

Biodiversity Assessment and Ecological Habitat Mapping of Environmentally Sensitive Sites at Huvadhu Atoll



Location: Laabadhoo (Dhigelaabadhuva)

**Small Island Research Group
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Prepared by

Hussain Zahir, Shahaama Abdul Sattar, Ahmed Fizal, Farah Amjad

Small Island Research Group



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1. Introduction

Maldives is a coralline atoll archipelago comprising over one thousand islands and many thousands of reefs in the central Indian Ocean. The islands and reefs form 26 geographic atolls and cover an area of approximately 89,000 km² between latitude 7° 6' 30" N to 0° 42' 30" S and longitude 72° 32' 30" E to 73° 46' 15" E. The total reef area of Maldives is estimated to be approximately 9,000 km² making it the eighth largest reef system in the world (Spalding et al., 2001). It is the largest group of coral reefs in the Indian ocean with a total reef area of approximately 3,500km² (Naseer and Hatcher, 2004).

The benefits to the Maldives derived from the coral reefs are both immediate and long-term, making them a priority for conservation and management. Coral reefs are central to the economy of the Maldives with the two main economic sectors, tourism and fisheries, solely dependent on the marine environment. In addition to these economic benefits, the reefs also provide coastal protection to these low-lying islands. Over 80% of the islands are less than 1-1.5 m above mean sea level and the reefs play a critical role in providing sea defense. In spite of the remoteness and the relatively low levels of human disturbance throughout most of the archipelago, there is evidence of incremental degradation to natural resources from pollution, over-exploitation of commercially important reef fish and other species (Shakeel and Ahmed, 1996), and direct habitat destruction such as coral mining and reclamation (Brown and Dunne, 1986; Sheppard et al., 1992). These important ecological, economic and sea defense functions of the reefs were undermined recently by severe mortality of coral in all areas of Maldives following the 1998 coral-bleaching event. The long-term consequence of this mortality and related physical and ecological changes are difficult to predict especially in the light of likely repeated episodes of natural mortality to the coral reefs as a result of global warming (Sheppard, 2003).

The coral reefs with their rich biodiversity, play a vital role in the livelihoods of Maldivians. The reefs host approximately 1,100 species of fish, 258 species of corals, 26 species of sponges, 258 species of algae and 5 species of sea grass (MEE, 2015). The islands and their terrestrial habitats although similar for majority of the islands, also have characterizing features which makes some islands unique and special in their own way. Two key economic sectors, tourism and fisheries are greatly dependent on the environment and natural resources. Exploitation of the environment and its resources without consideration for sustainability is not an option and hence management plays a key role and should be given its due importance. Measures such as protection of areas and species, identification of no-take, no use areas are in place for this purpose.

At present there are approximately 42 Marine Protected Areas (MPA) declared under the Environmental Protection and Preservation Act of Maldives, accounting to approximately 0.2% of the coastal area of the Maldives. In addition to these MPAs an “Environmentally Sensitive Area list” with over 270 environmentally significant areas has been identified by the Environmental Protection Agency of Maldives. These areas are given careful consideration to ensure no or minimum developmental practices are allowed. Apart from few, most of the protected areas have been designated based on desk review in consultation with relevant stakeholders resulting in lack of true understanding of the biodiversity and its significance to local, national and global biodiversity conservation and management.

Huvadhu Atoll in the Southern region of the Maldives is among the 10 largest atolls in the world. The atoll is administratively divided into two halves whereby the Northern half is known as Gaaf Alif Atoll and the Southern half is known as Gaaf Dhaal atoll. With a dialect that differs slightly between Gaaf Alif and Gaaf Dhaal, Huvadhu Atoll has a very significant history that dates as far back as the 17th Century. For anyone who has travelled around the atoll, Huvadhu has many uninhabited islands which have preserved its raw beauty and is a sheer joy to experience. Even among these island chains, the uninhabited island of Gaaf Dhaal Laabadhoo stands out for its scenic beauty.

Laabadhoo (or Dhigelaabadhuvaa as it is locally known within the Atoll) in South Huvadhu Atoll is one of the many islands listed in the Environmentally Sensitive Area list prepared by EPA. As reported by EPA (2010), the island was included in the list due to the uniqueness of the shape and geomorphology of the island with the presence of several ponds and semi enclosed bay.

1.1 Project Location

The island of Laabadhoo is located on the southern peripheral reef of Huvadhu Atoll, at geographic coordinates of 0°12' 29" N and 73° 09' 35" E (Figure 1). Laabadhoo is just a kilometer away from Gaaf Dhaal Fiyoari, which is its closest inhabited island. To reach the island from the capital city of Male', the easiest route is to take a flight to Gaaf Dhaal Kaadehdhoo and take a speed boat from Kaadehdhoo to Dhigelaabadhoo.

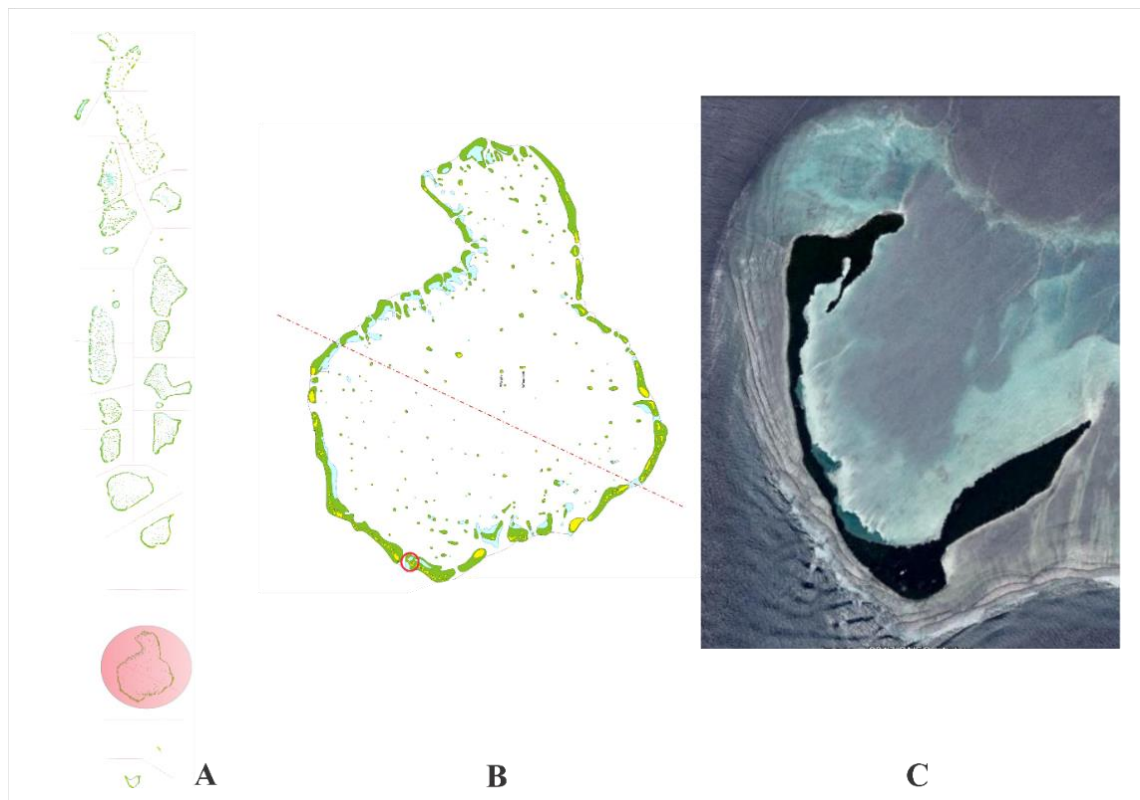


FIGURE 1. HUVADHU ATOLL AS LOCATED IN MALDIVES (A – RED HIGHLIGHT), SITE OF LAABADHOO IN SOUTH HUVADHU ATOLL (B – RED OUTLINE) AND AERIAL IMAGE OF LAABADHOO (C, SOURCE: GOOGLE EARTH IMAGES)

1.2 Objectives

The proposed project aims to assess the environment of Laabadhoo and develop detailed habitat and biodiversity assessment reports based on field surveys. This report with the findings will aid to have a better understanding of the site in terms of its various habitats and associated biodiversity to understand its ecological significance from local, national and global perspective. The findings of the surveys, in line with the project proposal will be used to prepare and develop an environmental management plan for Laabadhoo, e.g. marine protected area. The plan will be prepared in consultation with project partners that include Environmental Protection Agency, Marine Research Centre, Local Councils and Atoll Council of the project area. With significant habitat and biodiversity, the significance of the site can be enhanced from environmentally sensitive site to a marine protected area adding to the existing marine protected area in the Maldives.

1.3 Project context

The policy context in the Maldives is supportive of marine habitat conservation from the standpoint of biodiversity conservation and climate change adaptation. The Government of the Maldives (GOM) is a signatory to the Convention on Biological Diversity (CBD). Work is underway for Maldives to become a signatory to the Convention on Wetlands (Ramsar Convention) — an intergovernmental treaty for conservation and sustainable use of Wetlands of International Importance. The National Biodiversity Strategy and Action Plan and the Third National Environmental Action Plan (NEAP) stress the importance of protecting and restoring coral, wetlands and mangrove ecosystems. The Strategic Action Plan (SAP; also called National Framework for Development 2009–2013) stresses conserving and sustainably utilizing biological diversity to ensure maximum ecosystem benefits.

