

KINGDOM OF CAMBODIA

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FISHERIES ADMINISTRATION



**Koh Kong, Preah Sihanouk, Kampot and Kep--Biophysical update
SEAGRASS AND CORAL REEF DISTRIBUTION AND MONITORING**

2021-2022

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**Koh Kong, Preah Sihanouk, Kampot and Kep--Biophysical update
SEAGRASS AND CORAL REEF DISTRIBUTION AND MONITORING**

**Cambodia Programme for Sustainable and Inclusive Growth in the Fisheries Sector:
Capture Component (CAPFISH-Capture)**

with the support of FAO, FFI, MCC and EU

2021-2022

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Preface

Cambodia's coastal areas contain important coral reef, seagrass and mangrove habitats. The health and productivity of these habitats are crucial for diverse and productive fisheries and for livelihoods in coastal communities. However, these vital habitats have come under pressure from a range of human activities including nutrient enrichment, increased sedimentation, and destructive fishing practices, whilst rising sea surface temperatures and ocean acidification are additional and serious threats. It is therefore essential that Cambodia maintains an up-to-date and detailed inventory of the extent and health of seagrass areas and coral reef areas, so that their status can be monitored, and steps taken to ensure their protection.

This report, from the Ministry of Agriculture's Fisheries Administration, supported by its development partners, FAO, Marine Conservation Cambodia (MCC) and Fauna and Flora International (FFI), makes an invaluable contribution towards this goal. Findings on seagrass extent and condition will be incorporated into the scope of the National Plan for Control and Inspection (NPCI), to ensure that zone-based trawling and other habitat damaging fishing gears do not affect these areas, whilst new information on coral reef areas will be used to inform local fisheries and environmental management plans. This report and spatial data will be shared with other Government ministries and development partners working on coastal zone management.

I would like to take this opportunity to thank the EU, FAO, FFI and MCC for their assistance in carrying out this important work. I am particularly grateful for their efforts to develop the capacity of FiA officers through engagement in the surveys which will allow for future studies to be conducted and comparatives with the current situation to be made.

Poum Sotha

**Delegate of the Royal Government
Director General
Fisheries Administration**

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Online maps

Detailed maps of seagrass and coral areas in the coastal areas can be downloaded at

<https://fia.maff.gov.kh/documents/cmowWzihVC?lang=kh>

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Acronyms

CCRMN – Cambodian Coral Reef Monitoring Network

CFi – Community Fisheries

CR - *Cymodocea rotundata*

CS - *Cymodocea serrulate*

EA – *Enhalus acoroides*

FFI – Fauna & Flora International

FiA – Fisheries Administration

HD – *Halophila decipiens*

HM – *Halophila minor*

HO – *Halophila ovalis*

HP – *Halodule pinifolia*

HU – *Halodule uninervis*

KR-MNP – Koh Rong Marine National Park

MAFF – Ministry of Agriculture Forestry and Fisheries

MCC – Marine Conservation Cambodia

MFMA – Marine Fisheries Management Area

MNP – Marine National Park

MoE – Ministry of Environment

MPA – Marine Protected Area

NGO – Non-Governmental Organisation

NIA – Nutrient Indicator Algae

NPCI – National Plan for Control and Inspection

NUS – National University of Singapore

SI - *Syringodium isoetifolium*

SSF – Song Saa Foundation

TH – *Thalassia hemprichii*

UNEP – United Nations Environment Program

WEA – Wild Earth Allies

Executive Summary

Cambodia's coral reefs, and seagrass are important habitats for many aquatic animals. These habitats are highly productive but are coming under threat from illegal and destructive fishing practices such as trawls. The National Plan for Control & Inspection (2020-2024), calls upon the Fisheries Administration to undertake research in areas with seagrass beds and coral reefs, to map them accurately and thereby establish areas where trawling bans can be strictly enforced. Strengthening the survey capacity of FiA and FiAC officers has also been recognised as an important step in improving future fisheries management in the coastal provinces.

This report details the results from survey work on the location, extent and condition of seagrass and coral reef habitats in Cambodia's coastal waters. The survey work was carried out by Fisheries Administration with the support of Fauna Flora International (FFI), in Koh Kong and Preah Sihanouk; and Marine Conservation Cambodia (MCC) in Kampot and Kep. Detailed seagrass and coral reef maps have been developed for each province and in this way, a complete and accurate picture of the status of coral reefs and seagrass meadows in Cambodia's coastal waters has now been compiled, providing an invaluable baseline for future coastal habitat survey work and monitoring. These maps have been made freely available through the FiA website: <https://fia.maff.gov.kh/documents/cmowWzihVC?lang=kh> The skills and experience of FiA and FiAC officers involved in this work, have been enhanced through the formal training and survey opportunities provided by the development partners.

1. Introduction

Cambodia has a mainland coastline stretching for approximately 435 kilometers; constituting the four coastal province of Koh Kong, Preah Sihanouk, Kampot and Kep. These coastal areas encompass estuaries, bays, inlets and 69 islands (Steffen Johnsen and Munford, 2012). Within this marine area, important coral reef, seagrass and mangrove habitats can be found, either fringing the multitude of islands or as in the case of seagrass, along sheltered areas of the mainland (Ali Raza Rizvi and Singer, 2011). The health and productivity of these habitats are crucial for a diverse and functional marine environment and the livelihoods of the many people who rely on them. Aquatic resources constitute the largest proportion of protein sources for Cambodians, comprising 76% of the nation's annual protein intake (IFREDI, 2013). Therefore, intact, healthy and productive marine ecosystems are vital for the continuation of Cambodian societal resource prioritisation.

Cambodia's coastal marine habitats are threatened by numerous biotic and abiotic stressors from localised and global sources (Bellwood *et al.*, 2004). Localised stressors include nutrient enrichment and increased sedimentation that smothers coral reefs and seagrass (Burke, Selig and Spalding, 2002; Green, Lapointe and Gawlik, 2015; Pineda, Duckworth and Webster, 2016). Whilst unsustainable fishing practices have severely degraded some seagrass habitats and depleted the biomass and abundance of key trophic fish families (Jackson *et al.*, 2001; Feary *et al.*, 2007; Savage *et al.*, 2014). Meanwhile the pervasive influence of rising sea surface temperatures and ocean acidification are an increasing threat to all marine habitats (Pandolfi *et al.*, 2003; Bellwood *et al.*, 2004; Hughes *et al.*, 2018). For some Cambodian coral reef habitats, the build-up of thermal stress in April – May has resulted in bleaching events. Whilst these have yet to result in mass mortality of hard corals, a mass mortality event in future cannot be ruled out, with coral bleaching events increasing in frequency and duration (Teoh, 2018).

Following the establishment of the National Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Marine Fishing (NPOA-IUU) 2010-2024, the National Action Plan of Control and Inspection for Marine Fisheries (NPCI-MF) is the second five-year plan, with clear objectives, strategies and activities aimed at strengthening and enhancing the protection of coastal and marine fisheries resources. This is being achieved through; capacity building of government officers; purchasing and implementation of essential equipment; and the strengthening of cooperation between fisheries administrations at the national and sub-national level as well as with development partners and community fisheries. The main fisheries management measures proposed are; the prohibition of trawl fishing outside of the permitted zones and in waters shallower than 20m; the listing of authorised fishing gears and restricted mesh sizes; the proclamation of a closed season from January to March for species of short body and Indian mackerels; and the prohibition of fishing in fishery conservation areas including seagrass and coral reef areas.

Co-management through Community Fisheries (CFi) represents a secondary level of management measures undertaken. Strengthened by the 2006 fisheries law, the creation of coastal CFi's aimed to implement community resource management based on a conservation perspective and promote the livelihoods of local communities (Chap, Touch and Diepart, 2016). This allows fishing communities to co-manage specific coastal fishing areas. Within a Community Fisheries Area (CFA), there is usually at least one fisheries conservation area, which regulates fishing within a demarcated geographic area and may be classified as a "no-take marine protected area". Promoting the capacity of the CFi's has been a primary aim both government and Non-Governmental Organisations (NGOs) for several decades. This support has been through the provision of training in enforcement, management plans, management strategies, provision of patrol equipment and deployment of passive compliance measures. The health and condition of the marine habitats are key indicators towards national conservation goals that are strived to be achieved by supporting the CFi model.

Cambodia's coastal areas contain large expanses of sheltered bays and inlets, which are suitable for the proliferation of **seagrasses**. It has been suggested that some of the largest seagrass beds in Southeast Asia may be situated in Cambodian coastal waters. The most extensive tracts of seagrass are located in Kampot and Kep provinces and within Chrouy Pros Bay, in Koh Kong Province, covering a combined estimated area of 32,492ha (FiA, 2005; UNEP, 2008; A.R. Rizvi and Singer, 2011; S Johnsen and Munford, 2012). The seagrass habitats of Cambodia are diverse, with over 12 species identified throughout the seascape, with the large Kampot and Kep seagrass meadows having the most diverse, containing over 10 identified species (Ouk *et al.*, 2010). Many important ecosystem services are provided by these seagrass meadows including providing nursery grounds for fishery species, improving water quality and providing protection against flooding (Nordlund *et al.*, 2016). Moreover, seagrass provides crucial habitat and foraging grounds for threatened and endangered species such as green turtles (*Chelonia mydas*), dugong (*Dugong dugong*) and seahorse (*Hippocampus spp.*).

The management of coastal areas falls under the jurisdiction of a number of different government ministries. The Fisheries Administration, Ministry of Agriculture Forestry and Fisheries (MAFF) administer fisheries regulations and Marine Fisheries Management Areas (MFMA). The Ministry of Environment administrates Marine National Parks (MNP). In response to the compounding multitude of local anthropogenic stressors which are impacting marine habitats, FiA is protecting sections of the Cambodian

coastline through the establishment of MFMA's. Additional marine management areas have been established by the Ministry of Environment in the form of Marine National Parks.

The seagrass habitats of Cambodia can be broadly defined into two main categories; extensive meadows adjacent to the mainland and smaller patches/ meadows forming around the many islands (FiA, 2005). However, the vast majority of seagrass habitat occurs along sheltered areas adjacent to the mainland. Seagrass habitat throughout Cambodia is coming under pressure from a myriad of anthropogenic stressors. Threats such as destructive fishing practices, declining water quality, agricultural run-off and development projects are all diminishing Cambodia's remaining seagrass habitat (FiA, 2005; Glue, 2018; Reid, Haissoune and Ferber, 2019). The largest seagrass meadow in Cambodia, situated adjacent to the mainland of the Kampot and Kep Provinces has been estimated to have been reduced in extent by up to 50% (Ouk Vibol *et al.*, 2010). Similar declines of seagrass area have also been observed in the Koh Rong Archipelago (Leng, Benbow and Mulligan, 2014; Glue, 2018).

The monitoring of seagrass habitat has been conducted by government agencies and NGOs across the coastline of Cambodia. The first large scale seagrass assessment was conducted in Kampot, assessing the species diversity and distribution of seagrass by water depth (Ouk Vibol *et al.*, 2010). Additional seagrass surveys have been conducted in the Koh Rong Archipelago by FFI (Leng, 2013; Leng, Benbow and Mulligan, 2014; Louise, Benbow and International, 2015), Kep MFMA by MCC (Reid, Haissoune and Ferber, 2019), Kampot province by Wild Earth Allies/MCC and Koh Sdach (Koh Kong Province) by Kuda Divers (Kalisiak and Bruget, 2021). Organisations responsible for the collection of their own data, its management, analysis and reporting are encouraged to share information with FiA to assist with the development of improved management plans.

It has been estimated that the Cambodian seascape contains approximately 2,700ha of **coral reef habitat** located along the mainland coastline and fringing islands (S Johnsen and Munford, 2012). Of the 2,700ha it is estimated the vast majority can be found in Koh Kong and Preah Sihanouk provinces (S Johnsen and Munford, 2012). Environmental conditions adjacent to the mainland are generally not satisfactory to facilitate the growth of coral reef habitat, due to high sedimentation and freshwater influx. Therefore, the vast majority of coral reef habitat is classified as fringing reef, situated around Cambodia's 69 islands (Chou, Koh and Tun, 2003; S Johnsen and Munford, 2012; Savage, Osborne and Hudson, 2013).

Overexploitation of marine resources has impacted the condition of coral reef habitat throughout Cambodia. With all reefs surveyed over the last five years exhibiting signs of degradation and overfishing (i.e. low biomass and low abundance of commercial species) (Reid, Haissoune and Ferber, 2019; Glue and Teoh, 2020; Teoh *et al.*, 2020). However, efforts by FiA, FiAC and NGOs to rehabilitate coral reef and other marine habitats have shown signs of promise. FiA and Marine Conservation Cambodia (MCC) in the Kep archipelago have had success in restoring fish communities through the deployment of passive compliance measures in a strategic and coordinated manner (Reid, Haissoune and Ferber, 2019). Community-led enforcement in the Koh Rong Archipelago has managed to mitigate declines of key coral reef habitat (Glue, Teoh and Duffy, 2020).

