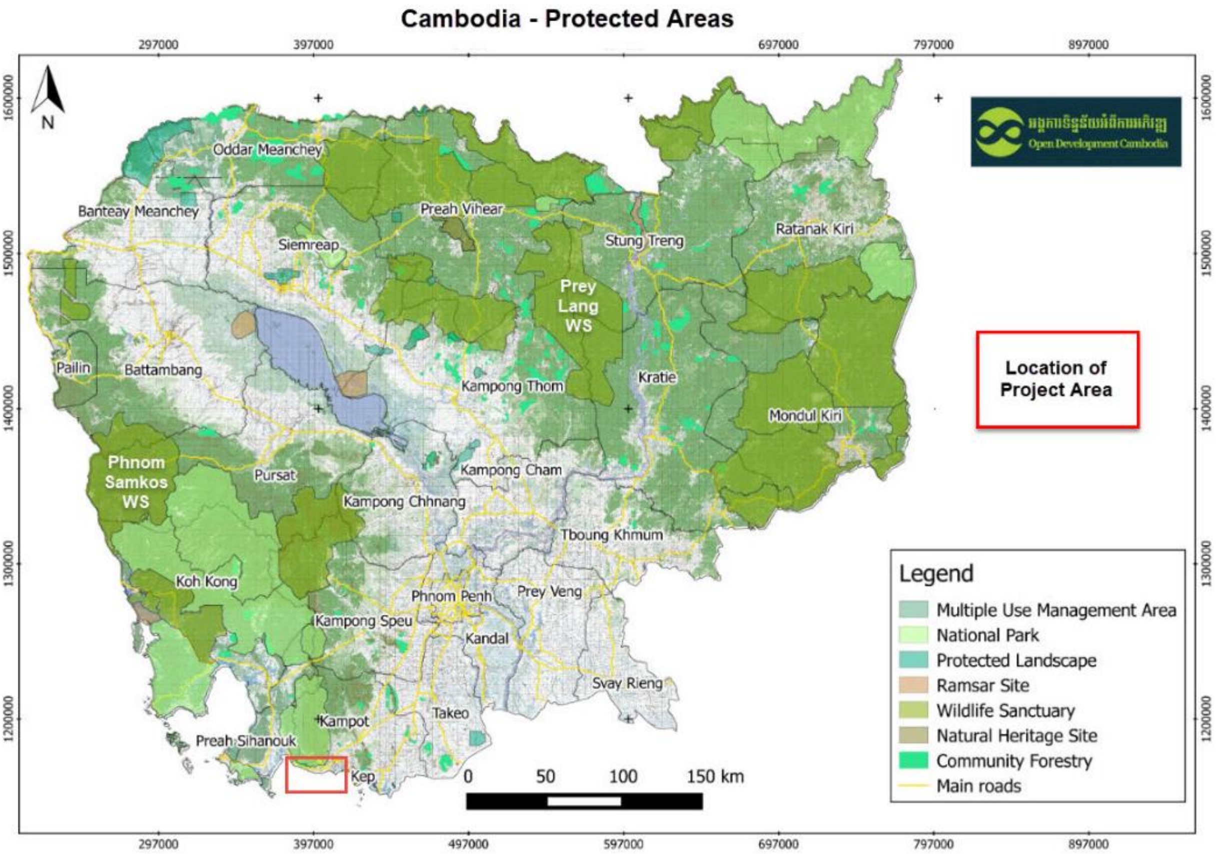

Figure 1. Location of the proposed Marine Fisheries Management Area in the Kampot Province (denoted by red box), relative to mainland Cambodia. (Figure modified from Open Development Cambodia)

1.2. Introduction: Fisheries and the Economy

Due to Illegal, Unreported and Unregulated (IUU) fishing – particularly electric bottom trawling - Kampot's seagrass meadows and coastal marine habitats have seen substantial degradation. Further, the proportion of fishing activity reported is likely underestimated as it is difficult to account for all small-scale fishers and larger foreign vessels operating illegally in Cambodian waters. In Kampot, marine fisheries provide livelihoods for much of the population, and fishers largely target seagrass-associated species such as shrimp, fish and the world-renowned blue swimming crab (PIC, 2017). Fishing and collecting valuable marine life on coral reefs is also commonly practiced. Moreover, marine ecosystems contribute to the economy through tourism, although in Kampot, this industry has not yet been fully developed.

Acknowledging the importance of these critical marine habitats and the services they provide, and highlighting the imminent threats of coastal development and land reclamation near such vulnerable marine ecosystems, the Cambodian Fisheries Administration (FiA), Kampot Fisheries Cantonment (FiAC), Wild Earth Allies (WEA) and Marine Conservation Cambodia (MCC) conducted an ecological assessment, focused on three key methods: seagrass point surveys, coral transects and marine mammal observations. The environmental assessment of seagrass, coral reef and marine mammals was conducted in Kampot Province, Cambodia.

Baseline data were collected by WEA and MCC, as part of an ongoing research and monitoring programme between the FiA, FiAC, WEA and MCC. Baseline data will be used to monitor ecosystem changes over time and to assess the effectiveness of conservation efforts and good management practices in the region. This initiative by WEA and MCC is the only research contributing towards assessing Kampot's marine biodiversity and is critical for managing Cambodia's marine environment.

1.3. Introduction: Threats to Marine Ecosystems

Important drivers behind changing tropical ecosystems (excluding climate change) have been attributed globally to human activities related to agricultural land-use, coastal development and overfishing (Mora, 2008; Wear, 2016). Currently, the proposed Kampot MFMA faces increasing pressures from IUU fishing and coastal industrial development in the form of an industrial port, land reclamation and dredging. As a result, important coastal habitats and the species they support are threatened.

Seagrass meadows and coral reefs are impacted through both direct and indirect effects of industrial development and land reclamation. Direct impacts from machine damage and construction in the coastal zone, as well as eutrophication and siltation are major sources of habitat disturbance. Land reclamation and dredging pose substantial threat to seagrass meadows through direct destruction and reductions in water transparency, reducing photosynthesising capacity (Duarte, 2002). Likewise, coral reefs downstream of land disturbance are often degraded and affected by disease, low larval recruitment and survival, low rates of calcification and photosynthesis, and mortality from hypoxia, tissue degradation, and macroalgal competition (Fabricius, 2005; Weber *et al*., 2012; Amato *et al*., 2016).

Industrial development and the resulting increase in marine traffic has been shown to elicit negative behavioural and direction responses in cetaceans, particularly in dolphin species, deterring them from critical habitats and potentially reducing the presence and health of resident populations (Ng and Leung, 2003; Huntington, 2009; Bas *et al.,* 2014; Jiang *et al.,* 2019). Increased marine traffic and noise pollution caused by industrial development has also been seen to directly correlate with an increase in marine mammal strandings (Weilgart, 2007; Wiley *et al.,* 1995), further threatening species such as the endangered Irrawaddy dolphin (*Orcaella brevirotris)*.

IUU fishing can substantially reduce ecosystem functioning (McClanahan *et al*., 2011; Edwards *et al*., 2014; Pratchett *et al*., 2014) and is one of the most immediate threats to marine ecosystems in Cambodia (Teh *et al.*, 2017). In the Kampot region, unsustainable, destructive fishing methods, such as bottom trawling (including electric trawling and pair trawling), seine netting and air-tube diving occur daily, despite fisheries laws prohibiting such practices (see Appendix A). Endangered species such as seahorses, green and hawksbill turtles, Irrawaddy dolphin, dugong and whale sharks are caught as bycatch. The IUU pressure, with a bycatch rate of over 80%, has changed the structure of the marine community, resulted in habitat destruction, over-sedimentation, and the disappearance of multiple species. Financial incomes in coastal communities have been severely impacted, where small-scale fishers currently catch less than 4% high-value fish and regularly lose fishing gear to illegal trawling.

1.4. Introduction: Conservation

Efforts have been made by Kampot's local fishers to establish "community fisheries" that adhere to agreed-upon fishing regulations to conserve marine resources (Kurien, 2017). These community fisheries (CFis) are a national initiative under the jurisdiction of the Cambodian Ministry of Agriculture, Forestry and Fisheries (MAFF) and have been an important first step towards improved conservation and management of Kampot's marine environment. However, it is the larger scale illegal fishing industry and the rate of coastal development that has had the greatest impact on Kampot's marine ecosystems, which have become increasingly exploited and degraded. In particular, a new proposal for a large-scale land reclamation project threatens wildlife, ecosystem function and the livelihoods of about 3,000 families.

The Fisheries Administration (FiA) Director of Conservation Department, Mr. Ouk Vibol, invited WEA to collaborate to design and implement a Marine Fisheries Management Area (MFMA) to mitigate against illegal fishing and unsustainable coastal development. In collaboration with provincial FiAC colleagues and three CFis (Tropaing Ropov, Prek Thnot and Chong Hourn), WEA proposed zoning for an 8,486ha MFMA, which will include protected no-take zones around coral reefs, seagrass meadows, bivalve beds and mangroves. A detailed representation of proposed zoning within the MFMA can be seen in Figure 2. In combination with this conservation strategy, WEA will work with Kampot's CFis to establish routine community-led patrols to monitor the MFMA in collaboration with government colleagues in the FiA, FiAC, and Navy. Community patrollers will report infractions to the Marine Fisheries Administration Inspectorate in the FiAC so they can respond quickly. CFi community patrollers may also request assistance from the Navy as needed. Additionally, WEA and MCC will deploy multipurpose artificial reefs throughout the proposed MFMA. These multipurpose structures are designed to deter illegal fishers by obstructing their activities and damaging illegal trawling gear, while also attracting marine life, and subsequently enhancing water filtration through the colonization of bivalves. It is envisioned that in the future the bivalves may be sustainably harvested by local fishers. These deployed structures have yielded positive results in the Kep MFMA by successfully reducing illegal trawling, providing habitat for marine life and promoting seagrass regrowth.

The proposed MFMA will safeguard marine ecosystems and their functions, including critical habitats and the species that live there. It is expected that this conservation strategy will help support the restoration of fish populations and fisheries, and over time we will begin to demonstrate increases in size and abundance of target species, which has been an outcome in other geographical areas where similar strategies have been applied (Brown *et al*., 2014). The MFMA will be largely managed by local fishers, with the help of WEA, MCC and local authorities in the FiAC. For effective management, regulations must be enforced by the FiA and FiAC. The effectiveness of this conservation strategy will be monitored over time in order to determine the long-term impact of implementation.

The proposed MFMA will work towards achieving Sustainable Development Goals (SDGs) by ensuring food security by protecting the artisanal fishing livelihoods of at least 3,000 families within the community fisheries. Implementation of the national commitments stated in the Cambodian Strategic Planning Framework for Fisheries 2015-2024 *to conserve at least 10% of coastal and marine areas* (Aichi target 11) will integrate ecosystem and biodiversity values into national and local planning. These goals will align with Cambodia's commitments to: Convention on International Trade of Endangered Species (CITES) and the Regional Plan of Action to Promote Responsible Fishing Practices (RPOA) of the South East Asian Fisheries Development Center (SEAFDEC).

Furthermore, implementation of Cambodia's Environmental and Natural Resources Code, at a local level, will facilitate *reducing overfishing and destructive fishing* [Chapter 3, Article 8, Clause (c)], whilst, *improving connectivity between critical habitats including mangroves, seagrasses and coral reef*s [Chapter 3, Article 7, Clause (c)]. Effective enforcement of the Cambodian legislations outlined here, will ensure sustainable resource use, provisioning and conservation of important marine ecosystems. Therefore, goals also align with the FAO Agreement on Port State Measures (PSMA) to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated (IUU) fishing, which the Kingdom of Cambodia signed earlier this year.

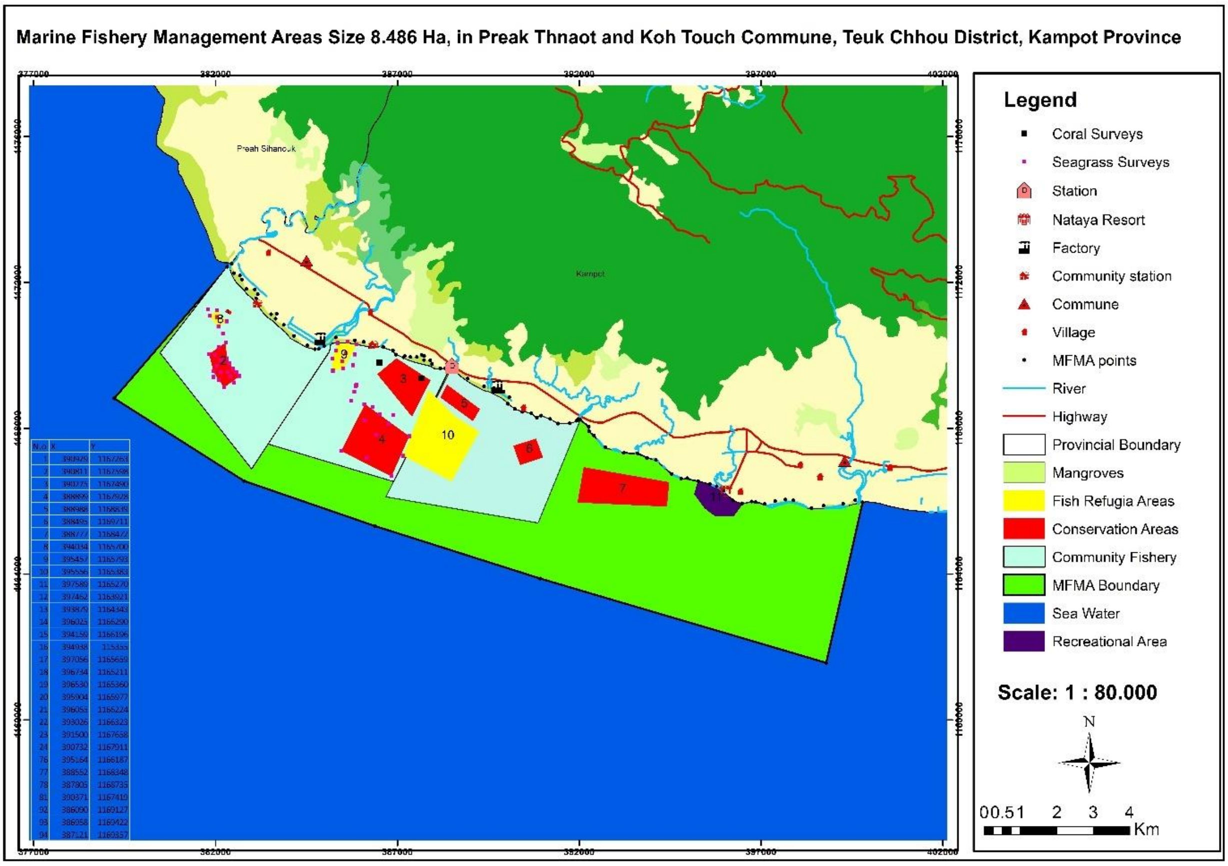

Figure 2. Proposed Marine Fisheries Management Area (MFMA) zoning, with green denoting the broader MFMA boundary, blue denoting Community Fisheries, red denoting Conservation Areas (permanent no-take zones), yellow denoting Refugia Areas (seasonal no-take zones), and purple denoting Recreational Areas for the nascent ecotourism industry. This study focused survey efforts in Conservation and Refugia areas labelled 2, 3, 4, 6 and 9. Black squares denote specific coral survey locations and pink squares denote specific seagrass survey locations.

