



Vattaru Atholhu



An Ecological Assessment on Biodiversity and Management

2021

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Authors: Charlie Dryden¹, Azim Musthag¹ and Ahmed Basheer¹

¹ IUCN (International Union for Conservation of Nature) Maldives, Malé, Maldives

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Introduction

In light of the extent and scale of natural and anthropogenic impacts threatening marine and island 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 habitat'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 Vattaru Atolhu 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 & 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 (Anderson & Shimal, 2020; Ministry of Environment and Energy, 2015).

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 & 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) comes from biodiversity-based sectors (Emerton et al., 2009). There are approximately 250 species of corals belonging to 57 genera (Pichon & 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 serve as a source of income, food, and socio-economic benefits 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. This highlights the significance of the natural environment to the Maldives as well as the need to protect and conserve valuable and threatened habitats across the country. Therefore, there is an immediate need for biodiversity assessments and management plans

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

Study Site

Vattaru Atholhu is one of five oceanic faros in the Maldives, making it a rare coral reef habitat, not just within the Maldives but also globally. Its Northern edge is approximately 5 km south of Vattaru Atoll and its Southern edge is 5 km north of Meemu Atoll (Figure 1). Unlike the other oceanic faro reefs Vattaru is uninhabited and there is only a single channel breaking up the reef structure. The relative isolation of the area means the island and reef habitats are less likely to suffer from direct impacts associated with human populations. There is a single uninhabited island located on the southern edge of the reef ring, adjacent to the eastern edge of the channel. The island is teardrop shaped and approximately 200 m long with a land area of 1.4 ha. There is also a 150 m long sandy spit stretching from the North of the island. The island is surrounded by a rocky shore with dense vegetation right up to the waterline. The spit is narrow where it joins the island and widens at the Northern end. There is some mangrove growth towards the South West of the island. The island has no permanent structures on it, but there are some man-made pathways through and around the island.

The circumference of the outer rim of the reef is approximately 25 km and the inner rim is approximately 20 km. The exposed, mostly rubble and sand dominated reef flat is widest at the Eastern edge, reaching 1.5 km and is less than 500 m wide around the rest of the atoll. The ocean facing reef on the outer edge is a wall dropping steeply to deep water and is constantly exposed to ocean currents. The lagoon reef in the inner atoll is a shallow slope with mixed coral and sand. The single channel experiences strong currents and there are two large giri reef structures where the channel feeds into the inner atoll lagoon.

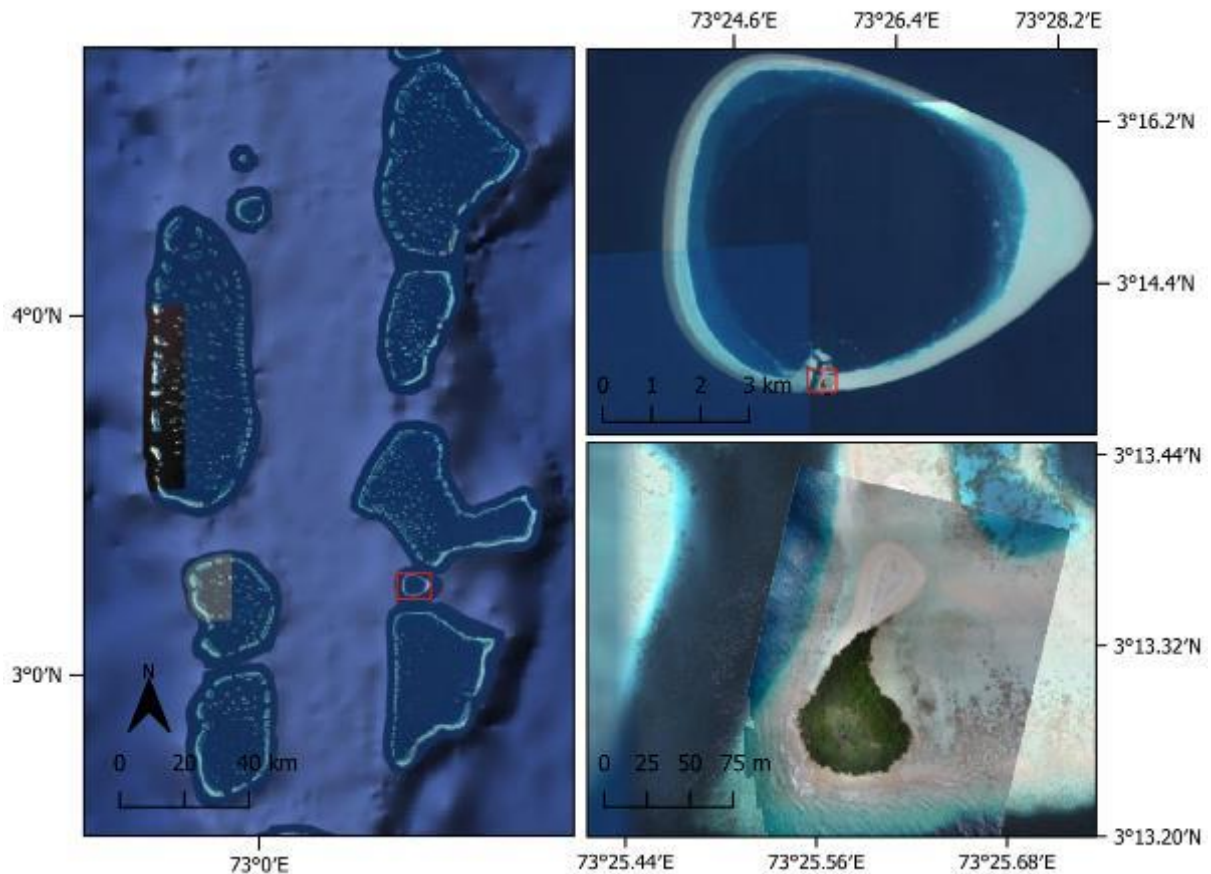


Figure 1. Vattaru Atholhu island and reef area

Methods

Terrestrial survey

The terrestrial survey area was divided into two zones: the coastal fringe and the inner island. Survey points were identified using a stratified sampling approach with sites selected across the inner island and around the coastal fringe area (Figure 2a). GPS coordinates were extracted from Google Earth© version 7.3.1 and entered into the android phone application SW Maps (©Softwell (P) Ltd. 2020) which was used for navigation to the point. Vegetation was surveyed using a point survey approach (Dryden and Basheer 2020). All birds observed were counted and identified to species. Due to the small size of the island it was not always possible to identify which habitat birds were observed in therefore counts were made for the whole island.

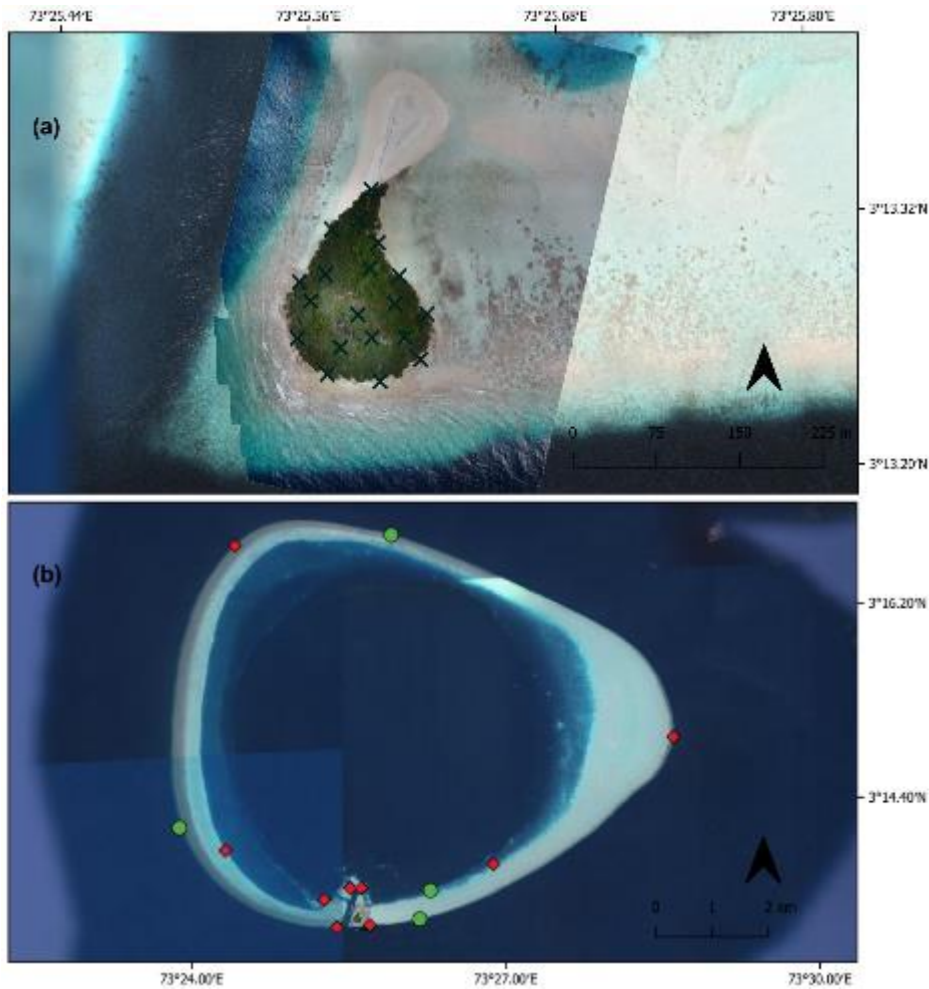


Figure 2. Location of (a) terrestrial and (b) marine survey sites. In (b) red \diamond indicates roaming survey sites and green \circ indicates transect survey sites.

Aerial survey

Aerial surveys were conducted to create an accurate, high resolution map of Vattaru island. 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 were 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, four 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 GCPs were

taken before the mapping of the island. A total of 424 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. Clockwise from top left, images from terrestrial, aerial, roaming and transect surveys

Marine survey

Marine surveys were performed using three methods. A manta tow was used to perform SCUBA and snorkel roaming surveys lasting 15 minutes were used assess fish and benthic communities on the reef slope on the oceanward and lagoonward reef, the channel habitat, on the giri reefs at the lagoon entrance to the channel (Figure 2b). Transect surveys were conducted at three locations around the oceanward reef and one on the lagoonward reef at a long-term monitoring site (Figure 2b). Three 50 m transects were set at a depth of 10 m, with a gap of at least 5 m between each transect to ensure independence of samples. Reef substrate was surveyed using photoquadrats. Photos were taken every 2 m on alternating

sides of the transect, a total of 75 photos per site. Mean percentage cover of each major benthic category, the genera of coral, and other significant benthic life forms for each transect survey site was calculated using CoralNet (<https://coralnet.ucsd.edu/>) (Beijbom et al. 2015). To quantify coral recruitment a 25 x 25 cm quadrat was placed above and below the transect every 10 m along the transect. Fish communities were surveyed along the same transects as the benthic surveys. All fish species were identified, and their total length was estimated to the nearest 5cm. Pomacentrids and smaller Serranids (Anthias) were counted within a 2 m belt along each transect, and all other species were counted within a 5m belt along each transect. The biomass of fish species was calculated using length-weight conversion: $W = aL^b$, where a and b are constants, L is total length in cm and W is weight in grams. Constants vary by species and were gathered from FishBase (Froese and Pauly 2017). For a full description of the three marine survey methods see (Dryden and Basheer 2020).