The first detailed assessment of Cambodia's coral reef habitats occurred in 2002 at the Koh Sdach Archipelago, Koh Kong Province. It was led by a team of researchers from the National University of Singapore (NUS) in collaboration with FiA, and funded by the United Nations Environment Program. This first assessment was a two pronged project, aimed at building the capacity of governmental officers to conduct marine surveys and filling in the unknowns regarding Cambodian coral reef habitat, the

publication described coral reef habitat with healthy fish assemblages and high live coral cover at some sites (Chou, Koh and Tun, 2003). However, high levels of anthropogenic impacts (anchor damage, debris and trash) and high rates of sedimentation revealed that coral reef habitat was already under considerable strain (Chou, Loh, T and Tunn, 2003). Some species valuable as trade commodities such as sea cucumbers were absent during reef surveys, (Chou, Loh, T and Tunn, 2003). Follow-up surveys in the Koh Sdach Archipelago a decade later (Savage *et al* (2014)) found that many reefs could be categorised as in ‘good’ condition but evidence of degradation was apparent in some areas. In the Koh Rong Archipelago, Preah Sihanouk province, a habitat assessment conducted by Coral Cay Conservation between 2010 – 2014 revealed a reef system that is comparable to other nations in Southeast Asia in regards to the abundance of specific commercial reef fisheries species (Thorne *et al.*, 2015). All studies recorded hard coral communities dominated by coral genera that primarily exhibit massive and encrusting morphological growth forms (Chou, Koh and Tun, 2003; Savage *et al.*, 2014; Thorne *et al.*, 2015; Glue and Teoh, 2020).

Coral reef monitoring data has been collected by a number of organisations since the establishment of long-term reef monitoring programs. The longest running coral reef monitoring program is from the Koh Rong Marine National Park, with the survey sites initially established by Coral Cay Conservation in 2010. Since then, two additional monitoring programs have been established in Koh Sdach (2012) and the Kep archipelago (2014). Coral reef monitoring programs collect data on fish communities (abundance and biomass), benthic substratum composition, invertebrate abundance and structural complexity of coral reefs, with all target indicators adapted to fit the context of Cambodian reef systems. In 2019, the Cambodian Coral Reef Monitoring Network (CCRMN) was established by FiA. The CCRMN is a multi-stakeholder group which seeks to standardise coral reef monitoring across Cambodia and act as a centralised hub for data storage. The CCRMN is managed by FiA with a custodian from FFI whom manages the database and calls for data among organisations. All reef monitoring data from Cambodia is stored within this database and can be accessed by anyone through a request to FiA.

2. Survey Objectives and Methodologies

2.1.1. Scope & Objectives

The scope of this study covers the four coastal province of Koh Kong, Preah Sihanouk, Kampot and Kep.

The objectives of the study are:

1. Develop accurate maps of seagrass habitat distribution in the four coastal provinces
2. Develop accurate maps and update the status of coral reef health in the four coastal provinces
3. Provide recommendations for follow up studies, seagrass and coral reef management strategies, and human resource capacity building.

2.1.2. Methodologies

FiA collaboration with the two development partners (FFI & MCC) resulted in slightly different methodologies for surveying seagrass and coral reef areas. The surveys conducted in Koh Kong and Preah Sihanouk did not survey coral reef extent, but monitored their health, because there were previously accurately mapped, whereas survey work in Kep and Kampot accurately mapped the coral reefs.

2.1.3. Collaboration with FFI: Koh Kong & Preah Sihanouk Provinces

In these provinces, the study explored seagrass and coral reef habitat throughout the entirety of Koh Kong and Preah Sihanouk's coastline, islands and reef features. The mapping of seagrass habitat was conducted during the period of December 2021 – December 2022. Coral reef monitoring surveys were conducted from June 2021 – December 2022. Survey sites were predefined via consultation with Community Fisheries (CFi) members. From these consultations, key priority areas for seagrass mapping were ascertained thanks to informative discussions between FFI and FiA officers. Local knowledge was crucial in establishing where data deficient areas of seagrass habitat could be found, helping focus the survey efforts. To compliment the seagrass mapping, coral reef monitoring was also conducted. Key locations for assessments were identified, with a combination of sites in close proximity to the mainland and those that can be classified as offshore island groups. Coral reef monitoring at sites in close proximity to the mainland included the Koh Ta Kiev Archipelago in Preah Sihanouk and Koh Kong Krao and Koh Krusa's in Koh Kong Province. The mapping of coral reef habitat in the provinces of Koh Kong and Preah Sihanouk was completed through ground-truthed mapping techniques, undertaken by site-based partners or through the visualisation from source material on locations that could not be mapped by teams on the ground. In addition to the monitoring of coral health, reef fish biomass, commercial fish abundance, species diversity and invertebrate diversity were assessed. Full details of the methodology used in Koh Kong and Preah Sihanouk, can be Seagrass habitat mapping can be found in Annex 1.

2.1.4. Methodology: Collaboration with MCC: Kampot & Kep Provinces

In these provinces, the main habitats focused on for this study were seagrass meadows, coral reefs, seaweed areas, and bivalve beds. Together with the distribution, extent, and indicative, fish and invertebrate species composition of these habitats, data on bathymetry and bottom composition were collected. In total, this survey effort covered more than 62 472 hectares (ha), including 5 826 points surveyed by the scientific team. In Kampot province, the research team performed 2 167 survey dives along transects for a total study area of 26 652 ha, whilst in Kep province, the team performed 3 659 survey dives along transects for a total study area of 35 820 ha. The coral reef surveys were conducted using a modified version of the globally recognised Reef Check methodology. This survey technique has been widely utilised throughout Cambodia and allows for comparability between other locations in Cambodia and the Southeast Asia region. The survey team implemented a free diving survey methodology recording habitat composition, diversity, density, bathymetry, bottom composition, noticeable events, and traces of human activities. To ensure the entire potential seagrass distribution areas were verified, some drone flights were conducted to identify marine habitats in coastal shallow waters that were difficult to reach by boat, and helped assess the extent of offshore corals reefs to plan survey methodology and logistics. Full details of the methodology used in Kampot and Kep, can be found in Annex 2.

3. Results

3.1. Koh Kong & Preah Sihanouk Provinces

3.1.1. Seagrass Areas

During the survey, the survey team mapped seagrass habitats at 11 locations throughout the provinces of Koh Kong and Preah Sihanouk. The combined area of seagrass habitat mapped combined was calculated at 2,277.84 ha (Table 1.),

Province	Site	Seagrass meadow size (ha)
Koh Kong	Chrouy Pros Bay	1338
Koh Kong	Koh Kong Krao	45.38
Koh Kong	Prek Ksach	102
Koh Kong	Koh Toteong	0.48
Koh Kong	Koh Sdach Mainland South	11
Preah Sihanouk	Steung Hav	610
Preah Sihanouk	Koh Bong	50.6
Preah Sihanouk	Koh Ta Kiev	64
Preah Sihanouk	Koh Tang	9
Preah Sihanouk	Prey Nub	98
Preah Sihanouk	Koh Thmei (Koh Thmei and Thmor Tom Combined)	4.98
Total Seagrass:		2,333.44

Table 1. Total hectares (ha) of each seagrass meadow in Koh Kong and Preah Sihanouk mapped during project timeline.

