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Vaavu Hulhidhoo



An Ecological Assessment on Biodiversity and Management

2021

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Contents

Figures	iv
Tables.....	v
Introduction	1
Natural environment of the Maldives	1
Study Site	3
Methods.....	4
Terrestrial survey.....	4
Aerial survey.....	5
Marine survey	7
Endangered, vulnerable or threatened species	7
Results.....	7
Terrestrial.....	7
Discussion	17
Management	24
References	26
Appendix.....	31

Figures

Figure 1. Vaavu Hulhidhoo island and reef area.....	4
Figure 2. Location of (a) terrestrial and (b) marine survey sites. In (b) "x" and "+" indicate the start and end points of dives respectively, three surveys were conducted per dive.	5
Figure 3. Images from (top) terrestrial and (bottom) marine surveys	6
Figure 4. Percent cover of tree species in the three areas of vegetation	8
Figure 5. Digital elevation map of the vegetation height	9
Figure 6. Mangrove basin at the NE of Hulhidhoo	9
Figure 7. Mean density of items of refuse found in per 20 m ² survey point in the three areas of vegetation.....	10
Figure 8. Images of shoreline erosion and (bottom right) one of the two the beach protection structures	10
Figure 9. Mean percentage cover of six substrate categories recorded on manta tow survey.	11
Figure 10. Mean percentage cover of substrate types at the three survey sites.....	12
Figure 11. Percentage of coral cover in each growth form at the three survey sites	13
Figure 12. Mean reef complexity at the three survey sites	13
Figure 13. Number of fish families observed at each site	14
Figure 14. Percentage of all surveys on which each fish family was observed	14
Figure 15. Mean time to first observation of fish families at each site. Where values are equal to zero the family was absent from that site.....	15
Figure 16. Images from the mangrove basin on Hulhidhoo	18
Figure 17. Images of shoreline erosion and (bottom right) the beach protection structures..	19

Figure 18. Image from the (top row) North Channel, (middle row) North West Corner and (bottom row) South Channel marine surveys.....	21
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Tables

Table 1. Pre-selected coral species quantified and their IUCN Red List category and CITES Appendix	7
Table 2. Bird species observed during the terrestrial surveys at Hulhidhoo	10
Table 3. Mean percentage cover of substrate at the three survey sites.....	12
Table 4. Abundance of non-coral Red List marine species	16
Table 5. Abundance of the five pre-selected IUCN Red List coral species.....	16
Table A1. All vegetation species recorded on surveys in Hulhidhoo and the island zone in which they were observed.	31
Table A2. All items of rubbish recorded on surveys in Hulhidhoo and the island zone in which they were observed.....	31
Table A3. All fish families observed on surveys in Hulhidhoo	32
Table A 4. GPS coordinates for the terrestrial survey points.....	33
Table A 5. GPS coordinates for the marine roaming surveys.....	33

Introduction

In light of the extent and scale of natural and anthropogenic impacts threatening marine and terrestrial habitats across the Maldives, it is crucial that areas with potentially high ecological value are identified and assessed to formulate ecological management plans specific to these habitats. The long-term goal is to create a network of well-managed, conservation-focused areas throughout the Maldives, increasing the environment's resilience against future change. In collaboration with the Ministry of Environment and Project REGENERATE (a Government of Maldives project, implemented by IUCN and generously funded by USAID) a series of ecological assessments were conducted at various key marine and terrestrial sites. This report describes the findings of habitat assessments conducted at Vaavu Hulhidhoo and presents elements that should be considered when developing management plans.

Natural environment of the Maldives

The Maldives is an archipelago of coralline islands located in the middle of Indian Ocean. Around 1192 islands are distributed across 25 natural atolls which are divided into 16 complex atolls, 5 oceanic faros, 4 oceanic platform reefs covering a total surface area of 21,372km² (Naseer and Hatcher 2004). The islands are considered low-lying, with 80% of the country less than a meter above the sea level and most islands are less than 5km² in size (Ministry of Environment and Energy 2015).

The terrestrial habitats present across the country includes: rocky and sandy shorelines, coastal shrublands, marshes, brackish ponds, mangroves and woodlands (Toor et al. 2021). There are at least 583 species of terrestrial flora, of which 323 are cultivated and 260 are natural. Mangrove ecosystems can be classified based on the system's exposure to the sea as either open or closed mangrove systems (Saleem and Nileysha 2003, Dryden et al. 2020b). Fifteen species of mangroves are found across approximately 150 islands (Ministry of Environment and Energy 2015, Dryden et al. 2020a). Over 200 species of birds have been

recorded in the Maldives consisting of seasonal migrants, breeding residents, and introduced birds (Ministry of Environment and Energy 2015, Anderson and Shimal 2020).

Coral reefs of the Maldives are the seventh largest reef system in the world, representing as much as 3.14% of the world's reef area. There are 2,041 individual reefs covering an area of 4,493.85km² (Naseer and Hatcher 2004). Coral reefs and their resources are the key contributors to the economic industry of the Maldives. It is estimated that approximately 89 percent of the country's national Gross Development Product (GDP) is contributed by biodiversity-based sectors (Emerton et al. 2009). There are approximately 250 species of corals belonging to 57 genera (Pichon and Benzoni 2007) and more than 1,090 species of fish recorded in the Maldives (Ministry of Environment and Energy 2015).

The natural environment in the Maldives is threatened by many local and global scale factors (Dryden et al. 2020b). Threats to the terrestrial biome include infrastructure development, human waste and land reclamation projects. Due to historical and continued undervaluation, many of these areas are not given the level of respect and protection they require. Many mangroves across the country have been reclaimed to pave the way for land and infrastructure development. The 2016 bleaching event impacted an estimated 75% of the coral reefs (Ibrahim et al. 2017), and has shown that even some of the most protected reef ecosystems could perish. Reefs are also at risk from local stressors such as overfishing, pollution and land reclamation (Burke et al. 2011). Despite these stressors, Maldivian reefs have previously shown resilience and recovery following such disturbances (Morri et al. 2015, Pisapia et al. 2016).

The terrestrial and marine biota provide essential socio-economic services to the community. Tourism and fishing industries depend directly on the natural resources, and the country's economy is primarily dependent on the profits around these industries. The social and economic reliance on the environment, as well as the need to protect and conserve valuable and threatened habitats across the country means there is an immediate need for biodiversity

assessments and management plans to ensure the sustainable use and effective management of these natural resources. Such approaches will play a key role in efforts to manage and monitor the resources in a co-managed concept.