1.5. Study Goal and Objectives

The overall goal of this study was to assess the baseline status of corals and seagrasses and record the presence of marine mammals within the proposed Marine Fisheries Management Area (MFMA) along Kampot's coastline. The following objectives address this goal: (1) assess the extent and distribution of seagrass meadows in proposed conservation zones and existing refugia areas within the proposed MFMA, (2) assess the extent and distribution of coral reefs in proposed conservation zones within the proposed MFMA, and (3) survey and record marine mammal presence within the proposed MFMA through the use of visual and acoustic observations. Taken together, these data can help inform regional marine management strategies and ensure the conservation and protection of critical marine species and habitats. Specific survey locations can be seen in Figure 2.

1.5.1. Seagrass

Background

Seagrass ecosystems are largely underrepresented in marine management, with other habitats receiving priority in conservation strategies (Unsworth *et al*., 2018). In Kampot, the implementation of community fishery areas (CFis) acknowledge the value of seagrass habitats for biodiversity protection and food security. However, knowledge of the extent and species composition of seagrass beyond these areas is limited. In order to provide tailored management to conserve seagrass in the proposed Kampot MFMA, baseline assessments of seagrass need to be undertaken.

Objective 1

This objective aimed to assess the extent of seagrass meadows in proposed conservation zones along Kampot's coastline, in order to inform regional marine management strategies. Surveys aimed to record seagrass distribution, coverage and species composition within proposed conservation zones and existing refugia areas. This study aimed to contribute to better understanding seagrass habitats, valuable for fishing and ecological purposes, and the threat posed to the local marine environment from industrial development.

1.5.2. Coral reefs

Background

Coral reefs cover less than 0.2% of the ocean and are among the most diverse and productive ecosystems in the world (Knowlton *et al*., 2010; Hoegh-Guldberg, 2011). They provide important services to approximately 500 million people, globally, as well as to surrounding seagrass, bivalve and mangrove ecosystems (Hoegh-Guldberg, 2011; Davis *et al*., 2014; Mumby and Hastings, 2008; Olds *et al*., 2013). According to a threat index used by Rizvi and Singer (2011), 90% of coral reefs in Cambodia are classified as being at high risk, while the remaining 10% are classified as being at very high risk. Strong protection and management efforts need to be undertaken to avoid their disappearance in the near future. The absence of recent information regarding the extent, health and diversity of the coral reefs in Kampot province needs to be addressed in order to maximise the conservation and management initiatives.

Objective 2

This objective aimed to assess the extent and health of the coral reefs inside the proposed Kampot MFMA to help tailor suitable management policies. This study will serve as a baseline for subsequent monitoring surveys inside the Kampot MFMA in order to track ecosystem changes and to assess the effectiveness of conservation efforts.

1.5.3. Marine mammals

Background

To date, three cetacean species have been confirmed within Cambodia's coastal waters, Irrawaddy dolphins (*Orcaella brevirostris*) (Beasley and Davidson, 2007; Tubbs *et al.* 2019), Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) (Beasley and Davidson, 2007) and Indo-Pacific humpback dolphin (*Sousa chinensis*) (Beasley and Davidson, 2007). Prior to this survey effort, literature regarding the knowledge of marine mammal presence in Kampot has been minimal, due to unfavourable environmental conditions and limited survey effort. Fishers have speculated on the sightings and decline in marine mammal presence. However, no study to date has recorded or published data regarding their presence, distribution and population abundance trends in Kampot. On a boat-based survey effort, spanning the Cambodian coastline, Beasley and Davidson (2007) conducted 4 days (totalling 3.4 hours) of observations through the Kep and Kampot region in 2001; however, no marine mammals were sighted. This absence of sightings was attributed to poor environmental conditions, restricting the survey effort.

Objective 3

This objective aimed to establish and record marine mammal presence through visual and acoustic observations to ensure the conservation and protection of critical marine mammal habitats. Furthermore, understanding of regional marine mammal populations can contribute to the application of nation-wide marine mammal legislation and targeted protection.

2. Methods

Study Area

The proposed area designated for the Kampot MFMA spans 18-km along the Kampot coastline. Proposed zones within the MFMA dictated the study areas for seagrass, coral and marine mammal surveys to be conducted between 1st and 3rd November 2019 (Figure 3).

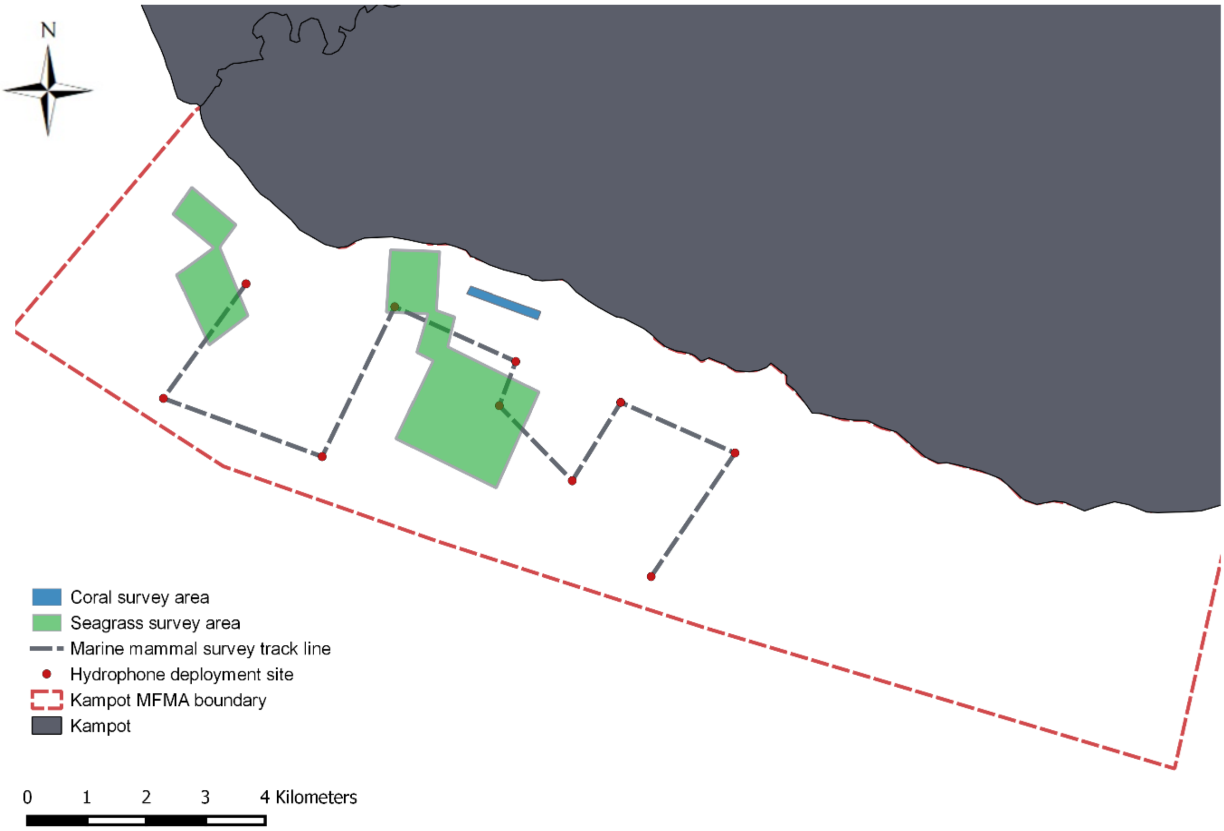

Figure 3. Kampot MFMA boundary highlighted by the red dashed line. This area included the survey sites for seagrass (green), coral (blue) and marine mammal (grey) exploration.

2.1. Seagrass Methods

2.1.1. Study area

The assigned area for assessment was a 7-km stretch of the Kampot coastline, located between N10.55285713 E103.96606 and N10.59375198 E103.91908. Within this area, four sites were split into two zones: conservation zones and refugia areas. Conservation zones have been selected by local communities as valuable fishing sites and identified as dolphin and fish hotspots. Conservation zones are areas with a depth more than 1.5m. Refugia zones (Figure 4) are located close to shore, in shallow waters between 0.5m and 2.5m, protected by concrete poles, which originally demarcated the community fishing areas (CFis). They offer refuge to fish and invertebrate species and support subtidal seagrass habitats by managing fishing activities through the creation of rotational no-take zones. The entire 7-km stretch has been encompassed within the proposed MFMA management plan for conservation of valuable habitat and species. Three rivers flow into the coastal waters of the study site around Kampot province. This shallow, coastal region is currently under pressure from industrial development and land reclamation, which already encroach on this marine conservation area. Regional pressure from trawling vessels on coastal ecosystems is also prevalent in Kampot province (Böhm, *pers. comms*., 2019).

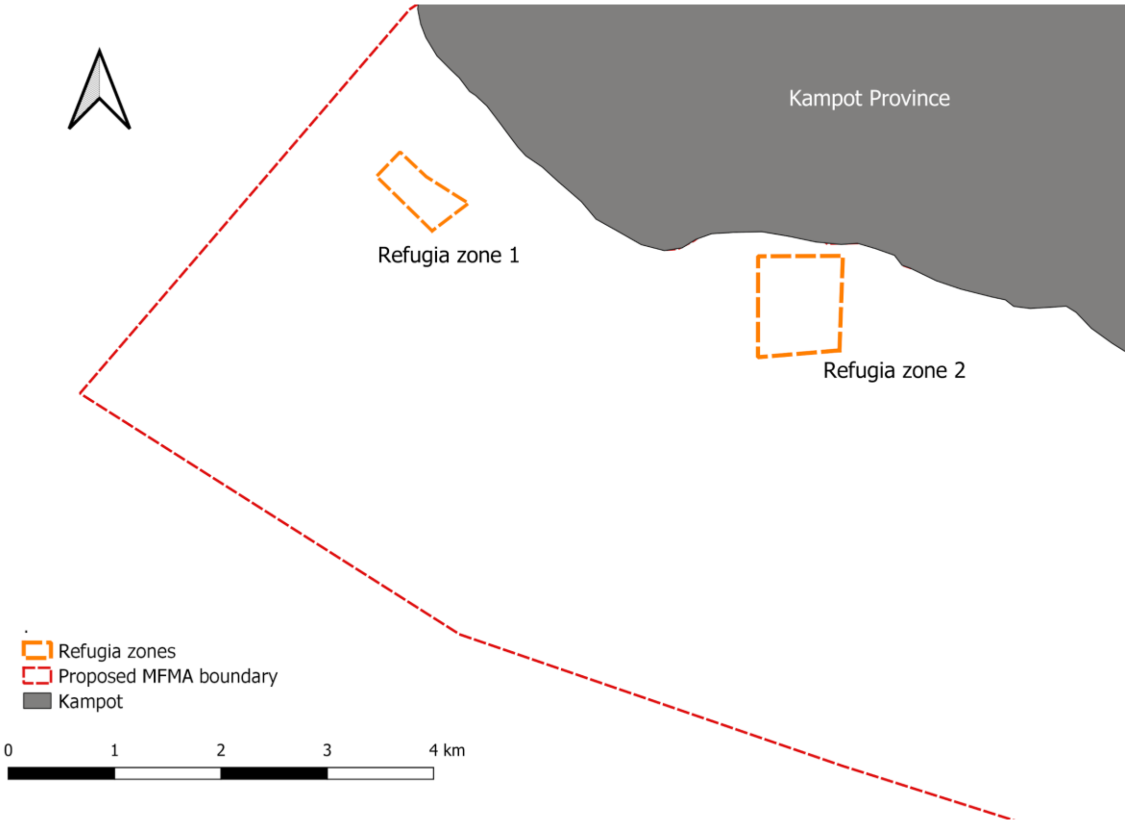

Figure 4. Seagrass surveys were conducted within Refugia zones 1 and 2 located within the proposed Kampot MFMA.

2.1.2. Survey methods

A team of two MCC surveyors, instructed by WEA Senior Marine Biologist, Phalla Leng, conducted 54 point-surveys across four sites. These assessments were conducted between the 1st and 3rd November 2019. The four sites included two conservation and two refugia zones (Figure 3). Additional points were surveyed between areas to better understand the ecosystems between these designated management zones, to assess potential habitat corridors. At each site, quadrated point-check surveys were undertaken to sample seagrass abundance and species composition.

Random sampling across sites was undertaken by free-diving from a fishing boat (5m) with an outboard engine (longtail). GPS points were generated across the study sites. Point locations were taken at intervals up to 500m apart and covered the extent of the conservation and refugia areas (methodology per Mckenzie *et al.,* 2003). Additional point checks were randomly sampled between sites to survey areas which fell outside direct management zones, to better understand seascape connectivity.