At the national level, Ministry of Environment and Energy (MOEE) and Ministry of Fisheries and Agriculture (MOFA) are two overarching agencies responsible for wetland and coral reef ecosystem conservation, respectively. Hence increasing the overall area of environmentally protected areas of the country to conform with the obligation of Convention on Biological Diversity as a member state is a priority. Currently the overall marine protected area of Maldives is less than 1% which is far below the target 15%.

1.4 Relevant legislations

Convention on Biological Diversity

The Convention on Biological Diversity is an international legally-binding treaty with the overall objective of encouraging actions which will lead to a sustainable future. The CBD has three main goals namely; conservation of biodiversity, sustainable use of biodiversity and fair and equitable sharing of benefits arising from the use of genetic resources. The CBD covers all levels of biodiversity including ecosystems, species (animals, plants, fungi and microorganisms) and genetic resources. Given the wide cover range for biodiversity, the main framework of action used under the CBD is the Ecosystem Approach, which is an integrated approach for management of resources. Furthermore, the Precautionary Principle as practiced under CBD states that “*where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat*” (United Nations, n.d.).

Environment Protection and Preservation Act (Law 4/93)

The Environment Protection and Preservation Act (Law 4/93) which came into effect in April 1993, states that “*The Natural environment and its resources are a national heritage that needs to be protected and preserved for the benefit of future generations. The protection and preservation of the countries land and water resources, flora and fauna as well as the beaches, reefs, lagoons and all-natural habitats are important for the sustainable development of the country*”. EPPA is the governing legislation for all environment related activities. Under Article 4 of the Environment Protection and Preservation Act, the Ministry of Environment is vested with the responsibility of identifying and registering protected areas and natural reserves and drawing up of rules and regulations for their protection and preservation.

National Biodiversity Strategy and Action Plan (NBSAP)

In compliance with CBD and to implement the CBD strategies, the first NBSAP was developed in 2002 and the objective of NBSAP was to “*achieve biodiversity conservation and sustainable utilization of biological resources in the Maldives*” by integration of biodiversity conservation into all areas of national planning, policy development and administration (MHAHE, 2002). The NBSAP has been more recently revised and published (NBSAP 2016 – 2025) with three guiding principles which take into account the three goals of CBD. The three principles are:

1. The people of this generation and the generations to come reserves the right to access and share benefits of rich biodiversity and ecosystem services

2. Responsibility of conserving and sustainably using biodiversity lies on everyone's shoulders and shall be taken as a shared responsibility
3. Biodiversity shall be mainstreamed into all sectors and in a manner whereby monitoring progress and accountability is ensured.

1.5 Methodology

Laabadhoo is an atypical island with various habitats within and around the island. One of the main objectives of this study is carry out rapid habitat assessment with biodiversity inventory of the flora and fauna of the island and associated ecosystems. Rapid assessments approach to environmental assessment was adopted due to the limited amount of time and resources (scope of the project). However, a range of different methodologies were also used in order to optimize the objectives and scope of the project where applicable.

The study proposal was based on two components;

1. Habitat mapping with classification of habitats; physical surveying of the island and associated habitats with
2. Biodiversity assessment and inventory of specific target animal and plant groups. The biodiversity component of the study has been classified to the following thematic areas;
 - i- Invertebrate diversity (mainly reef building coral)
 - ii- Fish diversity
 - iii- Terrestrial flora and fauna
 - iv- Mammal (terrestrial and marine) biodiversity
 - v- Birds (shore and sea birds) biodiversity
 - vi- Reptiles (marine and terrestrial) biodiversity
 - vii- Pests and invasive species

For each sub thematic area, rapid biodiversity assessment methodologies were applied to assess the biodiversity and abundance of target biota. The surveys were carried out between May 2017 and September 2017. This duration coincided with the southwest monsoon of Maldives.

2. Habitat Mapping

Habitat mapping and shoreline characteristics of the island was carried out using precision GPS (Trimble Geo Explorer 2008 series) and Phantom 4 Pro drone. Combination of these two with centimeter accuracy have been used to identify various geophysical features of the island and associated habitats within the island and across the reef. The outputs from Trimble (geo-referenced features such as lines) and Phantom 4 Pro (geo-referenced high-resolution imagery of the island and associated feature) were both processed and exported to ArcGIS Desktop 10.5. The geo-coordinates were read in ArcGIS as an undefined datum so the CAD datasets were checked against other existing datasets with WGS 1984 datum which aligned with them. Each dataset was projected to *WGS_1984_UTM_Zone_43N* shapefiles. Symbology for the datasets were colorized with the RGB representation of each layer field in each dataset. All features generated in the shapefiles were individually checked against the CAD features in each dataset before removal and cleaning of the annotation lines and points. Area of the *polygon* and *MultiPatch* datasets were calculated in square meters and summarized to show the total area for each type of layer. Perimeter for the *polyline* dataset was calculated in meters and summarized. Cartography represents of all the layer symbologies in the shapefiles. The outputs of this is provided in results section and GIS features files are provided in soft copies so that those can be viewed using appropriate software including ArcGIS.

3. Biodiversity Assessment

The following biota has been assessed in terms of their distribution and abundance within the project area.

3.1 Coral Diversity

Coral community and its health is regarded as an important aspect of the reef for ecological functioning of other associated flora and fauna in tropical coral reef systems. Several survey locations were established across various reef habitats in order to assess the health of the coral community and associated benthic substrate assessment. These include lagoon area, the reef flat, reef crest and the reef slope of the island. All survey depths were (1-5 meters) based on snorkeling depths. Survey location were partly based on an environmental condition assessment of Laabadhoo in 2010 (unpublished report, EPA 2010). The outputs of survey sites in this report were referenced as baseline and have been used to compare with findings of this survey. A replication of the methodology of the initial survey by EPA was carried out to ensure consistency of the methodology, thus giving more accurate comparisons. In addition to the 13 locations around the island which EPA had initially surveyed, four more locations were considered to include habitats that have not been considered previously and cover all possible habitats. The location and geo-coordinates of all surveys including coral and fish survey are shown in Figure 2 and Table 1 respectively

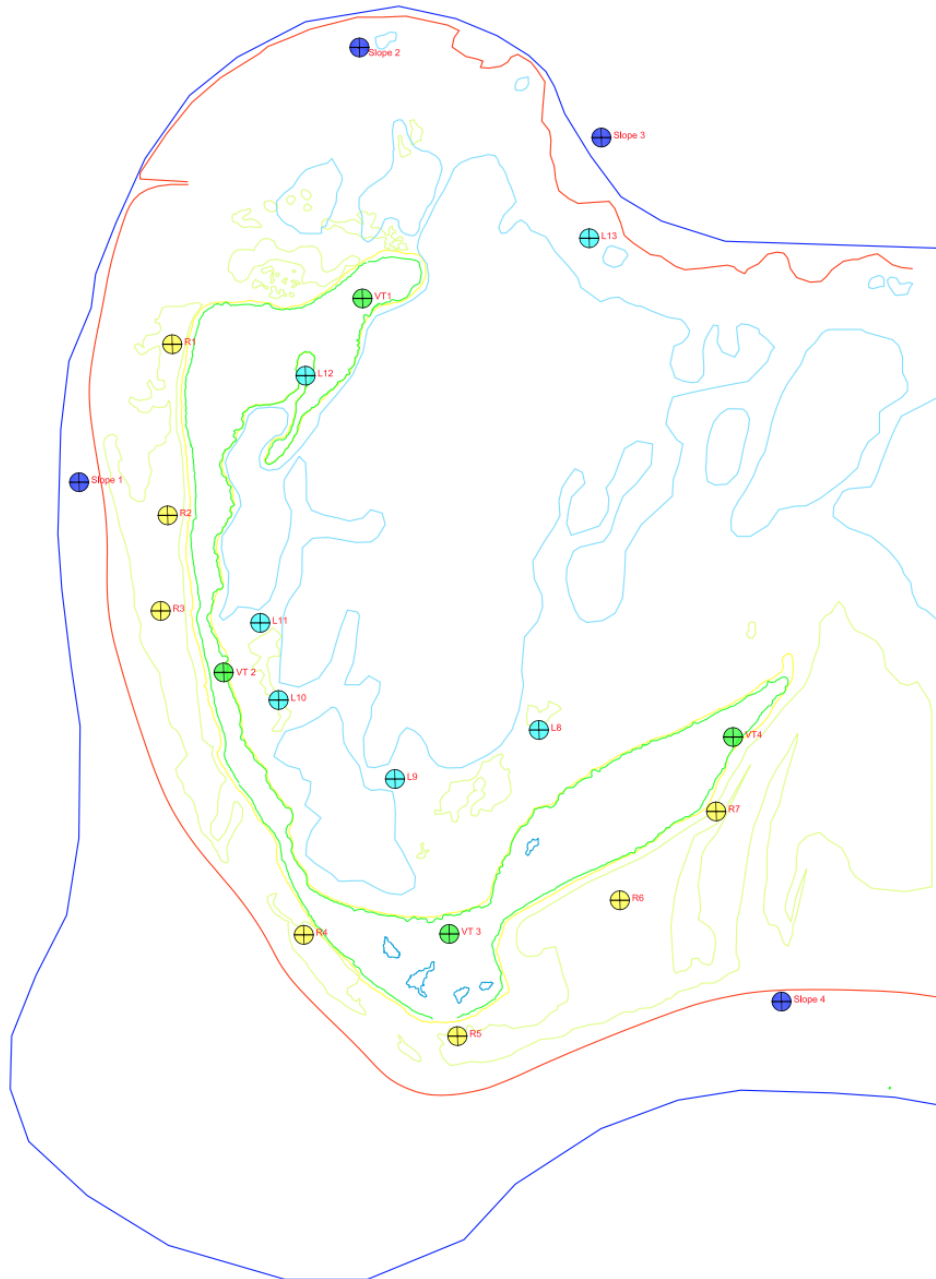


FIGURE 2 SURVEY LOCATIONS OF THE STUDY AREA. YELLOW AND TURQUOIS CIRCLES (CROSSED) WITH R AND L ANNOTATION REPRESENTS REPEATED SURVEY SITES ADHERED BY EPA IN 2010. BLUE CIRCLES (CROSSED) ARE ADDITIONAL REEF SURVEY SITES WHERE SAMPLING HAVE BEEN CONSIDERED AS PART OF THIS STUDY. GREEN CIRCLES (CROSSED) WITH VT ANNOTATIONS ARE TERRESTRIAL SURVEY LOCATIONS.