Study Site

Hulhidhoo is located on the Eastern Edge of Vaavu atoll between the newly opened resort island of Aarah Veli to the north and the inhabited island of Thinadhoo to the south, an island popular for local tourism (Figure 1). The island is under a long-term lease for agriculture (Ministry of Fisheries and Agriculture 2021). There is seasonal sand movement around the island creating depositional areas and areas with erosion scarfs. A sandy spit of about 60m forms seasonally on the Northwest corner of the island. The vegetation in the centre of the island is relatively mature and there is some mangrove growth at the Eastern Corner of the island.

There are several structures on the island including an unfinished powerhouse with some machinery inside, staff quarters, storerooms etc. In addition, some hydroponics equipment (pipes) and some construction materials were present. An area behind the coastal fringe has been cleared and beach sand has been used to make a small road. There is a jetty on the Western side of the island and groins have been put in to protect the coast on the Western and North-western sides. There is sandy shoreline habitat in these areas, whereas the rest of the island surrounded by a rocky shoreline of rubble and beach rock.

The reef is long and narrow measuring approximately 1.3 km from east to west and 0.23 km from north to south. The island is set back on the Western Edge of the reef with a reef flat on the East Side of the reef extending approximately 0.9 km to the atoll edge. This is an exposed reef flat dominated by sand and rubble with little live coral development. The channels to the

north and south of the island experience strong currents and the only sheltered area of reef is on the Western Edge between the jetty and the sand bank.

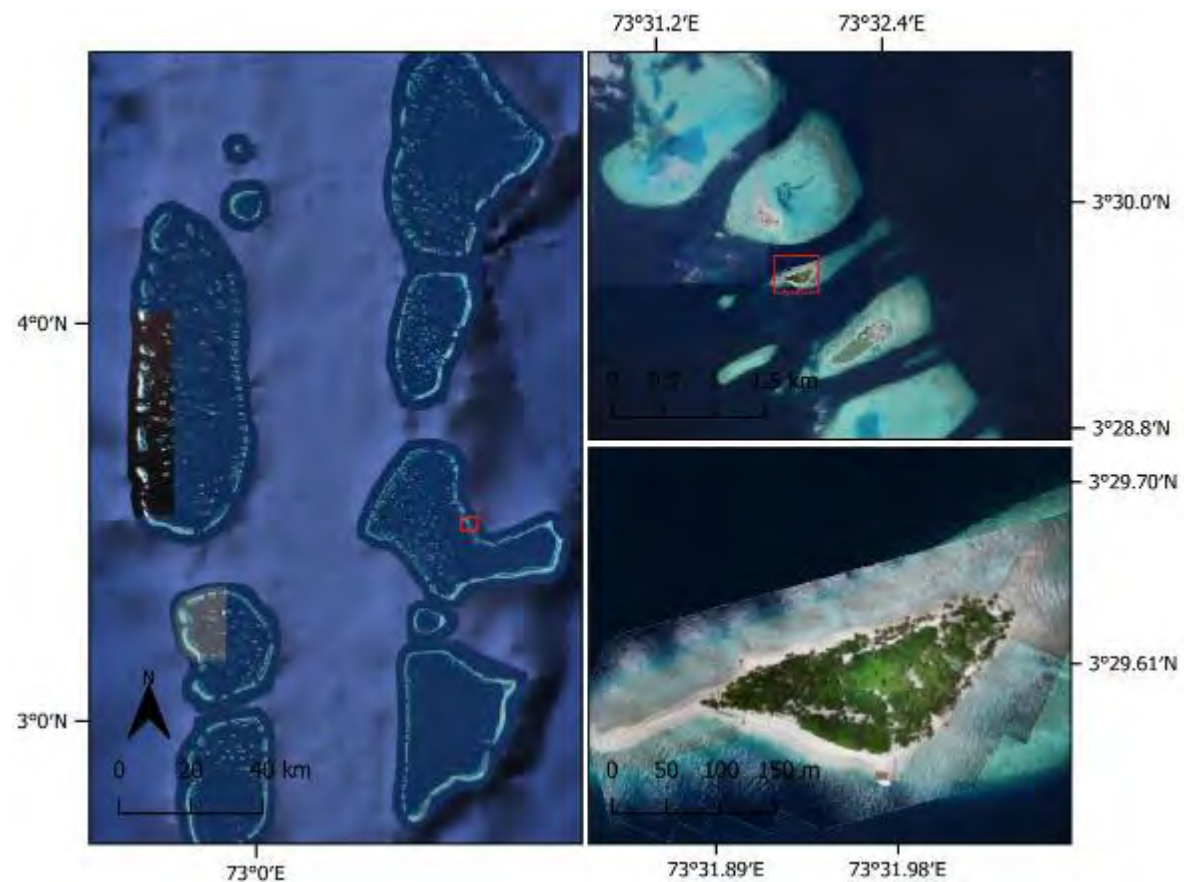


Figure 1. Vaavu Hulhidhoo island and reef area

Methods

Terrestrial survey

The terrestrial survey area was divided into two zones, the coastal fringe and the inner island, and 31 surveys points were identified using a stratified sampling approach (Figure 2). GPS coordinates were extracted from Google Earth© version 7.3.1 and entered into the android phone application SW Maps (Softwell (P) Ltd. 2020). Vegetation was surveyed using a point survey approach (Dryden and Basheer 2020).



Figure 2. Location of (a) terrestrial and (b) marine survey sites. In (b) "x" and "+" indicate the start and end points of dives respectively, three surveys were conducted per dive.

Aerial survey

Aerial surveys were conducted to create an accurate, high-resolution map of Hulhidhoo. Aerial imagery was collected using the DJI Phantom 4 Pro UAV with 1-inch 20 Mega Pixel CMOS sensor. The flight plans were created using DroneDeploy© Free Mobile App, with a height of 85 meters from ground level. At this height, with a small format camera it is possible to get a

pixel size of less than 5 cm. The overlay of the pictures was 75% on front-lap and 75% on side-lap. Ground control points (GCPs) were used to ensure the map was as accurate as possible. To increase geo-location accuracy during post-processing, five GCPs were randomly distributed across the island and marked in open areas using natural markers painted red. Horizontal GPS locations of these markers were taken with Topcon GR-5 GPS and Base Station at a ± 10.0 mm or ± 1 cm accuracy using the RTK mode. The GCP's were taken before the mapping of the island. A total of 223 geo-referenced images were processed using the Agisoft Metashape Software© which generated a high-resolution geo-referenced Orthomosaic and detailed digital elevation models.