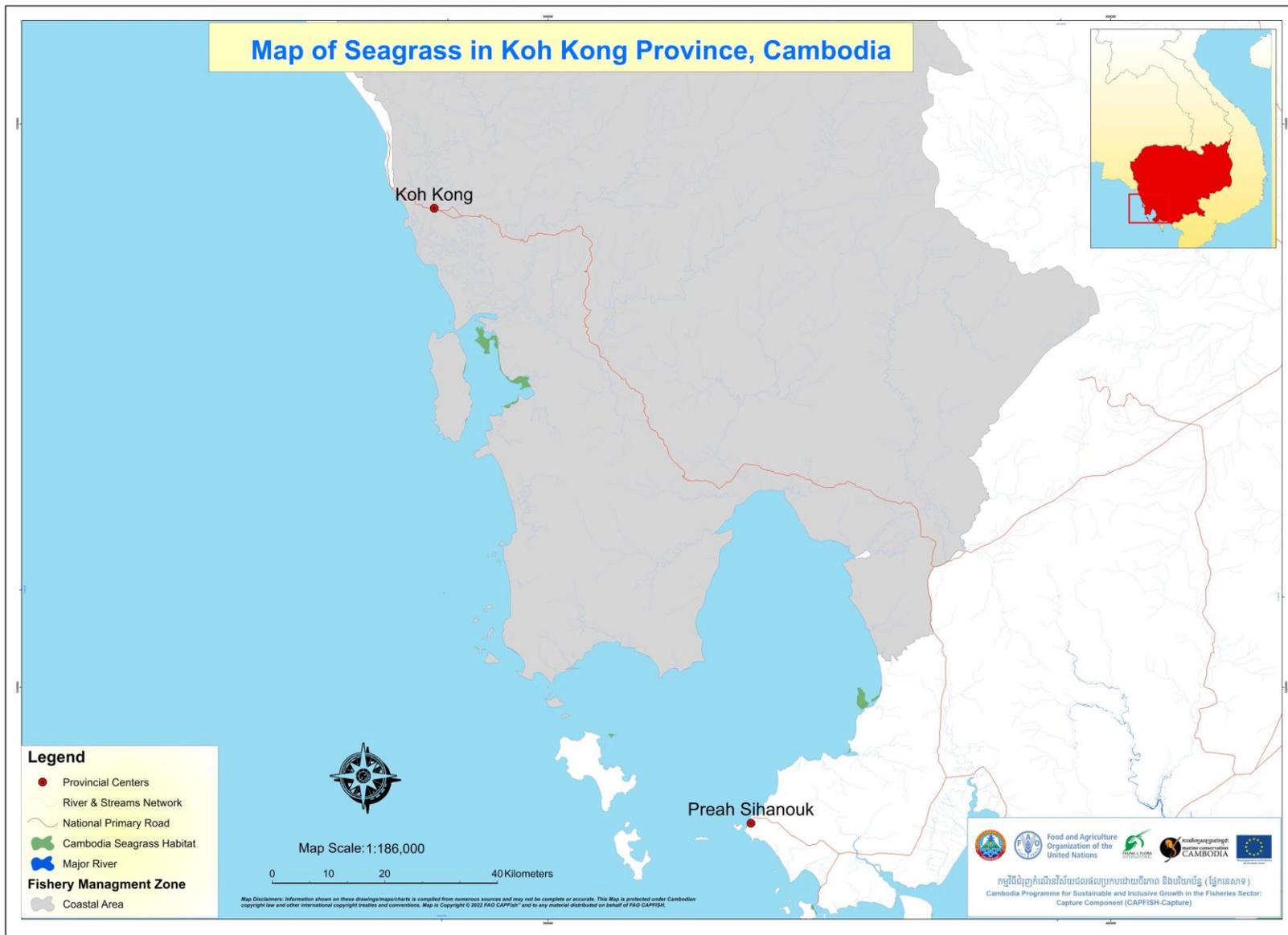


Fig 2: Map of Seagrass areas in Koh Kong Province

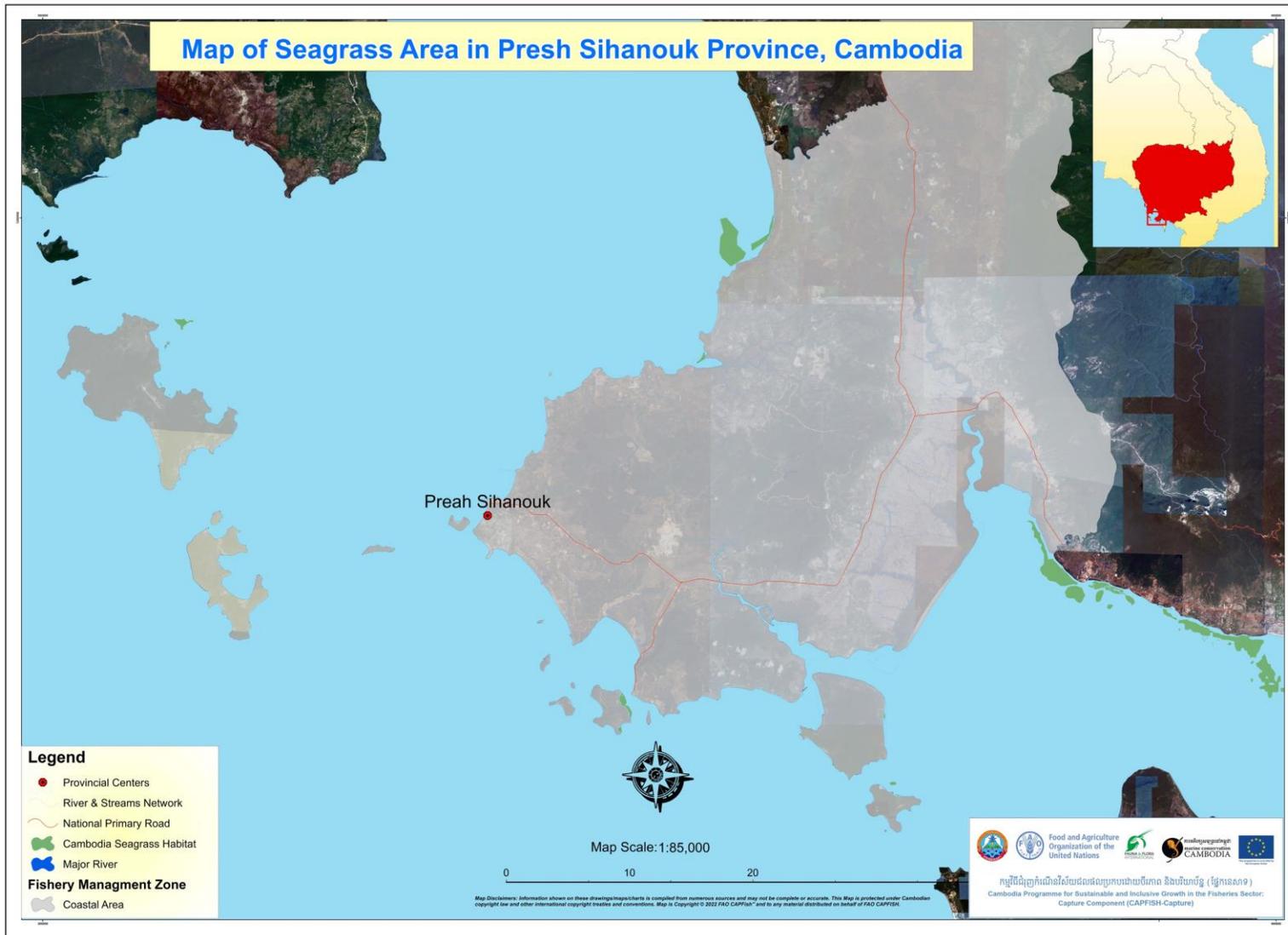


Fig 3: Map of Seagrass areas in Preah Sihanouk Province

The largest seagrass area of seagrass habitat encountered during the surveys in Koh Kong and Preah Sihanouk, was situated within the Chrouy Pros Bay, Koh Kong Province. This area is a large bay sheltered from exposure to strong winds and waves by Koh Kong Krao island. Within this bay, three distinctive seagrass habitats exist, a very large meadow, which is adjacent to the large mangrove habitat of Peam Krasop Wildlife Sanctuary and continues down along the coast past the village of Chrouy Pros, a smaller meadow to the south of the bay near Prek Ksach village, and smaller patches that can be found along the eastern flank of Koh Kong Krao. The total seagrass habitat mapped for this location was calculated at 1,485.38 ha. The second largest area of seagrass habitat was mapped at Steung Hav in Preah Sihanouk Province. This area is found on the eastern side of the large Kampong Som Bay. This section of the bay is very shallow and provides ideal habitat for the establishment of seagrass species. At this location, 610 ha of seagrass habitat was mapped by the survey team. Seagrass habitat in Prey Nob district, situated on the border with Preah Sihanouk and Kampot totalled 98 ha. This area is very shallow and the survey team often had to walk to complete their mapping transects. In the Koh Ta Kiev Archipelago, two major seagrass meadows were identified. Situated in the sheltered bays of the western side of the main island Koh Ta Kiev. Combined, both seagrass meadows adjacent to Koh Ta Kiev totalled 98ha. The seagrass meadow at Chrouy Pros was predominately monospecific, consisting primarily of *H. pinifolia* (Appendix I), with some occurrences of smaller pioneering species observed. The environmental conditions of the bay, with multiple large rivers, with the potential for high sedimentation load, favours the establishment of fast growing pioneer species such as *H. pinifolia* (Kawaroe *et al.*, 2016; Budiarsa *et al.*, 2021).

Elsewhere throughout the two provinces, the seagrass areas mapped by the team were quite small in size. At the outer island of Koh Tang, two small patches of seagrass were found in sheltered bays, totalling 9ha. Within the Ream National Park two small patches were identified. Of these, one was located to the east of Koh Thmei and the second was situated close to the small community of Thmor Tom. Within the Koh Sdach archipelago, small patches of seagrass were found running parallel to the mainland in thin strips and another small patch was mapped off the island of Koh Toteong. These seagrass areas combined totalled 11.48 ha. Within the Koh Rong Marine National Park, an area of seagrass habitat was mapped 2km northeast of the island of Koh Bong with a total area calculated at 58.6 h.

Detailed maps of all seagrass areas in Koh Kong and Preah Sihanouk Provinces can be found in Annex 4.

3.1.2. Coral reef surveys

Coral reef mapping through in-situ mapping techniques and visualisation from source material provided a grand total 2882.49 hectares of coral reef habitat estimated to occur in the Cambodian seascape. The province of Preah Sihanouk contained the most coral reef habitat, due to the occurrence of substantial fringing reefs in the Koh Rong Marine National Park, off shore island and reef bank features. Kep contained the least coral reef habitat, as expected due to the provinces small size and the small size of the islands in the Koh Tonsay archipelago.

Table 2. Total estimated hectares of coral reef habitat in all four coastal provinces

Province	Hectares
Preah Sihanouk	1627.23
Kampot	611.23
Koh Kong	576.36
Kep	67.83
Grand total	2882.49

Hard coral cover was calculated across the Preah Sihanouk and Koh Kong provinces and grouped by survey location (i.e. island group, geographical area, etc.). The highest mean hard coral cover was observed at the Koh Sdach archipelago, at 46.6 (± 1.8 SE) % (Fig. 23), whilst the offshore island of Koh Veal had the lowest hard coral cover at 7 (± 2.8 SE) %. There was a significant difference calculated for hard coral coverage between outer islands (Koh Polou Wai, Koh Tang, Koh Veal, Koh Pring, Condor Reef, Shark Island) and inner islands (Koh Kong Krao, Family islands, Koh Sdach, Koh Rong MNP, Koh Ta Kiev).

Composition of the benthos varied greatly between locations. At both Koh Kong Krao and the Family islands, the occurrence of silt on surveyed reefs constituted over 30% of survey points whilst it's occurrence at other locations was minimal. The presence of nutrient indicator algae (NIA) was significantly higher ($P = <0.01$, $df = 326$, $t = 10.07$) at inner island locations, Koh Rong MNP (29.6 %), Koh Sdach (16.7%) and Koh Ta Kiev (16.7%), whilst at the outer islands it was mostly absent. In contrast to the inner island locations the outer island locations had a higher proportion of the substrate occupied by bare bedrock (Fig. 24, Table 2). Soft coral, often a swift coloniser of substrate following significant disturbance events was only present at minimal proportions across all locations.

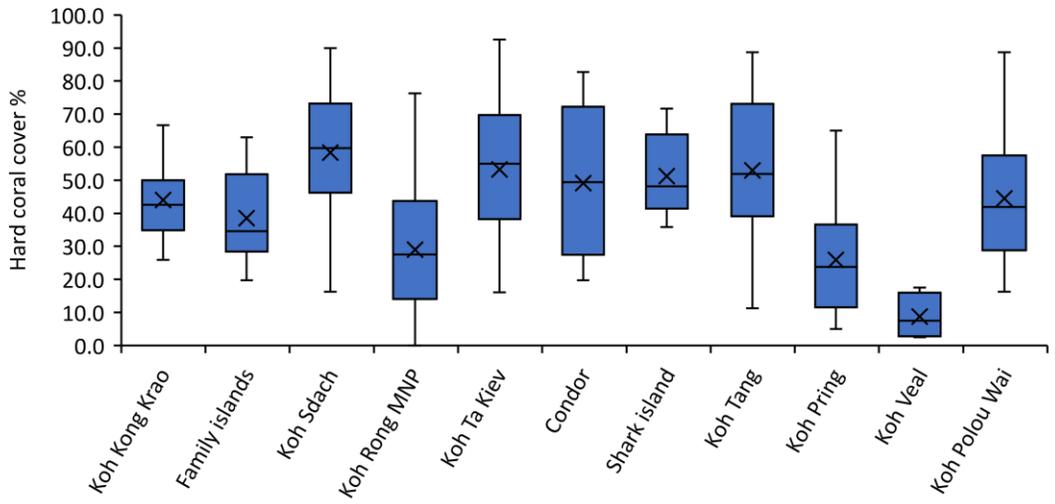


Fig. 4: .Box and whisker plot of hard coral cover percentage by coral reef survey location. Means represented by X marker, exclusive median represented by horizontal line in box and whisker plot.