Endangered, vulnerable or threatened species

The IUCN Red List of Threatened Species categories, critically endangered (CR) endangered (EN), vulnerable (VU), or near threatened (NT) were used to identify marine species globally at risk that were present. 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 to be counted and their IUCN Red List category and CITES Appendix

Species	Red List category	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

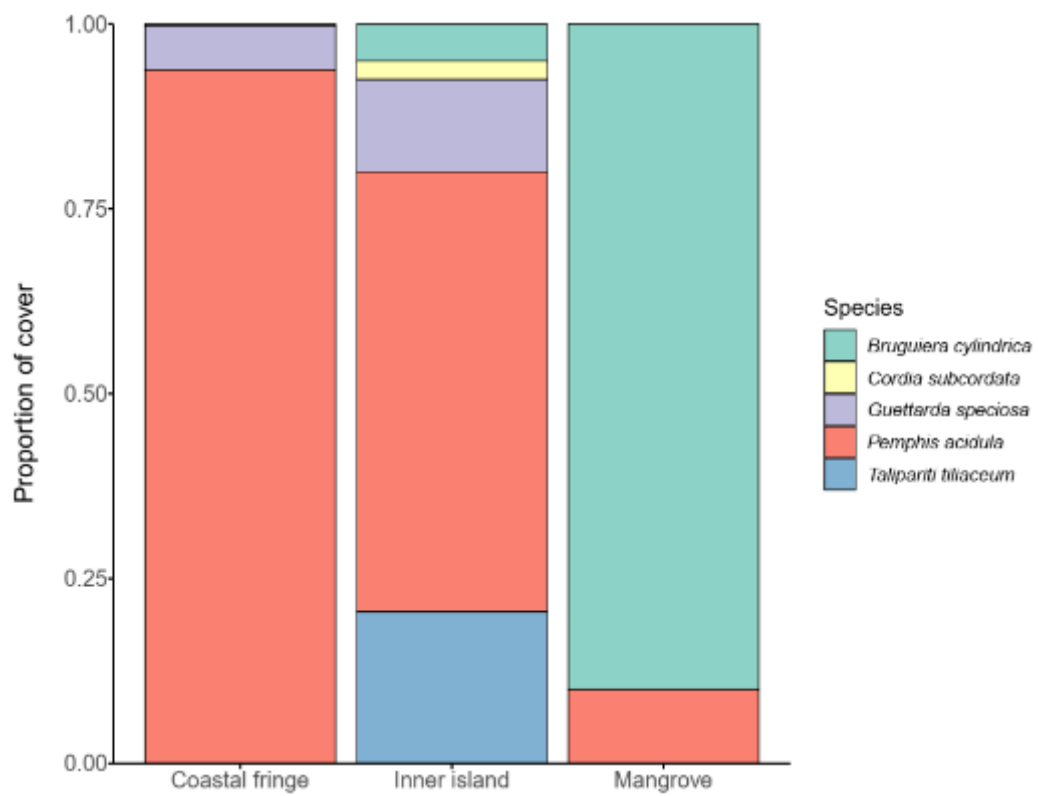
Five species of flora were identified during the terrestrial surveys (Table 2) which included a single species of mangrove, *Bruguiera cylindrica* (Dhivehi name: Kandoo). The majority of vegetation recorded from the island were species commonly associated with coastal shrubland vegetation. The most frequently observed species across the island was *Pemphis acidula* (Dhivehi name: Kuredhi). This species dominated the shoreline area where only one other species, *Guettarda speciosa* (Dhivehi name: uni), was recorded. The height of the coastal fringe vegetation averaged 4.2 m (± 0.3 S.E.).

Table 2. All vegetation species recorded on surveys and the island zone in which they were observed.

Species	Common name	Dhivehi name
<i>Bruguiera cylindrica</i>	Small-leafed orange mangrove	Kandoo
<i>Guettarda speciosa</i>	Beach gardenia	Uni
<i>Pemphis acidula</i>	Iron wood	Kuredhi
<i>Talipariti tiliaceum</i>	Sea hibiscus	Dhigga
<i>Cordia subcordata</i>	Sea trumpet	Kaani

The most species rich survey area was the inner island area where five different species were observed (Figure 4), though *P. acidula* was still dominant. Unusually for Maldivian islands no *Cocos nucifera* (coconut palm) were recorded or observed at all on the island during the surveys. The height of vegetation averaged 3.2 m (± 0.2 S.E.), with some trees reaching heights > 10 m (Figure 5).

The mangrove basin habitat was an approximately 510 m² area with a damp muddy bottom and some small patches of water (Figure 6). The area was dominated by *B. cylindrica* which grew sparsely throughout the small basin, with large spaces between trees. The trees all appeared to be relatively healthy with no evidence of disease or dying trees. No seedlings were observed growing. A small number of fruits were observed on the trees. The ground was muddy with areas of brackish water around 5 cm deep and deep mud > 30 cm. Despite the presence of water, no aquatic life was observed.



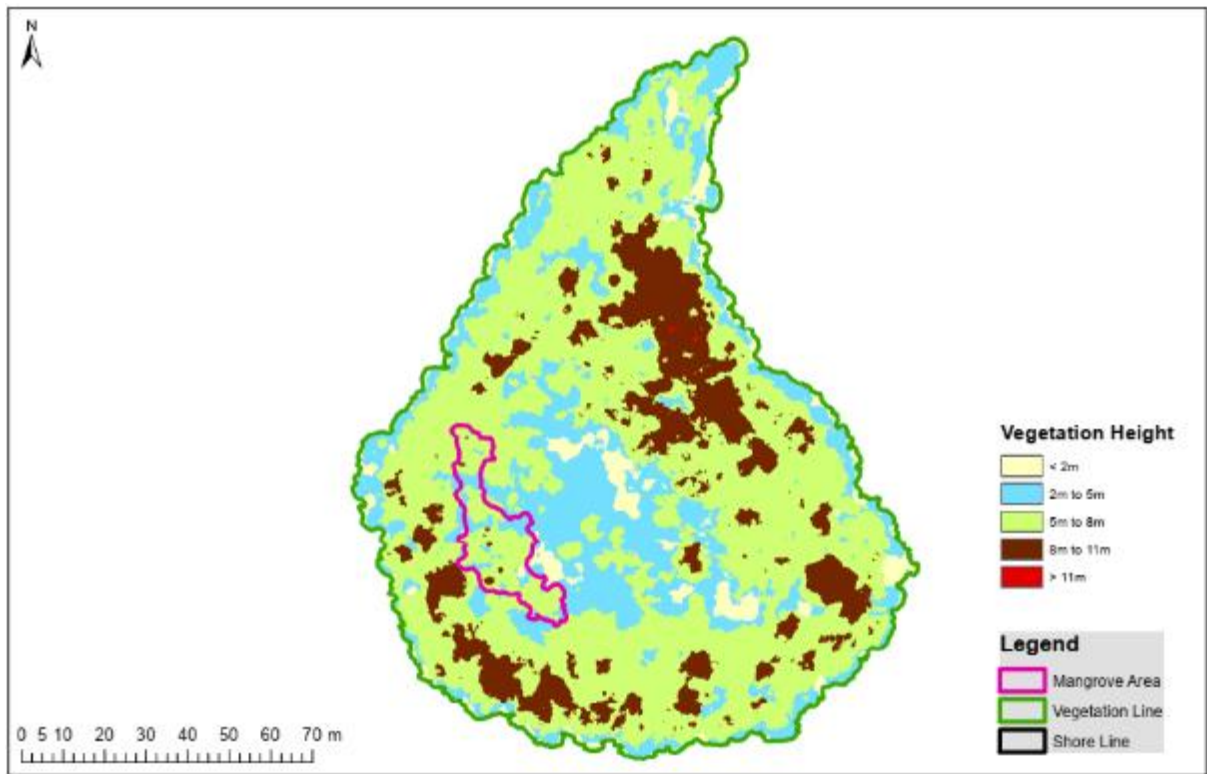


Figure 5. Digital elevation map of the vegetation height



Figure 6. Mangrove basin at the SW of Vattaru island

Though there were no permanent structures on the island, there was significant evidence of human island use. Building materials for creating temporary structures were present, including corrugated iron and bricks. There were several pathways, leading around and through the island. A number of oil drums were noted around the island. Refuse was found along both the coastal fringe and throughout the inner island area (Figure 7). The rubbish around the coastal fringe consisted of fishing gear including nets and rope and plastic waste that had drifted to the island and was caught in the shoreline vegetation. The inner island rubbish was predominantly plastic, but also metal (beer cans) and glass items (Figure 21). The majority of the rubbish was found in the inner island area.

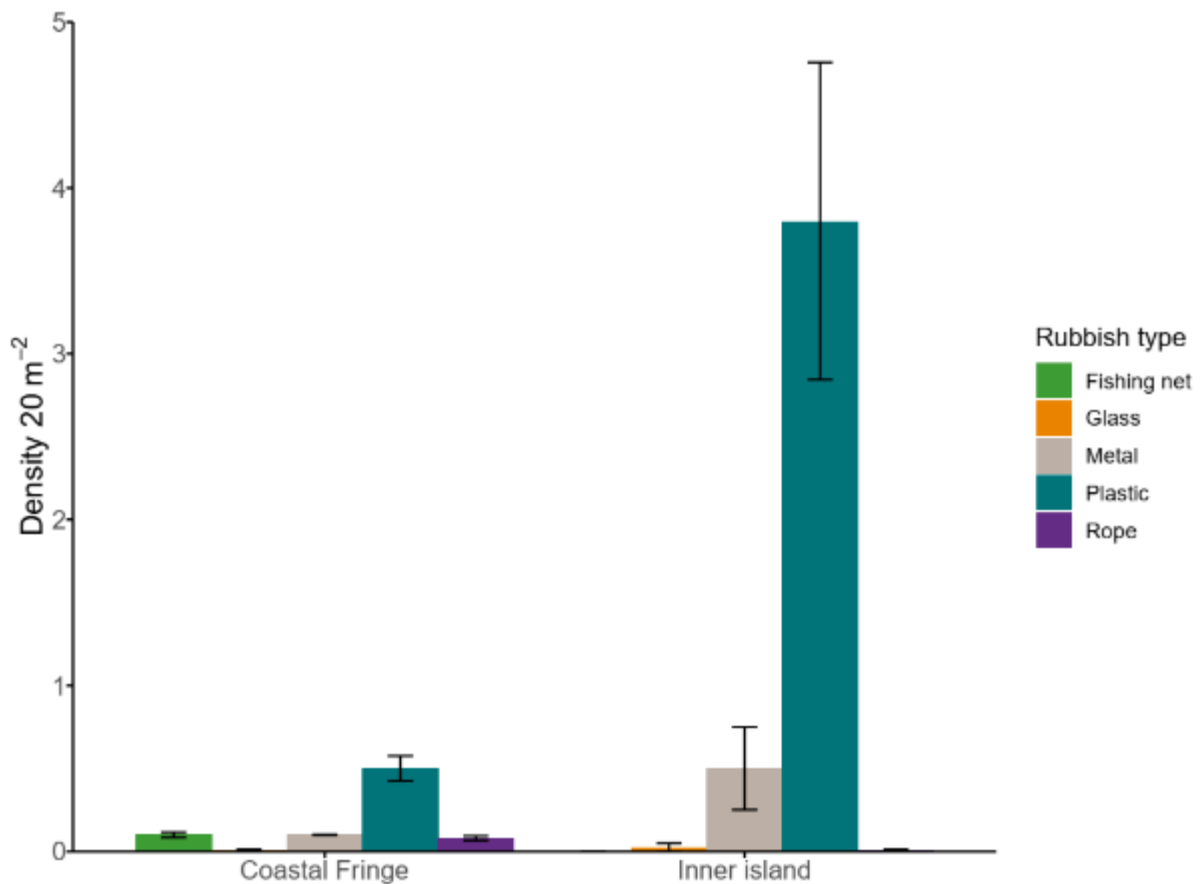


Figure 7. Mean density of items of refuse found in per 20 m² survey point in the coastal fringe and inner island areas.

Turtle nests were observed on the sandy spit area that extends from the north of the island and there were fresh tracks from some recently made nests. There was also evidence of egg poaching at these nests. Five bird species were recorded during the surveys (Table 3).

Table 3. Bird species observed during the terrestrial surveys at Vattaru

Family	Species	DhivehiName	Abundance
Ardeidae	<i>Ardea cinerea</i>	Maakanaa	3
Ardeidae	<i>Nycticorax nycticorax</i>	Raabondi	1
Charadriidae	<i>Charadrius mongolus</i>	Bondana	1
Corvidae	<i>Corvus corax</i>	Kaalhu	2
Scolopacidae	<i>Actitis hypoleucos</i>	Findhana	1

Marine

The manta tow identified rock as the dominant benthic cover around the reef flat/crest of all four regions (Figure 8). Rock cover ranged between 68.7 % (± 1.3 S.E.) cover across the Northern section of reef and 48.3 % (± 2.5 S.E.) across the South (Table 4). Hard coral was the second most common substrate at the North, East and Western regions. In the Southern region the cover of hard coral and rubble were similar. Sand cover was also high in the Southern region, in the three other regions sand cover was below 4 %. Algae cover was greater than 5 % at both the North and West regions.

Table 4. Mean percentage cover of substrate at the four manta survey regions.