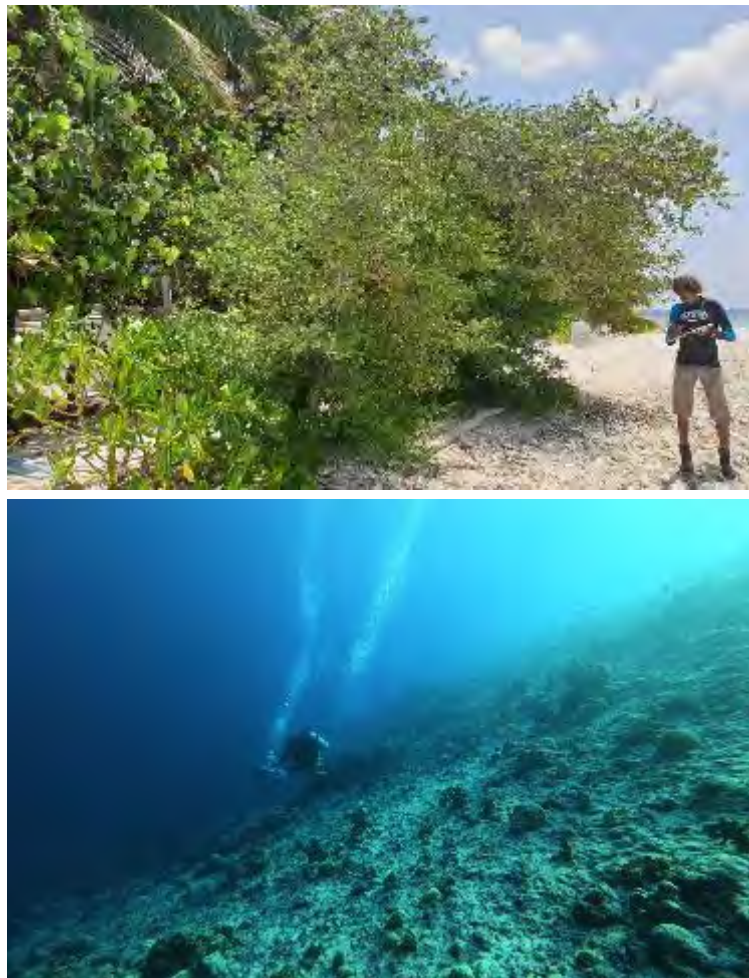


Figure 3. Images from (top) terrestrial and (bottom) marine surveys

Marine survey

Marine surveys were performed using two methods. A manta tow was used to perform coarse-scale assessments of the Hulhidhoo reef flat and SCUBA roaming surveys were used assess fish and benthic communities on the reef slope (Dryden and Basheer 2020).

Endangered, vulnerable or threatened species

The International Union for the Conservation of Nature (IUCN) Red List categories, critically endangered (CR) endangered (EN), vulnerable (VU) or near threatened (NT) were used to identify marine species globally at risk that were present in Hulhidhoo. Roaming surveys were used to quantify the presence and abundance of these species as this method covers a large area, which increases the likelihood of encounter. Five pre-selected VU coral species were surveyed as they were easy to identify during the rapid surveys (Table 1). All fish and marine reptile species (CR, EN, VU or NT) were counted and identified to species.

Table 1. Pre-selected coral species quantified and their IUCN Red List category and CITES Appendix

Species	Red category	List	CITES Appendix
<i>Galaxea astreata</i>	Vulnerable		II
<i>Pachyseris rugosa</i>	Vulnerable		II
<i>Pavona venosa</i>	Vulnerable		II
<i>Physogyra lichtensteini</i>	Vulnerable		II
<i>Turbinaria mesenterina</i>	Vulnerable		II

Results

Terrestrial

Fourteen species of flora were identified during the terrestrial surveys (Table A1), which included a single species of mangrove *Bruguiera cylindrica* (Dhivehi name: Kandoo). The majority of vegetation recorded from the island were species commonly associated with

coastal forest vegetation. The most species rich survey area was the coastal fringe where ten different species were observed (Figure 4). The most frequently observed species in this area was *Scaevola taccada* (Dhivehi name: magoo), though *Cocos nucifera* (coconut palm), *Guettarda speciosa* (Dhivehi name: uni) and *Talipariti tiliaceum* (Dhivehi name: Dhigga) were also common. The height of the coastal fringe vegetation averaged 3.4 m (± 0.4 S.E.), only coconut palms exceeded this height.

The inner island vegetation community was dominated by *T. tiliaceum* which made up greater than half of the vegetation cover recorded. The remaining cover was made of a relatively even mix of other coastal forest species. The vegetation in this area of the island was more developed than at the coastal fringe, growing to an average height of 6.3 m (± 0.7 S.E.), with some trees reaching heights > 10 m (Figure 5).

The mangrove basin habitat was an approximately 270 m² area with a damp muddy bottom and some small patches of water (Figure 6 & Figure 16). The area was dominated by *B. cylindrica* which grew in patches throughout the basin with larger trees surrounded by seedlings in the muddy ground at the foot of the tree. There was also a single dead *Heritiera littoralis* (Dhivehi name: Kaharuvah) recorded.