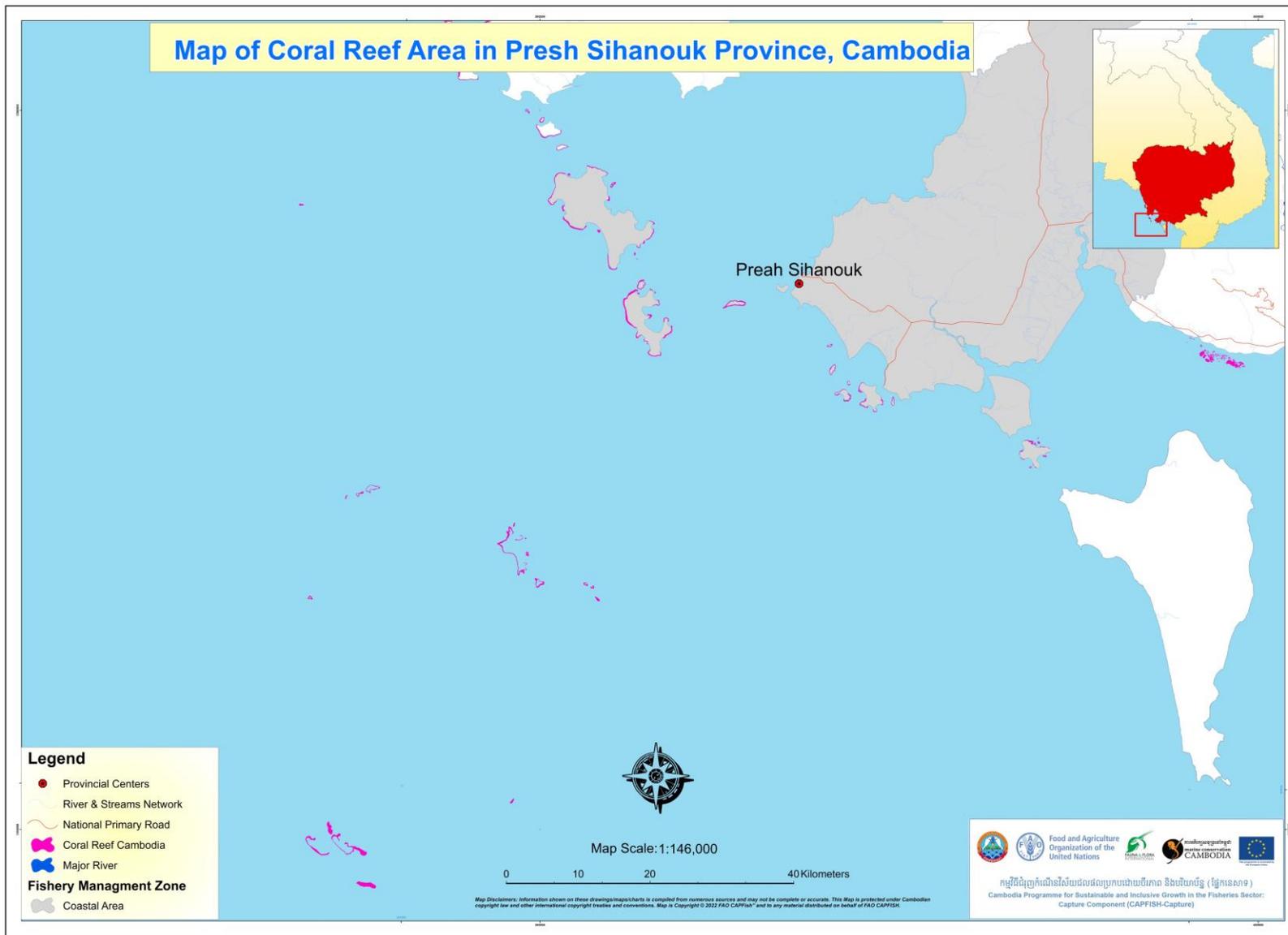


Fig 5: Map of Coral Reef areas in Preah Sihanouk Province

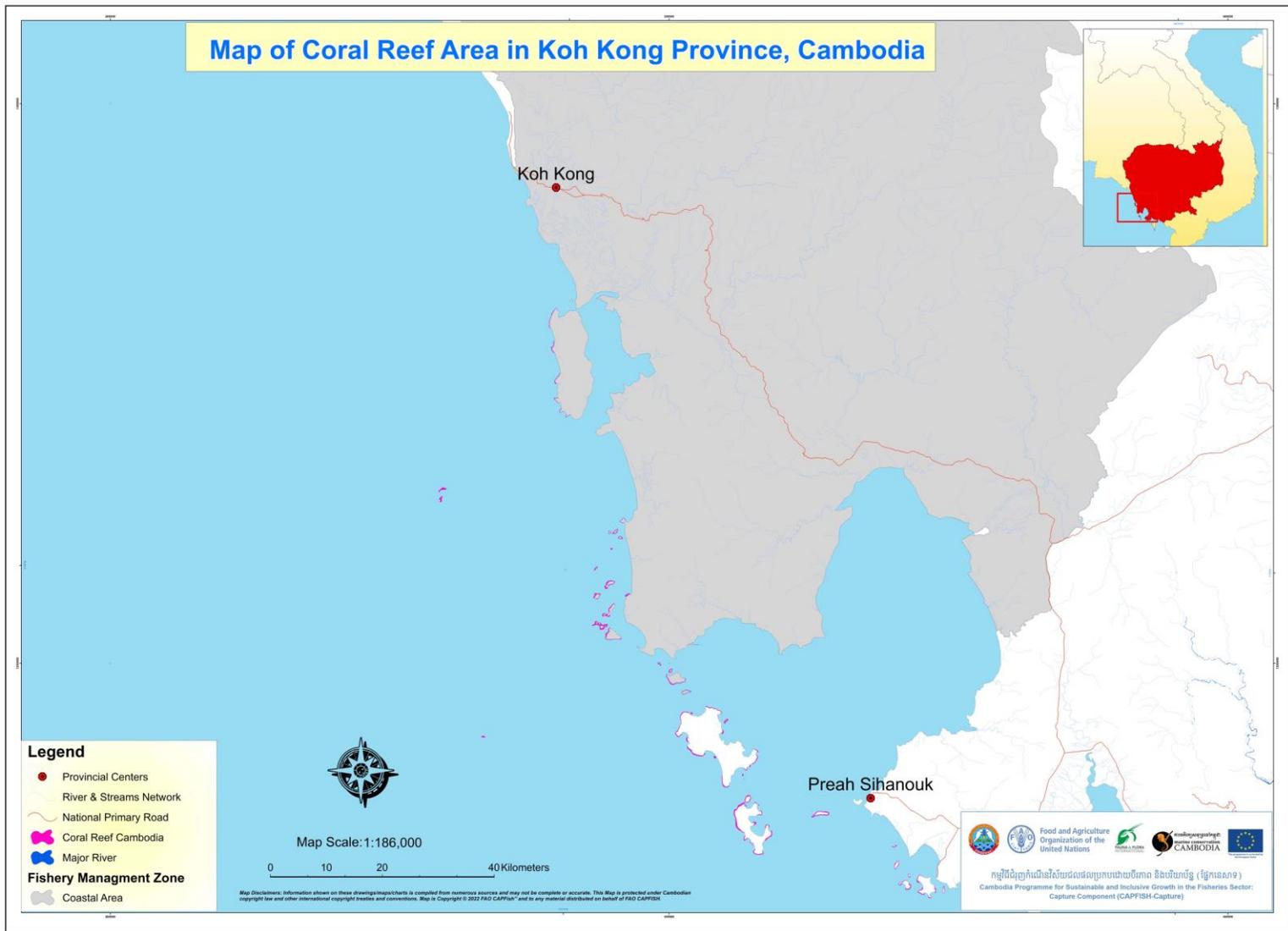


Fig 6: Map of Coral Reef areas in Koh Kong Province

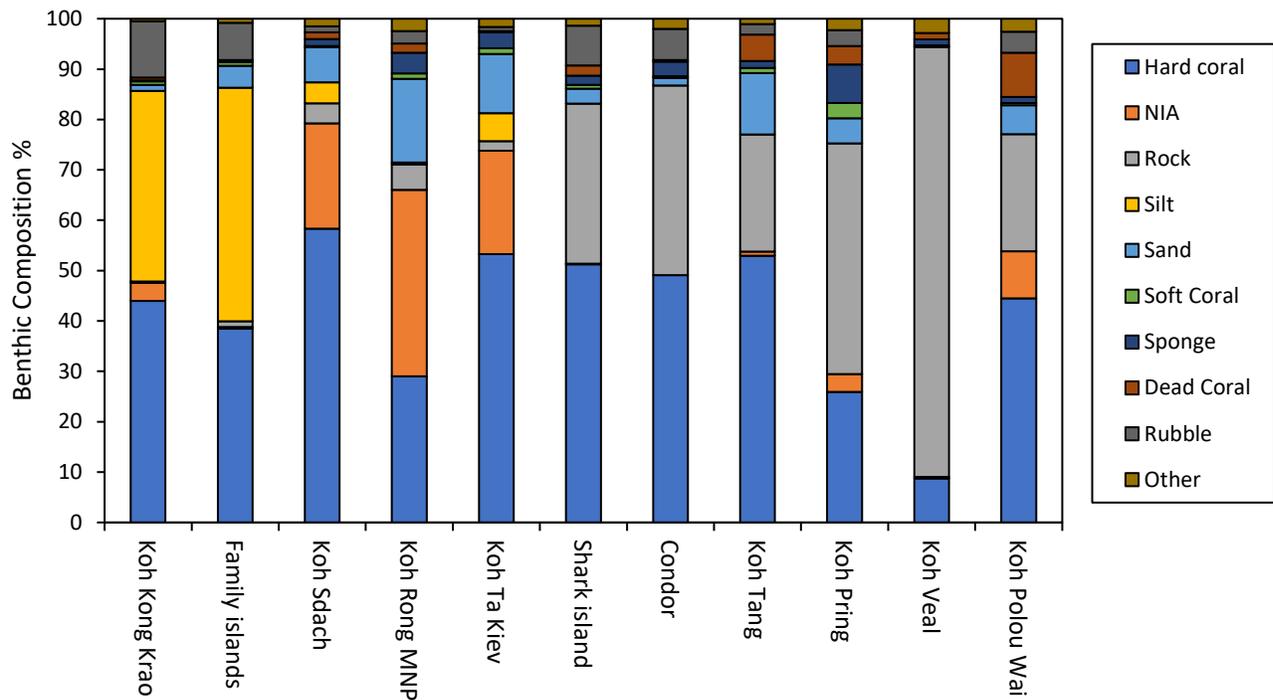


Fig 7. Benthic composition of each substrate class from all locations assessed during surveys in 2021 & 2022. Koh Kong Krao – Koh Ta Kiew are inner island locations. Shark island to Koh Polou Wai are outer island locations.

Hard coral community composition varied across all survey locations. At nearly all sites, excluding Koh Kong Krao and Koh Polou Wai, *Porites spp.* was the most abundant genera of hard coral observed. The presence of genera that possess higher structural complexity and act as drivers of species diversity such as Acroporids and Pocilloporid was low within hard coral communities surveyed at inner island locations. However, the presence of the genera *Acropora spp.* within hard coral communities became more apparent at the outer island sites. Acroporid's comprised 8.6% of the hard coral community at Koh Pring, 14.2% at Koh Tang and 10% at Koh Veal. The most remote location surveyed during these assessments, Koh Polou Wai was the only location dominated by *Acropora spp.*, constituting 41.6% of hard coral whilst *Porites spp.* accounted for a further 31.4%. The outer island location of Koh Veal had the lowest diversity of hard coral cover, with only the genera observed during surveys *Porites spp.* and *Acropora spp.*, with *Porites spp.* constituting 89.2% of hard coral. Koh Sdach had the highest number of coral genera recorded at 25. Interestingly, the presence of *Gonipora spp.* was high at both Koh Kong Krao and the Family islands.

Across all locations, sub-massive (36.1%), encrusting (28%) and massive (20.9%) constituted the majority of all hard coral. At a locational level, differences in dominant morphological growth form were observed. Sub-massive growth forms were dominant at Family islands (41.3%), Koh Sdach (38.5%), Koh Tang (63.3%), Condor (40.4%) and Koh Pring (41.4%). Massive morphological growth forms were most commonly observed at the Koh Rong MNP (36.9%) and Koh Ta Kiew (47.8%). Encrusting growth forms dominated the coral community at Koh Veal (57.1%), Shark Island (54.1%) and Koh Kong Krao (42.7%). Koh Polou Wai was the only location where branching growth forms constituted the highest proportion of the hard coral community, constituting 42.4%.

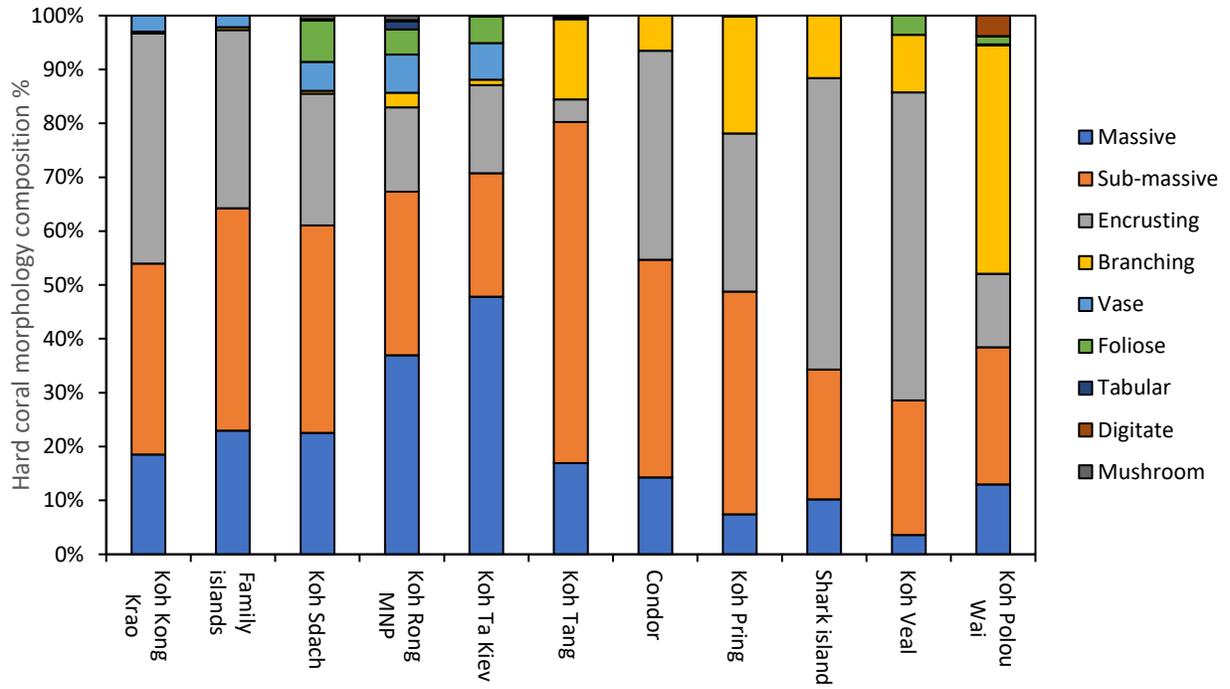


Fig 8. Composition of hard coral morphological growth forms observed at each survey location.

Detailed maps of coral reef areas in Koh Kong and Preah Sihanouk can be found in Annex 4.

3.1.2.1. Reef fish biomass

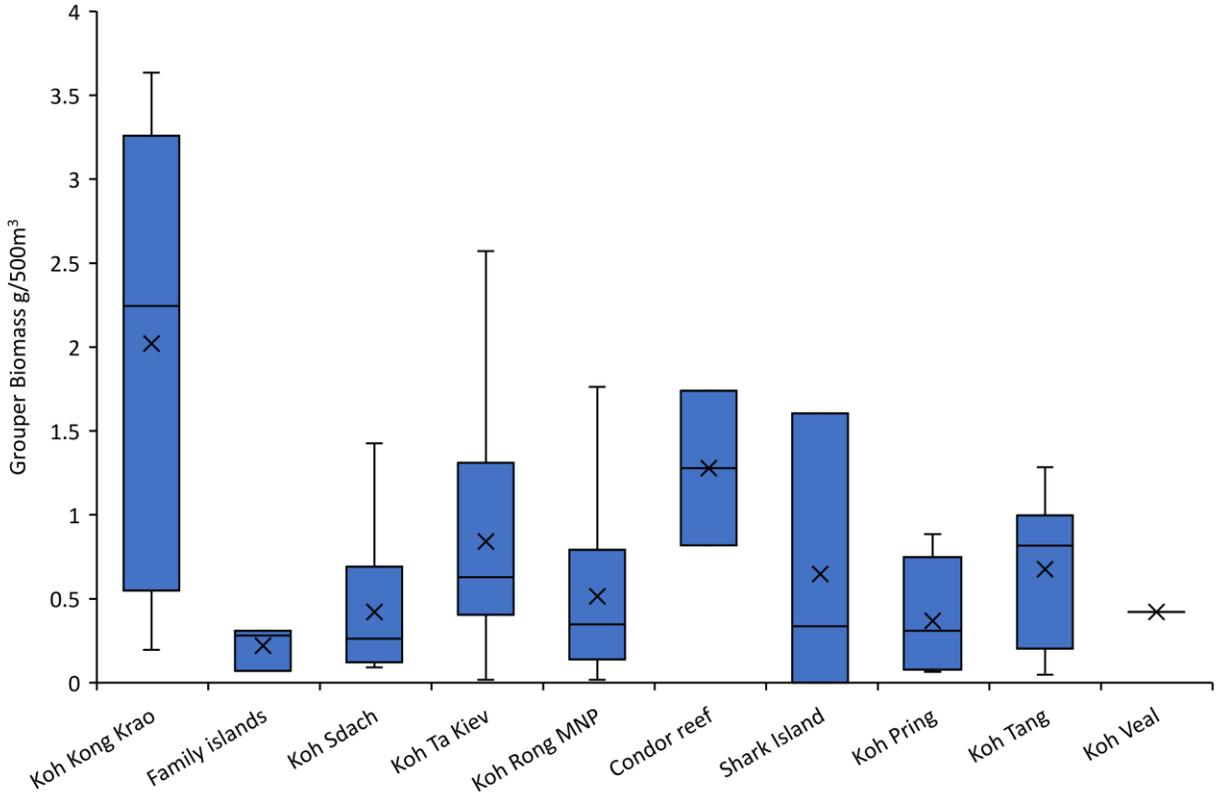


Fig 9. Grouper biomass g/500m³ for all sites surveyed between 2021 and 2022. X marker represents mean value.