Substrate	North		East		South		West	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Algae	6.4	1.2	0.7	0.3	3.4	1.3	8.5	1.1
Hard coral	15.6	1.1	29.0	1.9	17.2	2.7	19.5	2.2
Rock	68.7	1.4	54.0	1.9	48.4	2.5	62.8	2.1
Rubble	5.6	0.6	12.5	2.4	19.2	2.7	6.7	1.4
Sand	3.6	0.3	3.7	0.3	11.7	3.2	2.7	0.7
Soft Coral	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0

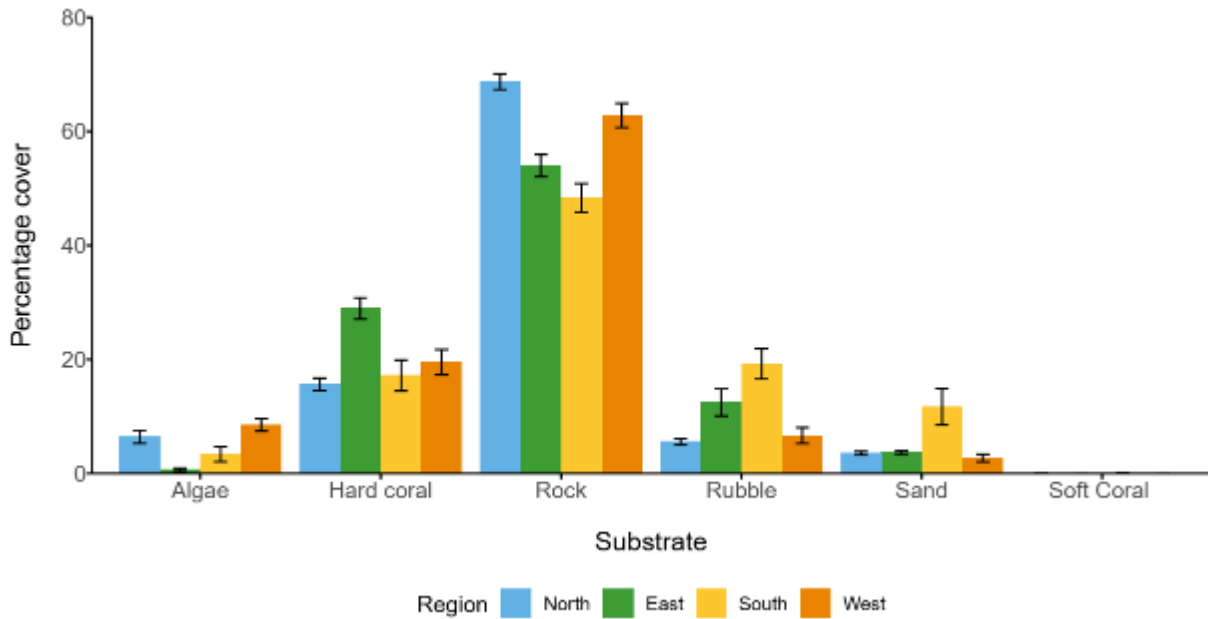


Figure 8. Mean percentage cover of six substrate categories recorded on manta tow survey.

The roaming surveys identified differences within and between habitat types (Table 5, Figure 9). Macroalgae was the dominant substrate cover at the Outer Reef – East, making up around 40 % of the substrate. Macroalgae, with 22 % was also the most common substrate type at Outer Reef – North West, though cover did not vary from hard coral. Hard coral made up around 20 % of the substrate at both outer reef sites. Rock was the third most common substrate type at the outer reef sites followed by CCA for Outer Reef – East and sand for Outer Reef – North West.

The most common substrate type at the inner reef sites was the unconsolidated substrate types of rubble and sand, which combined to make up over 55 % cover at both sites. Hard coral was the third most common substrate type with 25 % cover at Inner reef – East and 23 % at Inner reef – West. Macroalgae and Rock covered about 10 % each of the reef surface at Inner reef - East, whereas macroalgae was absent from Inner Reef - West and rock made up 15 % of the substrate.

Both sides of the channel were dominated by hard coral, macroalgae and rock with each substrate type making up 20 – 30 % of the benthos. The West side of the channel had 10 % cover of both CCA and sand. Unconsolidated substrate made up a greater proportion of the substrate on the Eastern side of the channel with sand comprising 15 % and rubble 8 % of the benthos.

The area around both Giri reefs was dominated by unconsolidated substrate. Sand and rubble each made up 30 % of the substrate at both sites. Hard coral cover was 20 % at Giri 1 and 15 % at Giri 2.

Encrusting corals were the dominant growth form at Outer reef – North West and both East and West channel areas (Figure 10). Massive corals were the most common at Outer reef – East and at the two Giri reefs. Massive corals were also the second most common coral type at Outer reef – North West and both channel areas. Both inner reef sites had a relatively even cover of massive, encrusting and branching corals. The inner reef was the only area where table corals found. Branching corals made up around 15 – 20 % of the corals at the outer reef sites and 20 – 25 % at the inner reef sites. Branching corals were also the second most common at the Giri reefs and third most common in the channel areas.

Table 5. Percentage cover of substrate categories recorded during the roaming surveys. Percent cover values are means from all surveys conducted at a site except for Giri 1, Giri 2 and Inner reef – East where only a single surveys was conducted

Substrate	Outer reef - East		Outer reef - North West		Inner reef - East		Inner reef - West		East channel corner		West channel corner		Giri 1		Giri 2	
	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.
CCA	9.7	1.5	8.3	1.7	0.0	-	0.0	0.0	1.3	0.3	10.7	2.7	0.0	-	0.0	-
Hard coral	21.0	7.4	18.3	4.4	25.0	-	23.0	8.0	21.7	4.4	18.3	8.3	20.0	-	15.0	-
Macroalgae	38.7	5.8	22.0	1.0	10.0	-	0.0	0.0	19.7	7.2	21.3	7.1	0.0	-	0.0	-
Rock	13.3	4.4	14.7	3.3	9.0	-	15.0	6.0	26.3	4.9	31.3	9.2	13.0	-	18.0	-
Rubble	5.7	2.3	4.0	3.1	25.0	-	30.0	0.0	7.7	3.7	4.7	2.7	30.0	-	30.0	-
Sand	8.3	2.0	14.3	5.7	30.0	-	33.0	3.0	15.0	2.9	10.0	5.0	30.0	-	30.0	-
Soft Coral	2.3	1.5	4.3	0.7	0.0	-	0.0	0.0	1.3	0.7	1.7	0.3	0.0	-	0.0	-
Sponge	0.7	0.3	9.3	3.5	1.0	-	1.0	1.0	1.3	0.7	0.7	0.7	0.0	-	2.0	-
Turf algae	0.0	0.0	4.3	2.6	0.0	-	0.0	0.0	4.0	1.2	1.3	1.3	5.0	-	4.0	-

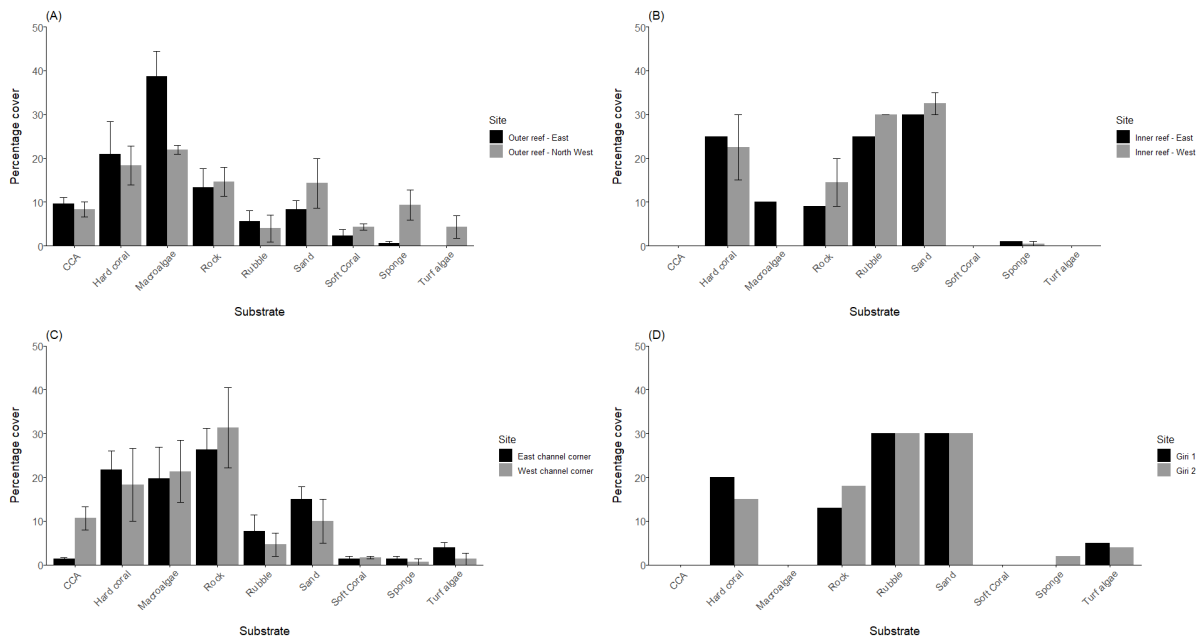


Figure 9. Mean percentage cover of substrate types at the survey sites. Percentage cover values are means from all surveys conducted at a site except for Giri 1, Giri 2 and Inner reef – East where only a single surveys was conducted

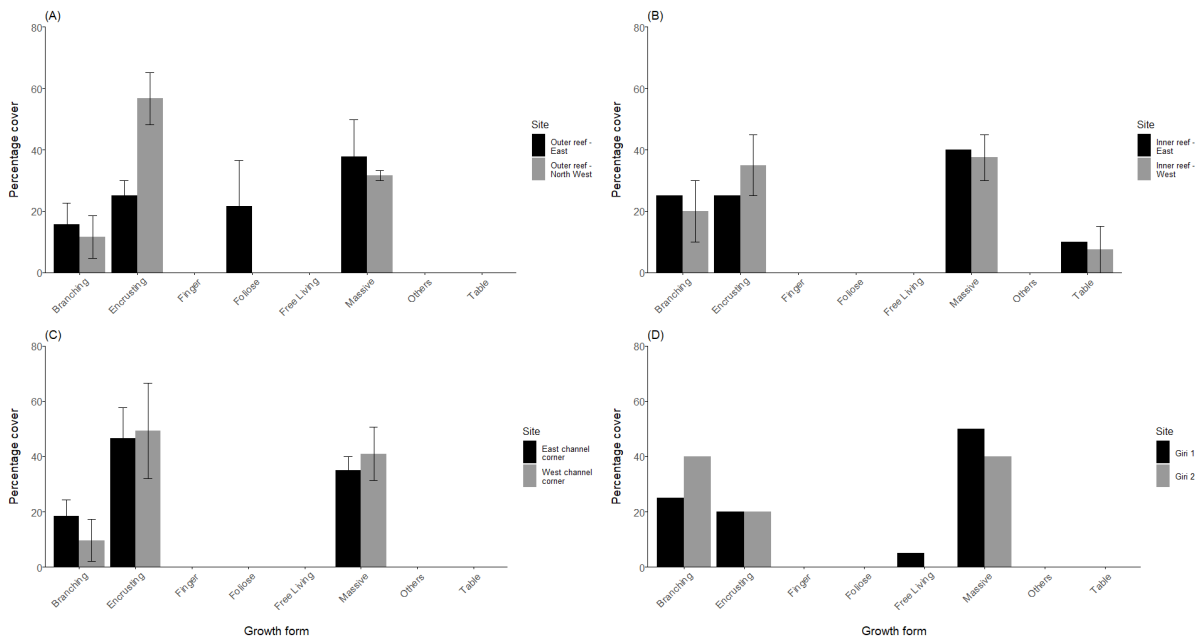


Figure 10. Percentage of coral cover in each growth form at the survey sites. Percentage cover values are means from all surveys conducted at a site except for Giri 1, Giri 2 and Inner reef – East where only a single surveys was conducted

Transect surveys at the outer reef sites found coral cover to range between 17.9 % at the North site and 8.2 % at the South East site (Table 6, Figure 11). Rocky hard substrate was the dominant cover at the North site (40.7 %). Rubble dominated the substrate at the South East site with 53.8 %. At the Western site hard substrate made up 32.1 %. Macroalgae also made up a very high proportion of the substrate at the Western site with 32.6 % of the benthos, and turf algae made up a further 7.2 % of the benthic cover. The majority of the macroalgae was *Halimeda* spp. At the North outer reef site rubble covered 18.9 % of the substrate, macroalgae (14.2 %) and turf algae (4.2 %) combined to also cover over 18 % of the benthos. At the South East outer reef site algae cover was much lower, with macroalgae covering 2 % and turf algae cover 1.2 % of the substrate. Sand made up a small proportion of the substrate at all three outer reef sites. The inner reef site in the South East of the atoll was a notably different reef habitat with patches of hard substrate and hard coral in between large areas of soft sediment. Sand was the dominant substrate cover in this area with 47.4 %. Hard coral (15.3 %), hard substrate (16.1 %) and rubble (14.7 %) made up approximately equal amounts of the benthos.