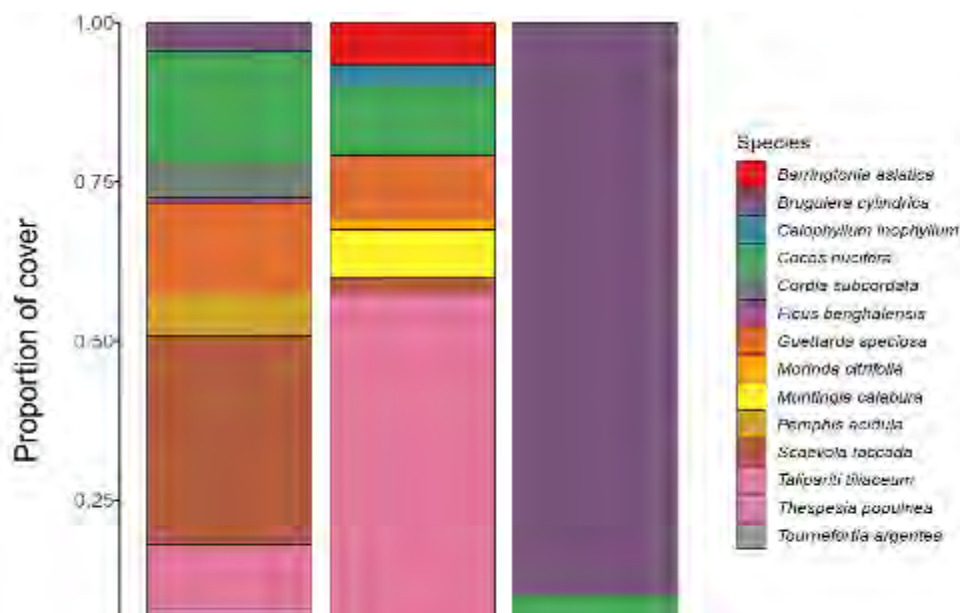


Figure 4. Percent cover of tree species in the three areas of vegetation

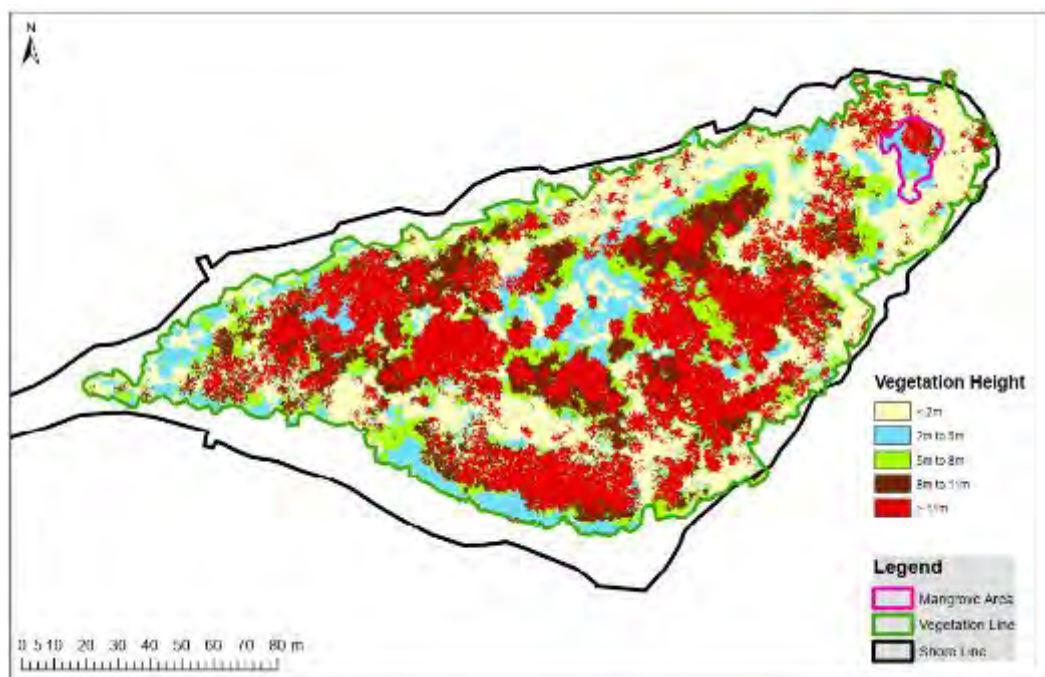


Figure 5. Digital elevation map of the vegetation height



Figure 6. Mangrove basin at the NE of Hulhidhoo

Rubbish was found across the entire island (Figure 7). Plastic was the most common type of waste recorded, while metal (scrap metal and cans) was the only other type found. The amount of rubbish was relatively even across the island.

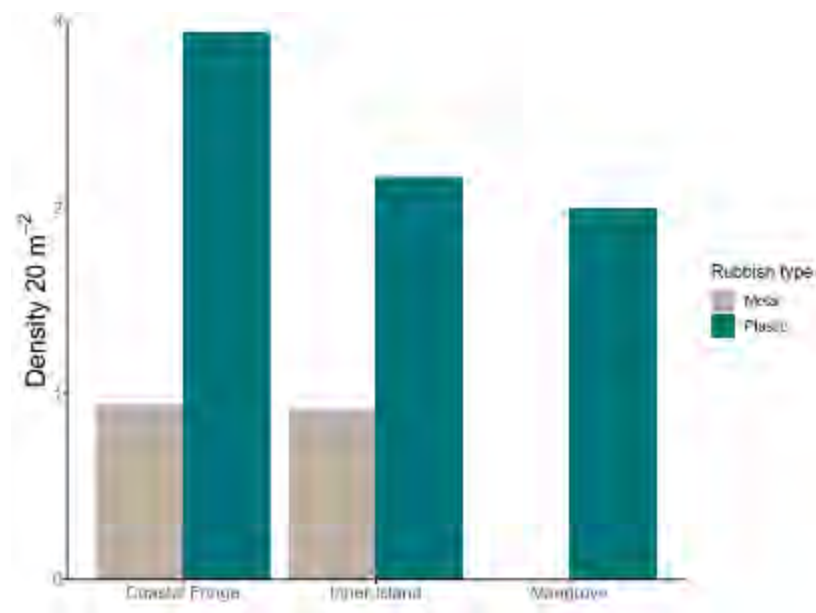


Figure 7. Mean density of items of refuse found in per 20 m² survey point in the three areas of vegetation

A number of a turtle nests were observed on the beach area along the west and south of the island with fresh tracks from some recently made nests. Four bird species were recorded during the surveys (Table 2).

Table 2. Bird species observed during the terrestrial surveys at Hulhidhoo

Family	Species	Dhivehi Name	Abundance
Corvidae	<i>Corvus corax</i>	Kaalhu	2
Cuculidae	<i>Eudynamis scolopaceus</i>	Dhivehi Kovel	1
Laridae	<i>Sterna sunatrana</i>	Kiru dooni	4
Scolopacidae	<i>Actitis hypoleucos</i>	Fin'dhana	1

Marine

The manta tow identified rock as the dominant benthic cover around the reef flat/crest area, comprising 56.8 % (± 1.4 S.E.) of the substrate (Figure 9). Hard coral was the second most common substrate type with 19.4 % (± 0.9 S.E.). The remaining substrate was rubble 11.4 (± 0.8 S.E.), sand 9.2 (± 0.9 S.E.) and algae 2.9 (± 0.4 S.E.).

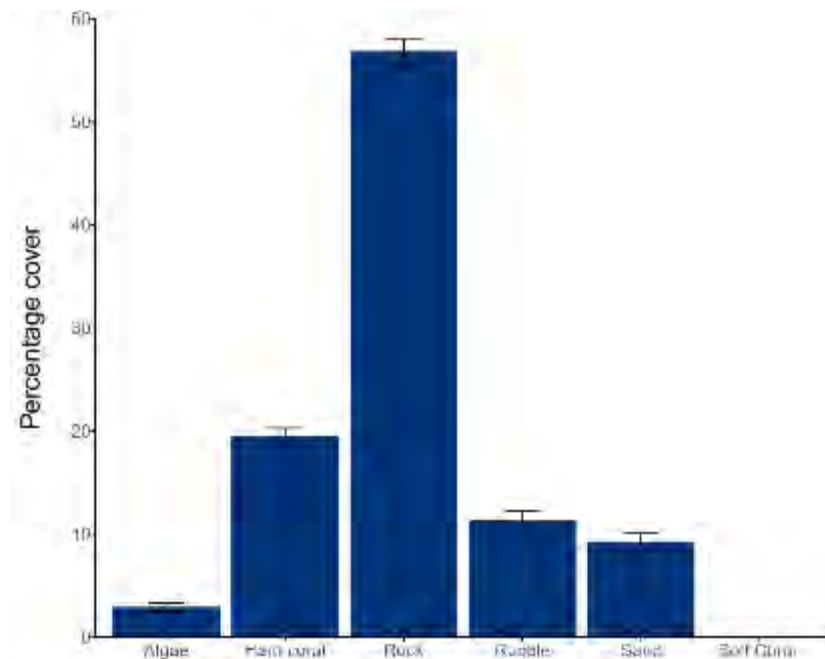


Figure 9. Mean percentage cover of six substrate categories recorded on manta tow survey.