The location with the highest grouper biomass recorded was Koh Kong Krao at 2.02 (± 0.021 SE) g/500m³ whilst lowest grouper biomass was observed at the Family islands 0.22 (± 0.02 SE) g/500m³. No location exhibited biomass values for grouper species that were significantly different from the others. The Chocolate Grouper (*Cephalopholis boenak*) was the most frequently observed species at Condor reef, Koh Pring, Koh Tang, Koh Sdach Koh Veal and Koh Polou Wai. Whilst at the Family islands, Koh Rong MNP, Koh Ta Kiev, Koh Kong Krao and Shark island, the most frequently observed species was the Blue line grouper (*Cephalopholis formosa*). Size estimations of grouper indicated that the mean size class for Koh Sdach, Koh Pring and Koh Plou Wai 0 – 10cm. Whilst at Condor, Family islands, Koh Rong MNP, Koh Tak Kiev, Koh Tang, Koh Veal, Koh Kong Krao and Shark island the mean size class was 11 – 20cm. The presence of grouper > 40cm was only observed at Koh Rong MNP, Koh Tak Kiev, Koh Kong Krao and Koh Polou Wai. However, grouper of this size were never observed in large numbers, with only a small number of individuals per location.

Parrotfish biomass was generally higher at most locations in comparison to grouper. The highest calculated parrotfish biomass was from Koh Polou Wai at 7.30 (± 0.77 SE) g/500m³, due to the presence of a large school of >400 individuals passing across the transect in front of the surveyor. This outlier surveyor resulted in the mean parrot fish biomass caused the mean parrotfish biomass for Koh Polou Wai to be considerably higher than the other locations (Fig. 28). The lowest parrotfish biomass was calculated from the outer island site of Koh Veal at 0.42 (± 0.00 SE) g/500m³.

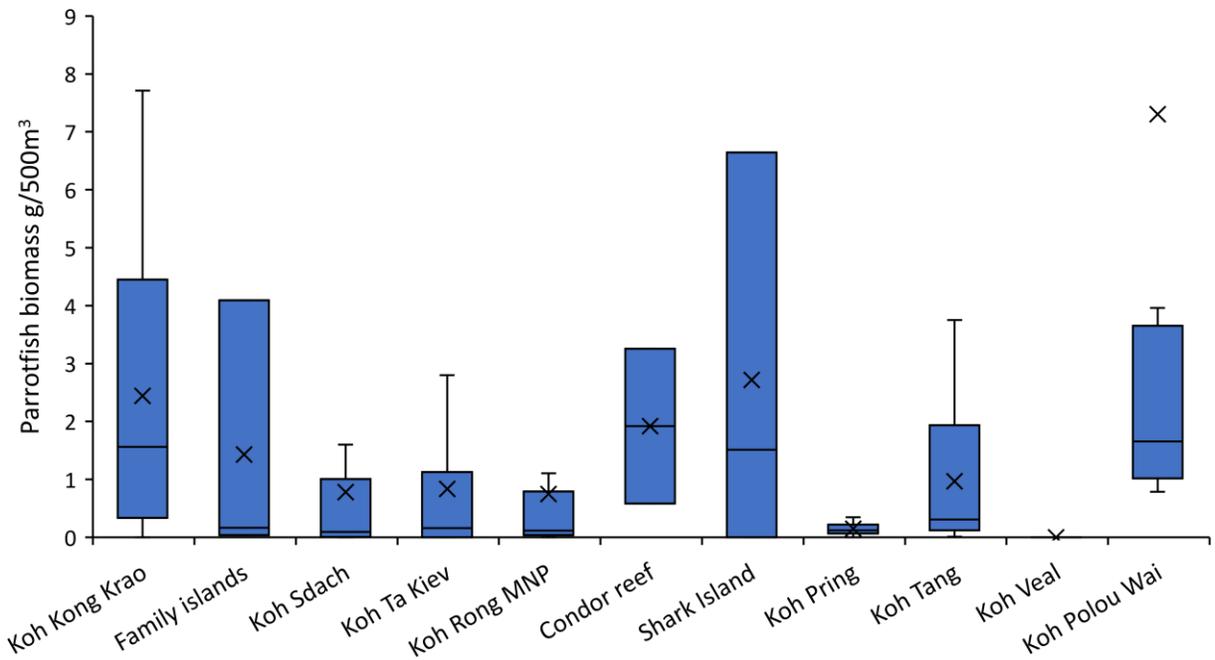


Fig 10. Parrotfish biomass g/500m³ for all sites surveyed between 2021 and 2022. X marker represents mean value.

Table 3. Mean biomass values (\pm standard error) in g/ 500m³ for Grouper and Parrotfish species at each location surveyed in 2021 & 2022.

Location	Grouper Biomass (\pm SE)	Parrotfish Biomass (\pm SE)
Condor reef	1.28 (\pm 0.012)	1.92 (\pm 0.15)
Family islands	0.22 (\pm 0.02)	1.43 (\pm 0.08)
Koh Polou Wai	0.59 (\pm 0.008)	7.30 (\pm 0.77)
Koh Pring	0.37 (\pm 0.005)	0.15 (\pm 0.02)
Koh Sdach	1.44 (\pm 0.014)	4.42 (\pm 0.34)
Koh Ta Kiev	0.84 (\pm 0.011)	0.83 (\pm 0.07)
Koh Tang	0.68 (\pm 0.009)	0.97 (\pm 0.10)
Koh Veal	0.42 (\pm 0.007)	0.00
Koh Kong Krao	2.02 (\pm 0.021)	2.44 (\pm 0.22)
Shark Island	0.77 (\pm 0.007)	3.05 (\pm 0.30)
Koh Rong MNP	0.51 (\pm 0.006)	0.75 (\pm 0.09)

3.1.2.2. Commercial fish abundance

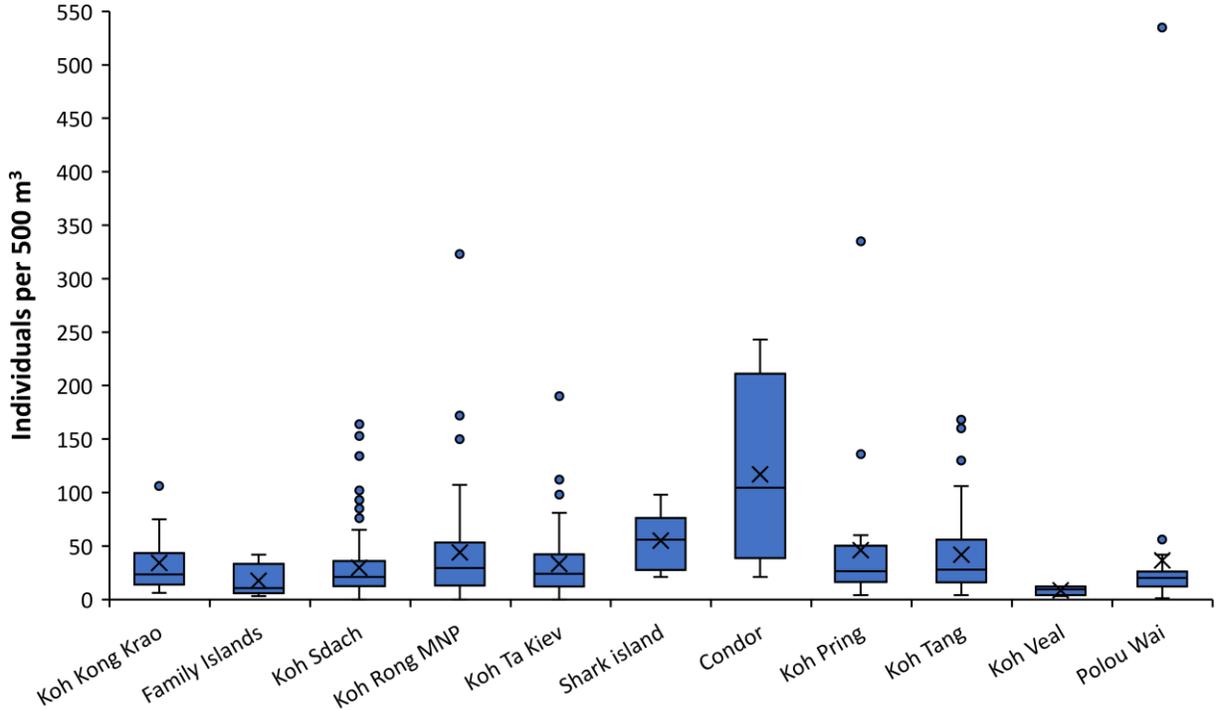


Fig 11. Abundance per 500m³ for all commercial fish families combined (Grouper, parrotfish, bream, barracuda, snapper, jack/trevally, emperors and rabbitfish)

The following fish taxonomic families classified as commercial fish species due to their importance in local fisheries were; grouper, parrotfish, barracuda, rabbitfish, bream, snapper, jack/trevally and emperor. When amalgamating all commercial fish families, the location Condor Reef displayed the highest mean abundance for commercial fisheries species at 117 (± 30.44 SE) indiv/ 500m³. The site with the lowest commercial fish mean abundance was the isolated island of Koh Veal, with only 8.5 (± 2.18 SE) indiv/500m³. Koh Polou Wai recorded the highest outlier of commercial fish abundance, with one record of > 500 indiv/500m³ (Fig. 29), due to the aforementioned large parrotfish school.. Snapper species were the most frequently observed commercial fish at Koh Sdach, Koh Rong MNP, Koh Ta Kiev, Condor and Shark Island Rabbitfish were the dominant commercial fish family at Koh Kong Krao and Family Islands. Parrotfish species were the dominant commercial fish species at Koh Tang and Koh Polou Wai (Fig. 30). At Koh Veal, grouper species were most frequently observed, whilst at Koh Pring, barracuda were the most frequently observed.

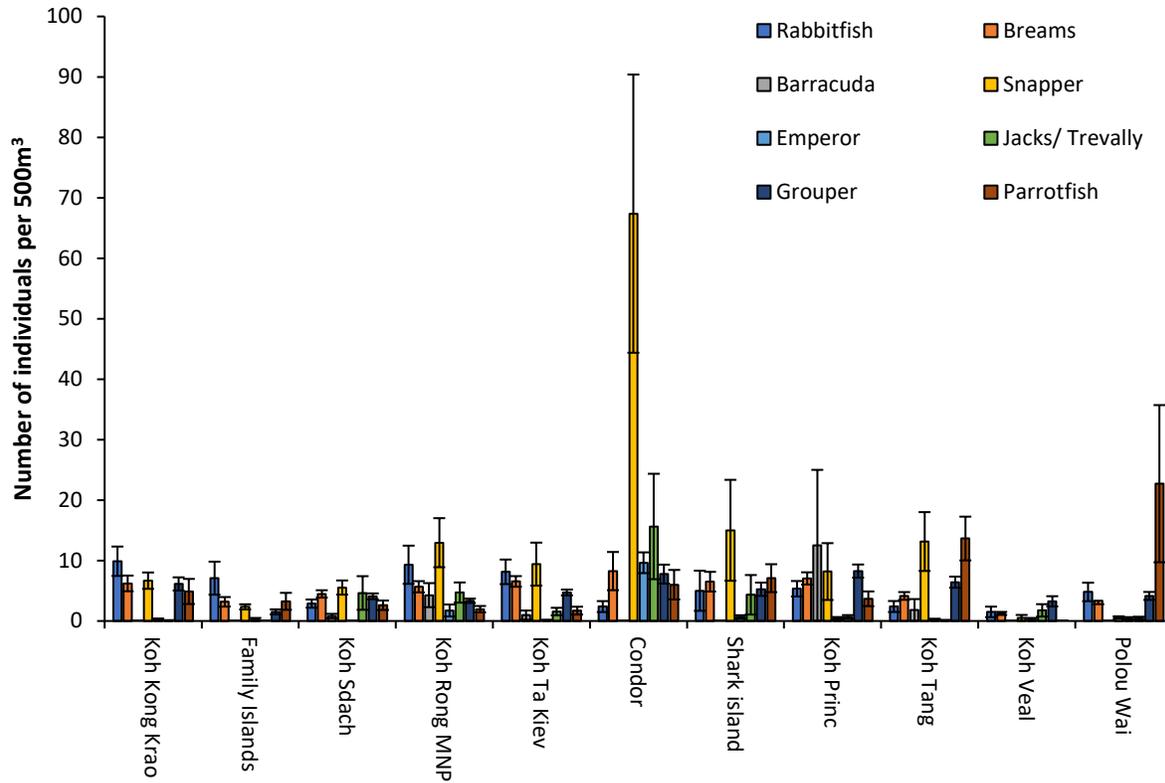


Fig 12. Commercial fish family abundance (indv/500m³) per survey location

3.1.2.3. Species Diversity

Simpson's index of diversity was selected to quantify the species diversity of fish and invertebrate assemblages and assess the variations in diversity between survey locations. The formula $D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right)$, was used to calculate Simpson's diversity index scores. Species or families that occurred in anomalously large numbers (i.e. Fusiliers and long spine urchins) were omitted from analysis due the potential for erroneously skewing index scores. Fish diversity was highest at Koh Kong Krao with a 0.88 (\pm 0.009 SE) mean index score. The lowest fish mean diversity index score was calculated for Koh Veal, measuring 0.71. Invertebrate species diversity was highest at Koh Kong Krao, with a mean index score of 0.82 (\pm 0.03 SE). The lowest invertebrate mean diversity index score was calculated for Condor reef, at 0.21 (\pm 0,15 SE).