Table 6. Percentage cover of substrate categories recorded during the transect surveys.

Substrate	North outer reef		West outer reef		South East outer reef		South East inner reef (LTMS)	
	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.	Percent cover	S.E.
Hard coral	17.9	2.9	15.6	1.4	8.2	0.9	15.3	1.3
Hard Substrate	40.7	2.8	32.1	2.3	27.6	3.3	16.1	1.3
Rubble	18.9	3.7	9.3	1.7	53.8	5.1	14.7	3.4
Sand	0.7	0.3	0.3	0.1	5.5	0.8	47.4	4.7
Macroalgae	14.2	2.6	32.6	5.2	2	0.8	1.6	0.4
Turf algae	4.2	0.4	7.2	2.1	1.2	0.3	1.2	0.4
Other Invertebrates	0.4	0	0.6	0.2	0.1	0	0.9	0.2
Other	3.1	0.5	2.3	0.4	1.7	0.2	2.8	0.2

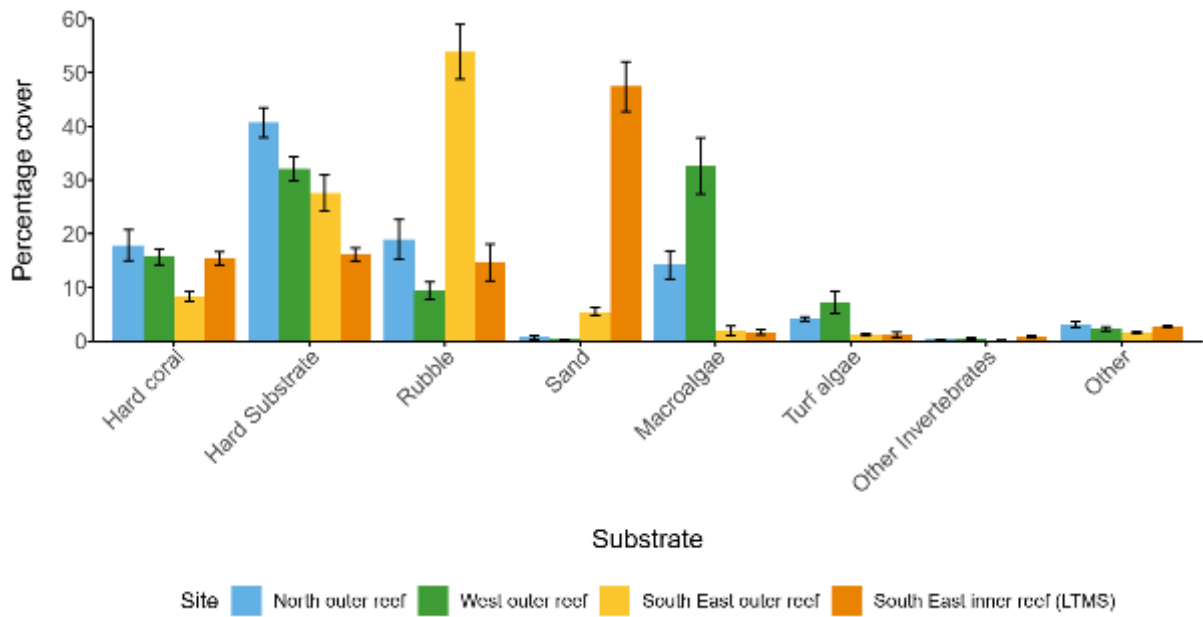


Figure 11. Mean percentage cover of substrate at the four transect survey sites

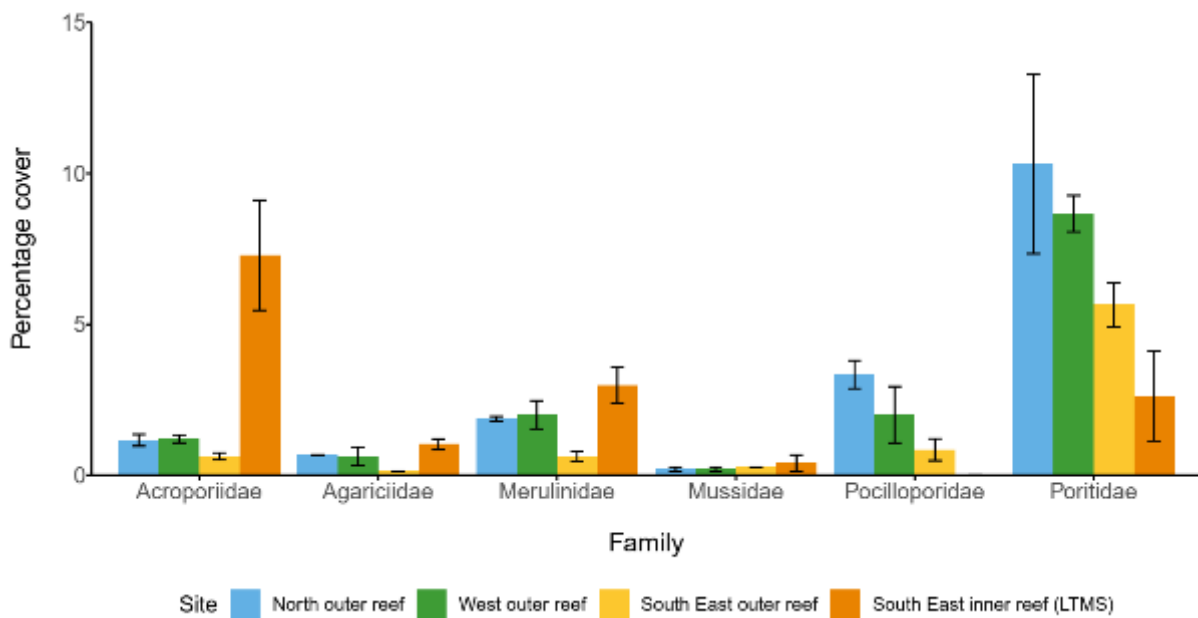


Figure 12. Percentage cover of the six most commonly observed coral families recorded on transect surveys

The six most common coral families were Poritidae, Pocilloporidae, Acroporiidae, Merulinidae, Agariciidae and Mussidae. Poritidae was the most common coral family at the outer reef sites (Figure 12). There was little difference between the North and West sites in the coral cover of the remaining families. The South East site had lower cover of Acroporiidae, Pocilloporidae, Agariciidae and Merulinidae. Acroporiidae was the most common family at the inner reef site, followed by Merulinidae and Poritidae. Pocilloporids were absent from the inner atoll site.

Density of recruits of all families did not vary between the North and West outer reef sites, but was noticeably lower at the South East outer reef site (Figure 13). Density of recruits was lowest at the South East inner reef site. Agariciidae was the most commonly recruiting family at all three outer reef sites (Figure 14), ranging from 5.7/ m² at the North site to 2.4/ m² at the South East site. At the North outer reef Merulinidae and Poritidae were the second most common families, followed by Acroporiidae and Mussidae. At the West outer reef site Acroporiidae, Merulinidae, Pocilloporidae and Poritidae recruited in approximately equal numbers with density ranging between 1.2/ m² for Acroporiidae to 1.7/ m² for Pocilloporidae. Recruitment was noticeably lower at the South East outer reef site. Poritidae was the only family other than Agariciidae that differed significantly from zero recruits per m². Recruitment was lowest for all families at the South East inner reef. Only Acroporiidae (0.7/ m²) and Agariciidae (0.9/ m²) differed from zero recruits per m².

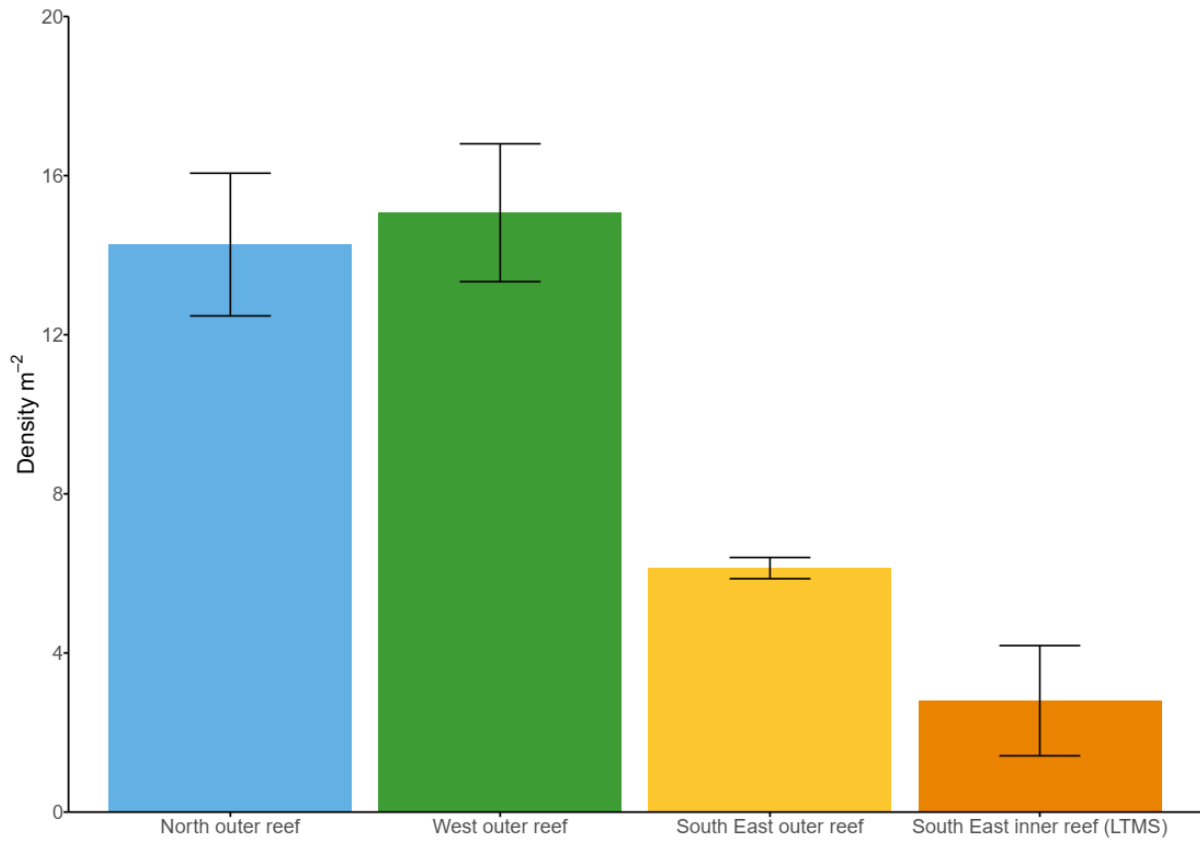


Figure 13. Average of the total density of recruits of all families recorded across transects at each site.

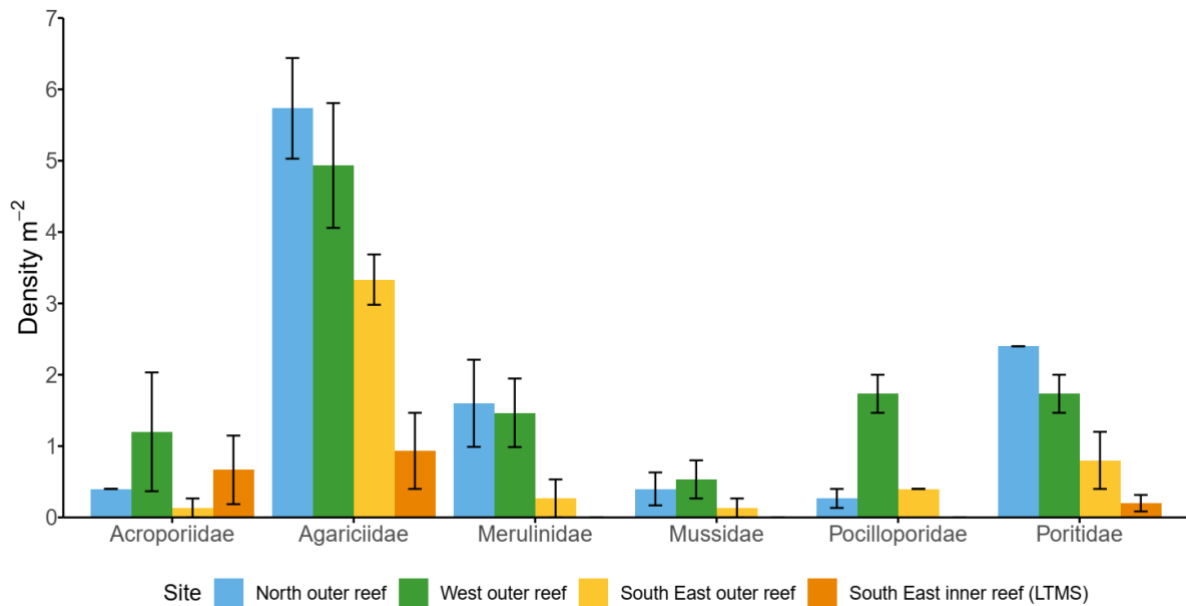


Figure 14. Density per m² of recruits from the six most common families observed.