TABLE 1 GPS COORDINATES OF MARINE SURVEY LOCATIONS

	Survey point	Type of benthic environment	GPS location	
			Latitude	Longitude
EPA 2010 survey points & this study sites	R1	Reef flat	0°13'10.89840"N	73°09'11.66040"E
	R2	Reef flat	0°12'58.43880"N	73°09'11.32920"E
	R3	Reef flat	0°12'51.48000"N	73°09'10.82880"E
	R4	Reef flat	0°12'27.88920"N	73°09'21.17160"E
	R5	Reef flat	0°12'20.52000"N	73°09'32.27040"E
	R6	Reef flat	0°12'30.40920"N	73°09'44.01000"E
	R7	Reef flat	0°12'36.87840"N	73°09'50.96160"E
	L8	Shallow lagoon	0°12'42.81120"N	73°09'38.16000"E
	L9	Shallow lagoon	0°12'39.24000"N	73°09'27.75960"E
	L10	Shallow lagoon	0°12'44.98920"N	73°09'19.35000"E
	L11	Shallow lagoon	0°12'50.60880"N	73°09'18.02160"E
	L12	Shallow lagoon	0°13'08.60880"N	73°09'21.29040"E
	L13	Shallow lagoon	0°13'18.62040"N	73°09'41.78880"E
SIRG points (this study)	Slope 1	Reef Slope	0°13'00.85080"N	73°09'04.93200"E
	Slope 2	Reef Slope	0°13'32.50920"N	73°09'25.18200"E
	Slope 3	Reef Slope	0°13'25.95360"N	73°09'42.66360"E
	Slope 4	Reef Slope	0°12'23.04000"N	73°09'55.68840"E

The method used by EPA was replicated for those sites (Table 1). A GPS was used to relocate accurately and visit the locations in the lagoon, the intertidal zone, the reef flat and the reef slope. A small dinghy was used to travel around to all the points. A quadrat (1m²) which had 16 equally divided subdivision squares within it was used to calculate percentage cover. Data from 5 quadrates were taken from each location by randomly placing it in the vicinity of each point respectively and noting down the percentage cover. The parameters analyzed during the benthic cover survey included percentage live coral cover, dead coral/rock, rubble, sand, sea grass and macro algae which were the most significant parameters observed in the benthic environment of the island.

The percentage cover was calculated for each parameter as per the formula below.

$$\text{Percentage cover} = \frac{\text{Number of quadrat subdivisions occupied by the respective parameter}}{\text{Total number of subdivisions in quadrat (16)}}$$

Note: Each parameter was noted as present within the quadrat subdivision only if it covered more than 50 percent of the quadrat subdivision square.

For each of the sites which were surveyed in the benthic surveys, a coral community inventory was listed out simultaneously with the benthic survey. All coral communities which were observed were identified in the field to the genus level where possible. Photographs using an underwater camera were taken of the coral communities where field identification was not certain. The photographs were later reviewed to identify the coral communities to genus level using the Coral Finder 2.0 and Corals of the World (Veron, 2000) for identification of corals.

The diversity of the coral community at site were compared with national coral species diversity list to discuss relative diversity and abundance.

3.2 Fish Diversity

Fish census and their abundance and diversity was assessed at the same sites where reef substrate surveys were carried out (see Figure 2 and Table 1). A timed snorkeling session was carried out at each of the locations. A list of all species of fish which were observed at each site were identified to species level at field and photography of the individuals were made on site. Video footages were taken from each site using an underwater camera, for further reference for fish identification. Fish identification guides such as “Fishes of Maldives” by Marine Research Centre (MRC, 2003) which provide an inventory of all identified fishes and Kuitert (2014) have been used for fish diversity comparisons.

3.3 Terrestrial Flora and Fauna

Line transect sampling method was used to obtain the species of vegetation prominent in 4 sites of the island (Figure 2 and Table 2). Four locations of the island were chosen as the points for which the vegetation transects were to be laid. 50 meters transect lines were laid parallel to the shoreline to ensure unbiased inland vegetation of the island. Each species that cut across the transect line was counted. In addition to this, major vegetation zones of the island were generated using aerial imagery derived from drone using ArcGIS software. This enabled relative area calculation for various flora and other habitats such as inland ponds.

In addition to flora, presence of terrestrial fauna (animals and significant insects) were assessed during the field visit. The presence of such individuals and their observations were mainly based on audio and visual observation. Photographs were taken and used to identify and document such organisms.

TABLE 2 GPS LOCATION OF TERRESTRIAL FLORA AND FAUNA

Survey point	GPS location	
	Latitude	Longitude
Vegetation transect 1	0°13'14.23200"N	73°09'25.40520"E
Vegetation transect 2	0°12'47.00520"N	73°09'15.37920"E
Vegetation transect 3	0°12'27.96120"N	73°09'31.68000"E
Vegetation transect 4	0°12'42.30000"N	73°09'52.18200"E

3.4 Mammals

Although terrestrial mammals are rare in the wild, marine mammals are in relative abundance. In order to document the diversity and abundance of marine mammals, specific emphasis have been given for visual observation during field visit and survey, both in and out of water. In addition, feedback from local knowledge has been used to relate to any history of presence and abundance of mammals. Observations and information made available from individuals of the local community who have historical knowledge of the island, were compared with diversity of mammals found in the Maldives to discuss relative diversity and abundance.

3.5 Birds (shore and seabirds)

In order to document the diversity and abundance of marine and shore birds, specific emphasis have been given for visual observation during field visit and survey of shoreline. Several hours of visual observation of shore and sea birds that roost or forage were made at the project location. In addition, feedback from local knowledge has been used to relate to any history of presence and abundance of birds. Observations and information made available were compared with diversity of birds found in the Maldives to discuss relative diversity and abundance.

3.6 Reptiles

In order to document the diversity and abundance of reptiles (specifically sea turtles) specific emphasis have been given for visual observation during field visit and survey of shoreline and beach. Several hours of visual observation and survey of shore line and beach were made for evidence of turtle nesting through tracks on the beach and nesting spoors (pits). In addition, feedback from local knowledge has been used to relate to any history of presence and abundance of turtle nesting sites. Observations and information made available were from local community individuals who possess such knowledge were used compared with diversity of turtles in the Maldives to discuss their relative diversity and abundance.

Relative abundance of lizards and geckos, though they are variable in abundance were also made through visual observations to document their presence at project location.

3.7 Pests and invasive species

In order to document the presence of pests and invasive species, visual observation was made during field visit and survey of terrestrial and marine environment. Presence of flora that has been identified and confirmed as invasive species that pose threat to local or endemic species have been given the focus of the survey. In addition, pests such as rats and beetles that has been a threat to agricultural yield such as coconuts were given specific focus. Observations and information made available were from local community individuals who possess such knowledge was also used to to discuss their relative diversity and abundance.

4. Findings

4.1 Habitats mapping

The island consisted of diverse habitats which could inhabit a range of different flora and fauna. These included the vast sandy lagoons, the reef flat, the reef crest, the reef slope, the outer atoll slope, the swampy intertidal areas filling up within the island during high tide and the small mangrove area. This wide range of habitats make possible for several species of flora and fauna to inhabit the island.

Detailed mapping and demarcation of shoreline features show that the size of the island is 36.59 ha (based on low tideline) which is roughly 2 ha less than the size of island (38.3 ha) as given in the Official atlas of Maldives (Ministry of Planning and National Development, 2008). The measured perimeter of the island is approximately 7.2 km. Beach area or relative intertidal area below the vegetation line is estimated as 3.42 ha. As the reef surrounding the island is not discrete or confined to the island, a feature not commonly associated with islands in the atoll peripheral reefs, the reef area calculation is arbitrarily estimated. A linear line drawn 100 meters off the eastern end of the island have been used to determine the reef area which is estimated as 459.3 ha (see Table 3 and Figure 3).

The total vegetation area is estimated as 33.1 ha. Selected vegetation zones or areas have been classified as 6 and their specific total areas quantified (Table 3). The total classified vegetation area is estimated as 8.3 ha and unclassified vegetation areas is 24.8 ha. The total mangrove area based on two dominant species is estimated as 4.2 ha.

Shallow lagoons of varying depths are associated with the reef within the V shaped setting of the island (Figure 4). The total areas of the shallow lagoons are estimated as 97 ha. Sea grass inhabit approximately 6.6 ha of the shallow lagoon areas

Four depressions that form as ponds are also found within the island fringed with vegetation. These are relatively small and brackish ponds; the total area been measured as 2ha.

GIS based output of the geomorphological and ecological features of the island and associated habitats are provided as associated documents of this study which is attached as hard copy to this report. A soft copy of the shape files and other associated files are part of the study outputs.