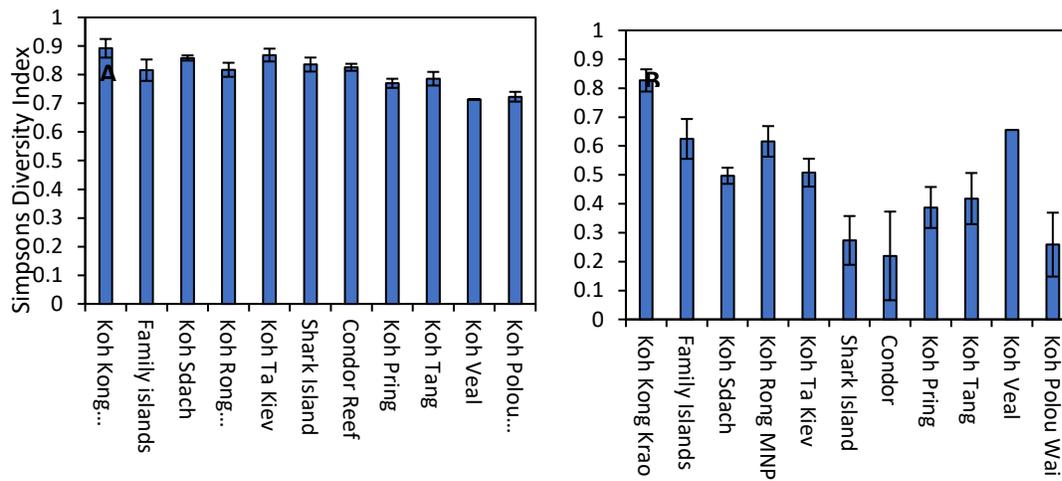


Fig 13. Species Diversity (Simpsons index).

3.1.2.4. Invertebrate survey results

Abundance for both invertebrates and impacts was calculated for the area of one singular survey transect at 200m² (5m x 20m survey area). The mean abundance of long spine urchins (*Diadema spp.*) was overall higher for outer island locations in comparison to nearshore locations. The highest mean abundance of long spine urchin as observed at Koh veal at 1167 (± 108.87 SE) individuals/200m². The lowest mean long spine urchin abundance was observed at Koh Kong Krao, with 0.041 (± 0.041 SE) individuals/200m². Long spine urchin abundance was significantly higher at outer island locations compared to inner island locations.

The abundance of giant clams is a key indicator for water quality, ecosystem health and fishing pressure, as these organisms are susceptible to increased water temperature, nutrient loading, pollutants and over harvesting. Giant clam abundance was highest at Koh Tang and Shark Island, with both locations recording 1.75 individuals per 200m². Their presence was lowest at Koh Kong Krao with 0.125 individuals per 200m². Observations of giant clams were categorised according to their size with five class sizes available. The highest mean size class observed was 31 – 40cm from Condor reef. The lowest mean size class of 0 – 10cm was observed at Koh Polou Wai.

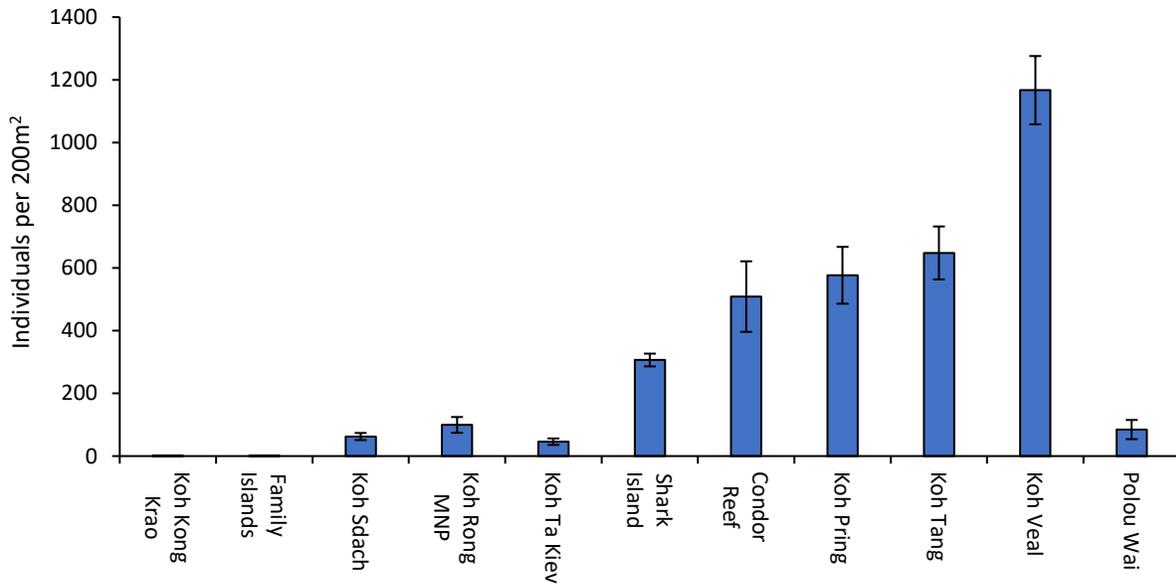


Fig 14. Long spine urchin (*Diadema* spp.) mean abundance per 200m² for each survey location.

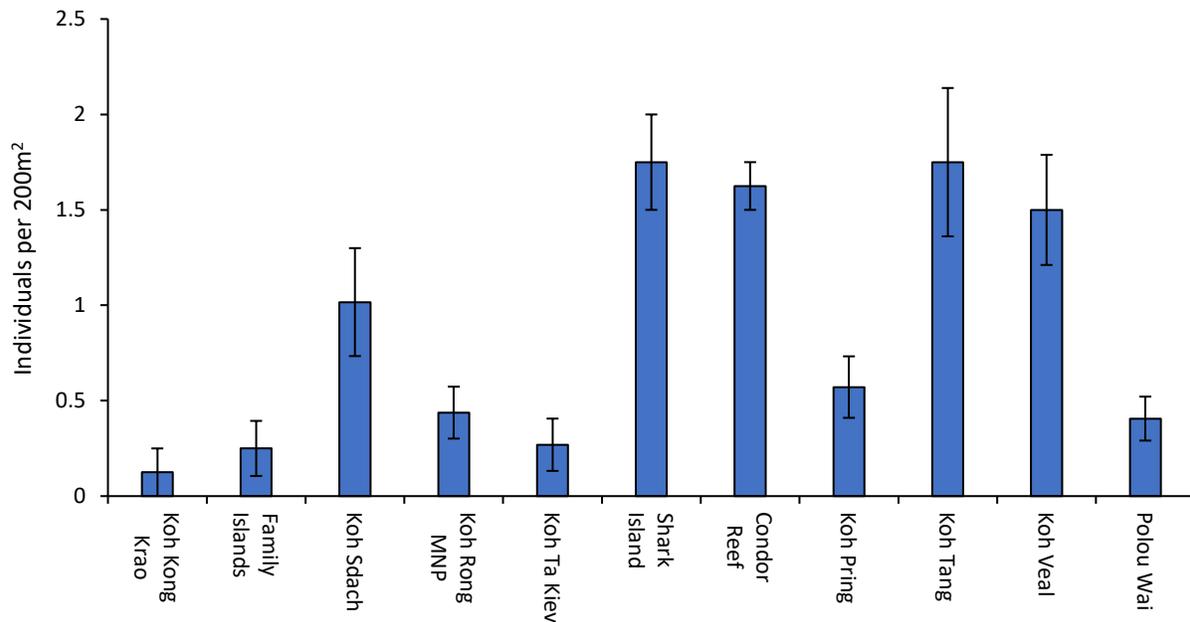


Fig 15 . Mean abundance of Giant Clam (*Tridacna* spp.) observed at each survey location.

3.2. Kampot & Kep Provinces

The survey team mapped seagrass and coral reefs and other habitats in the provinces of Kampot & Kep. The extent of each marine habitat evaluated in Kep was as follows: Seagrass meadows: 6 399 ha, Bivalves beds: 440 ha, Seaweed beds: 1 202 ha and Coral reefs: 65 ha. The extent of marine habitats evaluated, in Kampot was as follows: Seagrass meadows: 5 158 ha , Bivalves beds: 484 ha Seaweed beds: 133 ha and Coral reefs: 467 ha

Survey work in Kep and Kampot was organised into nine Sections, as follows:

Section A: Kep province’s section A encompasses the islands of Koh Ach Seh, Koh Angkrong, their conservation zones, Pirate Rock, and the corresponding marine habitats.

Section B: Kep’s province’s section B encompasses the islands of Koh Pou, Koh Makprang, and the corresponding marine habitats. The channel in between Koh Tunsai and Koh Pou marks the northern border of this section.

Section C: Kep province’s section C encompasses the islands of Koh Tunsai, Koh Tbal, Koh Svay, Koh Mates, Koh Kok, and the corresponding marine habitats. It is a portion of Koh Tunsai meadow, the largest seagrass meadow in Cambodia. This meadow has been split in 3 sections to better represent this meadow’s marine habitat diversity

Section D: Kep province’s section D encompasses the meadow located between the North of Koh Tunsai and Kep Coastline.

Section E: Kep province’s section E encompasses the meadow located between the East of Koh Tunsai and Kep Coastline.

Section F is located at the Eastern border of Kampot province, as part of Preaek Tnaot and Trapang Ropov Community Fisheries (Cfis).

Section G: is located in front of Nataya Resort and Prek Kdat Cfi. The eastern border of the section is marked by the beginning of Kampot new harbor.

Section H's western border has been placed at the East side of Kampot harbor and finishes at the border with Trapang Sangkae Cfi

Section I begins West of Trapang Sangkae Cfi and stretches until the border with Kep Province on its eastern side. Its particularity is to surround Kampot river mouth.

3.2.1. Kep Seagrass areas

Kep Province is by far the smallest of the 4 Cambodian coastal provinces. But despite this characteristic, it hosts the largest seagrass habitat in Cambodia, with 6 399 ha of seagrass recorded during this study. It is also the most diverse, together with Kampot meadows.

In Section A: Koh Ach Seh's seagrass meadow was found to include:

- 162 ha of seagrass.
- 8 different seagrass species (3 species of *Halophila*, 2 species of *Cymodocea* HP, TH and EA).
- The 2 main species in the meadow are HO (59%) and TH (30%).
- Its average depth is 4.9 meters, with seagrass found between 6.9 and 1.7 meters.
- The main sediment encountered is SSI.
-

Despite being the smallest seagrass bed in the province, Koh Ach Seh's meadow is the most diverse, together with Koh Tunsai eastern meadow. The highest seagrass density (~95%) and diversity (6 species in one spot check) has been observed in front of the East shore of the island.

This meadow has been under anthropogenic pressure for many years but is now showing encouraging signs of recovery. The research team recorded the presence of pioneer seagrass species at its north-western edge. This channel separating Koh Ach Seh and Koh Pou meadows is the deepest area where we have recorded seagrass presence in both Kep and Kampot provinces (<6 meters).

In Section B: Koh Pou's seagrass meadow is composed of:

- 982 ha of seagrass.
- 7 different seagrass species (2 species of *Halophila*, HU, TH, EA, CS and SI).
- The 3 main species in the meadow are TH (36%), HD (30%) and HO (20%).
- Its average depth is 4.1 meters, with seagrass found between 6.8 and 2.4 meters.
- The main sediment encountered is SS.

The Koh Pou seagrass bed is the second largest in Kep province. Its southern edge is separated from Koh Ach Seh meadow by a channel where pioneer seagrass species were encountered. This discovery is particularly interesting as this zone is also the area in where the highest density of conservation blocks has been deployed.

In Section C, Koh Tunsai's seagrass meadow is composed of:

- 1 318 ha of seagrass.
- 6 different seagrass species (2 species of *Halodule*, HO, TH, EA, and CS).
- The 2 main species in the meadow are TH (56%) and EA (25%).
- Its average depth is 2.9 meters, with seagrass found between 5.4 and 1.5 meters.
- The main sediment encountered is SSI.

Koh Tunsai meadow is at the heart of the largest meadow in Kep province, and in Cambodia. It is located on the East of Koh Tunsai and connects with 2 larger seagrass beds on both its North and East side. It is also an area with a high rate of marine mammal encounters.

Section D's seagrass meadow is composed of:

- 1 579 ha of seagrass.
- 7 different seagrass species (2 species of *Halodule*, 2 species of *Halophila*, TH, EA, and CS).
- The 2 main species in the meadow are TH (52%) and EA (37.5%).
- Its average depth is 2.7 meters, with seagrass found between 3.7 and 1.0 meters.
- The main sediment encountered is SS.