The density of fish recorded on transects did not vary between sites around the outer atoll rim, however fish density was considerably lower at the South East inner reef site (Figure 15). Species richness was marginally lower at the North outer reef site than the other outer reef sites (Figure 16). Species richness was considerably lower South East inner reef site in comparison to the outer reef sites.

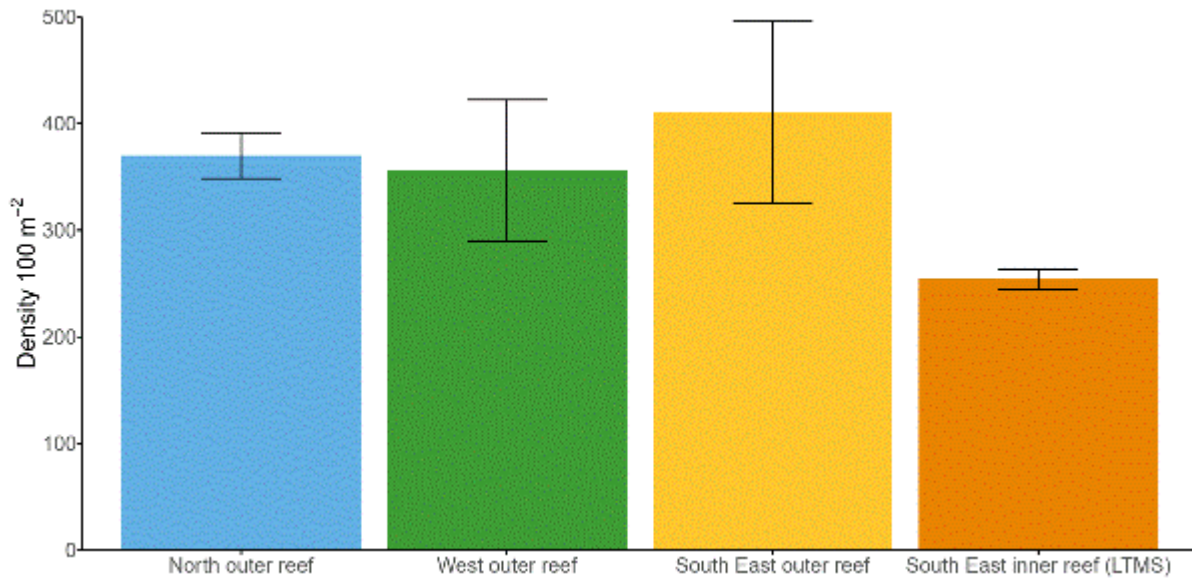


Figure 15. Average density of all fish per 100 m² recorded on transect surveys

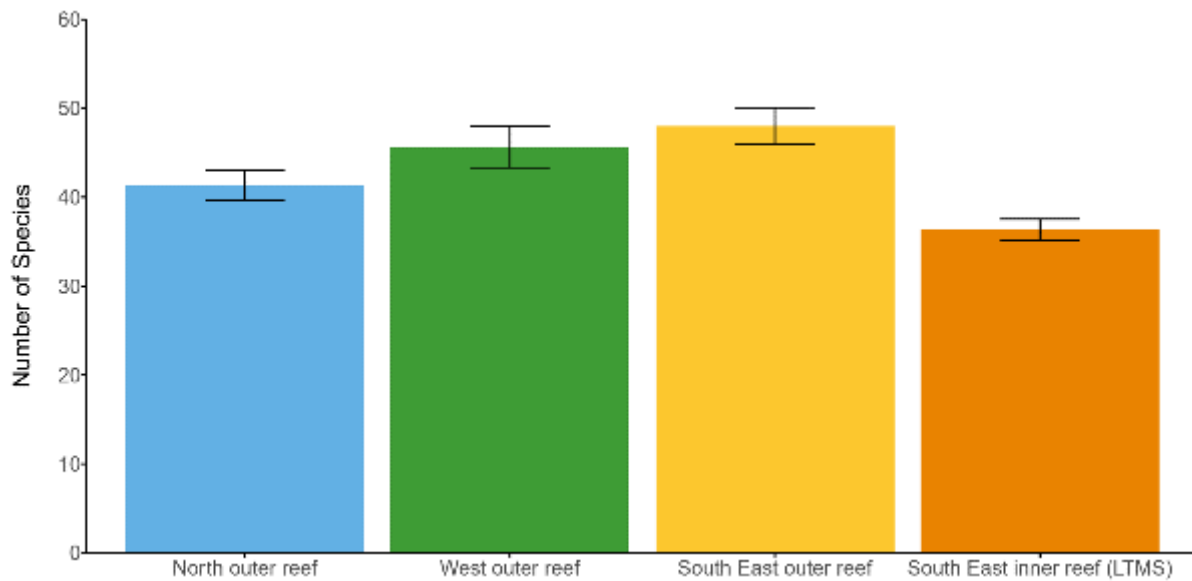


Figure 16. Average fish species richness recorded on transect surveys

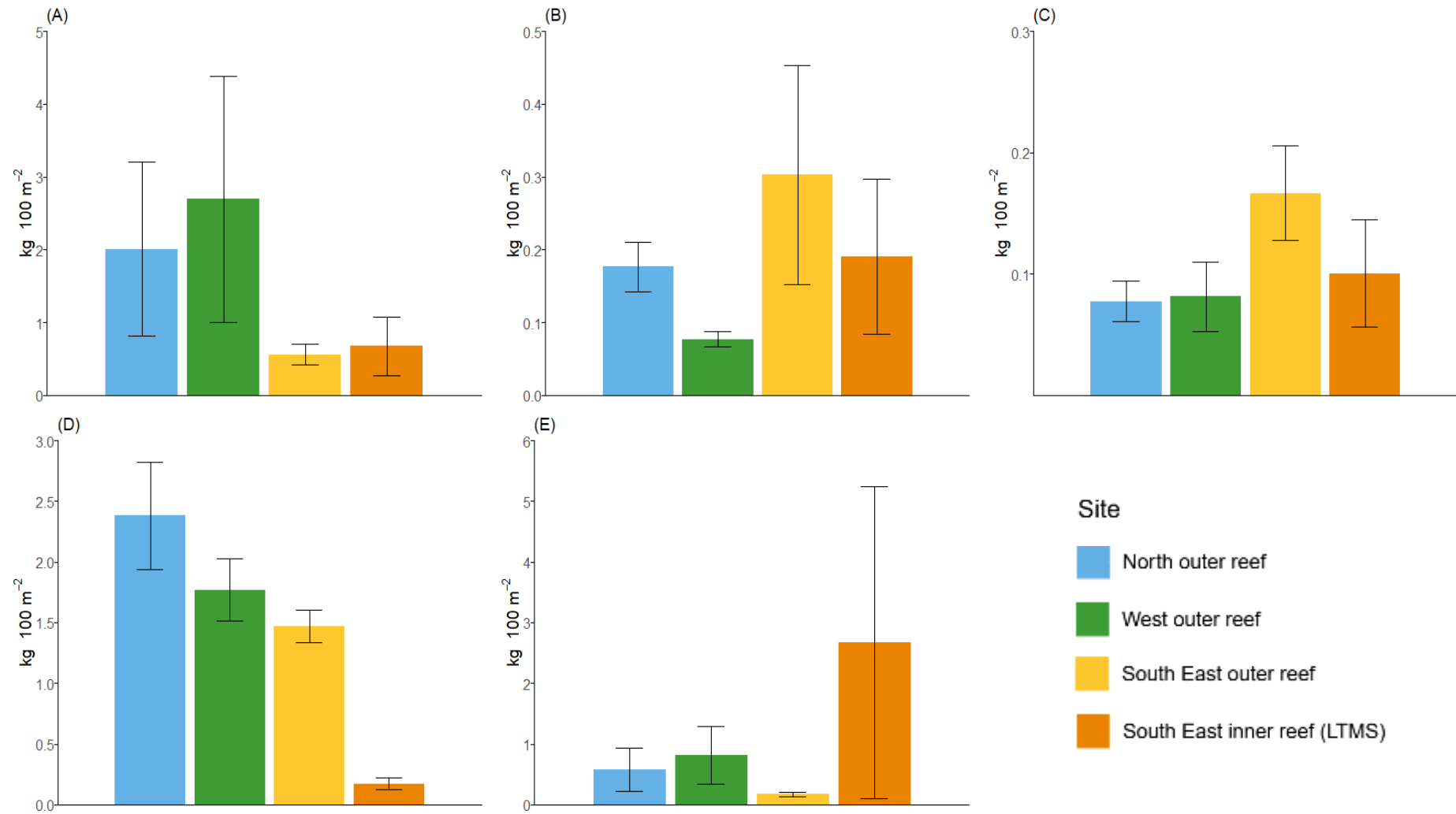


Figure 17. Biomass of the families (A) Acanthuridae, (B) Scaridae, (C) Chaetodontidae, (D) Serranidae (excluding Anthias) and (E) Lutjanidae recorded on transects across Vattaru

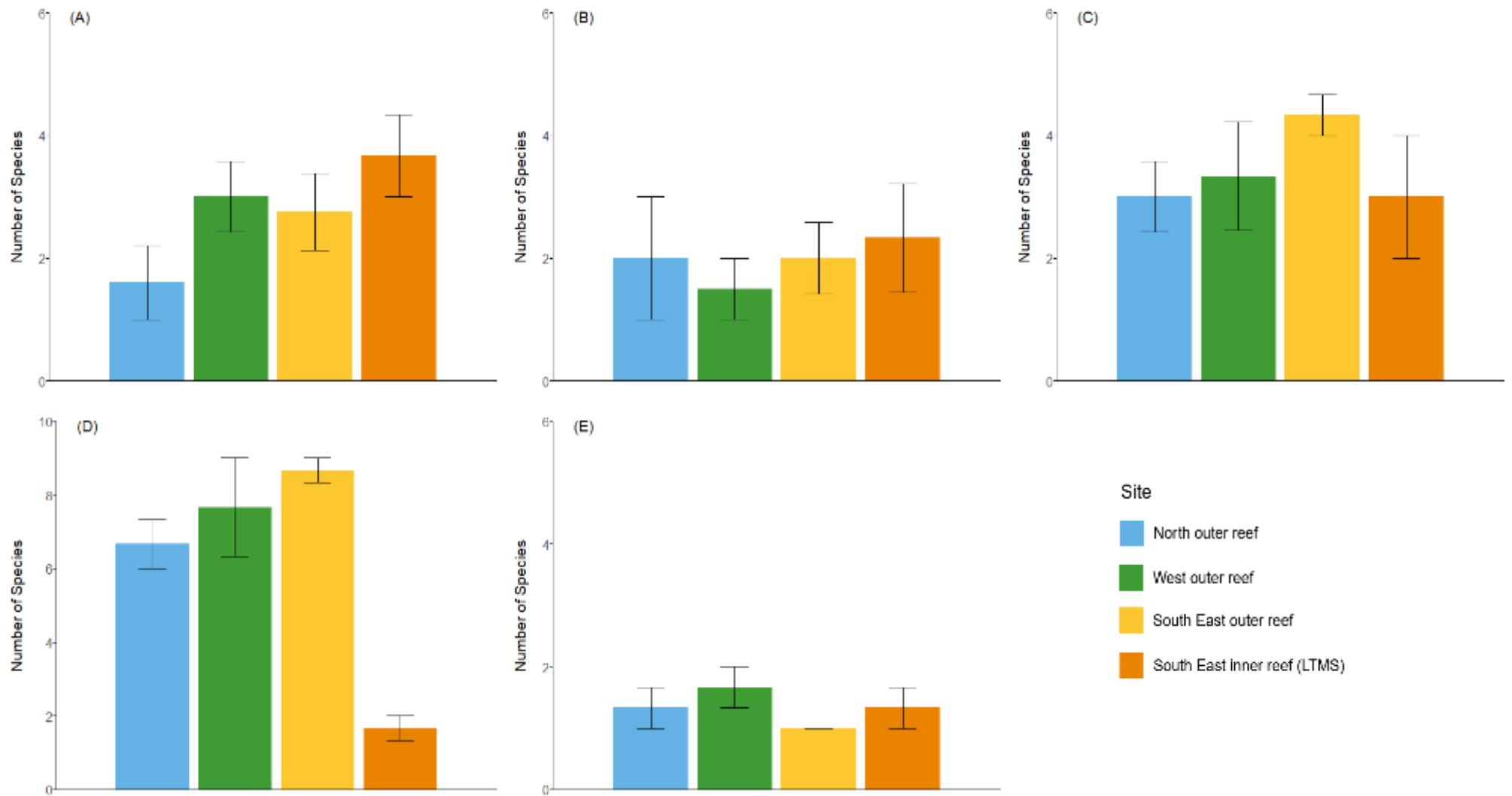


Figure 18. Species richness of the families (A) Acanthuridae, (B) Scaridae, (C) Chaetodontidae, (D) Serranidae (excluding Anthias) and (E) Lutjanidae recorded on transects across Vattaru