The roaming surveys revealed rock and hard coral to again be the most common substrate types, though there was no notable difference between them (Figure 10, Table 3). Hard coral cover did not differ greatly between the three survey sites. There was high variability between the three surveys conducted at the North West Corner site where the highest coral cover observed was 60 %. The cover of rock did not vary between sites. Rubble made up a greater proportion of the substrate at the North West Corner than at either North Channel or South Channel, whereas sand was more common at South Channel than at either North Channel or North West Corner. CCA, soft coral and sponges were relatively common in the North Channel. Sponges were also common at the North West Corner. Macroalgae and turf algae were relatively rare throughout the survey area.

Table 3. Mean percentage cover of substrate at the three survey sites.

Substrate	North Channel		NW Corner		South Channel	
	Percentage cover	S.E.	Percentage cover	S.E.	Percentage cover	S.E.
CCA	8.3	4.3	0.0	0.0	0.0	0.0
Hard coral	23.3	3.3	32.7	13.7	28.3	1.7
Macroalgae	1.0	0.6	3.3	1.7	3.0	0.6
Rock	29.7	2.6	25.0	5.1	31.0	13.6
Rubble	2.7	0.3	12.7	3.7	5.0	2.5
Sand	8.7	0.7	10.0	0.0	25.0	10.4
Soft Coral	10.0	5.0	1.3	0.7	3.0	1.0
Sponge	15.0	5.0	15.0	7.6	3.7	3.2
Turf algae	0.0	0.0	0.0	0.0	0.0	0.0

The most common coral growth forms observed were branching, encrusting and massive (Figure 11). Branching corals were the most common morphology at the more sheltered North West Corner site, whereas encrusting and a combination of massive and encrusting corals were the most common types at the North and South Channel sites respectively. Reef structural complexity was not noticeably different between the three sites.

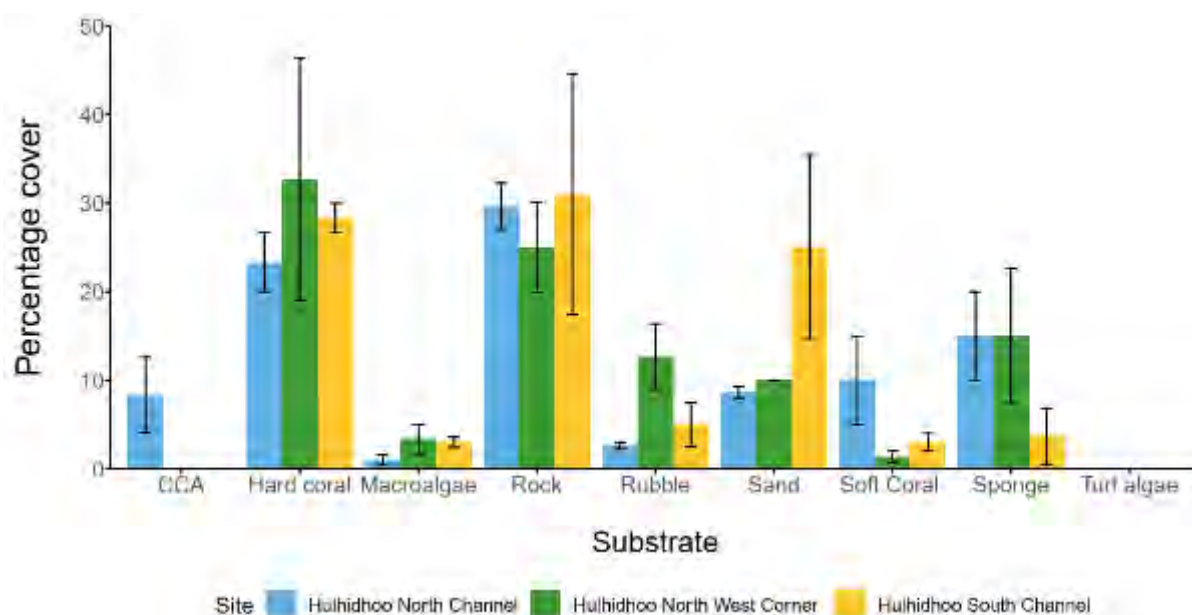


Figure 10. Mean percentage cover of substrate types at the three survey sites.

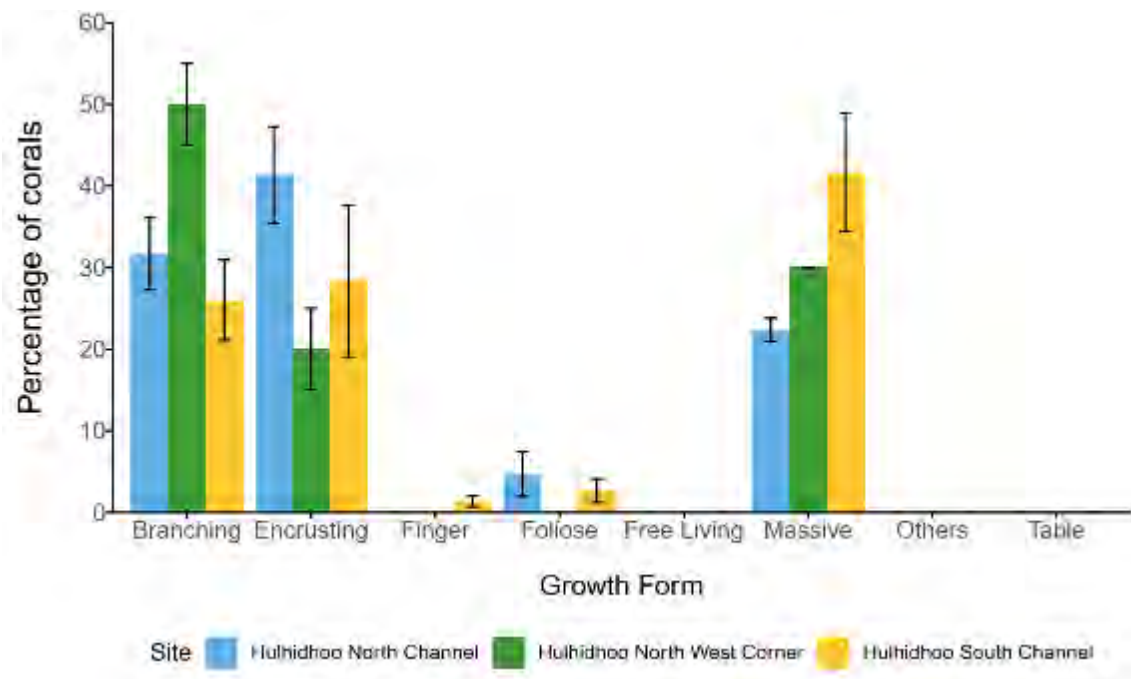


Figure 11. Percentage of coral cover in each growth form at the three survey sites