At each point, two 0.5m^2 quadrats were thrown randomly (Figure 5). In each quadrat biotic and abiotic factors were recorded. Time, depth, and substrate type were also recorded at each site (see Wentworth, 1922). When present, seagrass species and percentage cover of each species were recorded. Seagrass species were identified by: leaf shape, pattern of leaf veins and rhizome structure. Any other biota present, fishing activity and signs of disturbance/destruction were also noted (see Mckenzie *et al*., 2003). Water samples were taken across the surveyed region to record temperature, turbidity, salinity and pH.

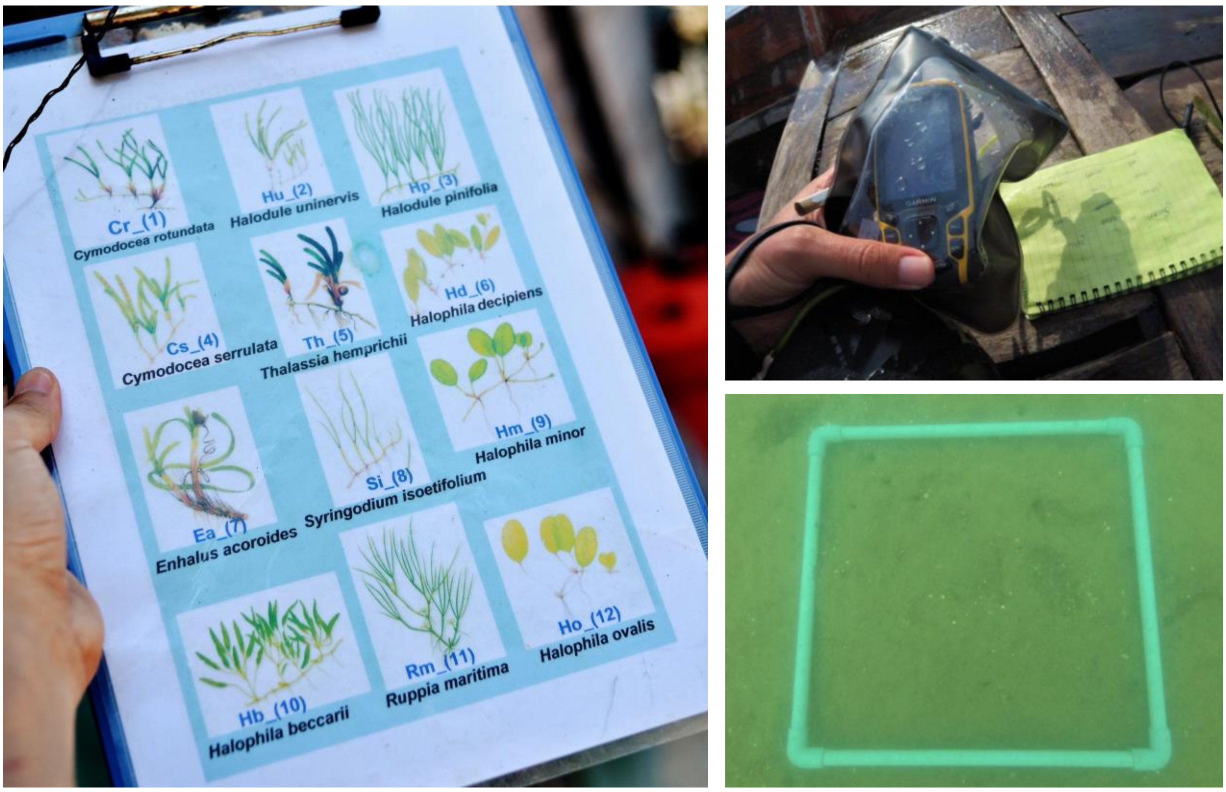

Figure 5. Seagrass survey equipment used. Left: dive slate with seagrass identification guide; Top Right: a handheld Garmin GPS device and a notepad for recording seagrass data and survey locations; Bottom Right: a 0.5m^2 quadrat distributed twice at each survey point, the area within the quadrat was measured for seagrass species, percentage cover and substrate type.

Data analysis:

Data were inputted to QGIS (V3.0.1.) to visualise distribution, abundance and species composition of seagrass across the study site. The mean percentage of biomass cover was used to show the abundance of seagrass species and substrate type within the study area.

2.2. Coral Reef Methods

2.2.1. Study area

The assigned area for assessment was a 1.2-km stretch of coastline near the western border of Kampot province situated in the proposed MFMA. The area is under threat from development and is located between *N10.58062279 E103.96259603 and N10.57675070 E103.97311964.* Within this area, a rapid assessment was conducted at two sites (based on local knowledge and previous rapid surveys conducted by WEA). The area is fished by commercial and subsistence fishers.

2.2.2. Survey methods

These surveys were conducted after establishing the coral reef locations, as advised by WEA Senior Marine Biologist Phalla Leng and the CFis, combined with exploratory dives between the 1st and 3rd November 2019.

Procedures for collecting field data followed a modified version of Reef Check's international guidelines for coral reef monitoring (Hodgson *et al.*, 2006). Two sites were selected for survey within the proposed MFMA: the conservation zone and the refugia zone. At each of the sites, a 100m transect line was followed along the reef (Figure 6). Four surveys, each conducted over a distance of 20m, were undertaken with 5m breaks in between each survey length where no data was collected. This was replicated twice, making *n*=8.

Separate surveys for fish, invertebrates, substrate and anthropogenic impacts were conducted by trained divers. For fish and invertebrate surveys, species data was collected from the seabed to 5m above the seafloor and 2.5m either side of the transect line. At these survey sites, depth did not exceed 3.5m. However, for fish and invertebrate data, 20m survey segments were measured. During substrate surveys, data was collected by logging the substrate every 0.5m, parallel with the transect line. Substrate was recorded at each interval in the following categories: live hard coral, recently killed coral, coral rubble, soft coral, nutrient indicator algae, sponge, zoanthid, rock, sand, silt/clay, and other.

The Reef Check methodology suggests a particular focus on the monitoring of coral reef indicator species. Indicator species are living organisms whose presence and abundance is able to indicate the state or condition of an environment where they are found (Siddig *et al.,* 2016).

Figure 6. The 100m line transect used for coral reef surveys (left) and healthy hard corals (right).

<u>Data analysis</u>

Statistics were determined for total median fish abundance, median herbivorous fish abundance and median alpha (α) diversity for fish (Shannon Diversity Index (H)) per $100m^2$. Fish herbivores considered for the herbivore analysis include species from the following key families: Acanthuridae, Ephippidae, Kyphosidae, Pomacanthidae, Scaridae and Siganidae (see Green and Bellwood, 2009). Median abundances have also been determined for Indo-Pacific indicator taxa, as recognised in Hodgson *et al*. 2006. Mean abundances have been displayed for certain taxonomic groups, including butterflyfish, rabbitfish, snapper, grouper, parrotfish and cardinalfish.

Invertebrate statistics are limited to the median abundances of indicator invertebrates presented in Table 1 due to low detections of invertebrates during surveys.

2.3. Marine Mammal Methods

<u>2.3.1. Study area</u>

The proposed Kampot MFMA is located within an internationally recognised Important Marine Mammal Area (MMPATF, 2019), with a depth ranging from 0.5 to 6.9m. The proposed area encompasses a diverse number of marine ecosystems, including seagrass, coral reefs and mangroves, integral to the presence and health of marine mammals. However, the region is threatened by Illegal, Unreported and Unregulated fishing activity as well as industrial development and land reclamation. The results of this assessment aim to contribute towards the adequate protection of these important marine habitats.

A total area of approximately 60-km^2 was assessed for marine mammal presence, using a crenelated boat transect (5-km x 12-km), parallel to the coastline, with ten hydrophone deployment sites located at the corner of each track. Data regarding marine mammal presence were recorded and analysed accordingly.

2.3.2. Survey methods

An intensive visual and acoustic survey effort was adopted to assess the presence of dolphins within the proposed Kampot MFMA during a three-day period (1st November to 3rd November 2019). Surveys were conducted from both a static, anchored research vessel situated at (N10.57151 E103.95607) and from a longtail fishing boat following a predetermined transect covering approximately 60-km^2 area of the Kampot MFMA. A total of ten sites were acoustically assessed for clicks and whistles, characteristic of dolphin communication.

Static boat surveys:

Static boat surveys were conducted from the research vessel anchored at N10.57151 E103.95607 highlighted in Figure 3. The boat engine was off for the duration of static surveys and was anchored from a single line at the bow.

Surveys were conducted in teams of five. Two researchers scanned the sea surface with Bushnell 8x42 binoculars, in search of cetaceans, from the viewing platform 3.8m above sea level. One observer scanned 180^0 from portside bow to portside stern; and one scanned 180^0 from starboard side bow to starboard side stern. One researcher manned a real-time hydrophone actively listening for clicks or whistles characteristic of dolphin vocalisations. Two researchers were on a rest shift to minimise the effects of fatigue. Roles were rotated every 10 minutes. Data sheets were used to record date, time, survey team, environmental conditions (Beaufort wind force scale, glare and cloud cover), and hydrophone deployment sites and times. Data sheets also allowed for the recording of visual sightings, including: time, group size, juvenile presence, behavioural states, events, group type and swim style, alongside boat vessel traffic within a radius of 100m, 400m, 1000m, and >1000m.

Transect surveys:

Surveys, in search of cetaceans, were conducted onboard a 5m ‘longtail’ fishing boat with an outboard engine. Surveys were conducted at and along the transects between hydrophone drop points, in teams of five. While travelling along the transect, between drop points, two researchers scanned with Bushnell 8x42 binoculars; one scanning portside to starboard side bow; the other scanning from starboard side to portside bow (Figure 7). At each drop point, visual observer scanning changed to portside stern to portside bow, and starboard side stern to starboard side bow. An additional researcher then deployed and actively monitored the soundscape using hydrophone, listening for clicks and whistles characteristic of dolphins. Roles were rotated every 10 minutes to reduce the effects of fatigue; two observation shifts were followed by actively listening to the hydrophone, followed by two rests shifts. The same data sheet format as above, was used during transect surveys.

Figure 7. Two surveyors scanning for marine mammals in the proposed Kampot MFMA; one scanning port to bow, the other scanning starboard to bow.

Opportunistic sightings:

Opportunistic sightings were defined as any cetacean observation made outside a dedicated survey effort (off-effort). Off-effort included travelling between survey sites (e.g. travelling from the mainland to the anchored research vessel) and observations from the anchored research vessel, by crew, in the absence of the research team.

Data analysis:

Acoustic data was converted from stereo to mono using Audacity. The left mono filter recording (identical to the right) was then analysed using SpectraPLUS-SC software, to identify and characterise dolphin clicks and whistles.

On and off-effort boat tracklines, hydrophone deployment sites and anchored research vessel site were mapped using *Esri® ArcGIS™*. Opportunistic sightings were mapped with a buffer zone of 500m to account for the swing of the boat around the anchor line and error margins in distance estimates.

3. Results

3.1. Seagrass

Seagrass extent

The total area for this study was 7-km^2, within this area seagrass was found to cover approximately 1.2-km^2 (Figure 8).

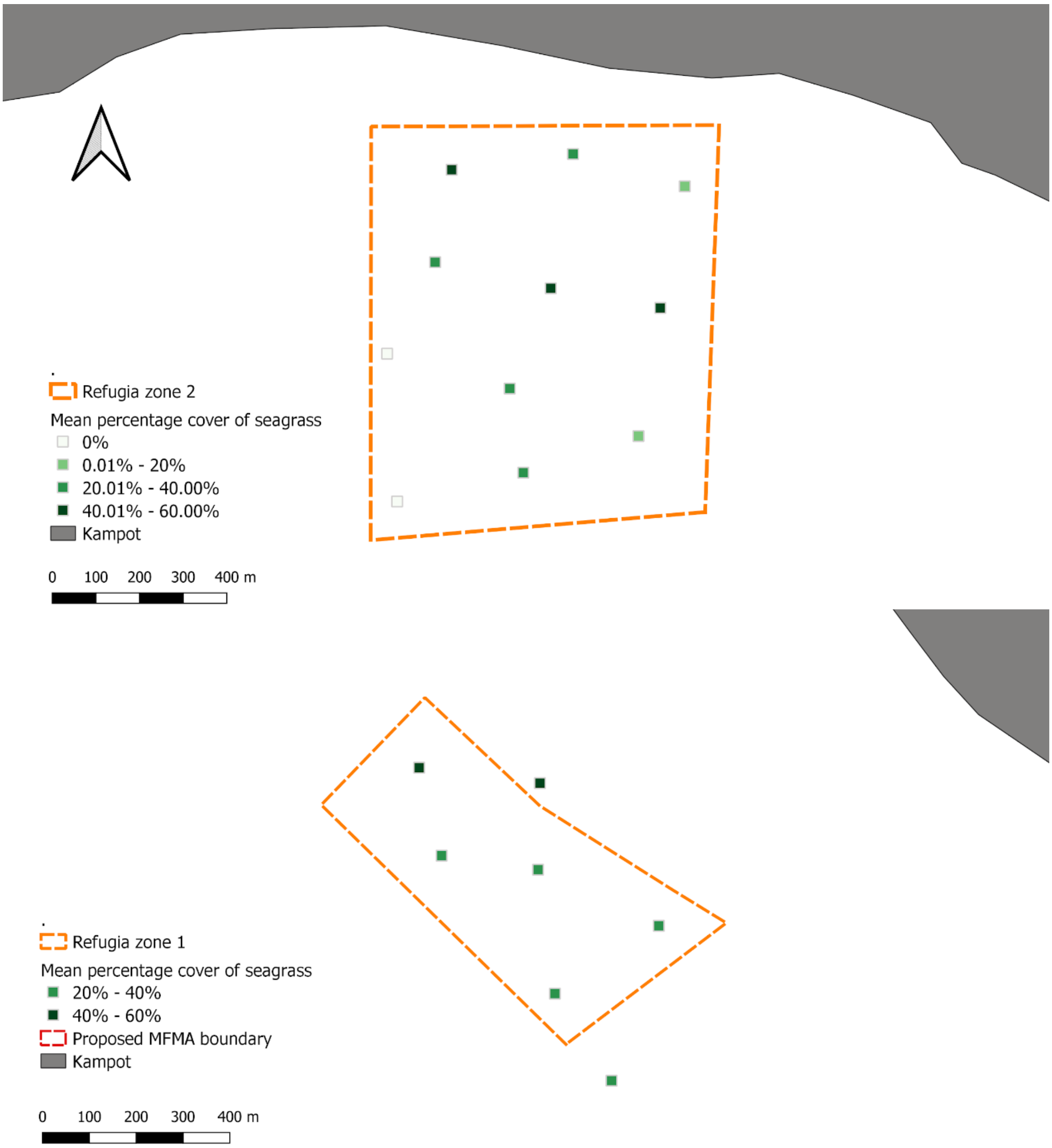

Figure 8. The mean percentage cover of seagrass in the refugia zones 2 (top panel) and 1 (bottom panel) within the proposed Kampot MFMA. Refer to Figure 2 for proposed MFMA.