Biomass of the key herbivore families, Acanthuridae and Scaridae indicated some differences between the outer atoll sites (Figure 17a). Though highly variable Acanthurid biomass was greatest at the North ($2.01 \text{ kg/ } 100 \text{ m}^2 \pm 1.19$) and West ($2.07 \text{ kg/ } 100 \text{ m}^2 \pm 1.69$) outer reef sites than at either the South East outer reef or the South East inner reef sites. Scaridae biomass was low across all sites with a highest value of $0.3 \text{ kg/ } 100 \text{ m}^2 (\pm 0.15)$ recorded at the South East outer reef (Figure 17b). Biomass was variable across transects at both the South East inner and outer atoll sites and this variability meant that they did not differ considerably from each other or the North outer reef site. Scaridae biomass was lowest at the West outer reef site where a biomass of $0.07 \text{ kg/ } 100 \text{ m}^2 (\pm 0.02)$ was recorded. Biomass of the primarily corallivorous Chaetodontidae family was highest at the South East outer reef site ($0.17 \text{ kg/ } 100\text{m}^2 \pm 0.06$) and did not differ greatly between the other three sites (Figure 17c). Serranidae biomass was highest at the North outer reef site ($2.38 \text{ kg/ } 100 \text{ m}^2 \pm 0.76$) followed by the West ($1.77 \text{ kg/ } 100 \text{ m}^2 \pm 0.27$) and South East ($1.47 \text{ kg/ } 100 \text{ m}^2 \pm 0.16$) outer reef sites (Figure 17d). Serranidae biomass was considerably lower at the South East inner reef site. Lutjanidae biomass averaged less than $1.0 \text{ kg/ } 100 \text{ m}^2$ at the outer reef sites and was similar across all three of these sites (Figure 17e). Though mean Lutjanid biomass was higher at the South East inner reef site ($2.78 \text{ kg/ } 100 \text{ m}^2 \pm 2.57$) due to significant variation between transects, the biomass did not vary between sites.

Species richness of Scarids and Lutjanids averaged less than 2 for all sites and did not vary between sites (Figure 18). Acanthurid species richness was similar at the West outer reef, South East outer reef and South East inner sites, ranging between $2.75 (\pm 0.6)$ and $3.6 (\pm 0.6)$. Acanthurid richness was lowest at the North outer reef site where $1.6 (\pm 0.6)$ species were observed per transect. Chaetodontidae species richness ranged from $4.3 (\pm 0.3)$ species per transect at the South East outer reef site to 3 species at both the North outer reef and South East inner reef. Serranidae species richness was similar across the outer reef sites, ranging from $8.7 (\pm 0.3)$ at the South East outer reef site to $6.7 (\pm 0.3)$ at the North outer reef site.

Serranid species richness was considerably lower at the South East inner reef site where only 1.7 (\pm 0.3) were observed.

Red Listed species

IUCN Red Listed species were observed throughout the Vattaru marine area. A total of 66 non-coral animals and 99 coral colonies were recorded (Table 7 & Table 8). Napoleon wrasse (*Cheilinus undulatus*) was the most frequently observed species. Grey reef sharks and Whitetip reef sharks were the only species of sharks recorded. Two reef manta rays were recorded, one on the outer reef and one in shallow waters inside the lagoon. Many juvenile stingray species were observed in the shallow rocky bottom habitat close to the island. *Pachyseris rugosa* was by far the most commonly observed Red List coral species observed, *Pavona venosa* was the only pre-selected coral species not found on any surveys. In addition to the Hawksbill turtles recorded on the surveys, turtle nests were observed on the sandy spit area North of the island.

Table 7. Abundance of non-coral Red List marine species

Species	Common name	Abundance	Red List category
<i>Carcharhinus amblyrhynchos</i>	Grey reef shark	5	Endangered
<i>Triaenodon obesus</i>	Whitetip reef shark	16	Vulnerable
<i>Manta alfredi</i>	Reef manta ray	2	Vulnerable
<i>Aetobatus narinari</i>	White spotted eagle ray	3	Endangered
<i>Pastinachus sephen</i>	Cowtail stingray	2	Near threatened
<i>Taeniura meyeni</i>	Blotched fantail ray	2	Vulnerable
<i>Urogymnus granulatus</i>	Mangrove whipray	1	Vulnerable
<i>Epinephelus fuscoguttatus</i>	Marble grouper	1	Vulnerable
<i>Plectropomus laevis</i>	Black-saddle coral grouper	4	Near threatened
<i>Cheilinus undulatus</i>	Napoleon wrasse	22	Endangered
<i>Eretmochelys imbricata</i>	Hawksbill turtle	8	Critically endangered

Table 8. Abundance of the five pre-selected IUCN Red List coral species

Species	Abundance
<i>Galaxea astreata</i>	11
<i>Pachyseris rugosa</i>	77
<i>Pavona venosa</i>	0
<i>Physogyra lichtensteini</i>	6
<i>Turbinaria mesenterina</i>	5

Discussion

Vattaru Atholhu is one of only five oceanic faros in the country, and is the only one that is completely uninhabited. Despite this the island shows clear signs of human impact with significant amounts of rubbish dumped across the island by visitors and signs of poaching of turtle eggs from nests on the sandy spit. The island consists of a range of habitats including a large sandy area, a small mangrove basin, dense coastal shrubland vegetation and a rocky shoreline. The mangrove appeared to be healthy, though only mature trees were observed. General reef condition around Vattaru appeared to be quite poor with a very high abundance of macroalgae, which covered over 30 % of the reef at some sites. There was also relatively low numbers of herbivores, which is particularly worrying for reef resilience. Hard coral cover was around 20 % for much of the reef area and unconsolidated substrate made up high proportions of the benthos at certain sites.

Terrestrial

The single island on Vattaru Atholhu had a number of different habitats considering the small island area. Despite its small size and the absence of any standing water a small mangrove habitat is present. The mangrove habitat was a small, relatively well defined mangrove basin (Lugo and Snedaker 1974, Ewel et al. 1998). The only species of mangrove present was *B. cylindrica*. Mangrove trees were spread sparsely throughout the depression with large spaces between. The mangrove was separated from the sea by the rocky shoreline and coastal shrubland vegetation meaning water entering through overwash will be limited to storm events. Therefore, most water will move between the sea and the wetland via groundwater seepage. The enclosed nature of the habitat means evaporation and precipitation cycles create a variable environment. The result is fluctuations in water and soil salinity, temperature and depth and areas will flood and dry based on rainfall. 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). However, soil and water quality parameters were not measured during these surveys. Salt ponds and mangrove basins

elsewhere in the world are known to play important roles for birds, insects and invertebrates (Jarecki 1999, Gangemi 2003). Due to their low connectivity, mangrove basins are nutrient and carbon sinks (Ewel et al. 1998) and are therefore important for environmental balance. The height of the mangrove trees was below the maximum height, possibly because growth in basin forests is often stunted due to limited water and nutrient flows. Enclosed ponds, known locally as kulhi, are a common feature of many islands however the dynamics of their formation, and vegetation development are poorly understood. Given their abundance throughout the country developing a greater understanding of their dynamics and ecological role should be a priority.



Figure 19. Images from the mangrove basin showing clockwise from the top left, the spread out growth of trees, a mature *B. cylindrica* tree, fruit growing and the defined edge of the basin.

Vegetation outside the mangrove basin was dominated by *P. acidula*, making up over 90 % of the coastal and 60 % of the inner island vegetation communities. This coastal shrubland habitat is a low productivity environment, with specialised plants, exposed to harsh conditions

from the wind, sun and salt that grows on unstable sand and rubble substrate and a water deficit (Keith et al. 2020). The vegetation grows along the rocky shore right up to the waterline and the canopy stretches out over the water. This provides shelter animals living in the shallow water around the island edge. This system provides important coastal structure around the island, mitigating the impacts of erosion and storm surges. There was an area of dead/dying *P. acidula* bordering the mangrove (Figure 20). There was no clear cause for this, though it may be due to drying or stagnation of the water/mud in the area. Remarkably for a Maldivian island there were no coconut palms observed during the terrestrial or drone surveys. This may be due to relatively inhospitable rocky shoreline surrounding the outer island and the absence of any other islands on the atoll to seed the island from the sandy inner lagoon side.



Figure 20. Area of dead/dying *P. acidula* bordering the mangrove

Large piles of rubbish were found throughout the inner island area that had been disposed of by people visiting the island (Figure 21). It is likely that people visit the island for picnics and leave their rubbish behind. The fact that beer cans were part of the rubbish also suggests that safari boats are disposing of their rubbish here. Along the coastal fringe, fishing nets and other gear were found. These can do significant damage to marine life whilst in the water (Matsuoka et al. 2005) and the number found here indicate there are likely to be many more still drifting in the sea. Waste management is a significant issue for the country, and it has been identified by the Maldivian government as a key issue for biodiversity management in their report to the UN on biological diversity (Ministry of Environment and Energy 2015). Regional waste strategy and action plans are being developed to identify and develop practical approaches for waste management (Ministry of Environment 2019). The recommendations in such plans should be incorporated in future management plans.



Figure 21. Images of rubbish dumped across the inner island areas.

Marine

Despite the isolated nature of Vattaru Atholhu the outer reef habitat did not appear to be in healthy state. The roaming and transect surveys both suggested there was high macroalgae cover around the reef. Hard coral cover was rarely greater than 15 % at the outer reef sites and was dominated by encrusting or massive morphologies. Additionally, herbivore numbers and species richness, particularly for Scarids, was low compared to other reefs in the Maldives (Dryden et al. 2019, 2020b, 2020c). However, total richness of the fish community was high and the biomass and diversity of Serranids in particular was noticeably high around the outer reef.

Macroalgae compete for space with corals (McCook 2001, Hughes et al. 2007) and widespread coral mortality can facilitate increases in cover of algal turfs and macroalgae, for example bleaching disturbances facilitated dominance by turf algae on shallow reefs of the Great Barrier Reef (Diaz-Pulido et al. 2009). Given the isolated nature of the reef it is unlikely that direct human impacts, such as eutrophication or overfishing are the cause of the poor reef health. However, reefs do not have to be close to humans to be impacted by anthropogenic driven climate change (Bruno and Valdivia 2016). As a result, it is likely that coral mortality associated with previous bleaching events could have contributed to the abundance of macroalgae around Vattaru.

Herbivores play a key functional role on reefs, feeding on turf algae, preventing them from developing into upright macroalgae assemblages that are more likely to outcompete corals (McCook et al. 2001, Hughes et al. 2007) and hinder coral recruitment (Birrell et al. 2008, Ceccarelli et al. 2018), thus increasing reef resilience (McClanahan et al. 2012). Increases in macroalgae are also associated with reduced removal of macroalgae biomass by herbivores (Hughes 1994, Hughes et al. 2007). Herbivory is generally highest on structurally complex reefs (Verges et al. 2011) and the flattening of the reefs will further decrease the effectiveness of herbivores in algae removal. Though sand cover was only 3 – 15 % on the outer reef surveys

there was sediment associated with the algae and reef complex (Figure 22) and reefs dominated by algae associated with sediments can deter fish grazing (Tebbett et al. 2017).