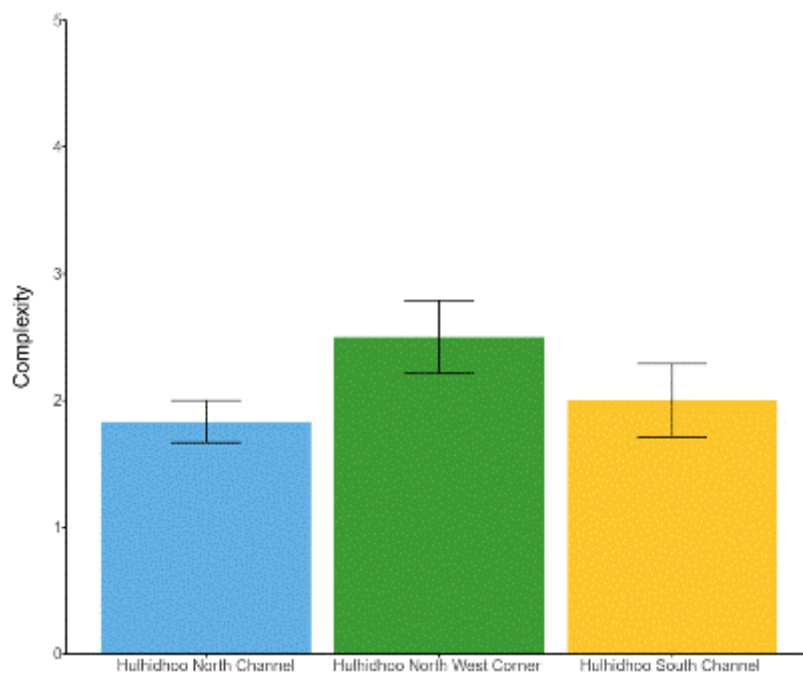
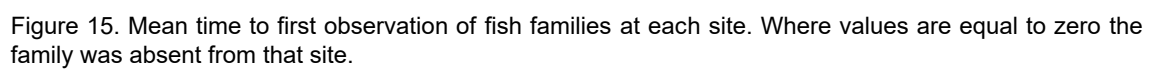


Figure 12. Mean reef complexity at the three survey sites

Location	Family richness (approx.)
Haulidhoo North West Corner	17.5
Haulidhoo North Channel	17.5
Haulidhoo South Channel	18.5





Few IUCN Red List species were observed throughout the Hulhidhoo marine area. A total of 11 non-coral animals and 38 coral colonies were recorded (Table 4 & Table 5). *Pavona venosa* was the only pre-selected coral species not found on any surveys. In addition to the Hawksbill turtle recorded on the surveys, turtle nests were observed on the sandy shores around the South and West coasts.

Table 4. Abundance of non-coral Red List marine species

Species	Common name	Abundance
<i>Carcharhinus amblyrhynchos</i>	Grey reef shark	2
<i>Carcharhinus melanopterus</i>	Blacktip reef shark	2
<i>Cheilinus undulatus</i>	Napoleon wrasse	1
<i>Epinephelus fuscoguttatus</i>	Marble grouper	1
<i>Eretmochelys imbricata</i>	Hawksbill turtle	1
<i>Plectropomus laevis</i>	Black-saddle coral grouper	4

Table 5. Abundance of the five pre-selected IUCN Red List coral species

Species	Abundance
<i>Galaxea astreata</i>	6
<i>Pachyseris rugosa</i>	5
<i>Pavona venosa</i>	0
<i>Physogyra lichtensteini</i>	2
<i>Turbinaria mesenterina</i>	25

Discussion

Hulhidhoo houses a diverse range of habitats considering the small size of the island and reef area. It is unusual for an island this small to have mangrove development, yet there is an abundance of growth in the mangrove basin. The beach environment is a turtle nesting area, and the extended sandbank is likely to be utilised by foraging sea birds. The channels to the North and South of the island have created a long narrow island and reef structure, exposed to strong currents. These channels have limited coral growth; however, the sheltered Western reef has areas where coral cover comprises up to 60 % of the substrate. The fish community was diverse and abundant, with a number of large IUCN Red List species including sharks, turtles and groupers recorded.

Despite its small size and the absence of any standing water, a small mangrove habitat is present. The mangrove habitat was a relatively well-defined mangrove basin (Lugo and Snedaker 1974, Ewel et al. 1998). The basin is closed off from the sea by a narrow berm made of rubble from the reef. Water likely enters the basin area through groundwater seepage. The ground was muddy with small puddles of water. The area was predominantly immature trees *B. cylindrica* < 5 m tall. There was an abundance of seedlings (< 60 cm tall plants). The largest *B. cylindrica* trees were found in the Northeast corner of the depression where some were greater than 10 m tall. Mangrove species are susceptible to changes in the surrounding environment and can be impacted by changing salinity, pH or the moisture content of muddy areas (Kathiresan and Bingham 2001). The mangroves in the area appeared to be in relatively good health with the exception of a single dead *H. littoralis* tree. The absence of any significant standing water meant there was no aquatic life in the area.



Figure 16. Images from the mangrove basin on Hulhidhoo

Hulhidhoo is under a long-term lease for agriculture, however there was no evidence of cultivated plots on any part of the island, though there were many coconut palms. The vegetation outside of the mangrove area was typical of Maldivian islands with coastal shrubland and littoral forest vegetation present (Toor et al. 2021). The coastal vegetation is an undervalued and understudied habitat in the Maldives. It stabilises the mobile sediments and protects against island erosion. This habitat is under threat from the expansion of agriculture, construction of roads and the resort development. The inner island vegetation did appear relatively well developed considering the small size of the island with several large *Barringtonia asiatica* (Dhivehi name: kinbi) and a *Ficus benghalensis* (Dhivehi name: nika) trees in the inner island area.

Despite the absence of agricultural activity there were several buildings on the island and coastal protection structures. Sandy shoreline was present where the coastal protection was in place, however there was erosion around much of the rest of the island. Islands in the

Maldives are dynamic, constantly changing in shape and size (Kench and Brander 2006). Island instability and increasing human populations have led to the reliance on engineered structures to combat erosion and maintain island shorelines. The introduction of such structures can result in a range of negative environmental impacts, including accelerated erosion and reef degradation (Maragos 1993). An examination of the efficacy of these engineered structures has proposed the revaluation of islands as “static landforms” with one that recognises the natural dynamism of the islands and emphasises the management of natural geomorphic processes (Kench 2012). It is possible the presence of structures to protect the beach areas may have accelerated the erosion around the rest of the island.