Seagrass distribution

Of the 54 point-check surveys, 31% the survey points were located within refugia areas. Of this 31%, only two of the samples within refugia areas did not contain seagrass (Figure 8). From all the points containing seagrass, 70% were located within refugia areas. Only one point-check located within the conservation areas contained seagrass. Four points located outside management zones also showed seagrass presence.

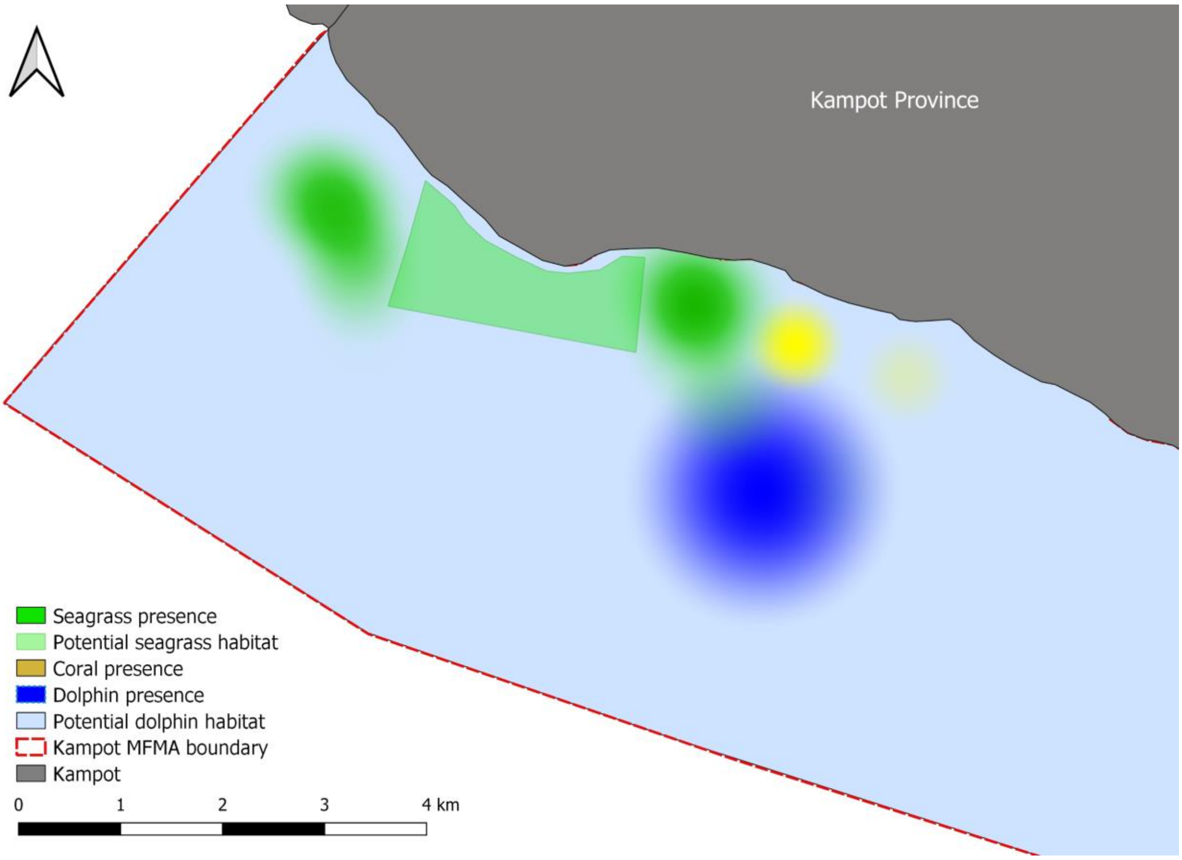

Figure 9. Seagrass presence in relation to coral presence and dolphin habitat, within the MFMA. Connectivity between seagrass survey sites was observed from the surface (light green polygon).

Seagrass presence was found to be uniform and consistent in areas close to shore, this meadow was connected to fringing mangrove forests located along the coastline (Figure 9). Surveys recorded seagrass growing at depths between 0.7m and 3.8m, and extended 1.4-km offshore. At greater depths, between 3.9m and 6.9m, no seagrass was observed. Areas designated as conservation zones were located in deeper waters with little to no protection from trawling vessels and boat traffic, and rare seagrass presence. Concrete poles throughout refugia areas were constructed to help protect the region by restricting fishing activities.

Species composition and abundance

The seagrass meadow in the study area was composed of two species; *Thalassia hemprichii* and *Enhalus acoroides* (Figure 10). At points where seagrass was present, *Enhalus acoroides* was the most dominant species. Total average seagrass biomass cover was found to be 40%. Of the survey points containing seagrass, *Enhalus acoroides* was present at 100% of points, and provided an average of 35% biomass cover. This long leaved species contributes towards the structural complexity of the seascape and provides nursery grounds and shelter for fish and invertebrate species.

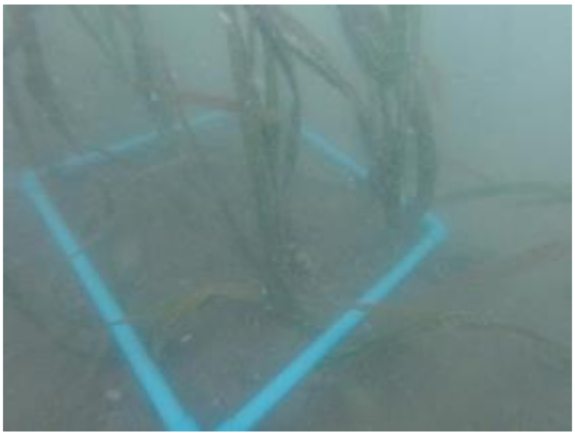

Figure 10. Enhalus acoroides (left) and Thalassia hemprichii (right) surveyed in refugia zones within the proposed Kampot MFMA.

Thalassia hemprichii was interspersed with *Enhalus acoroides*, but in lower frequency than *Enhalus acoroides*. *Thalassia hemprichii* was observed to have a patchier distribution than *Enhalus acoroides* across the surveyed area, with an average cover of 9%. *Thalassia hemprichii* was only observed in heterospecific areas, where *Thalassia hemprichii* and *Enhalus acoroides* coexisted.

<u>Disturbance and seagrass distribution</u>

Conservation zones were located at depths between 1.5m and 6.9m, with silt as the dominant substrate. Evidence of bottom trawling was recorded throughout the study site, with trawling lines and observation of trawling vessels documented; and continued despite the presence of in-water research activities (Figure 11).

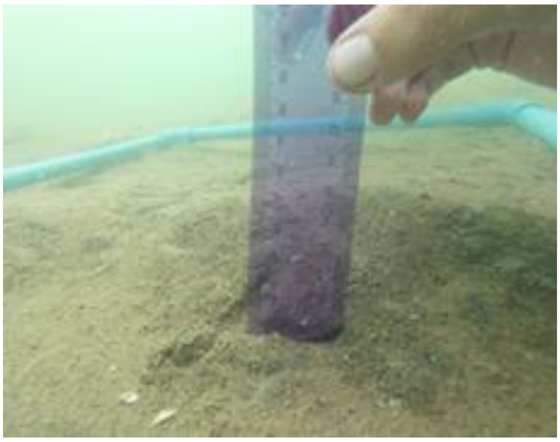

Figure 11. Left: Incidences of trawling vessels and trawling activity. Right: Evidence of a trawling path, within the designated conservation zones.

Seagrass presence largely fell within refugia areas, at depths between 0.7m and 2.6m, with predominantly sand substrate. These refugia areas also contained concrete poles to limit bottom trawling fishing vessel presence; as a result, no evidence of trawling activity was observed within these refugia zones (Figure 12).

Figure 12. Protective concrete poles within refugia zones, indicating community fishery areas.

Regions between conservation and refugia zones were also found to contain some seagrass. These points were at depths between 1.4m and 3.75m and contained no additional protection from concrete structures; as a result, evidences of trawling activity was observed.

Substrate type and depth

Substrate surveyed at depths of 3.9m or deeper were predominantly silt; all sites contained silt, and 25% also contained mud. At depths shallower than 3.9m, 91% of points consisted of sand or mud, with coarse sand, sand or fine sand recorded at 81% of points and mud at 13%.

Water testing

Through water testing, no relationships were found between co-variates of pH, turbidity, temperature and salinity at surveyed sites. As a result, these factors were not shown to influence seagrass cover here. However, pH, turbidity, temperature and salinity have been shown to influence seagrass extent and diversity (Fredley *et al.,* 2019).

3.2. Coral Reef

Substrate: The Kampot reef exhibited live hard coral dominance (Figure 13), with a mean cover of 60.3% (Figure 14). Rock was the most prevalent substrate with a mean cover of 20.6%. Sand, sponge, rubble and exhibited mean covers that were less than 10% and recently killed coral had the lowest mean cover of all the observed substrates at 0.3%. Areas with mud, seagrasses and bivalves were found between coral habitats within the survey site (Figure 15).

Figure 13. A sample of corals seen during surveys.

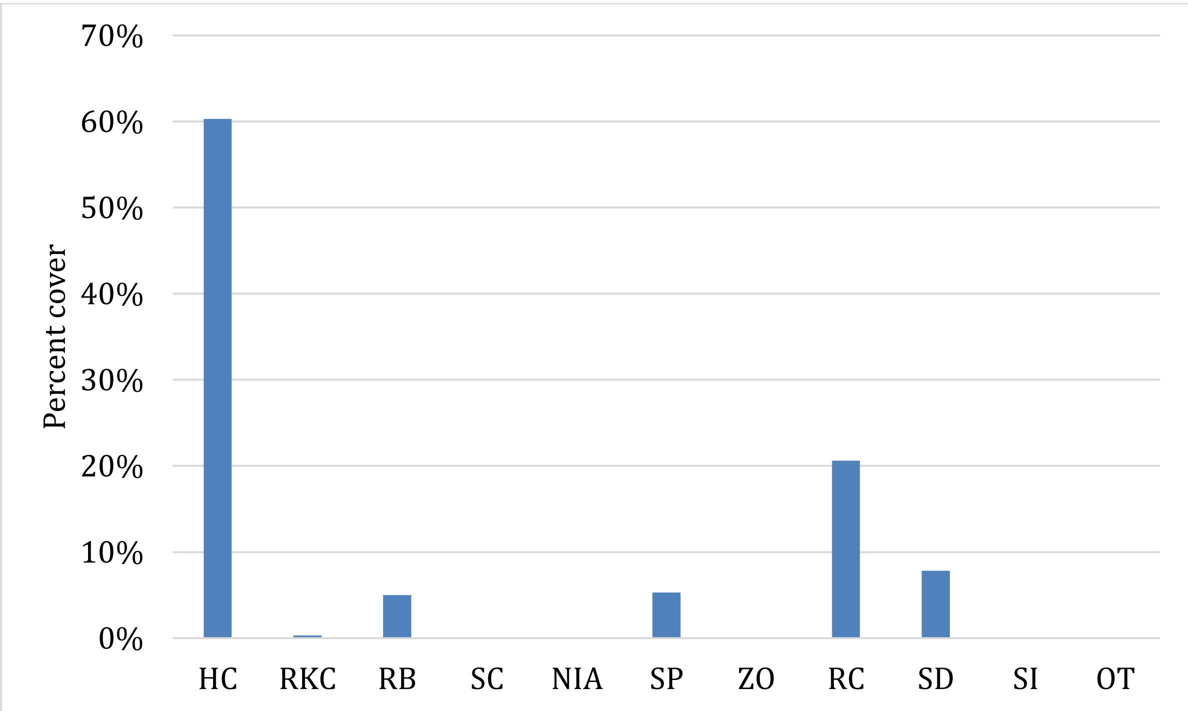

Figure 14. Mean percent substrate covers on Kampot reefs during baseline surveys. Live hard coral (HC); recently killed coral (RKC); coral rubble (RB); soft coral (SC); nutrient indicator algae (NIA); sponge (SP); zoanthid (ZO); rock (RC); sand (SD); silt/clay (SI); and other (OT). n=8.