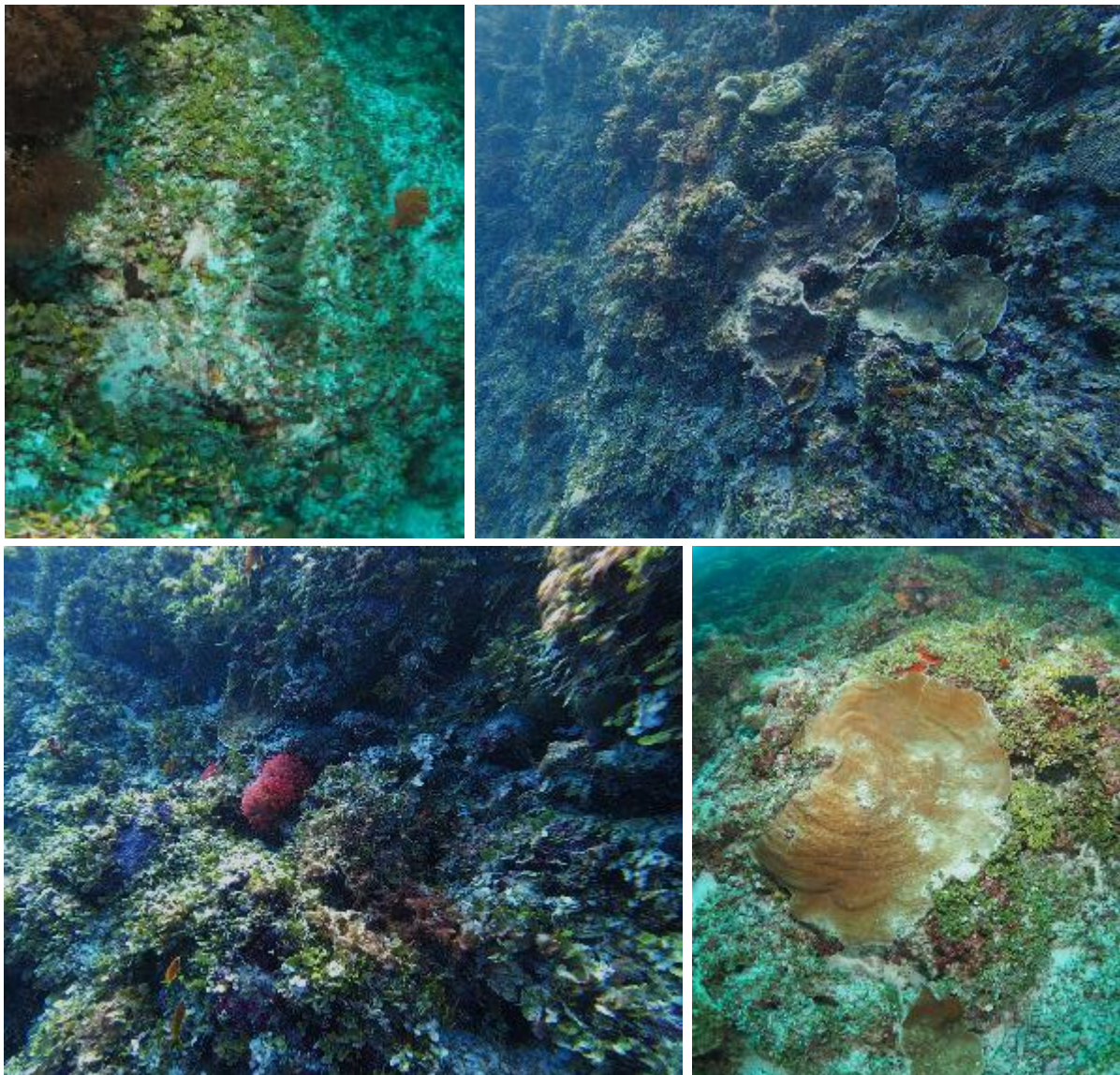


Figure 22. Macroalgae growth around the outer reef of Vattaru

The shallow reef flat/ crest area around the outer rim surveyed using the manta tow was dominated by rock. This is unsurprising given the exposed nature of this reef habitat around Vattaru. 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 indicates that exposure to waves and currents is a

strong determinant of the reef habitat, which is common among exposed reef areas (Done 1982).

The inner rim reef habitat was very different to the outer rim (Figure 23), It was characterised by a shallow slope with large patches of hard substrate and reef development on a sandy bottom. This makes direct comparison with the outer atoll reef using metrics such as percentage substrate cover difficult. Transect surveys in this habitat will inevitably cross large areas of sand, which though usual for this type of reef could be interpreted as unhealthy for a reef. In fact, the reef in this area appeared in good condition with many complex table and branching corals present and a low algae cover. Though recruitment was low here it is likely to be due to the limited availability of settlement space, as sand represents an uninhabitable surface for benthic organisms, which require a consolidated substrate to attach to survive (Smith and Hughes 1999, Kenyon et al. 2020). Substrate in this area would be better monitored using permanent quadrats, approximately 5 m x 5 m, set on the hard substrate/coral reef patches. The growth and health of the reef communities within these quadrats could then be surveyed without the sand confusing data interpretation. Though only one site was surveyed in this reef area, it is likely that much of the inner atoll rim has reefs of this type.

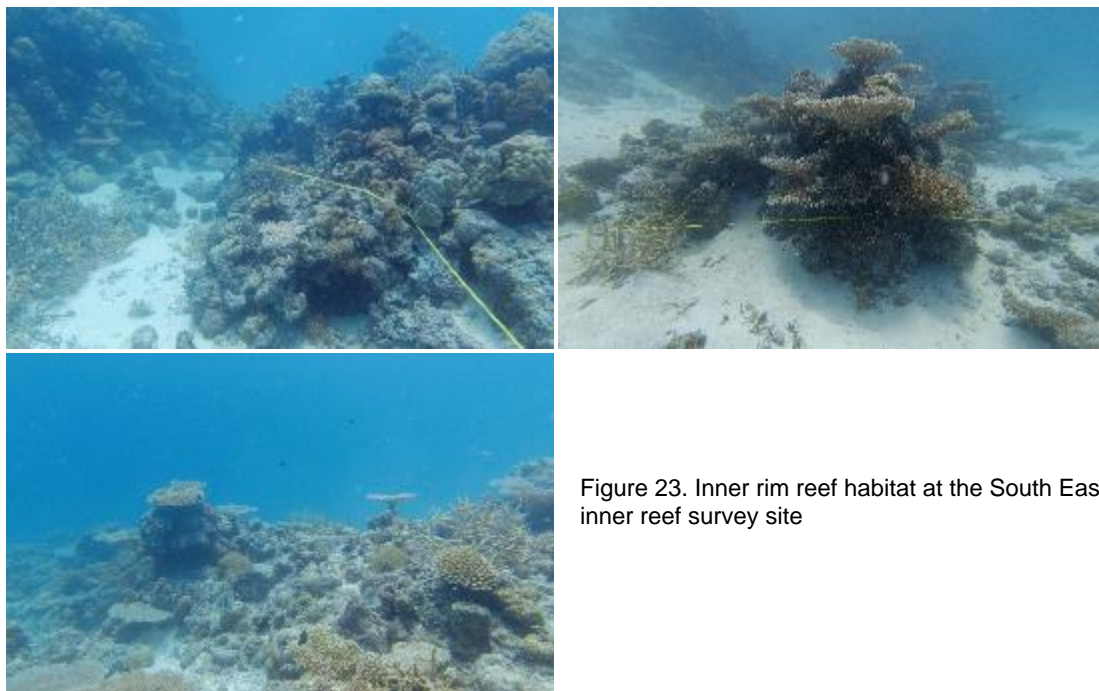


Figure 23. Inner rim reef habitat at the South East inner reef survey site

Though only two Giri reefs were surveyed there were many other small patches of reef throughout the inner atoll lagoon, between 5 and 20 m² in size (Figure 24). There were also small patches of massive corals, some with branching and table corals growing as well. This type of sheltered patch reef lagoon habitat can be important for juvenile reef fish (Adams 2002, Schroeder and Parrish 2006).



Figure 24. Giri reef structure viewed from the surface

The biomass and richness of groupers around Vattaru was higher than recorded on surveys elsewhere (Dryden et al. 2019, 2020c, 2020b). The presence of these species can be an indicator of healthy reefs and fish communities (Graham et al. 2013). These are common targets of reef fisheries and the distance of the reef from humans has likely afforded protection to these fish.

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. There was evidence of turtle egg poaching, which has also been recorded on previous surveys (Dryden et al. 2020b). This practice could threaten turtle populations around the country. Grey and hitetip reef sharks were recorded in the channels and around the outer reef. 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. A manta ray was observed several times in the shallow lagoon area behind the island, though we were unable to determine the reason for its presence in this area.

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 (IPCC 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 (IPCC 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 and 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).

Management

The ecological management goal for Vattaru Atholhu is to provide a means to promote and ensure the long-term conservation and protection of the ecosystem. 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). and Maldives Grouper Fishery Management Plan (MMRI 2020).

The findings of this report indicate that the reef around the outer atoll rim is already in poor health and any additional pressure from increased human presence may damage the reef further. The data collected here can be used as a baseline against which to monitor the future health of the reef and create reef resilience targets to achieve the core management 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 reef and island habitats and to protect the area's 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. High volume of rubbish dumped on the island.
3. The high cover of macroalgae on the outer reef.
4. The high abundance of groupers, a reef fishery target species.

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 map the island structure and development.
- Creation or enforcement of laws to prevent the dumping of rubbish on isolated islands by day visitors or safari boats.
- Protect herbivorous reef fish nationwide. This will strengthen natural controls by reef communities on the development of turf algae and macroalgae on reefs.
- Prevent any activities in the area that may cause or accelerate reef erosion, or that increase the presence of sand and particulate matter on reefs. Activities to consider include:
 - o Dredging of sand within the atoll.
 - o Land reclamation or island building projects that might deposit sediment near reef areas.
- A plan for development and enforcement of regulations in the area.
- Future monitoring of inner atoll reefs should focus on permanent quadrats on rocky reef patches rather than transects that cover both rock and sand patches and can vary greatly depending on the survey start point and direction.

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Appendix

Table A 1. GPS coordinates for the terrestrial survey points

Zone	Latitude	Longitude
Coastal Fringe	3.222148	73.426507
Coastal Fringe	3.221840	73.426187
Coastal Fringe	3.221425	73.425930
Coastal Fringe	3.220984	73.425910
Coastal Fringe	3.220703	73.426150
Coastal Fringe	3.220646	73.426579
Coastal Fringe	3.220816	73.426907
Coastal Fringe	3.221173	73.426958
Coastal Fringe	3.221474	73.426735
Coastal Fringe	3.221735	73.426565
Inner island	3.221911	73.426410
Inner island	3.221534	73.426501
Inner island	3.221253	73.426702
Inner island	3.220990	73.426780
Inner island	3.220989	73.426513
Inner island	3.221170	73.426402
Inner island	3.220909	73.426260
Inner island	3.221482	73.426138
Mangrove	3.221277	73.426017

Table A 2. GPS coordinates for the marine roaming surveys

Site	Latitude	Longitude
Outer reef - East	3.249340	73.476660
Outer reef - North	3.278830	73.406870
Inner reef - East	3.229678	73.448004
Inner reef - West	3.224186	73.421061
West channel corner	3.219940	73.423100
East channel corner	3.220260	73.428350
Giri 1	3.226021	73.426988
Giri 2	3.225969	73.425190

Table A 3. GPS coordinates for marine transect survey sites

Site	Latitude	Longitude
North outer reef	3.280500	73.431740
West outer reef	3.235300	73.398040
South East outer reef	3.221200	73.436280
South East inner reef (LTMS)	3.225555	73.437522

Table A 4. All coral genera observed on transects

Family	Genus
Acroporiidae	<i>Acropora</i>
Acroporiidae	<i>Montipora</i>
Agariciidae	<i>Leptoseris</i>
Agariciidae	<i>Pachyseris</i>
Agariciidae	<i>Pavona</i>
Euphylliidae	<i>Euphyllia</i>
Euphylliidae	<i>Galaxea</i>
Fungiidae	<i>Fungia</i>
Lobophyllidae	<i>Lobophyllia</i>
Merulinidae	<i>Cyphastrea</i>
Merulinidae	<i>Favites</i>
Merulinidae	<i>Goniastrea</i>
Mussidae	<i>Favia</i>
Paramonastreae	<i>Montastrea</i>
Pocilloporidae	<i>Pocillopora</i>
Poritidae	<i>Goniopora</i>
Poritidae	<i>Porites</i>
Psammocoridae	<i>Psammocora</i>
Siderastreidae	<i>Coscinaraea</i>