Figure 17. Images of shoreline erosion and (bottom right) the beach protection structures

The even distribution of rubbish across the island suggests that the source of the rubbish is both being washed up and disposed by people using the island. The channels to the North and South of Hulhidhoo likely carry much of the floating ocean waste past the island. This may explain why relatively little rubbish was found along the coastal fringe when compared to other islands such as Bodulhaimendhoo (16 pieces per 20 m²) or Dhiffushi Maadhoo (48 pieces per 20 m²) (Dryden et al. 2020c).

The shallow reef area surveyed using the manta tow was dominated by rock. This is unsurprising given the exposed nature of this reef habitat. The coral community in the channel areas was dominated by massive and encrusting corals such as those from the genera *Porites* or *Pavona*. The dominance of these growth forms and the low complexity of the reef indicate that exposure to waves and currents is a strong determinant of the reef habitat, which is common among exposed reef areas (Done 1982). The South Channel had a relatively high cover of sand suggesting this may be where sediment from island erosion or island construction projects is deposited. Sand represents an uninhabitable surface for benthic organisms, which require a consolidated substrate to attach and survive (Smith and Hughes 1999, Kenyon et al. 2020). Increases in the proportion of substrate covered by sand and other sediments reduces the amount of substrate suitable for the recruitment of corals and other benthic organisms (Birrell et al. 2005, Cameron et al. 2016). Higher levels of sand may also result in abrasion of corals and reduced survival of recruits.

There was a small, sheltered area on the leeward side of the island which is where the highest cover of live coral development was found. Branching corals were the most common coral growth form and as a result this area had the highest reef structural complexity. However, live coral still only made up around 30 % of the substrate.



Figure 18. Image from the (top row) North Channel, (middle row) North West Corner and (bottom row) South Channel marine surveys

Nine fish families were observed within the first five minutes of each survey, indicating they were common throughout the Hulhidhoo reef habitat. These families included the functionally important herbivores Acanthuridae and Scaridae. Herbivorous fish, are important in preventing coral reefs from becoming overgrown by algae following disturbances, providing a level of resilience to the reef habitat (Hughes et al. 2007, Mumby et al. 2007). There is no fishery targeting these species, however there is evidence that localised parrotfish is occurring. It is therefore key that management efforts include education on the importance of parrotfish to reef health. Parrotfish have also been found to play an important role in sediment creation and island development and maintenance (Morgan and Kench 2016). With future sea level change threatening to impact the low-lying islands of the Maldives healthy parrotfish populations will be important in maintaining reef health and island.

In addition to herbivores, higher trophic level fish families including groupers and snappers were abundant around the island. The presence of these species is also an indicator of healthy reefs (Graham et al. 2013). However, these are also common targets of reef fisheries and the proximity of the island to a new resort and a local island means these reefs are at risk of local fishing activities.

The island and the reefs provide valuable habitat for a number of IUCN Red List species. Turtles use the beach for nesting, and it was clear from the recent tracks that the area is in regular use. Though sandy shorelines are a common feature around Maldivian islands, continued island development, the use of sea walls and sea level rise could reduce the availability of suitable nesting habitat (Brock et al. 2009, Fuentes et al. 2010, Rizkalla and Savage 2011). Grey and blacktip reef sharks were recorded in the channels either side of the island. Many channels throughout the country are known to be areas where several species of sharks congregate. However, little is known about the reasons behind these aggregations and their spatial and temporal variability.

Human activities over the past 150 years have caused approximately 1.09°C of climate warming and it is likely that it will continue to warm by at least 1.5°C between 2021 and 2040

(Arias et al. 2021). The impacts of climate change will pose a significant threat to both the people and the natural environment of the Maldives. Global mean sea level rise is predicted to be between 0.38 – 0.77 m by 2100 (Arias et al. 2021). This increases the risk of storm damage to wetlands and ponds, as well human settlements and may result in eventual inundation of them by sea water. Healthy coastal vegetation, mangrove, seagrass and coral reef systems are predicted to act as a buffer against the impacts of sea level rise. They act as protection against storm damage and help fix and consolidate island sediments which may limit island erosion and may enable island growth to keep pace with any sea level change.

The warming climate will also lead to more frequent and severe coral bleaching events (Hoegh-Guldberg 2011). The Maldives archipelago is built up by millions of years of coral growth (Perry et al. 2013) and healthy coral reefs are essential to the survival of these small islands (Kench et al. 2005). Local factors can significantly affect the resilience of corals. Competition between algae and coral is often finely balanced in reefs and both are important for a healthy reef habitat, however, increases in nutrients from pollution or declines in certain herbivorous fish species can enable algae to proliferate and outcompete corals, especially following coral die-offs (Bellwood et al. 2004).

Hulhidhoo is a vulnerable island habitat. It is located between a newly developed resort and an inhabited local island, potentially putting the island and reef at risk of high usage. Further development of the island itself presents a risk to the mangrove and shoreline habitats. Agricultural development may result in a nutrification, while infrastructure could alter the island's hydrology. There is evidence of significant erosion around the island and changes to the sediment flow around the island by further infrastructure development or shoreline protection could worsen this. Changes to sediment flow may result in an increase in sediment deposition on the reef area This may pose a significant risk to the reef health, particularly in the South Channel.

Management

The ecological management goal for Hulhidhoo is to provide a means to promote and ensure the long-term conservation and protection of the island's ecosystem. Local management efforts should be developed with this goal in mind. The aim should also be to utilise strategies and action plans local and national governments have developed such as the Regional Waste Management Strategy and Action Plan for Zone 6, Republic of Maldives (Ministry of Environment 2019), the reports on biodiversity, Fifth national report to the United Nations convention on Biological Diversity (Ministry of Environment and Energy 2015) and National Biodiversity Strategy and Action Plan 2016-2025 (Ministry of Environment and Energy 2015), Maldives Clean Environment Project Environmental and Social Assessment and Management Framework (ESAMF) & Resettlement Policy Framework (RPF) (Ministry of Environment 2016), and Current status of the reef fisheries of Maldives and recommendations for management (Sattar et al. 2014).

The findings of this report and the data collected can be used as a baseline against which to measure this goal. The main goal is broken down into two sub-goals:

- 1) To maintain the resilience of biological communities to stressors associated with anthropological change; and
- 2) To maintain populations of natural communities for social development, fishery enhancement and island health.

Future efforts should aim to monitor and manage the habitat to maintain overall system health and function (Flower et al. 2017, Lam et al. 2017).