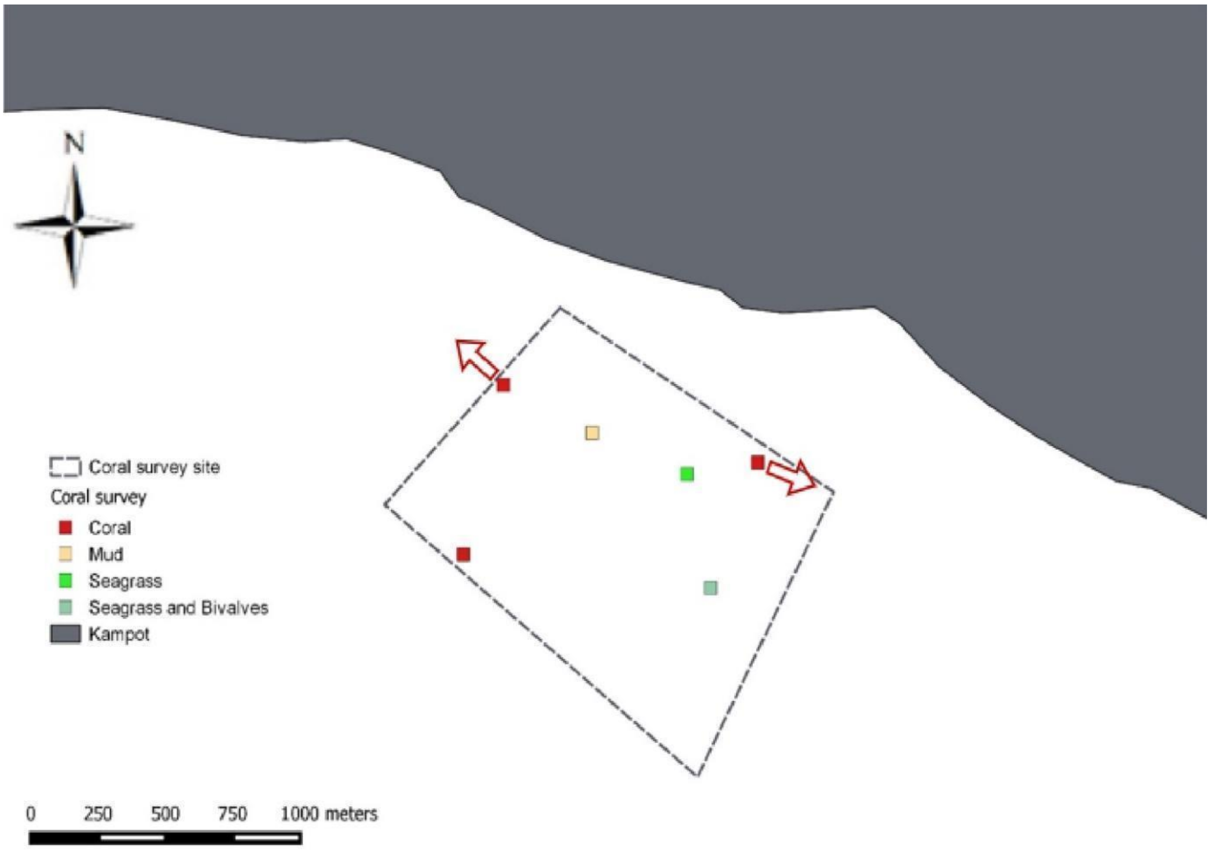

Figure 15. Biota and substrate found in coral survey site.

<u>Fish</u>

There was a total median fish abundance of 17 individuals/100m^2 (Figure 16). The taxa observed to be most abundant on the Kep reef were rabbitfishes and snappers (Figure 17). Relatively few of the taxa surveyed for (Appendix B) were present on the Kampot reef. Other taxa observed included butterflyfishes, wrasses and cardinalfishes. No grouper or parrotfish were observed on the Kampot reef.

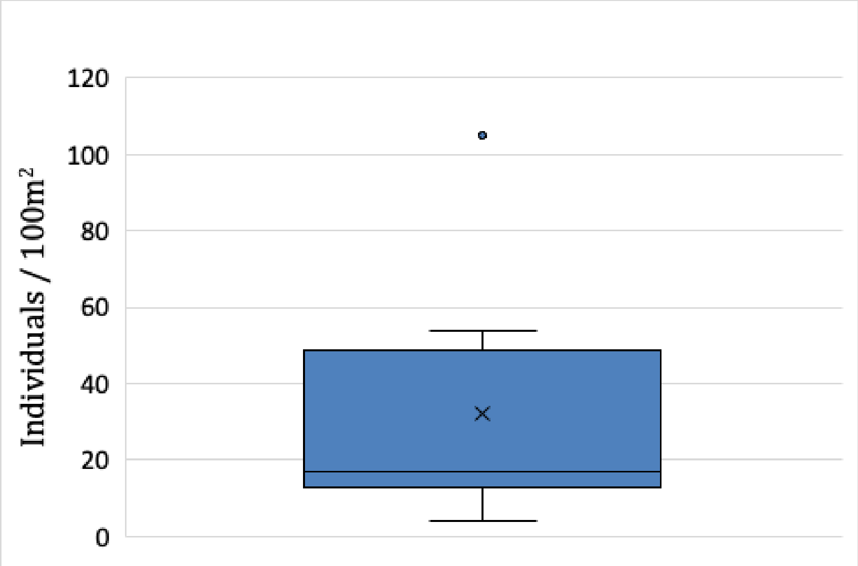

Figure 16. Total median fish abundance on the Kampot reef.

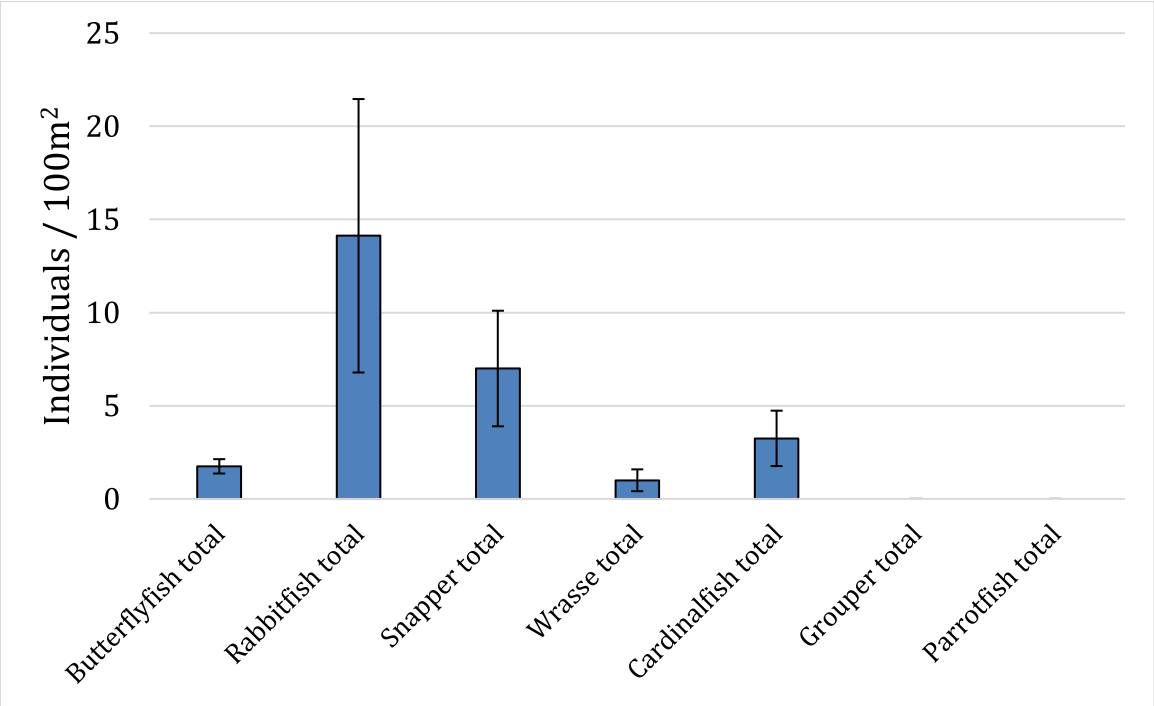

Figure 17. Total mean (±SE) abundances of butterflyfish, rabbitfish, snapper, wrasse, grouper and parrotfish per 100m^2.

The scarcity of Indo-Pacific indicator taxa (Hodgeson *et al*. 2006) detected on the Kampot reef indicate overfishing and collecting of marine life (Table 1). Most of the indicator taxa were not observed during baseline surveys and the long-spined black sea urchin (in high numbers, is an indicator of overfishing of urchin predators) was observed in greater abundances than other indicator taxa present, snapper and butterflyfish.

Table 1. Median abundances of Indo-Pacific indicator species (Hodgson *et al*. 2006) on the Kampot reef.

Indicator taxa		Indicator of	Median abundance (per 100m^2)	Interquartile range
Fish	Barrimundi cod (*Cromileptes altivelis*)	Overfishing, live fish trade and spearfishing	Absent	
	Bumphead Parrotfish (*Bolbometopon muricatum*)	Overfishing	Absent	
	Butterflyfish (Chaetodontidae)	Overfishing and aquarium trade	2	1 - 2
	Grouper (Serranidae)	Overfishing and live fish trade	Absent	
	Grunts/sweetlips (Haemulidae)	Overfishing	Absent	
	Humphead wrasse (*Cheilinus undulates*)	Overfishing and live fish trade	Absent	
	Jacks (Carangidae)	Overfishing	Absent	
	Moray eel (Muraenidae)	Overfishing	Absent	
	Other parrotfish (Scaridae)	Overfishing	Absent	
	Snapper (Lutjanidae)	Overfishing	2	0.3 - 17.8
Invertebrates	Banded coral shrimp (*Stenopus hispidus*)	Aquarium collection	Absent	
	Collector urchin (*Tripneustes* sp)	Overfishing	Absent	
	Crown-of-thorns starfish (*Acanthaster planci*)	Crown-of-thorns population outbreaks	Absent	
	Long-spined black sea urchin (*Diadema* sp)	In high numbers, indicator of overfishing of urchin predators	16	3.3 - 19.3
	Eadible sea cucumbers (*Holothuria edulis, Stichopus chloronotus, Thelenota ananas*)	Beche-de-mer fishing	Absent	
	Giant clam (*Charonia tritonis*)	Overharvesting	Absent	
	Lobster (Decapoda)	Overfishing and aquarium trade	Absent	
	Pencil urchin (*Heterocentrotus mammillatus)*	Collection for curio trade	Absent	
	Triton (*Charonia tritonis*)	Collection for crio trade	Absent	

Fish Diversity

The α-diversity analysis revealed a median Shannon Diversity Index value of 1.06 (Figure 18). The diversity analysis shows only diversity among the fish that were surveyed (Appendix B).

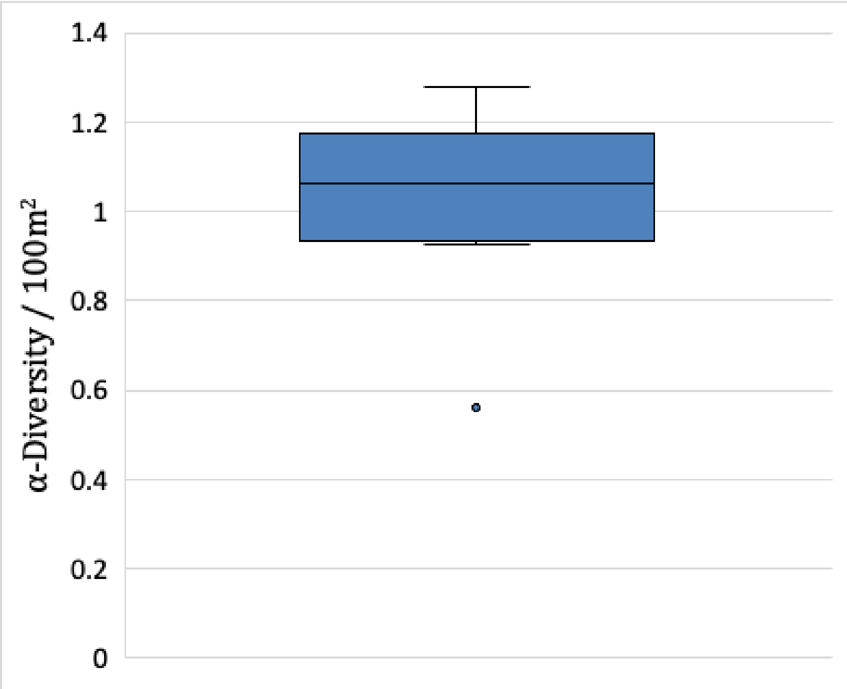

Figure 18. Median α-Diversity for fish on the Kampot reef.

Herbivore abundance

There was a median herbivore fish abundance of 7 individuals/100m^2 (Figure 19). Fish herbivores were solely represented by rabbitfish on the Kampot reef during baseline surveys. Java rabbitfish dominated the herbivore community, along with the long-spined black sea urchin (Table 1), with a median abundance of 6.5/100m^2. Other species of rabbitfish observed included the golden and virgate rabbitfishes. The species observed belong to the grazing/detritivore functional group that feed on epiphytic algal turfs. Other herbivore functional groups, such as scrapers, large excavators/bioeroders or browsers were not seen to be represented by any fish species on the Kampot reef.

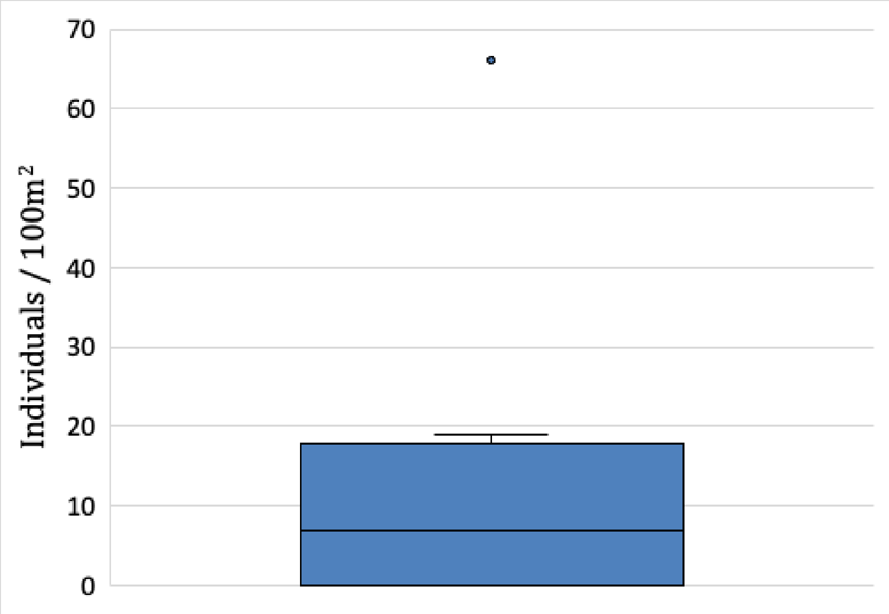

Figure 19. Median herbivorous fish abundance on the Kampot reef.