Table A 5. All coral recruit genera observed on transects

Family	Genus
Acroporiidae	<i>Acropora</i>
Acroporiidae	<i>Astreopora</i>
Acroporiidae	<i>Montipora</i>
Agariciidae	<i>Coeloseris</i>
Agariciidae	<i>Leptoseris</i>
Agariciidae	<i>Pachyseris</i>
Agariciidae	<i>Pavona</i>
Dendrophylliidae	<i>Turbinaria (coral)</i>
Diploastreidae	<i>Diploastrea</i>
Euphylliidae	<i>Galaxea</i>
Fungiidae	<i>Fungia</i>
Insertae sedis	<i>Leptastrea</i>
Lobophyllidae	<i>Lobophyllia</i>
Lobophyllidae	<i>Symphyllia</i>
Merulinidae	<i>Cyphastrea</i>
Merulinidae	<i>Favites</i>
Merulinidae	<i>Goniastrea</i>
Merulinidae	<i>Leptoria</i>
Merulinidae	<i>Platygyra</i>
Mussidae	<i>Favia</i>
Paramonastreae	<i>Montastrea</i>
Pocilloporidae	<i>Pocillopora</i>
Poritidae	<i>Goniopora</i>
Poritidae	<i>Porites</i>
Psammocoridae	<i>Psammocora</i>

Table A 6. All fish species observed on transects

Family	Species	Common name
Acanthuridae	<i>Acanthurus leucosternon</i>	Powder-blue surgeonfish
Acanthuridae	<i>Acanthurus tennentii</i>	Lieutenant surgeonfish
Acanthuridae	<i>Acanthurus xanthopterus</i>	Yellow-fin surgeonfish
Acanthuridae	<i>Ctenochaetus striatus</i>	Fine-lined bristletooth
Acanthuridae	<i>Ctenochaetus truncatus</i>	Gold-ring bristletooth
Acanthuridae	<i>Naso brevirostris</i>	Spotted unicornfish
Acanthuridae	<i>Naso hexacanthus</i>	Sleek unicornfish
Acanthuridae	<i>Paracanthurus hepatus</i>	Blue tang
Acanthuridae	<i>Zebrasoma scopas</i>	Brown Tang
Apogonidae	<i>Apogon angustatus</i>	Narrow striped cardinalfish
Balistidae	<i>Balistapus undulatus</i>	Striped triggerfish
Balistidae	<i>Balistoides conspicillum</i>	Clow triggerfish
Balistidae	<i>Balistoides viridescens</i>	Titan triggerfish
Balistidae	<i>Melichthys indicus</i>	Indian triggerfish
Balistidae	<i>Odonus niger</i>	Blue triggerfish
Balistidae	<i>Pseudobalistes flavimarginatus</i>	Yellow-margin triggerfish
Balistidae	<i>Sufflamen bursa</i>	Bommerang triggerfish
Blenniidae	<i>Meiacanthus smithi</i>	Disco blenny
Blenniidae	<i>Plagiotremus tapeinosoma</i>	Piano fangblenny
Caesionidae	<i>Caesio lunaris</i>	Moon fusilier
Caesionidae	<i>Caesio varilineata</i>	Thin-lined fusilier
Caesionidae	<i>Caesio xanthonota</i>	Yellow-back fusilier
Caesionidae	<i>Pterocaesio trilineata</i>	Striped fusilier
Carangidae	<i>Caranx ignobilis</i>	Giant trevally
Carangidae	<i>Caranx melampygus</i>	Blue-fin jack
Carangidae	<i>Decapterus macarellus</i>	Mackerel scad
Chaetodontidae	<i>Chaetodon auriga</i>	Threadfin butterflyfish
Chaetodontidae	<i>Chaetodon collare</i>	Head-band butterflyfish
Chaetodontidae	<i>Chaetodon falcula</i>	Double-saddle butterflyfish
Chaetodontidae	<i>Chaetodon guttatissimus</i>	Spotted butterflyfish
Chaetodontidae	<i>Chaetodon kleinii</i>	Brown butterflyfish
Chaetodontidae	<i>Chaetodon madagaskariensis</i>	Madagascar butterflyfish
Chaetodontidae	<i>Chaetodon meyeri</i>	Meyers butterflyfish
Chaetodontidae	<i>Chaetodon triangulum</i>	Triangular butterflyfish
Chaetodontidae	<i>Chaetodon trifasciatus</i>	Pinstriped butterflyfish
Chaetodontidae	<i>Chaetodon xanthocephalus</i>	Yellow-head butterflyfish
Chaetodontidae	<i>Forcipiger longirostris</i>	Very long-nose butterflyfish
Chaetodontidae	<i>Heniochus pleurotaenia</i>	Phantom bannerfish
Cirrhitidae	<i>Cirrhitichthys falco</i>	Dwarf hawkfish
Cirrhitidae	<i>Paracirrhites arcatus</i>	Ring eye hawkfish
Cirrhitidae	<i>Paracirrhites forsteri</i>	Forster's hawkfish
Ginglymostomatidae	<i>Nebrius ferrugineus</i>	Tawny nurse shark
Gobiidae	<i>Amblygobius semicinctus</i>	Halfbarred goby
Gobiidae	<i>Eviota sp.</i>	Eviota species unknwn
Gobiidae	<i>Fusigobius duospilus</i>	Double-spot sand goby
Gobiidae	<i>Koumansetta hectori</i>	Hector's goby
Gobiidae	<i>Ptereleotris microlepis</i>	Blue gudgeon
Gobiidae	<i>Valenciennesa sexguttata</i>	Sixspot goby
Holocentridae	<i>Myripristis adusta</i>	Shadowfin soldierfish

Family	Species	Common name
Kyphosidae	<i>Kyphosus vaigiensis</i>	Brassy rudderfish
Labridae	<i>Allocoris formosa</i>	Queen rainbow wrasse
Labridae	<i>Biochoeres cosmetus</i>	Adorned wrasse
Labridae	<i>Biochoeres leucoxanthus</i>	Lemon meringue wrasse
Labridae	<i>Bodianus axillaris</i>	Coral hogfish
Labridae	<i>Bodianus diana</i>	Diana hogfish
Labridae	<i>Cheilinus fasciatus</i>	Banded Maori wrasse
Labridae	<i>Cheilinus oxycephalus</i>	Snooty wrasse
Labridae	<i>Cheilinus undulatus</i>	Napoleon wrasse
Labridae	<i>Cirrhilabrus exquisitus</i>	Exquisite wrasse
Labridae	<i>Gomphosus caeruleus</i>	Bird wrasse
Labridae	<i>Halichoeres chrysotaenia</i>	Vrolik's wrasse
Labridae	<i>Halichoeres hortulanus</i>	Checkerboard wrasse
Labridae	<i>Hemicoris batuensis</i>	Batu rainbow-wrasse
Labridae	<i>Hemitautoga scapularis</i>	Zigzag wrasse
Labridae	<i>Labrichthys unilineatus</i>	Tube-mouth wrasse
Labridae	<i>Labroides bicolor</i>	Two-colour cleaner wrasse
Labridae	<i>Labroides dimidiatus</i>	Blue-streak cleaner wrasse
Labridae	<i>Labropsis xanthonota</i>	V-tail tubelip wrasse
Labridae	<i>Macropharyngodon bipartitus</i>	Splendid leopard wrasse
Labridae	<i>Novaculichthys taeniourus</i>	Reindeer wrasse
Labridae	<i>Oxycheilinus digramma</i>	Cheek-line Maori wrasse
Labridae	<i>Pseudocheilinus hexataenia</i>	Six-line wrasse
Labridae	<i>Stethojulis albovittata</i>	Blue-lined wrasse
Labridae	<i>Thalassoma amblycephalum</i>	Two-tone wrasse
Labridae	<i>Thalassoma hardwicke</i>	Six-bar wrasse
Labridae	<i>Thalassoma lunare</i>	Moon wrasse
Lethrinidae	<i>Lethrinus obsoletus</i>	Orange-stripe emperor
Lethrinidae	<i>Lethrinus xanthochilus</i>	Yellow-lip emperor
Lethrinidae	<i>Monotaxis grandoculis</i>	Large-eye bream
Lutjanidae	<i>Aphareus furca</i>	Small-tooth jobfish
Lutjanidae	<i>Lutjanus bohar</i>	Red bass
Lutjanidae	<i>Macolor macularis</i>	Midnight snapper
Microdesmidae	<i>Nemateleotris magnifica</i>	Red fire goby
Microdesmidae	<i>Ptereleotris evides</i>	Arrow goby
Mullidae	<i>Parupeneus cyclostomus</i>	Yellow saddle goatfish
Mullidae	<i>Parupeneus macronema</i>	Long-barbel goatfish
Mullidae	<i>Parupeneus pleurostigma</i>	Round-spot goatfish
Muraenidae	<i>Gymnothorax breedeni</i>	Black cheek moray
Muraenidae	<i>Gymnothorax flavimarginatus</i>	Yellow-margin moray
Muraenidae	<i>Gymnothorax javanicus</i>	Giant moray
Mylobatidae	<i>Mobula alfredi</i>	Reef manta ray
Nemipteridae	<i>Scolopsis bilineata</i>	Monocle bream
Ostraciidae	<i>Ostracion meleagris</i>	Black Boxfish
Pinguipedidae	<i>Parapercis hexophthalma</i>	Black-tail grubfish
Pinguipedidae	<i>Parapercis millipunctata</i>	Thousand spot grubfish
Pomacanthidae	<i>Apolemichthys trimaculatus</i>	Three-spot angelfish
Pomacanthidae	<i>Centropyge multispinis</i>	Many-spined angelfish
Pomacentridae	<i>Amblyglyphidodon batunai</i>	Green sergeant
Pomacentridae	<i>Amphiprion clarkii</i>	Clarks anemonefish
Pomacentridae	<i>Chromis dimidiata</i>	Two-tone puller

Family	Species	Common name
Pomacentridae	<i>Chromis opercularis</i>	Double-bar puller
Pomacentridae	<i>Chromis ternatensis</i>	Swallow-tail puller
Pomacentridae	<i>Chromis viridis</i>	Green puller
Pomacentridae	<i>Chromis weberi</i>	Weber's puller
Pomacentridae	<i>Chromis xutha</i>	Buff puller
Pomacentridae	<i>Dascyllus aruanus</i>	Humbug damsel
Pomacentridae	<i>Dascyllus carneus</i>	Indian humbug
Pomacentridae	<i>Plectroglyphidodon dickii</i>	Narrowbar damsel
Pomacentridae	<i>Plectroglyphidodon lacrymatus</i>	Jewel damsel
Pomacentridae	<i>Pomacentrus caeruleus</i>	Blue-yellow damsel
Pomacentridae	<i>Pomacentrus indicus</i>	Indian damsel
Pomacentridae	<i>Pomacentrus philippinus</i>	Philippine damsel
Rhinidae	<i>Rhina ancylostoma</i>	Bowmouth guitarfish
Scaridae	<i>Cetoscarus bicolor</i>	Two-colour parrotfish
Scaridae	<i>Chlorurus sordidus</i>	Shabby parrotfish
Scaridae	<i>Hipposcarus harid</i>	Longnose parrotfish
Scaridae	<i>Scarus frenatus</i>	Bridled parrotfish
Scaridae	<i>Scarus niger</i>	Dusky parrotfish
Scaridae	<i>Scarus quoyi</i>	Green-blotched parrotfish
Scaridae	<i>Scarus rubroviolaceus</i>	Ember parrotfish
Scaridae	<i>Scarus tricolor</i>	Three-colour parrotfish
Scombridae	<i>Gymnosarda unicolor</i>	Dogtooth tuna
Scorpaenidae	<i>Pterois volitans</i>	Common lionfish
Serranidae	<i>Aethaloperca rogaa</i>	Red-flushed grouper
Serranidae	<i>Cephalopholis argus</i>	Peacock rock cod
Serranidae	<i>Cephalopholis leopardus</i>	Leopard rock cod
Serranidae	<i>Cephalopholis miniata</i>	Vermilion rock cod
Serranidae	<i>Cephalopholis nigripinnis</i>	Blackfin rock cod
Serranidae	<i>Cephalopholis sonnerati</i>	Tomato rock cod
Serranidae	<i>Epinephelus fasciatus</i>	Blacktip grouper
Serranidae	<i>Epinephelus fuscoguttatus</i>	Marble grouper
Serranidae	<i>Plectropomus laevis</i>	Black-saddle coral grouper
Serranidae	<i>Pseudanthias ignitis</i>	Flame basslet
Serranidae	<i>Pseudanthias squamipinnis</i>	Orange basslet
Serranidae	<i>Variola louti</i>	Lunar-tailed grouper
Synodontidae	<i>Saurida nebulosa</i>	Clouded lizardfish
Tetraodontidae	<i>Arothron nigropunctatus</i>	Black-spotted pufferfish
Tetraodontidae	<i>Canthigaster valentini</i>	Saddled pufferfish
Zanclidae	<i>Zanclus cornutus</i>	Moorish idol