Aside from being a dense and diverse part of this meadow, this area appears to have the best marine habitat diversity, as the eastern edge of the meadow transitions to large patches of seaweed (mostly *Caulerpa sp.*) covering an area of 1 202 ha, whilst bivalve beds cover its South-West border.

Section E's seagrass meadow is composed of:

- 2 358 ha of seagrass.
- 8 different seagrass species (2 species of *Halodule*, 2 species of *Cymodocea* TH, EA, HO, and SI).
- The 2 main species in the meadow are TH (67.5%) and EA (29.5%).
- Its average depth is 2.2 meters, with seagrass found between 3.9 and 0.8 meters.
- The main sediment encountered is SS.

This section is the core of Kep province's seagrass beds. It is Kep's largest (and shallowest) seagrass meadow, which presents the highest density overall, and the most important species diversity (with Koh Ach Seh meadow).

3.2.2. Kampot Seagrass areas

The team surveyed Kampot coastline to assess the extent, diversity, and density of its marine ecosystems. The free diving survey dives along the transects performed 2 167 dives for a total study area of 26 652 ha. To verify the extent of the area of potential seagrass distribution, drone flights were conducted in coastal shallow waters (difficult to reach by boat) and assessed the extent of offshore coral reefs. In certain areas of Kampot Province, seagrass density has not been monitored due to difficulties to access sites.

The survey team mapped 5 158 ha of seagrass beds. Presence of seaweed was also found in an extremely diverse habitat, mixing coral reefs and bivalve beds.

Seagrass species richness of Kampot Province's meadows was 10 species:

- *Thalassia hemprichii* (TH)
- *Enhalus acoroides* (EA)
- *Cymodocea serrulate* (CS)
- *Cymodocea rotundata* (CR)
- *Halodule pinifolia* (HP)
- *Halodule uninervis* (HU)
- *Halophila ovalis* (HO)
- *Halophila decipiens* (HD)
- *Halophila minor* (HM)
- *Syringodium isoetifolium* (SI)

Seagrass areas in Section F are composed of:

- 684 ha of seagrass.
- 8 different seagrass species (2 species of *Halodule*, HO, TH, EA, CS, CR and SI).
- The 2 main species in the meadow are EA (61%) and TH (11.5%).

This section presented shallow murky waters, with areas of thick anaerobic mud. Precise depth, density, and bottom composition could not be recorded in this section. It was noticed in other areas that these environmental conditions were particularly suitable for seagrass growth, for example for species like *Enhalus acoroides* (EA). However, despite this environmental potential, the meadow's size we recorded was surprisingly small; more data would be needed to confirm t

This seagrass meadow area in Section G was composed of:

- 874 ha of seagrass.
- 7 different seagrass species (2 species of *Halodule*, HO, TH, EA, CS and SI).
- The 2 main species in the meadow are TH (44%) and EA (34%).
- Its average depth is 2.2 meters, with seagrass found between 3.4 and 1.2 meters.
- The main sediment encountered is SS.

A lower density was noticed in the seagrass bed directly neighboring the new harbor. One particularity of this meadow is to be placed between the shoreline and the largest coral reef in both provinces.

In section H, seagrass meadows neighboring the new harbor were mapped using satellite imageries since diving or assessment with was prohibited in this area. Thus, this section (as well as section H) are classified as data deficient for some parameters.

This seagrass meadow area in Section H was composed of:

- 2 296 ha of seagrass.
- All 10 different seagrass species of the province (3 species of *Halophila*, 2 species of *Halodule*, 2 species of *Cymodocea*, TH, EA, and SI).

- The 2 main species in the meadow are EA (40%) and TH (34%).
- Its average depth is 2.2 meters, with seagrass found between 3.5 and 1.0 meters.
- The main sediment encountered is SS.

Section I's seagrass meadows are composed of:

- 1 291 ha of seagrass.
- 9 different seagrass species (2 species of Halophila, 2 species of Halodule, 2 species of Cymodocea, TH, EA, and SI).
- The 2 main species in the meadow are EA (43%) and HP (20%).
- Its average depth is 1.2 meters, with seagrass found between 2.9 and 0.2 meters.
- The main sediment encountered is SSI.

This meadow is the shallowest documented during the study, with an average depth below 2 meters. It remains narrow along the coastline but spread widely offshore at the river mouth thanks to these suitable conditions for seagrass growth. Despite a low general density, it presents an interesting diversity with 9 species identified in the area. In addition, a small offshore coral reef was noticed at the Southern tip of this section.

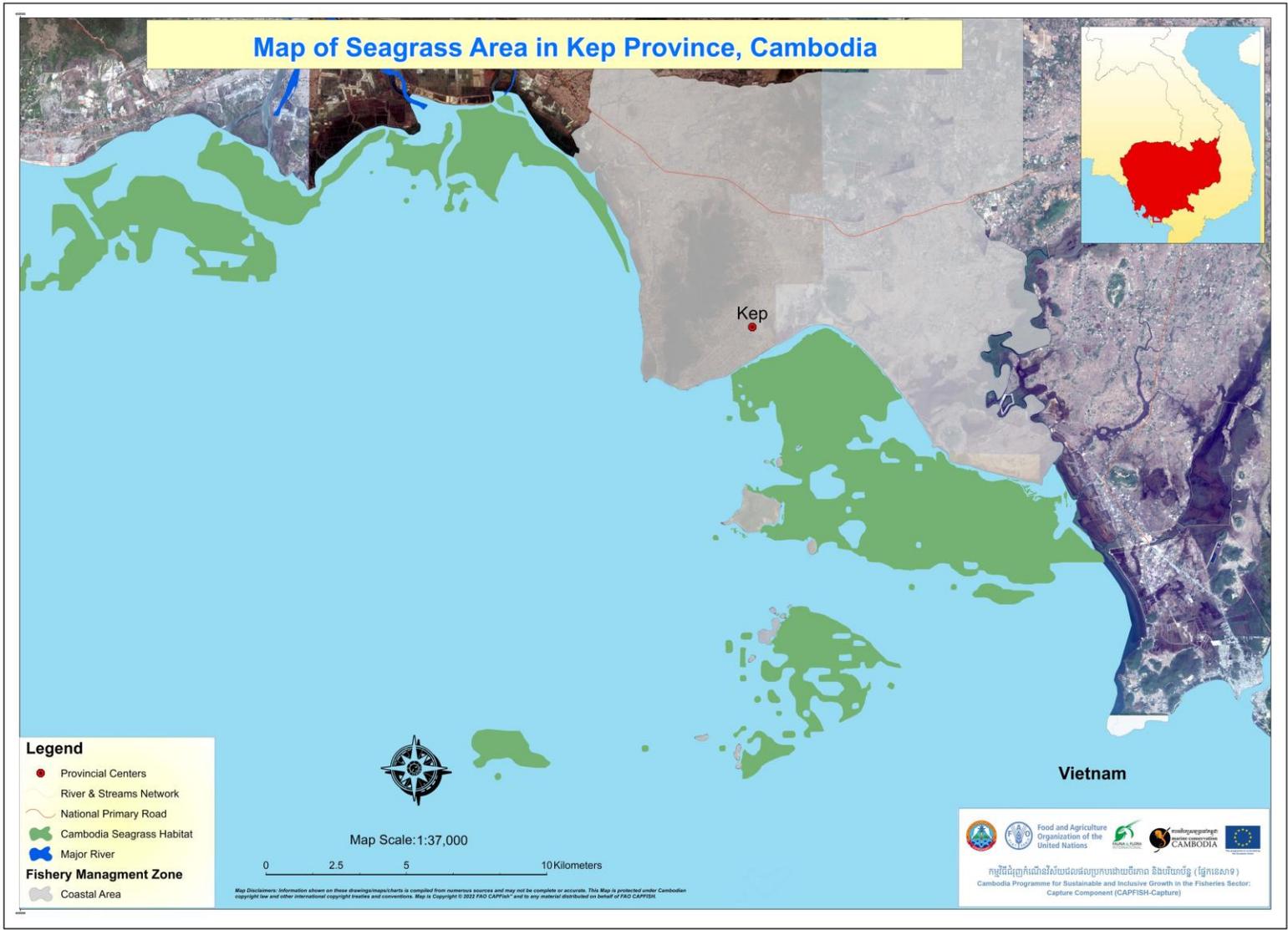


Fig 16: Map of Seagrass areas in Kep Province

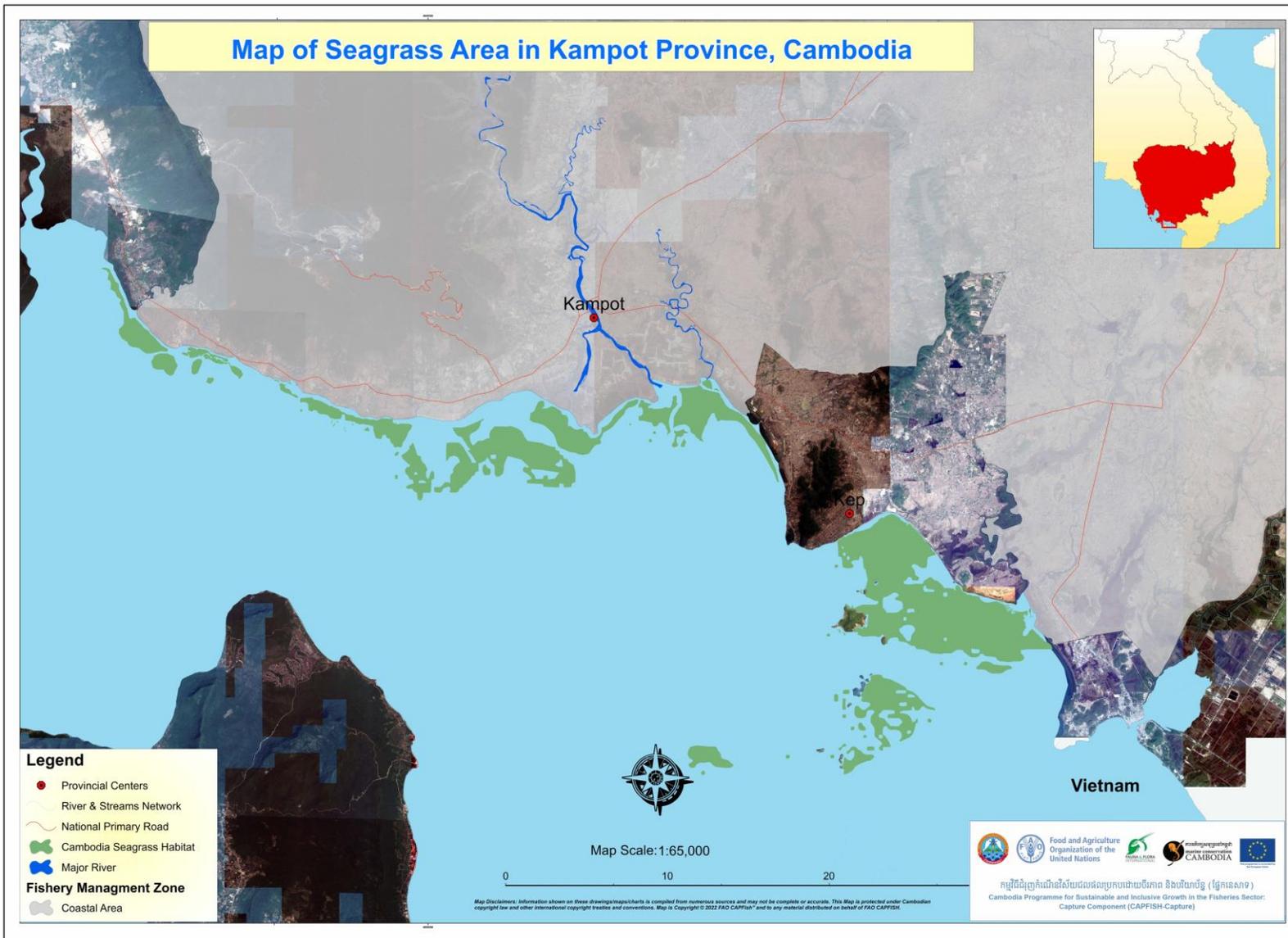


Fig 17: Map of Seagrass areas in Kampot Province

Detailed maps of seagrass areas in Kampot and Kep can be found in Annex 4.

3.2.3. Kep Coral Reef Areas

Detailed maps of coral reef areas in Kampot and Kep can be found in Annex 4.

Section A: In this section, the coral reefs' extents are:

- Koh Ach Seh: 6 ha.
- Koh Angkrong: 6 ha.
- Pirate Rock 1 ha

Section B: In this section, the coral reefs' extents are:

- Koh Pou and Northern islands: **18 ha.**
- Koh Makprang: **2 ha.**

Section C: In this section, the coral reefs' extents are:

- Koh Tunsai: **17 ha.**
- Koh Tbal: **2 ha.**
- Koh Svay, Koh Mates and Koh Kok: **4 ha.**

3.2.4. Kampot Coral Reef areas

Nataya's reef is the largest amongst both provinces with 305 ha of coral reef. It is one of the only reefs encountered in the study which is not surrounding an island

Koh Trongol island is located at the West of Koh Karang and mark the maritime border between Kep and Kampot Province. The reef size is 2 ha.