3.3. Marine Mammals

Acoustic and visual observations can confirm and verify the presence of dolphins within the proposed Kampot MFMA. One acoustic recording, taken at N103.967152 E10.563384 coordinates, displayed 13 whistles characteristic of Delphinidae. The species could not be acoustically identified.

Dolphins were visually sighted opportunistically on Day 2 and 3. These sightings were observed from the anchored research vessel, located at N10.57151 E103.95607 coordinates. The overlap of acoustic and visual observations, both recorded at approximately 14:00 on the afternoon of Day 2 (2nd November 2019), confirm with absolute certainty, the presence of dolphins within the MFMA. However, due to the opportunistic nature of these visual sightings, species could not be identified with 100% certainty. These observations can only show presence of dolphins within the proposed MFMA but cannot assume residency. The survey effort is outlined in Figure 20.

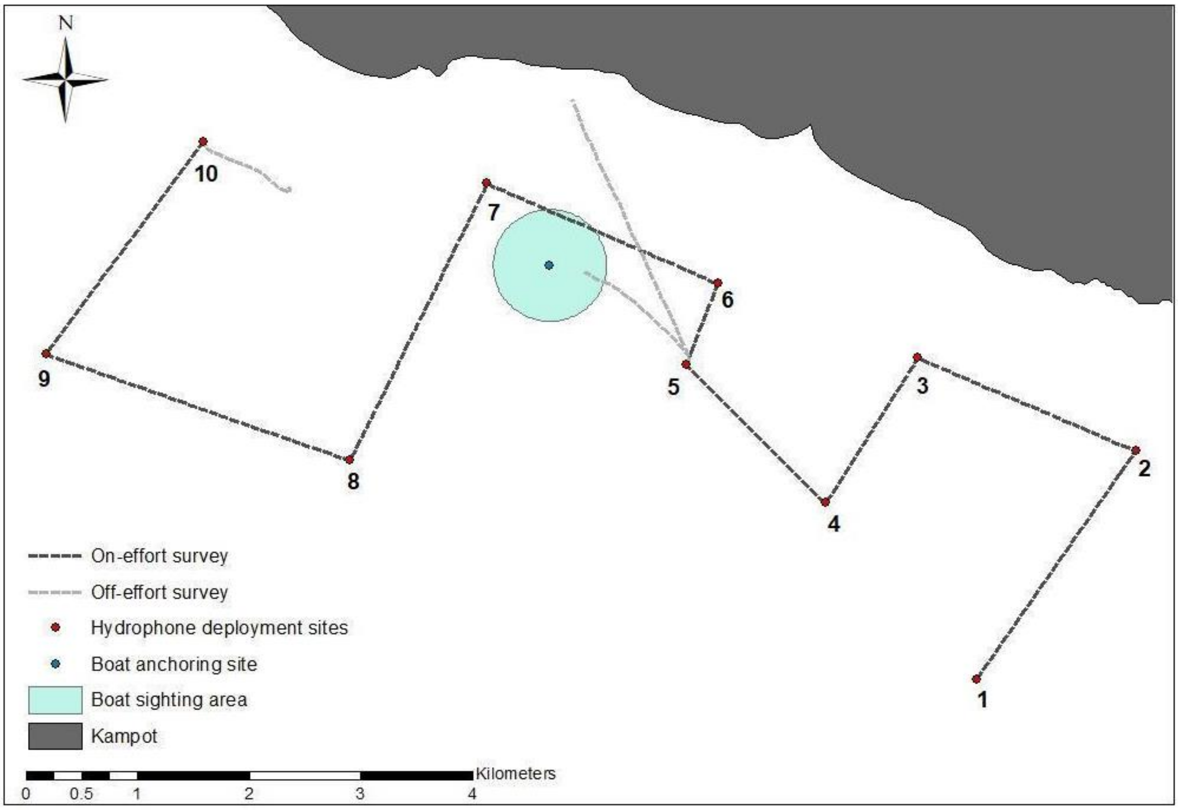

Figure 20. Map displaying transect survey effort and research vessel anchor site. Day 1 survey effort was conducted from the anchored research vessel; Day 2 followed the transect survey from Point 1 to 5; Day 3 followed the transect from Point 5 to 10, with another static survey effort from the anchored research vessel in the afternoon of Day 3. Two visual observations of dolphins were made within 50m of the anchored research vessel on the afternoon of Day 2 and the morning of Day 3. One acoustic recording of dolphins was taken at Point 5.

<u>Field observations</u>

Two opportunistic visual observations were made from the anchored research vessel. Group 1 was sighted at approximately 14:00 in the afternoon of Day 2 (2nd November 2019), at an estimated distance of 20m from the vessel. This visual sighting aligned with that of the acoustic recording taken at Point 5, verifying both results (Figure 20).

The second group, composed of 2 individuals, was sighted during the early morning of Day 3 (3rd November 2019), at approximately 06:00, at an estimated distance of 50m from the research vessel. The species of both sightings were unidentifiable due to the opportunistic nature of the sighting.

Visual observations were restricted by environmental conditions. The Beaufort wind force scale exceeded a 3 during 100% of the Day 1 survey effort; 80% of Day 2 survey effort; and 27% of Day 3 survey effort. The transect survey of Day 3 was also concluded early due to rain and reduced visibility.

Acoustic observations

A positive identification of dolphins was made at N103.967152 E10.563384 coordinates (Point 5 in Figure 20) at 14:22. A total of 13 independent dolphin whistles were recorded, between 14:22 and 14:26, with a mean peak frequency of 3.2kHz (range: 3-3.5kHz) and a mean relative amplitude of 67dBFS (range: 60-77dBFS). Figure 21 exemplifies the acoustic data recorded and analysis conducted via SpectraPLUS-SC. This data verifies the presence of dolphins within the region and exemplifies the complimentary uses of both visual and acoustic methods when assessing marine mammal presence.

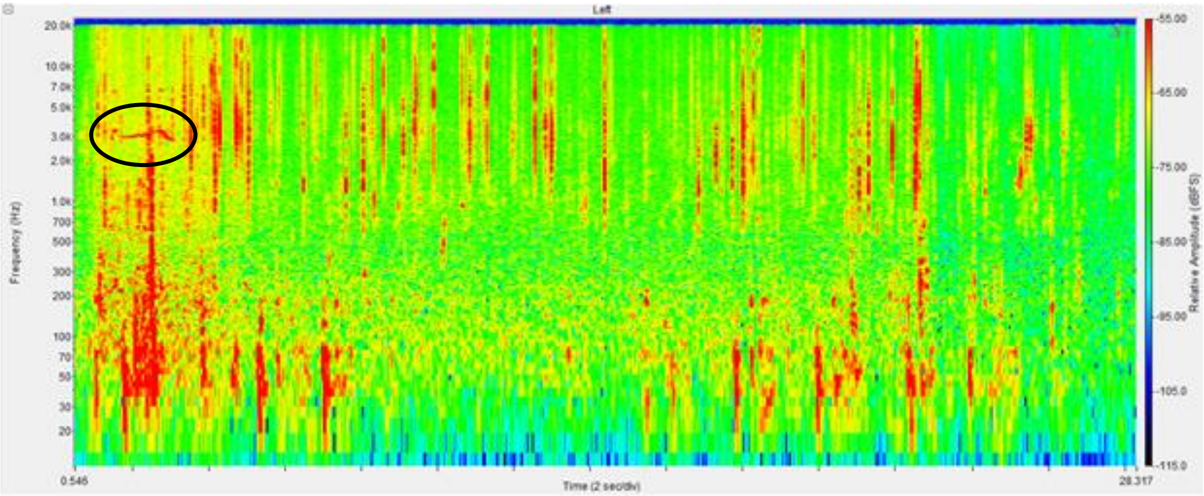

Figure 21. First identifiable dolphin whistle at Point 5 (see Figure 20). Identified whistle is highlighted by the black oval. Peak frequency: 3.5kHz; relative amplitude: 55-65dBFS. The whistle was visually identified in SpectraPLUS-SC by colour through manual variation in relative amplitude (dBFS) and the contrasting horizontality of the whistle.

4. Discussion

This report presents a sample of the current state of Kampot's marine environment and highlights the necessity of protecting local ecosystems and the services they provide. The coral reef and seagrass systems support local fisheries and provide food security and income to coastal communities, and opportunities for other developing industries (e.g., ecotourism). The data collected on the state of seagrass meadows and coral reefs as well as the confirmed presence of marine mammals in Kampot highlights the importance of creating a MFMA to safeguard ecosystem functions and biodiversity in the region.

The key pressures facing this region are industrial development and associated land reclamation, and IUU fishing. Coastal development and illegal fishing have been linked to a reduction in water quality, primarily through an increase in suspended sediment generated by dredging and activities disturbing the seafloor. Further, terrestrial habitat degradation has been increasingly shown to threaten marine ecosystems, such as mangroves, coral and seagrass (Hansen, 2008; Grech *et al.*, 2012; Mills *et al*., 2016). Elevated sediment levels can smother coral and other suspension feeders, reduce light availability to coral and seagrass, and inhibit the settlement of coral larvae (Hodgson, 1990; Rodgers, 1990; McCulloch *et al*., 2003; Fabricius *et al*., 2013; Bartley *et al*., 2014).

Conservation measures and adequate protection are integral to maintaining habitat connectivity between coral reef, seagrass and mangrove habitats to protect the functioning of the wider ecosystem network and the species within, including threatened species. Thus, effective implementation and enforcement of specific legislation for seagrass, corals and marine mammals outlined by Cambodian fisheries law is fundamental to the conservation of Kampot's marine ecosystems.

The data collected during seagrass surveys showed a high seagrass presence in regions that are protected by concrete poles (i.e., refugia areas), and within shallow areas. While extensive seagrass was not observed within the proposed conservation areas (no-take zones) during this study, WEA found widespread seagrass coverage across the region during rapid surveys in 2018 and 2019. The loss of seagrass since that time may be attributed to illegal benthic trawling, as active trawling was observed throughout the survey effort. Fast growing, pioneer seagrasses, such as *Halophila* sp. are more tolerant to unfavourable conditions than slower growing species such as *Thalassia hemprichii*, and may be able to recolonise damaged areas effectively, if provided protection from repeated fishing disturbance and if connectivity is maintained between the adjacent seagrass meadows. This would allow for successional growth from pioneer to larger colonising species (Olesen *et al.,* 2004). Within protected shallow water seagrass provides seascape complexity, creating shelter and nursery grounds for species that support subsistence and commercial fisheries, and for megafauna such as sea turtles and marine mammals.

The Kampot reef exhibited live hard coral dominance with very low rates of recently killed corals. Fish abundance and diversity on the reef were low and only two species of invertebrates were present (i.e., long-spined black sea urchins and boring bivalves). Indicator fish taxa were not observed but long-spined black sea urchins were prevalent (Table 1). Taken together, these results are strong indicators of overfishing on the reef. Overall, the data collected during coral reef surveys revealed similarities between the present state of Kampot's coral reefs and the state of Kep's coral reefs before the creation of the MFMA and the deployment of the multipurpose artificial reef structures. Encouraging results obtained by Reid *et al*. 2019 within Kep MFMA suggest that ecosystem-based management and associated reduction in illegal fishing might encourage the recovery of Kampot's coral reefs.

The positive identification of dolphins through both visual and acoustic observations, highlights the proposed Kampot MFMA as an important marine mammal habitat, in need of tailored conservation measures and adequately enforced legislation. Protection of the marine environment by the Kampot MFMA is integral to providing habitat connectivity for marine mammals along the Cambodian coastline and will likely result in an increase of marine mammal presence, health and abundance (Hoyt, 2012; Slooten, 2013).

The centralised overlap of seagrass, coral and dolphin presence exemplifies the necessity of heterogeneous habitats for increased marine biodiversity, thus highlighting the importance of implementing the proposed MFMA to ensure extensive area protection, and increased biodiversity recovery (Figure 9). Figure 9 also highlights the importance of seagrass meadows as a nursery ground for fish and squid. The spillover of small bony fish and squid, from such nursery grounds, provides ideal feeding grounds for foraging megafauna such as Irrawaddy dolphins (Ponnampalam *et al.,* 2013; Jeyabaskaran *et al.,* 2018). Further, habitat connectivity between mangroves, seagrasses and coral reefs will likely increase fish diversity and abundance and enhance fish nursery function by increasing the availability of shelter and food provision (Unsworth *et al.,* 2008). Habitat connectivity is considered essential for supporting ecosystem function and productive fisheries.

4.1. Limitations of the Studies

This study was designed to sample biodiversity within the proposed MFMA area; however, further investigation is required to gain a greater insight into the marine biodiversity of this region. In regard to the field surveys, time was a limiting factor for collecting data on species composition and distribution. We recommend more thorough collecting of baseline data. For seagrass and coral, this would involve expanding the survey area to include a larger and more representative study area within the proposed MFMA.

Time was also a factor limiting the understanding of marine mammal presence, abundance, distribution and behaviour. Through continued observation, both visually and acoustically, baseline data could be provided to reliably inform marine mammal conservation within the proposed Kampot MFMA and surrounding areas.

Unfavourable environmental conditions were also a limiting factor. Restricted visibility limited the seagrass research team to only two experienced free divers as seagrass was not easily observable from the surface, even in shallow waters. Trawling activity within the surveyed conservation zone postponed survey efforts due to proximity to vessel nets. Surveys resumed once risks to the research team had sufficiently diminished. High sediment loads have been identified as a problem around Kampot (Muylaert, 2015). Suspended sediment affects water turbidity and clarity, and has been attributed to illegal trawling activities, industrial development and riverine output; this was a limiting factor for both seagrass and coral reef surveys. The minimum recommendation required for an accurate reef survey is a visibility of 3m. Coral species richness and abundance may be underrepresented in this dataset due to the environmental limitation outlined.

During marine mammal surveys the Beaufort wind force scale exceeded a 3 for 48% of the total survey effort, substantially reducing the likelihood of a marine mammal sighting, due to wave height exceeding dorsal fin height. Survey effort was also restricted by rain, which delayed the transect survey on the morning of Day 2 and postponed the transect survey during the afternoon of Day 3, also limiting sighting likelihood.