TABLE 3 GEOMORPHOLOGICAL AND ECOLOGICAL FEATURES ASSOCIATED WITH LAABADHOO WITH THEIR MORPHOMETRICS

ISLAND NAME	CATEGORIES	AREA (SQM)	PERIMETER (M)
DHIGULAABADHOO	LOW TIDE LINE (LWL)	365,944.86	7,214.90
	VEGETATION LINE (VEG)	331,707.53	8,086.30
	REEF LINE	4,593,438.78	8,578.02
VEGETATION	VEGETATION CATEGORY	AREA (SQM)	PERIMETER (M)
	MANGROVE	4,268.58	1,205.63
	IRON WOOD	317.59	4,168.22
	KAANI	11,476.43	1,921.20
	SEA LETTUCE	270.85	18,011.03
	COCONUT GROVE	953.27	1,523.45
	SCREWPINE	66,391.10	657.61
MANGROVE PONDS	ALL PONDS (ENCLOSED)	1,998.14	736.79
SEA GRASS	TOTAL SEAGRASS	66391.10	18011.03
LAGOONS	TOTAL SHALLOW LAGOONS	970027.15	13748.38

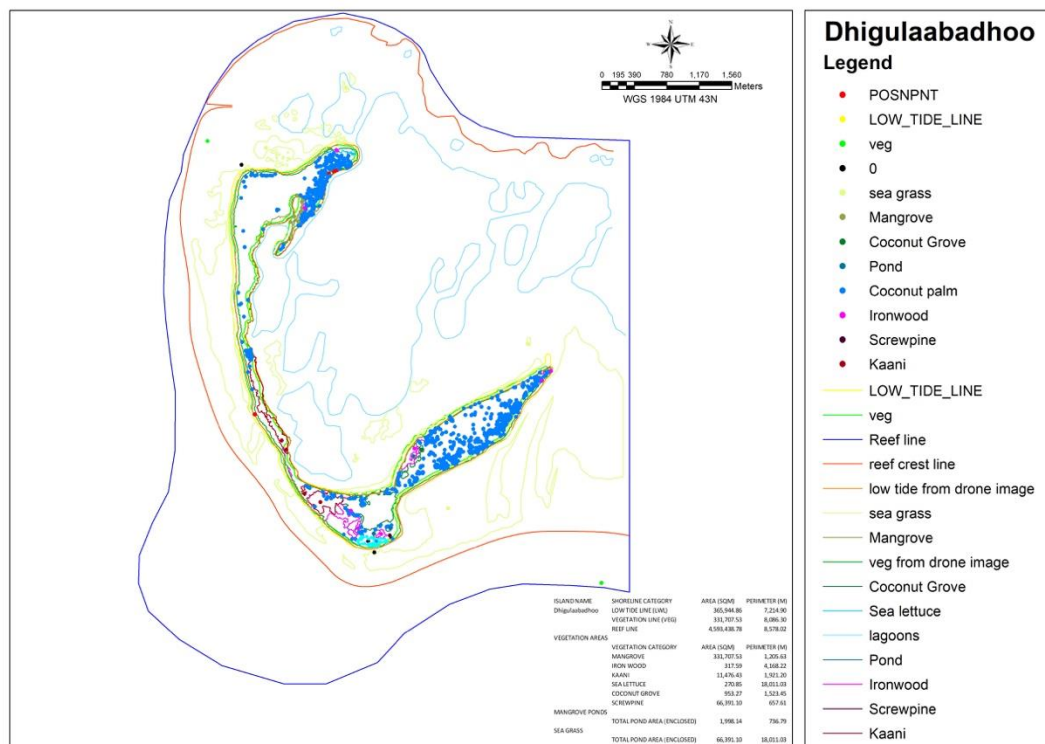


FIGURE 3 GEOMORPHOLOGICAL AND BIOTIC FEATURES (TERRESTRIAL AND MARINE) ASSOCIATED WITH THE STUDY SITE. A3 SIZED IMAGE OF THE FIGURE IS GIVEN IN APPENDIX 1.



FIGURE 4 VARYING SHAPES AND DEPTH BASED LAGOONS ASSOCIATED WITH STUDY SITE

4.2 Biodiversity assessment

Corals and other benthic substrates

The Maldives underwater life is rich and diverse with a large number of coral and fish species amongst other marine life. Our reefs are comprised of approximately 250 species of corals belonging to 60 genera (Zahir and Naeem, 1996). Marine surveys were carried out at the 13 sites earlier surveyed by EPA and at 4 new sites which focused on reef slope around the island. Results of these surveys showed that the reef habitats associated with Laabadhoo account for 18 of these 60 coral genera. An inventory of the coral genus observed at Laabadhoo and the Coral Inventory based on published literature is given in Appendix 2.

Overall, the reefs were observed to have low levels of live coral cover, with live coral observed at only 2 of the 13 sites (L13 and R1 of the EPA sites repeat monitored). Live coral cover was less than 15% at both of these sites (Figure 4), while highest coral cover on the reef slope survey sites was observed to be 27.5% at the site on eastern side of Laabadhoo (site 1, see Figure 2 for referenced location). Sandy substrate was seen to dominate the substrate cover at majority of the sites, while rock and rubble dominated benthic cover along the slopes. Sea grass and sand dominate benthic substrate at sites R2-R7. In comparison, sites R1 to R7 surveyed in 2010 showed live coral cover ranging between 1% to 35% (EPA, 2010). Thus, there is significant decrease in live coral cover for same sites as indicated by this study. The cause for this decrease in coral cover is largely uncertain, however can be linked to either natural or human induced impacts on these reefs. Major coral

bleaching episodes have caused wide spread and localized impacts to the reefs of all atolls of Maldives in 2010, 2012 and 2016. Human related impacts at this specific reef area is considered as relatively low, hence relative degradation of the reefs all around Maldives can be caused by increase in sea surface temperature and consequent coral bleaching. Substrate cover composition for all survey sites are shown in Figure 5 (EPA baselined sites) and Figure 6 (additional sites as part of this study)

a. EPA sites

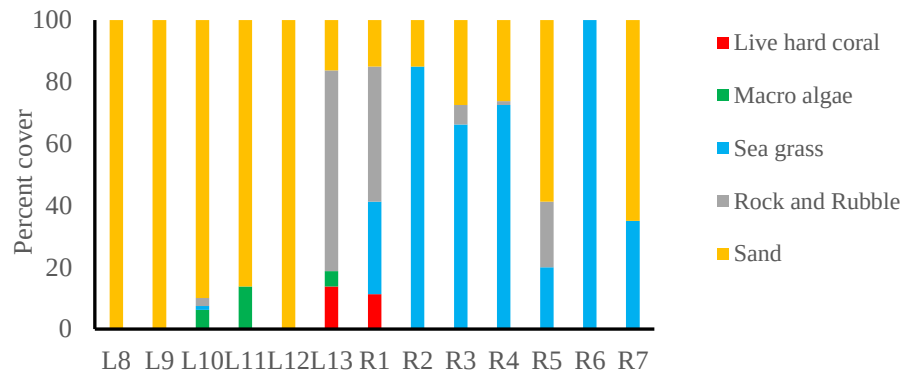


FIGURE 5 BENTHIC SUBSTRATE COMPOSITION AT THE SURVEY SITES ADHERED BY EPA (EPA 2010)

b. Reef slope sites

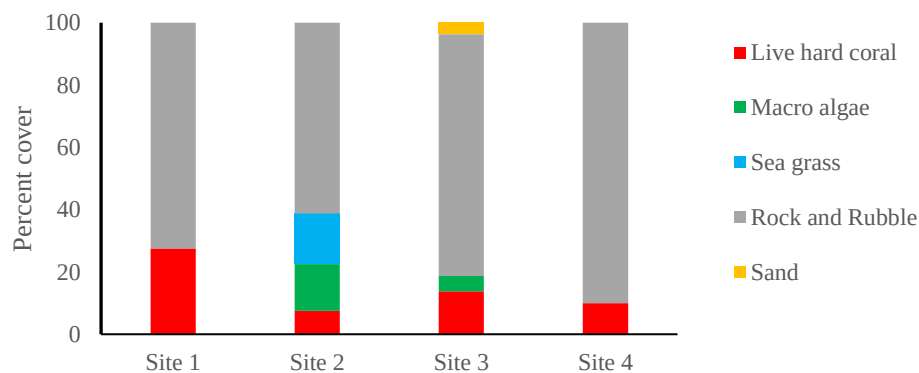


FIGURE 6 BENTHIC SUBSTRATE COMPOSITION AT THE NEW SITES (BASE LINED FOR THIS STUDY)

Overall live coral composition at all the sites was mainly composed of species belonging to 9 families of which highest number of species were observed for family Faviidae. Other dominant corals are of genus porites, acropora, pocillopora, lobophyllia and leptoria. Appendix 2 shows results of the reef survey in terms of presence/absence of the 9 coral families (and 18 genera) at the survey sites. Photo plates of the dominant coral species are shown in Appendix 3.

Fish abundance and diversity

A total of 92 species of fish belonging to 25 families were observed during these surveys. Figure 7 shows percent composition of each family recorded during the survey. Appendix 4 gives an inventory of fish species recorded in Laabadhoo during current survey, with their relative abundance.

As shown from the survey results the most number of species were observed for the family Labridae (21.3%), while Pomacentridae and Acanthuridae contributed approximately 12% and 10% respectively (Figure 7). The most diverse group of fish in the Maldivian waters is reported as Gobies (90 species) with Labrids being the second most diverse group with approximately 70 species so far having been sighted (MEE, 2016).