Koh She island is part of Ream National Park in Sihanoukville Province. It was nonetheless designated as part of our study area and surveyed last by the research team. 59 ha of coral reefs and 12 ha of seagrass meadow were recorded (TH 70%, EA 25%, CS 5%).

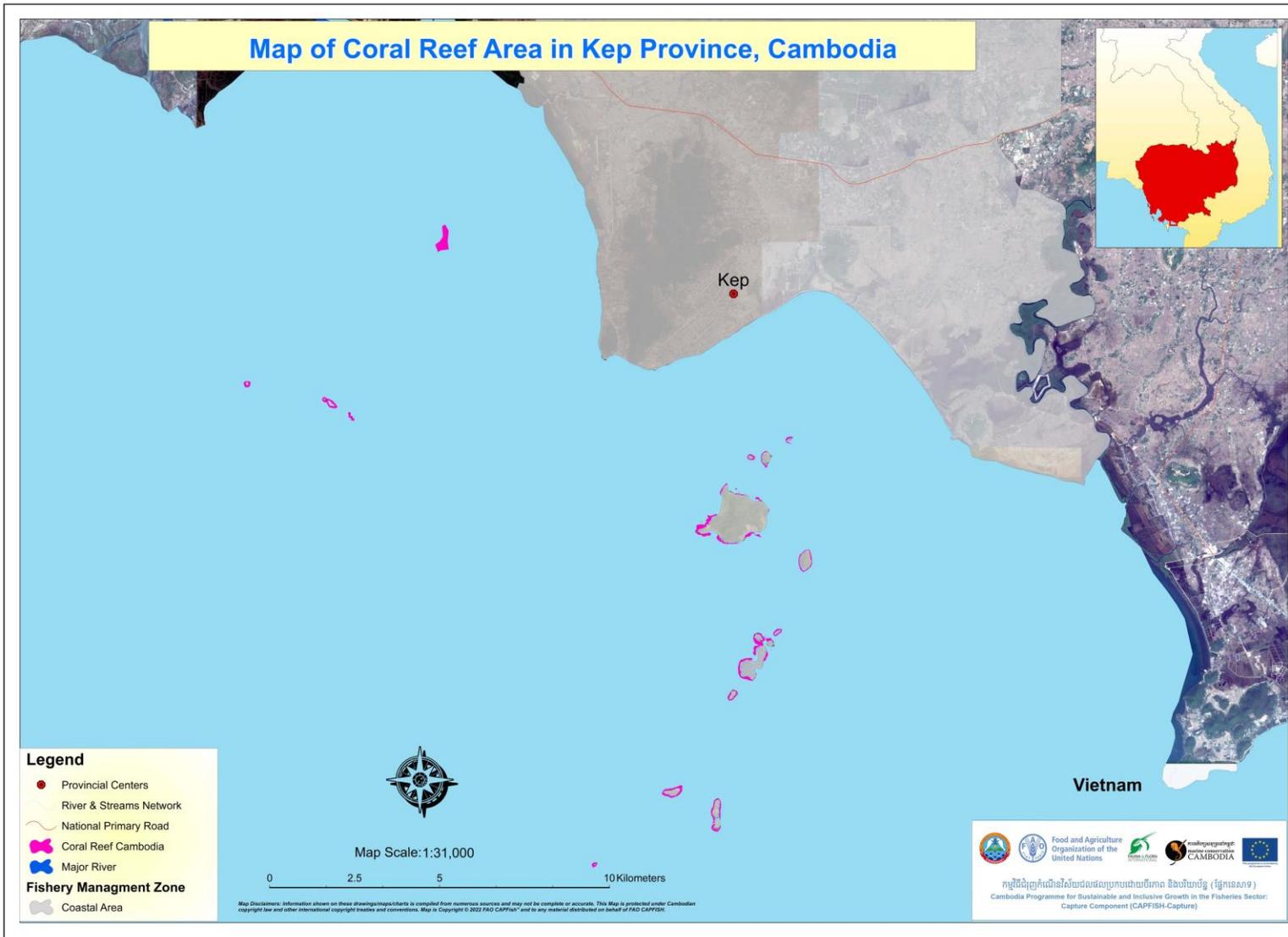


Fig 18: Map of Coral areas in Kep Province

4. Discussion

The completion of this survey has vastly improved and updated the knowledge on seagrass and coral distribution in Cambodia. . There were key differences in the seagrass habitats observed across this section of Cambodia's mainland coastline and islands. With environmental factors at the sites dictating the distribution and establishment of seagrass species.

The extent of seagrass at each location varied considerably, with locations consisting of vast expanses of seagrass meadows to small patches. Often overshadowed by the larger seagrass habitats Kampot and Kep province, important tracts of seagrass habitat were found in Koh Kong and Preah Sihanouk and these must also be protected by marine management strategies.

The largest seagrass area recorded in Koh Kong and Preah Sihanouk provinces was found in Chrouy Pros Bay, to the east of Koh Kong Krao in Koh Kong Province. It would appear that the seagrass meadow has changed little since the first mapping assessments conducted by Bock (2007), with much of the original boundary extent appearing to remain intact. Throughout the Chrouy Pros seagrass habitat, mapping teams frequently encountered demarcation poles and submerged blocks, deployed by a local CFI to prevent the incursion of fishing vessels. The deployment of these passive compliance measures has been highly effective elsewhere in Cambodia and would have definitely made an impact in ensuring the longevity of this seagrass habitat (Reid, Haissoune and Ferber, 2019). Elsewhere throughout the two provinces, the seagrass areas found and mapped by the team were much smaller in size.

Although Kep Province is the smallest of the 4 Cambodian coastal provinces it hosts the largest seagrass habitat in Cambodia, with 6 399 ha of seagrass recorded during this study. In Kampot, the survey team also found significant seagrass areas; mapping 5 158 ha of seagrass beds. Seagrass in these two provinces are also the most species diverse.

The map of Kep Province (below) highlights areas where the survey team recorded the presence of pioneer seagrass species (*Halophila* spp.) known to settle on available substrate before the establishment of other seagrass species (Razalli et al., 2011; Liu and Hsu, 2021). The research team discovered patches of these species in areas where seagrass had been previously absent, probably due to commercial fishing activities. This area is where the highest density of passive anti trawling measures had been deployed. Suggesting that these conservation efforts have been effective enough to allow for the damaged ecosystem to recover, even where conditions for seagrass regrowth did not seem ideal due to depth and siltation. The size of the seagrass recovery area was calculated as 1 012 ha.

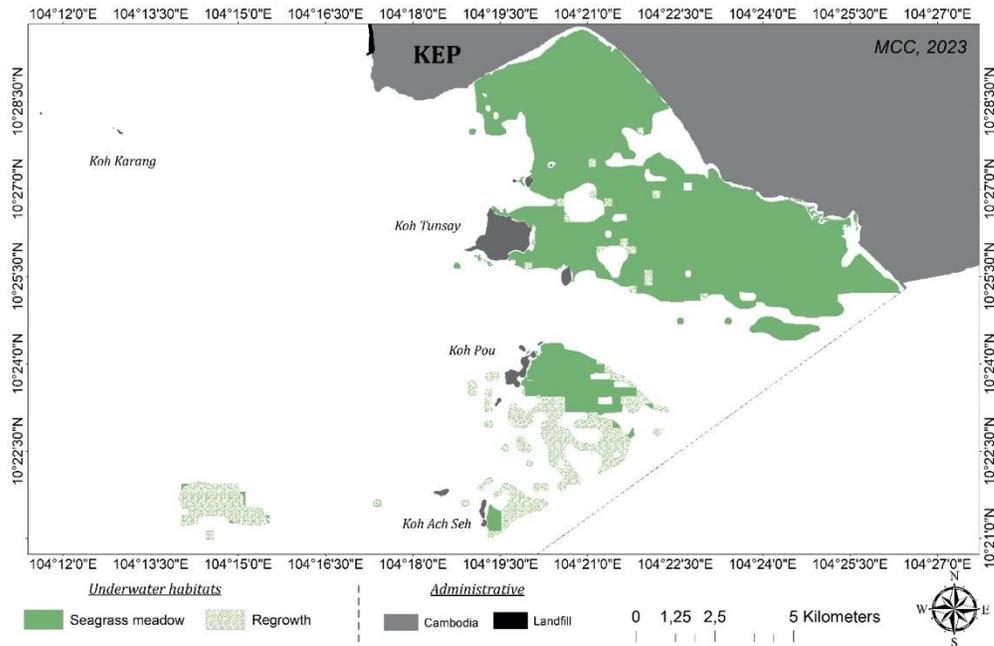


Fig.20 Seagrass meadows recovery, Kep Province

The survey mapped a total of 2,882 ha of corals with the largest areas found in Preah Sihanouk (1,627 ha). Kampot and Koh Kong also had significant areas (611 ha & 576 ha respectively), whilst Kep corals were mapped at 68 ha. Hard coral community composition varied across all survey locations. Nataya's reef was the largest amongst Kep and Kampot provinces with 305 ha of coral reef. It is one of the only reefs encountered in the study which does not fringe an island. At nearly all sites, excluding Koh Kong Krao and Koh Polou Wai, *Porites* spp. was the most abundant genera of hard coral observed.

In the surveys of Koh Kong and Preah Sihanouk, fish diversity was highest at Koh Kong Krao and lowest fish for Koh Veal. The location with the highest grouper biomass recorded was Koh Kong Krao g/500m³, whilst lowest grouper biomass was observed at the Family islands. Parrotfish biomass was generally higher at most locations in comparison to grouper. The highest calculated parrotfish biomass was from Koh Polou Wai. Condor Reef displayed the highest mean abundance for commercial fish species whilst the site with the lowest commercial fish mean abundance was the isolated island of Koh Veal. The abundance of giant clams; a key indicator for water quality, ecosystem health and fishing pressure, was highest at Koh Tang and Shark Island, with both locations recording 1.75 individuals per 200m². Their presence was lowest at Koh Kong Krao with 0.125 individuals per 200m².

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Annexes

- 1. Methodology Preah Sihanouk and Koh Kong**
- 2. Methodology: Kampot & Kep**
- 3. Seagrass species at survey sites**
- 4. Detailed maps of surveyed areas**
- 5. Additional data tables and charts**
- 6. Plates**



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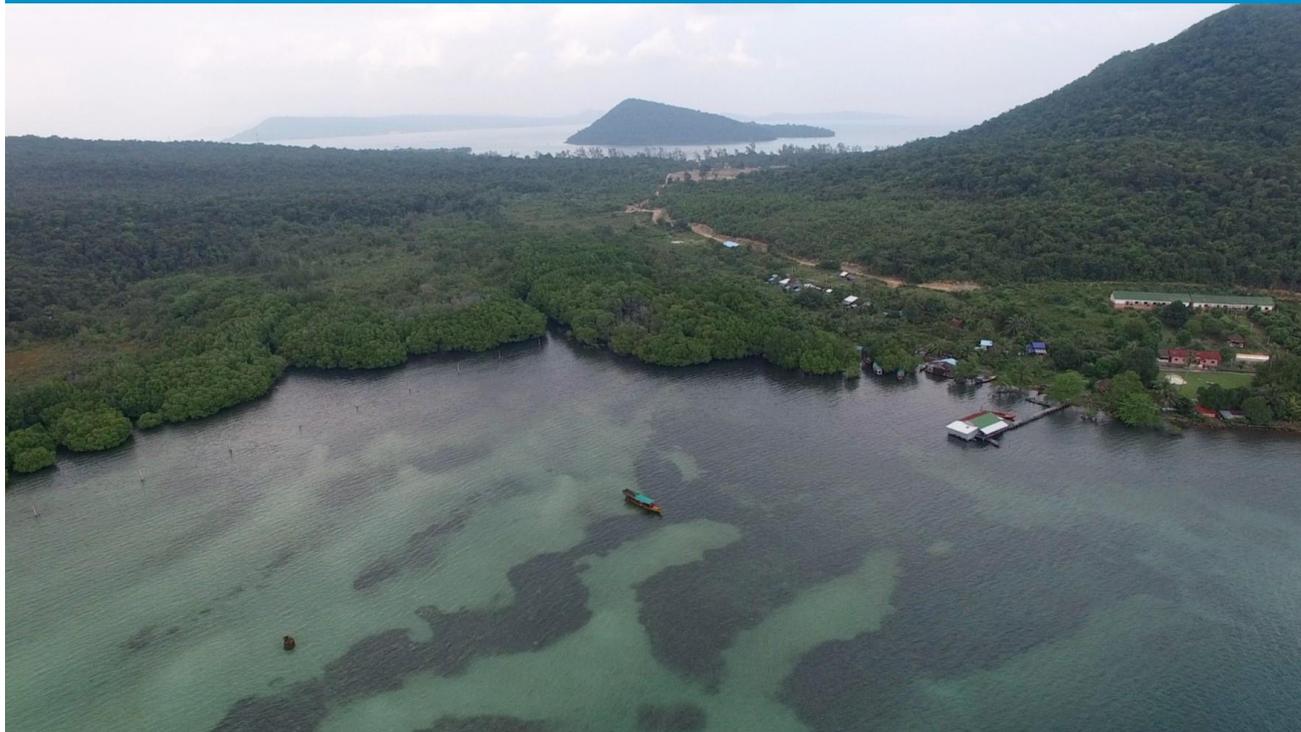


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