In order to preserve the ecological resilience of the island and to protect its biodiversity for future generations, it is recommended that a management plan is developed.

Key findings from this report that should be addressed by management:

1. The identification of a small but healthy mangrove basin on the island.

2. Future infrastructure development on the island, including beach shoreline management practices, should be planned to ensure minimal impact on vegetation and changes to sedimentation around the island.
3. The abundance of reef fishery target species.
4. Turtle nesting on the beaches.

The management plan could consider the following elements:

- The development of a long-term monitoring programme for mangrove and coral reef habitats in order to track ecological changes over time.
- Island geographical and topographical monitoring programme to monitor and island movement and sediment pathways as well as any changes as a result of infrastructure development.
- Establish measures to stop local stresses to coral reefs (e.g. sedimentation from dredging, pollution, waste disposal, nutrient inputs to the marine environment, fishing of herbivores) on all reefs.
- Protect herbivorous reef fish. This will strengthen natural controls by reef communities on the development of turf algae and macroalgae on reefs.
- Limit activities that cause or accelerate reef erosion, or that increase the presence of sand and particulate matter on reefs. Activities to consider include:
 - o Sand pumping for beach replenishment
 - o Dredging of sand within atolls
 - o Land reclamation and island building projects that require depositing sediment near reef areas
- A plan for development and enforcement of regulations in the area.

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Appendix

Table A1. All vegetation species recorded on surveys in Hulhidhoo and the island zone in which they were observed.

Zone	Species	Common name	Dhivehi name
Coastal fringe	<i>Bruguiera cylindrica</i>	Small-leafed orange mangrove	Kandoo
	<i>Cocos nucifera</i>	Coconut palm	Dhivehi ruh
	<i>Cordia subcordata</i>	Sea trumpet	Kaani
	<i>Ficus benghalensis</i>	Banyan tree	Nika
	<i>Guettarda speciosa</i>	Beach gardenia	Uni
	<i>Pemphis acidula</i>	Iron wood	Kuredhi
	<i>Scaevola taccada</i>	Sea lettuce	Magoo
	<i>Talipariti tiliaceum</i>	Sea hibiscus	Dhigga
	<i>Thespesia populnea</i>	Thespesia	Hirun'dhu
	<i>Tournefortia argentea</i>	Beach heliotrope	Boshi
Mangrove	<i>Bruguiera cylindrica</i>	Small-leafed orange mangrove	Kandoo
	<i>Cocos nucifera</i>	Coconut palm	Dhivehi ruh
	<i>Barringtonia asiatica</i>	Fish poison tree	Kinbi
	<i>Calophyllum inophyllum</i>	Alexander Laurel wood	Funa
	<i>Cocos nucifera</i>	Coconut palm	Dhivehi ruh
Inner island	<i>Guettarda speciosa</i>	Beach gardenia	Uni
	<i>Morinda citrifolia</i>	Indian mulberry	Ahi
	<i>Muntingia calabura</i>	Jamaican cherry	Jam
	<i>Scaevola taccada</i>	Sea lettuce	Magoo
	<i>Talipariti tiliaceum</i>	Sea hibiscus	Dhigga

Table A2. All items of rubbish recorded on surveys in Hulhidhoo and the island zone in which they were observed.

Zone	Rubbish type	Total	Density (pieces per 20 m ²)
Coastal Fringe	Metal	17	0.94
	Plastic	53	2.94
Inner Island	Metal	11	0.92
	Plastic	26	2.17
Mangrove	Metal	0	0
	Plastic	2	2

Table A3. All fish families observed on surveys in Hulhidhoo

Family	Common name
Acanthuridae	Surgeonfish
Balistidae	Triggerfish
Caesionidae	Fusilier
Carangidae	Jack
Carcharhinidae	Requiem Shark
Chaetodontidae: Bannerfish	Bannerfish
Chaetodontidae: Butterflyfish	Butterflyfish
Cirrhitidae	Hawkfish
Congridae	Conger Eel
Dasyatidae	Stingray
Diodontidae	Porcupinefish
Ephippidae	Batfish
Gobiidae	Goby
Haemulidae	Sweetlips
Holocentridae	Squirrelfish
Kyphosidae	Rudderfish
Labridae	Wrasse
Lethrinidae	Emperor
Lutjanidae	Snapper
Monacanthidae	Filefish
Mullidae	Goatfish
Muraenidae	Moray Eel
Nemipteridae	Spinecheek
Ostraciidae	Boxfish
Pinguipedidae	Grubfish
Pomacanthidae	Angelfish
Pomacentridae: Anemonefish	Anemonefish
Pomacentridae: Pullers	Chromis
Pomacentridae: Damselfish	Damselfish
Scaridae	Parrotfish
Scombridae	Tuna
Serranidae: Anthias	Anthias
Serranidae: Groupers	Grouper
Siganidae	Rabbitfish
Synodontidae	Lizardfish
Tetraodontidae	Pufferfish
Zanclidae	Moorish idol

Table A 4. GPS coordinates for the terrestrial survey points

Zone	Latitude	Longitude
Coastal Fringe	3.492754	73.532927
Coastal Fringe	3.492755	73.532691
Coastal Fringe	3.492856	73.532446
Coastal Fringe	3.492961	73.532235
Coastal Fringe	3.493087	73.532001
Coastal Fringe	3.493086	73.531772
Coastal Fringe	3.493128	73.531575
Coastal Fringe	3.493194	73.531427
Coastal Fringe	3.493315	73.531652
Coastal Fringe	3.493481	73.531918
Coastal Fringe	3.493579	73.532113
Coastal Fringe	3.493618	73.532436
Coastal Fringe	3.493761	73.532831
Coastal Fringe	3.493858	73.533119
Coastal Fringe	3.493913	73.533749
Coastal Fringe	3.493564	73.533714
Coastal Fringe	3.493945	73.533458
Coastal Fringe	3.493856	73.533900
Inner Island	3.493220	73.533437
Inner Island	3.492952	73.533229
Inner Island	3.492812	73.533082
Inner Island	3.493678	73.533323
Inner Island	3.493452	73.533136
Inner Island	3.493553	73.532806
Inner Island	3.493465	73.532360
Inner Island	3.493302	73.531949
Inner Island	3.493097	73.532270
Inner Island	3.493250	73.532925
Inner Island	3.493155	73.533122
Inner Island	3.493059	73.532709
Mangrove	3.493809	73.533668

Table A 5. GPS coordinates for the marine roaming surveys

Site	Start Latitude	Start Longitude	End Latitude	End Longitude
North Channel	3.497900	73.541017	3.493683	73.535917
North West Corner	3.493883	73.531717	3.492400	73.531533
South Channel	3.498633	73.540500	3.495200	73.534700