Other families of importance observed during the surveys are seen to be Cheatodontidae, Scaridae and Serranidae. This is similar to what has been reported for fish composition in Baa Atoll, which was thoroughly studied prior to making it a UNESCO Biosphere Reserve. Chabanet et. al. 2012, report a total of 349 fish species for Baa Atoll, with more than 50% of these belonging to the families of Labridae, Pomacentridae, Cheatodontidae, Gobiidae, Acanthuridae and Serranidae (in order of highest to lowest).

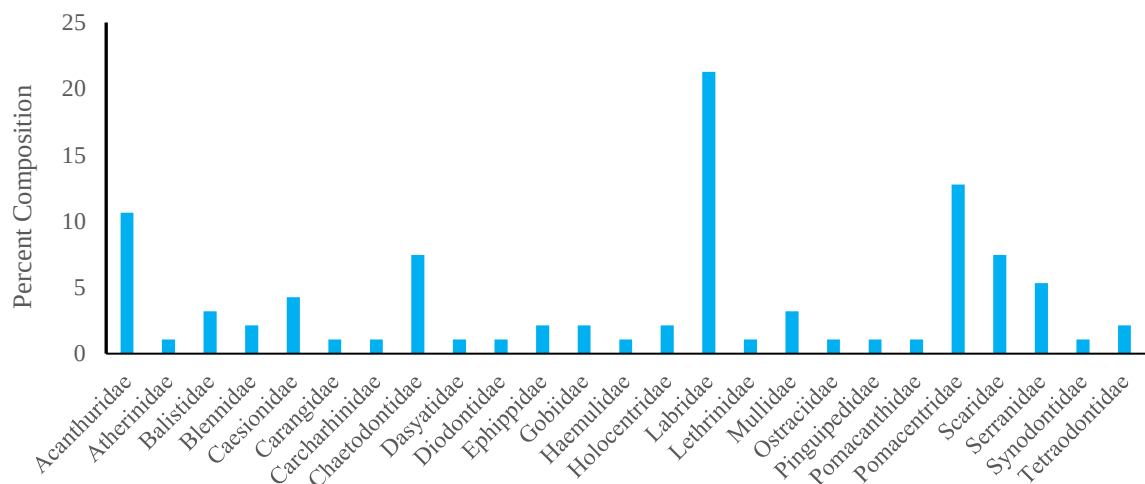


FIGURE 7 PERCENT COMPOSITION OF EACH FAMILY OF FISH RECORDED DURING THE SURVEY AT LAABADHOO

Table 4 gives a list of all the species observed during the surveys. A breakdown of these species by sites of observation and relative abundance is given in Appendix 4. As evident from Table 4, protected species such as the Napoleon wrasse (*Cheilinus undulates*) and one shark species (White-tip reef shark, *Trianodon obesus*) were also observed around the area. While sightings of Napoleon wrasse were noted as “rare” occurrences, sightings of the White-tip reef shark were noted as “common” for one survey area and “rare” for another. In comparison, EPA (2010) reports schools

of sharks in some survey areas. Thirty-seven (37) species of sharks are reported from the Maldivian waters (MRC, 2009). A “Rare” sighting of the Pink whipray, *Himantura fai*, which is listed as “Vulnerable” in the IUCN Red List (and protected in the Maldives) was also observed during the survey.

Commercially important food fish species were found to be rare, with mainly 4 species of Serranids (groupers) being observed. Groupers are one of the most diverse families of reef fish in the Maldivian waters, with 40+ species being recorded. The grouper fishery is a targeted fishery, mainly for the export market. A number of species which are exported in the aquarium fish trade were recorded, mainly those belonging to Labridae and Cheatodontidae.

TABLE 4 LIST OF ALL SPECIES OBSERVED DURING THE SURVEY

Family	Common Name	Scientific Name
Acanthuridae	Convict Surgeonfish	<i>Acanthurus triostegus</i>
Acanthuridae	Powder-blue Surgeonfish	<i>Acanthurus leucosternon</i>
Acanthuridae	Lieutenant Surgeonfish	<i>Acanthurus tennentii</i>
Acanthuridae	Lined Surgeonfish	<i>Acanthurus lineatus</i>
Acanthuridae	White-spotted Surgeonfish	<i>Acanthurus guttatus</i>
Acanthuridae	Pale Surgeonfish	<i>Acanthurus mata</i>
Acanthuridae	Two-coloured Parrotfish	<i>Cetoscarus bicolor</i>
Acanthuridae	Spotted Unicornfish	<i>Naso brevirostris</i>
Acanthuridae	Big-nose Unicornfish	<i>Naso vlamingii</i>
Acanthuridae	Sleek Unicornfish	<i>Naso hexacanthus</i>
Atherinidae	Robust hardyhead	<i>Atherinomorus lacunatus</i>
Balistidae	Stripped Triggerfish	<i>Balistapus undulates</i>
Balistidae	Picassa Triggerfish	<i>Rhinecanthus aculeatus</i>
Balistidae	Titan Triggerfish	<i>Balistoides viridescens</i>
Blenniidae	Crested Sabretooth Blenny	<i>Petroscirtes mitratus</i>
Blenniidae	Bearded Sabretooth Blenny	<i>Petroscirtes xestus</i>
Caesionidae	Moon Fusilier	<i>Caesio lunaris</i>
Caesionidae	Yellowback Fusilier	<i>Caesio xanthonota</i>
Caesionidae	Gold-spot Emperor	<i>Gnathodentex aurolineatus</i>
Caesionidae	Thin-lined Fusilier	<i>Caesia varilineata</i>
Carangidae	Blue-fin Trevally	<i>Caranx melampygus</i>
Carcharhinidae	White-tip Reef Shark	<i>Triaenodon obesus</i>
Chaetodontidae	Black Pyramid Butterflyfish	<i>Hemotaurichthys zoster</i>
Chaetodontidae	Yellow Butterflyfish	<i>Chaetodon andamanensis</i>
Chaetodontidae	Eclipse Butterfly fish	<i>Chaetodon bennetti</i>
Chaetodontidae	Head-band Butterfly fish	<i>Chaetodon collare</i>
Chaetodontidae	Meyer's Butterfly fish	<i>Chaetodon meyeri</i>
Chaetodontidae	Long-nose Butterfly fish	<i>Forcipiger Flavissimus</i>

Family	Common Name	Scientific Name
Chaetodontidae	Black Pyramid Butterflyfish	<i>Hemitaenichthys zoster</i>
Dasyatidae	Pink whipray	<i>Himantura fai</i>
Diodontidae	Blotched Porcupinefish	<i>Diodon litorosus</i>
Ephippidae	Rounded Batfish	<i>Platax orbicularis</i>
Ephippidae	Tall-fin Batfish	<i>Platax tiera</i>
Gobiidae	Bandit Goby	<i>Gladiogobius rex</i>
Gobiidae	Pretty lagoon Goby	<i>Oplopomus oplopomus</i>
Haemulidae	Oriental Sweetlips	<i>Plectorhinchus vittatus</i>
Holocentridae	Big-eyed Soldierfish	<i>Myripristis pralinia</i>
Holocentridae	Sabre Squirrelfish	<i>Sargocentron spineferum</i>
Labridae	Moon Wrasse	<i>Thalassoma lunare</i>
Labridae	Blue-lined wrasse	<i>Stethojulis albobittata</i>
Labridae	Knife Wrasse	<i>Cymolutes praetextatus</i>
Labridae	Blue-spot Wrasse	<i>Leptojulis cyanopleura</i>
Labridae	Checkerboard Wrasse	<i>Hemitautoga hortulanus</i>
Labridae	Silver-streaked Wrasse	<i>Stethojulis stringiventer</i>
Labridae	Ornate Leopard Wrasse	<i>Macropharyngodon ornatus</i>
Labridae	Splendid Leopard Wrasse	<i>Macropharyngodon bipartitus</i>
Labridae	Blue-lined wrasse	<i>Stethojulis albobittata</i>
Labridae	Banded thick lip wrasse	<i>Hemigymnus fasciatus</i>
Labridae	Zigzag wrasse	<i>Hemitautoga scapularis</i>
Labridae	Bird Wrasse	<i>Gomphosus caeruleus</i>
Labridae	Six-bar Wrasse	<i>Thalassoma Hardwicke</i>
Labridae	Napoleon wrasse	<i>Cheilinus undulates</i>
Labridae	Banded Maori Wrasse	<i>Cheilinus fasciatus</i>
Labridae	Oriental Maori Wrasse	<i>Cheilinus rhodochrous</i>
Labridae	Ribbon Wrasse	<i>Thalassoma schwanenfeldii</i>
Labridae	Blue-streak cleaner Wrasse	<i>Labroides dimidiatus</i>
Labridae	Two-tone Wrasse (juvenile)	<i>Thalassoma amblycephalum</i>
Lethrinidae	Black-bellied Emperor	<i>Lethrinus harak</i>
Mullidae	Round-spot goatfish	<i>Parupeneus pleurostigma</i>
Mullidae	Long-barbel Goatfish	<i>Parupeneus macronema</i>
Mullidae	Schooling Goatfish	<i>Upeneus taeniopterus</i>
Ostraciidae	Yellow Boxfish	<i>Ostracion cubicus</i>
Pinguipedidae	Maldivian Grubfish	<i>Parapercis signata</i>
Pomacanthidae	Regal Angelfish	<i>Pygoplites diacanthus</i>
Pomacentridae	Blue-yellow Damsel	<i>Pomacentrus caeruleus (juvenile)</i>
Pomacentridae	Indian Damsel	<i>Pomacentrus indicus (juvenile)</i>
Pomacentridae	Green Sargent	<i>Amblyglyphidodon batunai</i>
Pomacentridae	White band Damsel	<i>Plectroglyphidodon leucozonus</i>
Pomacentridae	Sharp eye Damsel	<i>Plectroglyphidodon imparipennis</i>