4.2. Implications for Conservation

Combining the results of the biodiversity assessment, we conclude that the Kampot area is an important and valuable marine environment, which is threatened by increasing pressure from development and land reclamation. Terrestrial and marine development have been shown to diminish marine ecosystem resilience and ecosystem service provisioning (Mills *et al.,* 2016). This assessment indicates that the proposed industrial development in the Kampot coastal region has the potential to directly impact the persistence of seagrass, corals and marine mammals in Kampot. Although coastal industrial development may present economic opportunities for the region, many of the social, ecological and economic systems which depend on coastal resources may be negatively impacted by the development, such as small-scale fisheries. Conservation initiatives within Kampot need to reflect the needs of all resource users and ensure the sustainability of local livelihoods, food security, and regulating services of the marine environment, as well as the potential for ecotourism and livelihood diversification. Legislative reform should reflect socio-economic and environmental improvements by addressing resource use while maintaining ecosystem functioning (Hargreaves-Allen *et al*., 2011; Pratchett *et al*., 2014).

Protecting ecosystem connectivity is an important underlying component of ecosystem resilience (Mumby and Hastings, 2008; Nystrom *et al*., 2008; Olds *et al*., 2013). Adopting an ecosystem-based management approach within the legislative design of the proposed MFMA will improve habitat protection, trophic linkages and support marine functionality, biodiversity and spatial heterogeneity (McClanahan *et al*., 2011; Aswani *et al*., 2012; Menzel *et al*., 2013; Samhouri *et al*., 2013).

Coastal development may restrict access to marine resources, which are essential for food provisioning and sustaining local livelihoods (Frocklin *et al.,* 2014). In light of habitat conservation, industrial development of any form would be detrimental to marine mammal populations, due to noise pollution and habitat loss. As echolocating mammals, dolphins map their environment through a collection of clicks and whistles. Industrial development within the region would inevitably result in substantial noise pollution within the seascape, which has been known to cause an increase in dolphin strandings due to disorientation and confusion (Weilgart, 2007; Wiley *et al.,* 1995). Development and land reclamation will also directly impact marine mammal health as a result of critical habitat loss and disturbance. Protection of this region from industrial development and land reclamation is paramount in the conservation and preservation of Kampot's marine mammal populations.

5. Recommendations for Future Management

The proposed MFMA conservation strategy developed by FiA, FiAC, WEA and MCC will combine the use of multipurpose artificial reef structures, community management techniques, and the enforcement of fisheries legislation. Adaptive management of the MFMA is required to ensure the protection of important marine ecosystems and engagement of local stakeholders.

From the findings of this study, we suggest the following recommendations for sustainable ecosystem management in order to maintain ecosystem functionality and ecosystem service provisioning, in the form of income and food resources for local people.

5.1. Recommendations for Seagrass Conservation

1. **Restriction of terrestrial and marine industrial development** will limit direct damage, and destruction of seagrass meadows, thus reducing the impact on diversity, biomass and ecosystem service provisioning potential.
2. **Multipurpose artificial reef and anti-trawling structures** will deter destructive fishing vessels and gear types, through preventing bottom-trawling vessels and reducing direct anthropogenic damage to seagrass meadows. These structures will help attenuate wave action and retain sediment to facilitate seagrass recovery.
3. **Improve protection and connectivity** within the seascape, between management zones, to facilitate long-term recolonization of seagrass habitat. This will create interconnected corridors between habitats improving accessibility for marine mammals, fish and other foraging species.
4. **Outreach** within local communities to ensure sustainable management and use of seagrass habitat.

5.2. Recommendations for Coral Conservation

1. **Restriction of terrestrial and marine industrial development** will limit direct damage, and contamination of ecosystems which heavily impacts coral reef service provisioning, its diversity and richness as well as coral reef fauna.
2. **Multipurpose artificial reef and anti-trawling structures** will deter destructive fishing activities such as bottom-trawling causing increased suspended sediment and coral smothering. These devices act as protective structures, reducing bottom-trawling activity, allowing for the retention of benthic sediment to facilitate coral recovery. Multipurpose artificial reef deployment will also facilitate coral regrowth, increase fish and invertebrate diversity and improve connectivity between habitats.
3. **Further coral assessments** to ascertain overall coral distribution within the proposed MFMA and highlight these sites as requiring additional conservation management and zonation.
4. **Outreach** within local communities to ensure sustainable management and use of coral habitat.

5.3. Recommendations for Marine Mammal Conservation

1. **Baseline data collection** on marine mammal abundance, distribution and behaviour is required in order to delineate and propose adequate protection of critical habitats within

the proposed MFMA. Marine mammal critical habitats are defined as the spaces used for critical behaviours such as feeding, breeding, resting and nursing.

2. **Restriction of land reclamation and industrial development** is integral to the protection of these critical habitats ensuring the presence, health and viability of marine mammal populations within Kampot, facilitating continuous distribution along the Cambodian coastline, thus reducing the prevalence of habitat fragmentation.
3. **The deployment of multipurpose artificial reef and anti-trawling structures** have been proven to be effective in the protection of marine mammal habitats from illegal fishing activities, within the Kep MFMA. Given the similarity of circumstance, deployment of such structures is likely to replicate similar successes with regard to the protection of critical marine mammal habitats within the area.
4. **Outreach**, in the form of educational workshops, within the fishing communities may improve the knowledge and understanding of coastal marine ecology to ensure local engagement in marine mammal conservation activities and continued research.

6. References

Amato, D. W., Bishop, J. M., Glenn, C. R., Dulai, H., and Smith, C. M. (2016) 'Impact of submarine groundwater discharge on marine water quality and reef biota of Maui'. *PLoS One.* 11:e0165825. https://doi.org/10.1371/journal.pone.0165825

Aswani, S., Christie, P., Muthiga, N., Mahon, R., Primavera, J. H., Cramer, L. A., Barbier, E.B., Granek, E.F., Kennedy, C.J., Wolanski, E., Hacker, S. (2012). 'The way forward with ecosystem-based management in tropical contexts: reconciling with existing management systems.' *Marine Policy.* 36 (1), pp. 1–10. doi: 10.1016/j.marpol.2011.02.014.

Bartley, R., Bainbridge, Z. T., Lewis, S. E., Kroon, F. J., Wilkinson, S. N., Brodie, J. E., and Silburn, D. M. (2014) 'Relating sediment impacts on coral reefs to watershed sources, processes and management: a review'. *Science of the Total Environment*. 468, pp. 1138-1153.

Bas, A.A., Ozturk, A.A. and Ozturk, B. (2014) 'Selection of critical habitats for bottlenose dolphins (*Tursiops truncatus*) based on behavioural data, in relation to marine traffic in the Instanbul Strait, Turkey'. *Marine Mammal Science*. 31(3).

Beasley, I.L. and Davidson, P.J.A. (2007) 'Conservation status of marine mammals in Cambodian waters, including seven new cetacean records of occurrence'. *Aquatic Mammals.* 33(3), pp.368-379.

Böhm, A. B. (2019) In the context of a technical report for the marine harvesting network of Cambodia.

Brown, L. A., Furlong, J. N., Brown, K. M., and La Peyre, M. K. (2014) 'Oyster reef restoration in the northern Gulf of Mexico: effect of artificial substrate and age on nekton and benthic macroinvertebrate assemblage use'. *Restoration ecology*. *22*(2), pp. 214-222.

Coen, L. D., Brumbaugh, R. D., Bushek, D., Grizzle, R., Luckenbach, M.W., Posey, M.H., Powers, S.P., and Tolley, S. G. (2007). 'Ecosystem services related to oyster restoration'. *Marine Ecology Progress Series*. 341, pp. 303-307.

Davis, J. P., Pitt, K. A., Fry, B., Olds, A. D., and Connolly, R. M. (2014) 'Seascape-scale trophic links for fish on inshore coral reefs'. *Coral Reefs*. 33(4), pp. 897-907.

Duarte, C.M. (2002) 'The future of seagrass meadows'. *Environmental Conservation.* 29(2), pp. 192-260.

Edwards, C. B., Friedlander, A. M., Green, A. G., Hardt, M. J., Sala, E., Sweatman, H.P., Williams I.D., Zglicynski, B., Sandin, S.A., and Smith, J. E. (2014) 'Global assessment of the status of coral reef herbivorous fishes: evidence for fishing effects'. *Proceedings of the Royal Society B: Biological Sciences*. 281(1774), 20131835.

Fabricius, K. E. (2005) 'Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis'. *Marine Pollution Bulletin.* 50, pp. 125–146.

Fabricius, K. E., De'ath, G., Humphrey, C., Zagorskis, I., and Schaffelke, B. (2013) 'Intra-annual variation in turbidity in response to terrestrial runoff on near-shore coral reefs of the Great Barrier Reef'. *Estuarine, Coastal and Shelf Science*. 116, pp. 57-65.

Fredley, J., Durako, M. J., and Hall, M. O. (2019). Multivariate analyses link macrophyte and water quality indicators to seagrass die-off in Florida Bay. Ecological Indicators, 101, 692-701.

Frocklin, S., de la Torre-Castro, M., Hakansson, E., Carlsson, A., Magnusson, M. and Jiddawi, N. (2014) 'Towards improved management of tropical invertebrate fisheries: including time series and gender'. PLoS One. 9(3).

Grabowski, J. PIER., and Peterson, C. PIER. (2007). Restoring oyster reefs to recover ecosystem services. *Ecosystem engineers: plants to protists*, *4*, 281-298.

Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, R., Taylor, H., Coles, R.G. (2012) 'A comparison of threats, vulnerabilities and management opportunities in global seagrass bioregions'. *Environmental Resources Letters.* 7.

Green, A. L., and Bellwood, D. R. (Eds.). (2009). Monitoring functional groups of herbivorous reef fishes as indicators of coral reef resilience: a practical guide for coral reef managers in the Asia Pacific Region (No. 7). IUCN.

Hansen, M. C. et al. 2008. "Humid Tropical Forest Clearing from 2000 to 2005 Quantified by Using Multitemporal and Multiresolution Remotely Sensed Data." Proceedings of the National Academy of Sciences 105(27), pp. 9439–9444.

Hargreaves-Allen, V., Mourato, S. and Milner-Gulland, E. J. (2011) 'A Global Evaluation of Coral Reef Management Performance: Are MPAs Producing Conservation and Socio-Economic Improvements?'. *Environmental Management* 47(4), pp. 684–700. doi: 10.1007/s00267-011-9616-5.

Hodgson, G, Hill, J, Kiene, PIER, Maun, L, Mihaly, J, Liebeler, J, Shuman, C and Torres, R. (2006) 'Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring'. *Reef Check Foundation*, Pacific Palisades, California, USA.

Hoegh-Guldberg, O. (2011) 'Coral reef ecosystems and anthropogenic climate change'. *Regional Environmental Change*. 11(1), pp. 215-227.

Hodgson, G. (1990) 'Sediment and the settlement of larvae of the reef coral *Pocillopora damicornis'*. *Coral Reefs.* 9, pp. 41-43.

Hoyt, E. (2012) *Marine Protected Areas for Whales, Dolphins and Porpoises: A World Handbook for Cetacean Habitat Conservation and Planning.* New York: Earthscan.

Huang, D., Licuanan, W.Y., Hoeksema, B.W. *et al.* (2015) ‘Extraordinary diversity of reef corals in the South China Sea’. *Marine Biodiversity.* 45**,** pp.157–168. https://doi.org/10.1007/s12526-014-0236-1

Huntington, H.P. (2009) 'A preliminary assessment of threats to artic marine mammals and their conservation in the coming decades'. *Marine Policy*. 33(1), pp.77-82.

Jeyabaskaran, R., Jayasankar, J., Ambrose, T.V., Vineetha Valsalan, K.C., Divya, N.D., Raji, N., Vysakhan, P., John, S., Prema, D., Kaladharan, P. and Kripa, V. (2018) ‘Conservation of seagrass beds with special reference to associated species and fishery resources’. *Journal of the Marine Biological Association of India*. 60(1), pp.62-70.

Jiang, Y., Zhang, X., Yang, Z., Jaaman, S.A., Xu, Q. and Muda, A.M. (2019) 'Preliminary analysis of echolocation signals produced by fleeing Irrawaddy dolphins (*Orcaella brevirostris*)'. *Acta Oceanologica Sinica.* 38(1), pp.85-89.

Kim S., Chou L.M. and Tun K. (2004) ‘The coral reefs of Cambodia: present state of information and management capacity: first draft’. Unpublished report to the Ministry of Agriculture, Forestry and Fisheries, Phnom Penh, Cambodia.

Knowlton, N., Brainard, R. E., Fisher, R., Moews, M., Plaisance, L., and Caley, M. J. (2010) ‘Coral reef biodiversity’ in McIntyre, A.D. (ed.) *Life in the World’s Oceans: Diversity Distribution and Abundance*. pp. 65-74.

Kurien, J. (2017) ‘Community Fisheries Organizations of Cambodia’. *FAO Fisheries and Aquaculture Circular*, No. 1138, 102 pp.

Lee, S.Y., Primavera, J.P., Dahdouh-Guebas, F., McKee, K., Bosire, J.O., Cannicci, S., ... and Sydne, R. (2014) ‘Ecological role and services of tropical mangrove ecosystems: a reassessment’. *Global Ecology and Biogeography*. 23(7), pp. 726-743.

MAFF (2011) ‘The Strategic Planning Framework for Fisheries: 2010 - 2019 Cambodia’ in Administration, F. (ed.). Kingdom of Cambodia.

Mangroves for the Future (2013) ‘Cambodia National Strategy and Action Plan 2014–2016’. Ministry of Environment and Mangroves for the Future, Phnom Penh, Cambodia.

Marine Conservation Cambodia. (2016) ‘Koh Seh Marine Environmental Assessment’. *Unpublished manuscript*.