Family	Common Name	Scientific Name
Pomacentridae	Scribbled Damsel	<i>Pomacentrus nagasakiensis</i>
Pomacentridae	White tailed Damsel	<i>Pomacentrus chrysurus</i>
Pomacentridae	Blue-yellow Damsel	<i>Pomacentrus caeruleus (juvenile)</i>
Pomacentridae	Azure Damsel	<i>Pomacentrus pavo (juvenile)</i>
Pomacentridae	Green Puller	<i>Chromis viridis</i>
Pomacentridae	Jewel Damsel	<i>Plectroglyphidodon lacrymatus</i>
Pomacentridae	Sergeant Major	<i>Abudefduf vaigiensis</i>
Scaridae	Five-saddle parrotfish	<i>Scarus scaber</i>
Scaridae	Spinytooth Parrotfish	<i>Calotomus spinidens</i>
Scaridae	Two-coloured Parrotfish	<i>Cetascarus bicolour</i>
Scaridae	Shabby Parrotfish	<i>Chlorurus sordidus (juvenile)</i>
Scaridae	Sheep headed Parrotfish	<i>Chkirus strongylocephalus</i>
Scaridae	Ember Parrotfish	<i>Scarus rubroviolaceous</i>
Scaridae	Fine-lined Bristletooth	<i>Ctenochaetus striatus</i>
Serranidae	Squartail coral grouper	<i>Plectropomus areolatus (juvenile)</i>
Serranidae	Four saddle Grouper	<i>Epinephelus spilotoceps</i>
Serranidae	Vermillion Rock Cod	<i>Cephalopholis miniata</i>
Serranidae	Peacock Rock Cod	<i>Cephalopholis argus</i>
Serranidae	Threadfin Basslet	<i>Nemanthias carberryi</i>
Synodontidae	Variegated Lizardfish	<i>Synodus variegatus</i>
Tetraodontidae	Saddled Pufferfish (juvenile)	<i>Canthigaster valentine</i>
Tetraodontidae	Bennett's Pufferfish	<i>Canthigaster bennetti</i>

Sea grass abundance

Sea grass meadows or sea grass beds occur in shallow, soft bottom marine coastlines and estuaries of the world. Sea grass meadows can be monospecific or may comprise of multiple species. Despite having only 58 described species of sea grasses worldwide, they are still very prominent for aquatic habitats as sea grass species are foundation species which provide shelter and a nutrient rich habitat for diverse flora and fauna.

Maldives is recorded to have 5 species of sea grass; *Syringodium isoetifolium*, *Thalassia hemprichii*, *Thalassodendron ciliatum*, *Cymnodocea rotundata*, *Cymnodocea* sp. of which *Thalassia hemprichii* is the most commonly observed (Ahmed and Saleem, 1999, cited in Ministry of Housing and Environment, 2010).

Sea grass abundance surveys carried out at Laabadhoo showed the presence of seagrass between 10 to 40m from shoreline. Sea grass abundance was highest between 15 to 25m from shoreline (Figure

8). Areas closer to shore were seen to be sandy bottoms, devoid of sea grass. The main species of sea grass observed at the site was *Thalassia hemprichii* and *Thalassondron ciliatum*

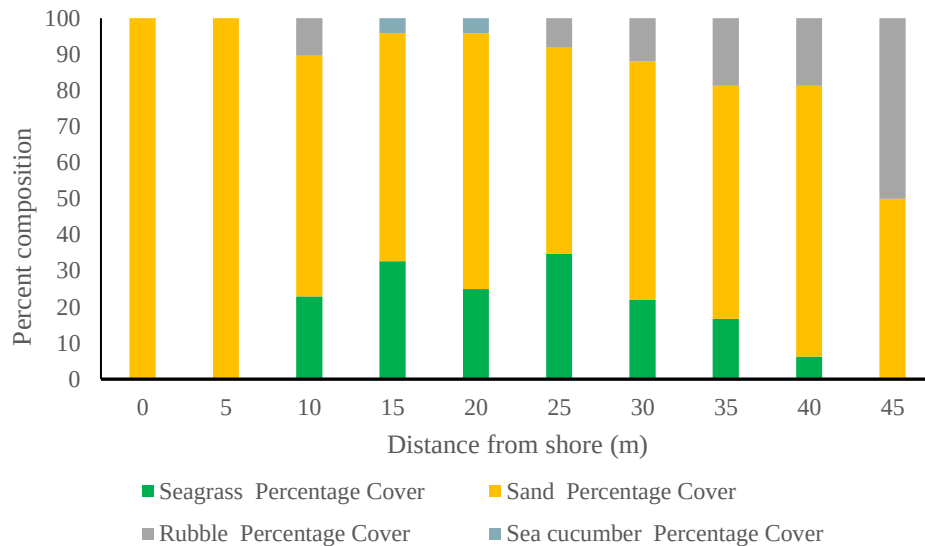


FIGURE 8 MEAN PERCENTAGE COVER OF THE BENTHIC SUBSTRATE AMONG THE SEA GRASS MEADOWS BASED ON TRANSECTS PERPENDICULAR TO THE SHORE

For comparison purpose, during an extensive study done back in 2012, Payri, Claude, Yuert & Mattio documented that there were two species found in the lagoons of Baa Atoll in Central Maldives. The two species identified in this study were *Syringodium isoetifolium* and *Thalassia hemprechii*. Despite the low species richness of the sea grasses present, it was reported that the density of the present species was very high. Dominant species of sea grass associated with study site is given in Appendix 3.

Terrestrial flora and fauna

Flora

The flora of Maldives consists of 583 vascular plants, of which 323 are cultivated plant species while 260 are native and naturalized plants (Adam, 1984). The vegetation cover at Laabadhoo island was similar to that of other islands of Maldives, which is as expected, since the Maldivian islands are quite similar in terms of island vegetation types. Overall general types of vegetation observed include coconut palms, screw pine, tulip tree. A total of 11 types of vegetation were recorded during the surveys. Table 5 and Figure 9 gives the vegetation cover observed at the 4 survey areas.

TABLE 5 VEGETATION COMPOSITION AT SURVEY SITES

Local Name	Scientific name	Common Name	Abundance			
			Site 1	Site 2	Site 3	Site 4
Magoo	<i>Scaevola taccada</i>	Sea Lettuce	24		11	6
Dhivehi Ruh	<i>Cocos nucifera</i>	Coconut palm	21		3	
Velan'buli	<i>Cassytha filiformis</i>	Love vine	8			
Ahi	<i>Morinda citrifolia</i>	Cheese fruit / Noni	1		7	
Kudhihui	<i>Panicum repens</i>	Victoria grass	4			
Boa kashikeyo	<i>Pandanus tectoris</i>	Wild screw pine		16		21
Hirun'dhu	<i>Thespesia populnea</i>	Tulip tree		7		1
Uni	<i>Guettarda speciosa</i>	Nit pitcha			2	
Dhiggaa	<i>Hibiscus tilaceus</i>	Sea hibiscus			4	
Bakari Nukaa maa	<i>Turner a ulmifolia</i>	Yellow alder			3	
Dhumburi	<i>Ochrosia oppositifolia</i>	Cork wood				6