McClanahan, T.R., Graham, N.A., MacNeil, M.A., Muthiga, N.A., Cinner, J.E., Bruggemann, J.H., and Wilson, S. K. (2011) ‘Critical thresholds and tangible targets for ecosystem-based management of coral reef fisheries’. *Proceedings of the National Academy of Sciences*. 108(41), pp. 17230-17233.

McCulloch, M., Fallon, S., Wyndham., Hendy, E., Lough, J., Barnes, D. (2003) ‘Coral record of increased sediment flux to inner Great Barrier Reef since European settlement’. *Nature.* 421, pp. 727-730.

Mckenzie, L.J., Campbell, S.J. and Roder, C.A. (2003) *Seagrass-Watch : Manual for Mapping and Monitoring Seagrass Resources*. Cairns: QFS, NFC.

Menzel, S., Kappel, C., Broitman, B., Micheli, F., Rosenberg, A. (2013) 'Linking human activity and ecosystem condition to inform marine ecosystem based management', *Aquatic Conservation: Marine and Freshwater Ecosystems*, onlinelibrary.wiley.com/doi/10.1002/aqc.2365. doi: 10.1002/aqc.2365.

Mills, M., Leon, J.X., Saunders, M.I., Bell, J., Liu, Y., O'Mara, J., Lovelock, C.E., Mumby, P.J., Phinn, S., Possingham, H.P., Tulloch, V.J.D., Mutafoglu, K., Morrison, T., Callaghan, D.P., Baldock, T., Klein, C.J., Hoegh-Guldberg, O. (2016) 'Reconciling Development and Conservation under Coastal Squeeze from Rising Sea Level: Planning for coastal squeeze'. *Conservation Letters* 9(5), pp. 361–368. https://doi.org/10.1111/conl.12213.

MMPATF (Marine Mammal Protected Area Task Force) (2019) *IMMA e-Atlas- Marine Mammal Protected Area Task Force.* Retrieved from: http://www.marinemmalhabitat.org/imma-eatlas/#.

Mora, C. (2008) 'A clear human footprint in the coral reefs of the Caribbean'. *Proceedings of the Royal Society B: Biological Sciences*. 275(1636), pp. 767-773.

Mumby, P. J., and Hastings, A. (2008) 'The impact of ecosystem connectivity on coral reef resilience'. *Journal of Applied Ecology*. 45(3), pp. 854-862.

Muylaert, P-E. (2015) 'Assessing coastal resilience in Kampot: A pathway to adapt to climate change'. Thailand: IUCN. 40 pp.

Ng, S.L. and Leung, S. (2003) 'Behavioural response of Indo-Pacific humpback dolphin (*Sousa chinesis*) to vessel traffic'. *Marine Environmental Research*. 56(5), pp.55-567.

Nordlund, L.M., Jackson, E.L., Nakaoka, M., Samper-Villarreal, J., Beca-Carretero, P., and Creed, J.C. (2017) 'Seagrass ecosystem services–What's next?'. *Marine Pollution Bulletin*. 134, pp. 145-151.

Nyström, M., Graham, N.A.J., Lokrantz, J., Norström, A. (2008) 'Capturing the cornerstones of coral reef resilience: linking theory to practice'. *Coral Reefs* 27, pp. 795–809.

Olds, A. D., Albert, S., Maxwell, P. S., Pitt, K. A., and Connolly, R. M. (2013) 'Mangrove-reef connectivity promotes the effectiveness of marine reserves across the western Pacific'. *Global Ecology and Biogeography*. *22*(9), pp. 1040-1049.

Olesen, B., Marba, N., Duarte, C.M., Savela, R.S. and Fortes, M.D. (2004) 'Recolonization dynamics in a mixed seagrass meadow: the role of clonal versus sexual processes'. *Estuaries*. 27(5), pp.770-780.

Ostroumov, S. A. (2005). 'Suspension-feeders as factors influencing water quality in aquatic ecosystems' in *The comparative roles of suspension-feeders in ecosystems.* Springer, Dordrecht, pp. 147-164.

PIC (2017) ‘Situation of marine fisheries and the establishment of fishing communities’. *Briefing Note, Senate Commission 1.* Kingdom of Cambodia.

Pilcher, N.J. (2006) Proceedings of the twenty-third annual symposium on sea turtle biology and conservation. NOAA Technical Memorandum NMFS-SEFSC-536, 261 p.

Ponnampalam, L.S., Hines, E.M., Monanunsap, S., Ilangakoon, A.D., Junchompoo, C., Adulyanukosol, K. and Morse, L.J. (2013) ‘Behavioural observations of coastal Irrawaddy dolphins (*Orcaella brevirostris*) in Trat Province, Eastern Gulf of Thailand. *Aquatic Mammals.* 39(4), pp.401-408.

Pratchett, M.S., Hoey, A.S., and Wilson, S.K. (2014) ‘Reef degradation and the loss of critical ecosystem goods and services provided by coral reef fishes’. *Current Opinion in Environmental Sustainability.* 7, pp. 37-43.

Reid, A.E.A., Haissoune, A. and Ferber, P. (2019) ‘The status of coral reefs and seagrass meadows in the Kep Archipelago, Cambodia’. *Cambodian Journal of Natural History*. 2019, pp. 24–39.

Rizvi, A.R. and Singer, U. (2011). ‘Cambodia Coastal Situation Analysis’, Gland, Switzerland: IUCN. 58 pp

Rodgers, C. S. (1990) ‘Response of coral reefs and reef organisms to sedimentation’. *Marine Ecology.* 62, pp. 185-202

Royal Government of Cambodia (2014). ‘National Strategic Development Plan 2014-2018’. Phnom Penh: Royal Government of Cambodia.

Siddig, A, Ellison, A, Ochs, A, Villar-Leeman, C and Lau, M (2016) ‘How do ecologists select and use indicator species to monitor ecological change? Insights from 14 years of publication in Ecological Indicators’, *Ecological Indicators*. 60, pp. 223–230.

Sigman, D.M. & Hain, M.P. (2012) ‘The Biological Productivity of the Ocean: Section 4’. *Nature Education Knowledge.* 3(10), pp. 19.

Slooten, E. (2013) ‘Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin’. *Endangered Species Research.* 20, pp.121-130.

Teh, L.S., Witter, A., Cheung, W.W.L., Sumaila, U.R., and Yin, X. (2017) ‘What is at stake? Status and threats to South China Sea marine fisheries’. *Ambio*. 46(1), pp. 57-72.

Tubbs, S.E., Bas, A.A., Cote, G., Jones, A.L. and Notman, G. (2019) ‘Sighting and stranding reports of Irrawaddy dolphins (*Orcaella brevirostris*) and Dugongs (*Dugong dugon*) in Kep and Kampot, Cambodia’. *Aquatic Mammals.* 45(5), pp.563-568.

Unsworth, R.K., and Cullen, L.C. (2010) ‘Recognising the necessity for Indo-Pacific seagrass conservation’. *Conservation Letters*. 3(2), pp. 63-73.

Unsworth, R.K., De León, P.S., Garrard, S.L., Jompa, J., Smith, D.J., and Bell, J.J. (2008). 'High connectivity of Indo-Pacific seagrass fish assemblages with mangrove and coral reef habitats'. *Marine Ecology Progress Series*. 353, pp. 213-224.

Unsworth, R.K.F. McKenzie, L.J., Collier, C.J., Cullen-Unsworth, L.C., Duarte, C.M., Eklof, J.S., Jarvis, J.C., Jones, B.L. and Nordlund, L.M. (2018) 'Global challenges for seagrass conservation'. *Ambio.* (48), pp.801–815.

Wear, S.L. (2016) 'Missing the boat: Critical threats to coral reefs are neglected at global scale'. *Marine Policy*. 74, pp. 153-157.

Weber, M., de Beer, D., Lott, C., Polerecky, L., Kohls, K., Abed, R.M.M., et al. (2012) 'Mechanisms of damage to corals exposed to sedimentation'. *PNAS.* 109(24), E1558–E1567.

Weilgart, L.S. (2007) 'A brief review of known effects of noise on marine mammals'. *International Journal of Comparative Psychology*. 20, pp.157-168.

Wentworth, C. K. (1922) A scale of grade and class in terms of clastic sediments. *Journal of Geology*. 30, pp.377–392.

Wiley, D.N., Asmutis, R.A., Pitchford, T.D. and Gannon, D.P. (1995) 'Stranding and mortality of humpback whales, *Megaptera novaeangliae*, in the mid-Atlantic and southeast United States, 1985-1992'. *Fisheries Bulletin*. 93, pp.196-205.

APPENDIX A – Key Policy and Legislation

Fisheries reform in Cambodia was undertaken during the 2000's. It aimed to promote the livelihoods of people in local communities for both socio-economic and environmental benefit. This includes the sustainability of natural resources, the conservation of biodiversity and cultural heritages.

Key policy and legislation for fisheries in Cambodia include the following:

Policy Statement

Management, conservation, and development of sustainable fisheries resources to contribute to people's food security and socio-economic development in order to enhance people's livelihood and the nation's prosperity. (Royal Government of Cambodia, 2014)

Rules:

Article 49:

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

Article 52:

Shall be prohibited:

1. Fishing or any form of exploitation, which damages or disturbs the growth of seagrass or coral reef.
2. Collecting, buying, selling, transporting or stocking of corals.
3. Making port calls and anchoring in a coral reef area.
4. Destroying seagrass or coral by other activities.

All of the above activities mentioned in points 1, 2 and 3, may be undertaken only when permission is given from the Minister of Agriculture, Forestry and Fisheries. (FiA, 2007)

*The Fisheries Administration (FiA) define inshore fishing areas (or inshore coastal areas) as being the area, "which extends from the coastline at higher high tide to the 20 metre deep line."

APPENDIX B – Species Monitoring List

Table B1: Common names for monitored species and their scientific name/classification.

COMMON NAME	SCIENTIFIC NAME
Big Eye Trevally	*Caranx sexfasciatus* (species)
Black-Spot Snapper	*Lutjanus ehrenbergii* (species)
Blue Swimmer Crab	*Portunus pelagicus* (species)
Blue-Lined Grouper	*Cephalopholis formosa* (species)
Boring Bivalves	*Bivalvia* (class)
Boxfish	*Ostrasiidae* (family)
Bream Total	*Nemipteridae* (family)
Butterflyfish total	*Chaetodontidae* (family)
Cardinalfish	*Apogonidae* (family)
Carpet Blenny Eel	*Congrogadus subducens* (species)
Catfish	*Plotosidae* (family)
Chocolate Grouper	*Cephalopholis boenak* (species)

Christmas Tree Worm	*Spirobranchus* (genus)
Cleaner Wrasse	*Labroides* (genus)
Collector Urchin	*Tripneustes* (genus)
Conch	*Strombidae* (family)
Cowrie	*Cypraeidae* (family)
***Diadema* Sea Urchin**	*Diadema* (genus)
Drupella	*Drupella* (genus)
Dusky Rabbitfish	*Siganus fuscescens* (species)
Duskytail Grouper	*Epinephelus bleekeri* (species)
Eight Banded Butterflyfish	*Chaetodon octofassiatus* (species)
Emperor	*Lethrinus* (genus)
Feather Duster Worm	*Sabellastarte* (genus)
Feather Star	*Crinoidea* (order)
Filefish	*Monacanthidae* (family)

Flatworm	*Platyhelminthes* (phylum)
Fusilier	*Caesionidae* (family)
Giant Clams	*Cardiidae* (family)
Gold Spotted Sweetlips	*Plectorhinchus flavomaculatus* (species)
Golden Rabbitfish	*Siganus guttatus* (species)
Golden Trevally	*Gnathanodon spesiosus* (species)
Grouper total	*Serranidae* (family)
Gurnard	*Triglidae* (family)
Jacks	*Carangidae* (family)
Java Rabbitfish	*Siganus javus* (species)
Long-Beaked Coral Fish	*Chelmon rostartus* (species)
Longfin Grouper	*Epinephelus quoyanus* (species)
Monogram Monocle Bream	*Scolopsis monogramma* (species)
Mullet	*Mugilidae* (family)

Needlefish	*Belonidae* (family)
Nudibranch	*Nudibranchia* (order)
Ocellated Butterflyfish	*Parachaetodon ocellatus* (species)
Orange-Spotted Grouper	*Epinephelus coioides* (species)
Other Bream	*Nemipteridae* (family)
Other Butterflyfish	*Chaetodontidae* (family)
Other Gastropods	mostly *Turbo* (genus)
Other Grouper	*Serranidae* (family)
Other Rabbitfish	*Siganidae* (family)
Other Snapper	*Lutjanidae* (family)
Other Trevally	*Carangidae* (family)
Other Wrasse	*Labridae* (family)
Paradise Whiptail	*Pentapodus paradiseus* (species)
Pencil Urchin	*Heterocentrotus mammilatus* (species)

Pipefish	*Syngnathinae* (sub family)
Rabbitfish total	*Siganidae* (family)
Scad	*Carangidae* (family)
Scatfish	*Scatophagus argus* (species)
Seahorse	*Hippocampus* (genus)
Sergeant Fish spp.	*Abudefduf* (genus)
Shark Sucker	*Echeneidae* (family)
Snapper total	*Lutjanidae* (family)
Spadefish	*Ephippidae* (family)
Spanish Flag Snapper	*Lutjanus carponotatus* (species)
Sweeper	*Pempheris* (genus)
Synaptic Sea Cucumber	*Synaptidae* (family)
Toadfish	*Batrachoididae* (family)
Top Shell	*Trochus* (genus)

Unknown Bream	*Nemipteridae* (family)
Unknown Butterflyfish	*Chaetodontidae* (family)
Unknown Snapper	*Lutjanidae* (family)
Unknown Wrasse	*Labridae* (family)
Virgate Rabitfish	*Siganus virgatus* (species)
Volute Snails	*Volutidae* (genus)
Weedy Surge Wrasse	*Halichoeres margaritaceus* (species)
Whiptail	*Pentapodus paradiseus* (species)
White-spotted Rabbitfish	*Siganus canaliculatus* (species)
Whitecheek Monocle Bream	*Scolopsis torquate* (species)
Wrasse total	*Labridae* (family)
Xanthid Crab	*Xanthidae* (family)