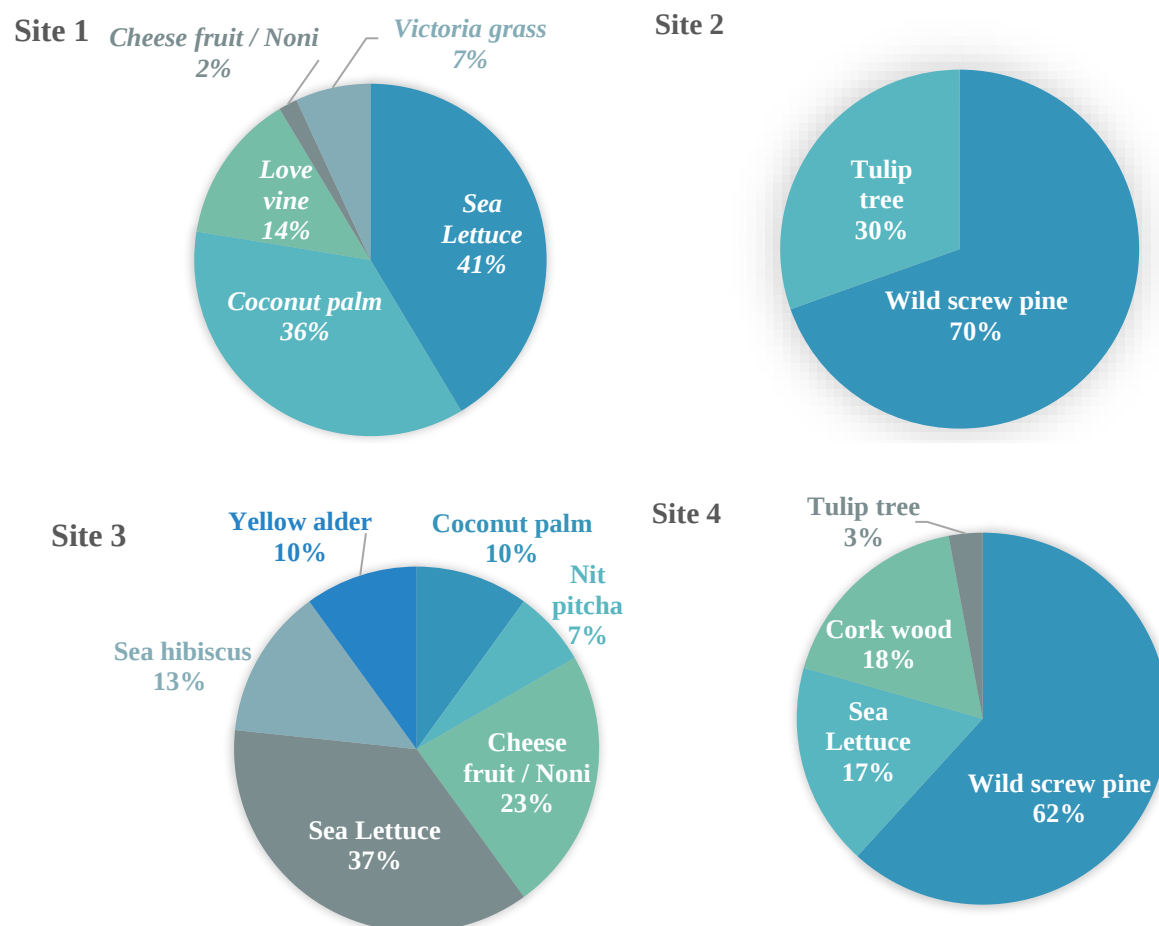


FIGURE 9 VEGETATION COMPOSITION AT SURVEY SITES 1 TO 4

Results of the survey were compared with an inventory of trees observed for Kunfunadhoo (Sonevafushi Resort and Spa), which was assumed to be similar to what would be observed in other islands of Baa Atoll as well. The inventory shows the presence of 47 species of plants belonging to 36 families (Bers, 2005). In comparison, Laabadhoo shows the presence of 11 species of plants belonging to 8 families.

Mangroves

Mangrove are not commonly associated with general coastline of island of Maldives. They are rather formed as small to medium size depressions within islands where few or several species grow as fringed vegetation in association with brackish water bodies. It can be regarded as important coastal ecosystems in the Maldives, home for several mangroves associated plants, animals, fishes, crustaceans and many microorganisms in addition to a habitat for migratory and resident birds. Mangrove ecosystems not only render invaluable services to the ecology but also socio-economic benefits to the community, and hence are regarded as natural resources that provide environment services and socio-economic benefits. Mangrove ecosystems in the Maldives consist of 14 species belonging to 10 genera (Shazra et al, 2008 and MEE, 2015).

Two species of mangroves are recorded;

- Yellow mangrove (*Ceriops tagal*)
- Red mangrove (*Bruguiera gymnorhiza*)

Fauna

Terrestrial fauna, both invertebrate and vertebrate are not well documented and literature on these groups of animals are limited. Limited collection of insects, arachnids, molluscs and bees have been made (Holmes, 1993). Spider diversity were found to be particularly rich. In contrast to marine vertebrate fauna, terrestrial fauna is regarded limited.

The focus of this assessment was reptiles where the emphasis was made on presence and abundance of lizards and geckos. Although it may be prevalent, neither lizards or geckos were found during the study period. Further study is required to ascertain this and document biodiversity aspect of this group of fauna.

Mammal (terrestrial and marine) biodiversity

Terrestrial mammal fauna is depauperate in the Maldives. Two endemic sub species of fruit bats, *Pteropus gigantus ariel* and *Pteropus hypomelanus maris* have been recorded (Holmes, 1993). Common rats, *Rattus sp.* are common as vermin both in inhabited and uninhabited islands.

Only few individuals of bats most likely *Pteropus hypomelanus maris* were observed during the field visit, flying over the mangrove area of the islands. Being fruit bats, these animals are more common in areas where fruit bearing trees are more abundant. With limited agriculture mainly based on home gardening, fruit bats are regarded as pests in the Maldives.

Maldives has been regarded as rich in marine mammalian biodiversity where over 20 species of whales and dolphins has been recorded (Anderson, 1996). Many cetacean records from Maldives are based on strandings which includes blue whales (*Balaenoptera musculus*) and Sperm whale (*Physeter macrocephalus*). No records of these specimens were made at the study site.

Seven species of Dolphins have been identified in the Maldives. Of these only one species was recorded during the field visit. These were spinner dolphins (*Stenella longirostris*). The seven species of dolphins recorded from the Maldives and relative encountered species at the study site is given in Table 6. Spinner dolphins are commonly seen near the reef particularly moving through the passes across the atoll rim reef during changing tide.

TABLE 6 SPECIES DIVERSITY OF MARINE MAMMAL (DOLPHINS) OF MALDIVES COMPARED TO STUDY SITE

English name	Scientific name	Record at study site
Spinner dolphin	<i>Stenella longirostris</i>	yes
Stripped dolphin	<i>Stenella coeruleoalba</i>	No
Pan tropical spotted dolphin	<i>Stenella attenuata</i>	No
Bottle nose dolphin	<i>Tursiops bredanensis</i>	No
Risso's dolphin	<i>Grampus griseus</i>	No
Fraser's dolphin	<i>Lagenodelphis hosei</i>	No

Birds (terrestrial and seabird) biodiversity

Given the isolation and small atoll-based island nature there are few resident bird species in the Maldives. Many bird species recorded in the Maldives are seasonal migrants, vagrants and introduced species as pets which are either naturalized or compete with local species for space and resources.

There are over 170 species of birds which include, shorebirds, seabirds and land birds reported from various sources in Maldives First National Report to CBD (MHAHE, 2002). Among these, five species have been identified as endemic and three of these endemic species have been recorded at project site (Table 7). In addition, Grey heron have been found as common at site. The abundance of individual species is however, low. With the lack of seasonal migrant bird species data, bird biodiversity can be regarded as low.

TABLE 7 BIRD SPECIES RECORDED FROM THE PROJECT SITE

Dhivehi Name	English Name	Scientific Name
Maakana	Grey heron	<i>Ardea cinerea</i>
Dhandifulhu Dhooni	White-Tailed Tropicbird	<i>Phaethon lepturus</i>
Dhivehi Kanbili	Maldivian Water Hen	<i>Amaurornis phoenicurus maldivus</i>
Rathafai	Ruddy Turnstone	<i>Arenaria interpres</i>

Reptile (terrestrial and marine) biodiversity

Terrestrial reptiles in the Maldives are limited to only few. Similarly, marine reptiles are limited to marine turtles. Although five species of sea turtles have been identified from the Maldives the common species are limited to only Green turtle (*Chelonia mydas*) and Hawksbill turtle (*Erytmochelys imbricata*).

Sub adult green and Hawksbill turtle were recorded foraging off sea grass areas and reef slope during the field assessment. No recent records of turtle nesting have been observed during the period of field survey although anecdotal reports of frequent nesting have been reported by the locals who visit the island for coconut picking and aggregate collection. All species of sea turtles as animals are protected by law, however, egg harvesting is still legal except few nesting hotspots.

Pests and invasive species

Due to geographic isolation of the islands majority of the terrestrial vegetation is either endemic or naturalized over long period of time. However, this naturalization of vegetation to the local environment get disturbed through accidental or deliberate introduction of exotic plants or animals into the Maldives. With the introduction of tourism in the Maldives some 40 years back several species of plants have seen introduced to the Maldives. With these, some plant and animal pests also get introduced and becomes a threat to local vegetation. It is estimated that more than 60% of the flora is composed of exotic species and some of these have become invasive.

The major invasive plants observed in the Maldives include *Wollastonia biflora*, *Cassytha filiformis* and *Lecuaena leucocephala* (Sujanapal and Sankaran, 2016). Coconut hispid beetle (*Brontispa longissima*) is one of the most damaging pests of coconut in Asia and the Pacific and has spread to Maldives. The beetle can cause significant production losses, and high infestation levels may result in tree death. None of these species are identified among the vegetation during the field visit.

Marine invasive species are rare in the Maldives but have the potential to be an issue through ballast water discharge to the near-shore marine environment. No invasive species that are a threat to local environment were identified. *Holothuria scabra*, an exotic sea cucumber species has been introduced to the Maldives in late 1980s and shallow lagoon based growout farming is on the increase recently. This has spread to several atolls of Maldives. So far there has been no reports of

this species as a threat to local species. No records of *Holothuria scabra* have been identified at the study site.

Tilapia is another example of introduced species mainly to the freshwater ponds in southern atoll in 1950s. Tilapia are mainly freshwater fish (chichilid) inhabiting shallow streams, ponds, rivers and lakes and less commonly found living in brackish water. This fish is now common in almost all water bodies associated with islands including uninhabited islands. Several species of chichilids including tilapia are found in the brackish water ponds of the island. These have been reported to outcompete with milkfish that used to be fattened in such ponds whereby fighting for space and food.

5. Conclusions and Recommendations

Based on the limitation of study it can be concluded that the biodiversity aspects of the overall environment of Laabadhoo were relatively low in comparison to published literature on national biodiversity.

Habitat diversity was however, high from the perspective of terrestrial to marine habitats or morphological characteristics. Given the geographic location of the setting of the island and surrounding reef associated with Huvadhoo atoll, all major reef morphological features are associated with the study site. These includes;

- Ocean side reef which is exposed to equatorial channel and is subjected to high wave energy associated with swells and wind waves breaking to atoll rim reef
- Shallow channel and associated habitats
- Atypically shaped island perhaps several islands joined over recent geological history

Laabadhoo is peculiar in the context, whereby it encompasses most of the ecosystems found in the atoll-island systems and geomorphological features such as brackish ponds and an embayment area fringed with mangroves. Due to these special features, the island is listed in the Environmentally Sensitive Areas List of the Environmental Protection Agency and the argument for justification has been reported in environmental description of G DH Laabadhoo (EPA, 2010).

However, biodiversity aspects of the area were not particularly high. This include coral diversity, fish diversity, mangrove diversity, mammal diversity among other thematic areas that have been assessed and findings presented in the respective section of the study. Thus, findings of this study, in the context of project design and survey limitations (limited study time allocated for biodiversity surveys which also coincided with SW monsoon) may be a limiting factor for this poor biodiversity. For example, although this site is infamous for migratory birds, none were recorded at the time of survey. Typically, several species of migratory birds visit Maldives during NE monsoon. Marine surveys are also limited to shallow depths.

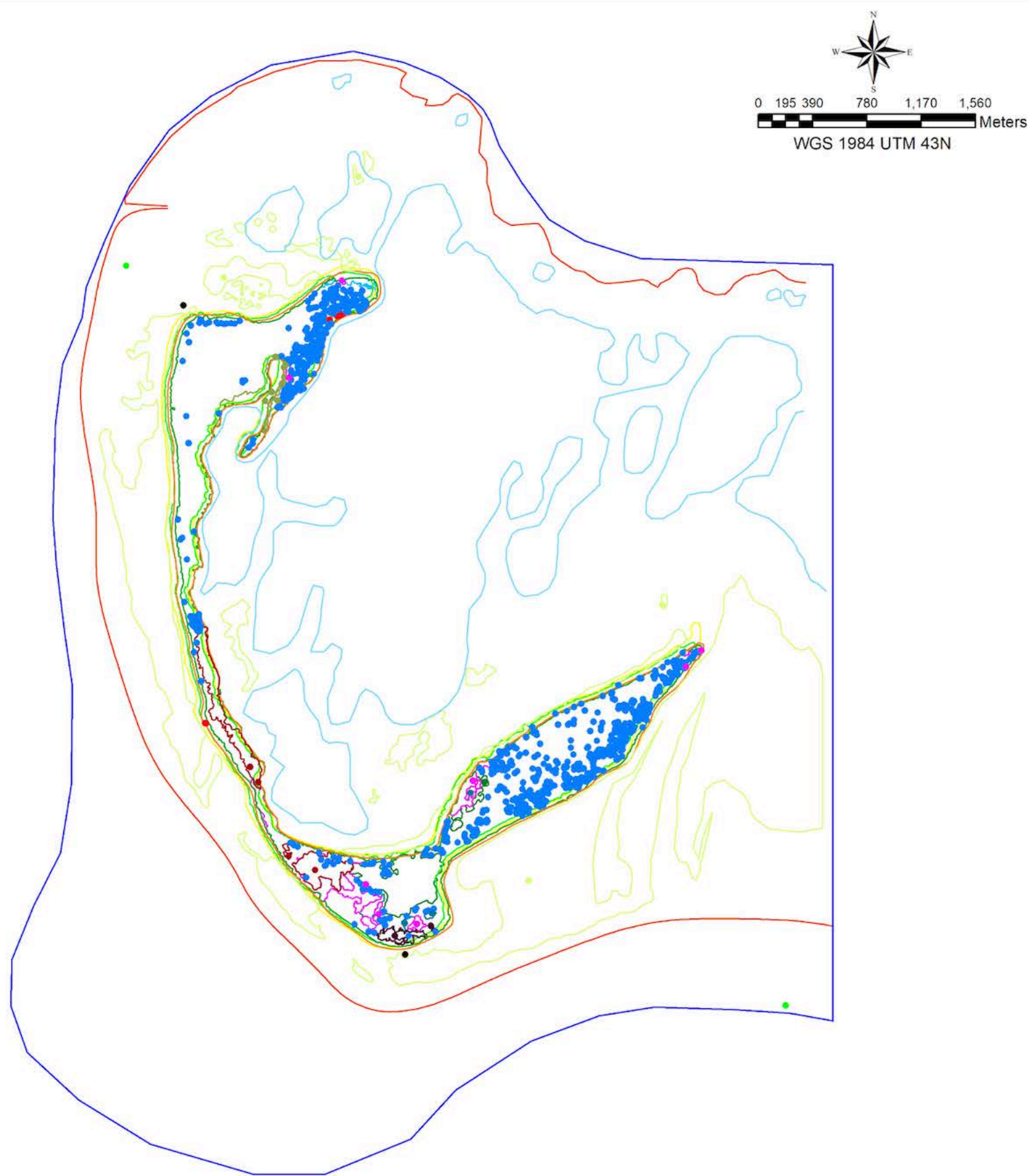
It is therefore recommended to do additional surveys on the same thematic areas to consider both monsoons that occur in the Maldives. Inclusion of scuba in marine surveys will also enable assessment of deeper habitats to improve biodiversity inventory.

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Appendix 1



Dhigulaabadhoo

Legend

- POSNPNT
- LOW_TIDE_LINE
- veg
- 0
- sea grass
- Mangrove
- Coconut Grove
- Pond
- Coconut palm
- Ironwood
- Screwpine
- Kaani
- LOW_TIDE_LINE
- veg
- Reef line
- reef crest line
- low tide from drone image
- sea grass
- Mangrove
- veg from drone image
- Coconut Grove
- Sea lettuce
- lagoons
- Pond
- Ironwood
- Screwpine
- Kaani

Appendix 2

Coral inventory

Genus	National Coral inventory (Pichon and Benzoni (2006))	Baa Atoll Coral Inventory (ARB, 2012)	Dhigelaabadhoo Coral inventory (this study)
Stylocoeniella	x	x	
Madracis	x		
Psammocora	x	x	
Seriatopora	x		
Stylophora	x		
Pocillopora	x	x	x
Acropora	x	x	x
Montipora	x	x	x
Astreopora	x	x	
Pavona	x	x	x
Coeloseris	x		
Gardineroseris	x	x	
Leptoseris	x	x	x
Pachyseris	x	x	
Pseudosiderastrea	x		
Coscinaraea	x	x	
Fungia	x	x	x
Ctenactis	x		
Herpolitha	x	x	
Polyphyllia	x		
Sandalolitha	x	x	
Halomitra	x	x	
Zoopilus	x		
Podabacia	x		
Goniopora	x	x	
Porites	x	x	x
Alveopora	x	x	
Caulastrea	x		
Favia	x	x	x
Barabattoia	x	x	
Favites	x	x	x
Goniastrea	x	x	x
Platygyra	x	x	x
Leptoria	x	x	x

Genus	National Coral inventory (Pichon and Benzoni (2006))	Baa Atoll Coral Inventory (ARB, 2012)	Dhigelaabadhoo Coral inventory (this study)
Oulophyllia	x	x	
Hydnophora	x	x	
Montastrea	x	x	
Plesiastrea	x	x	
Diploastrea	x	x	x
Leptastrea	x	x	x
Cyphastrea	x	x	x
Echinopora	x	x	
Trachyphyllia	x		
Galaxea	x	x	
Merulina	x	x	x
Acanthastrea	x	x	
Blastomussa	x		
Lobophyllia	x	x	
Symphyllia	x	x	
Scolymia	x		
Cynarina	x	x	
Pectinia	x	x	
Mycedium	x	x	
Echinophyllia	x	x	
Oxypora	x	x	
Physophyllia	x		
Heteropsammia	x		
Euphyllia	x	x	
Catalaphyllia	x		
Plerogyra	x		
Physogyra	x	x	
Turbinaria	x	x	x
Heliopora	x	x	x

Appendix 3

Appendix 3 Reef Building Coals



Acroporidae - *Acropora* sp



Acroporidae – *Acropora* sp



Agaricidae - *Pavona venosa*



Faviidae - *Goniastrea* sp



Poritidae – *Porites lutea*



Pocilloporidae – *Pocillopora damicornis*



Poritidae - *Porites rus*



Faviidae - *Goniastrea retiformis*



Siderastreidae – *Psammocora* spp



Fungiidae- *Fungia* spp



Acroporidae - *Acropora* sp.



Acroporidae - *Acropora* sp.



Acroporidae - *Acropora* sp.



Faviidae – *Echinopora lamelosa*



Faviidae – *Favites* sp



Faviidea – *Leptoria phrygia*



Faviidae – *Pavona varians*



Mussidae – *Symphilla hassi*



Pocilloporidae – *Pocillopora eydouxi*



Pritidae – *Porites* sp



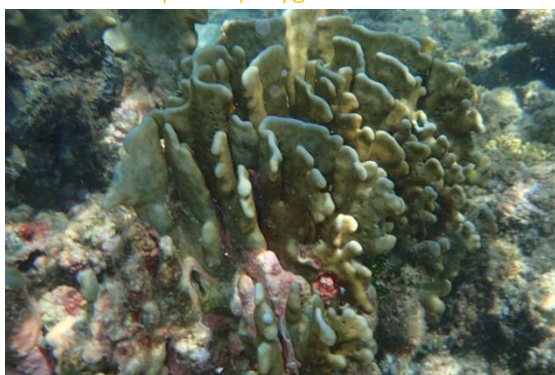
Faviidae – *Favites* Sp



Faviidae – *Leptoria phrygia*

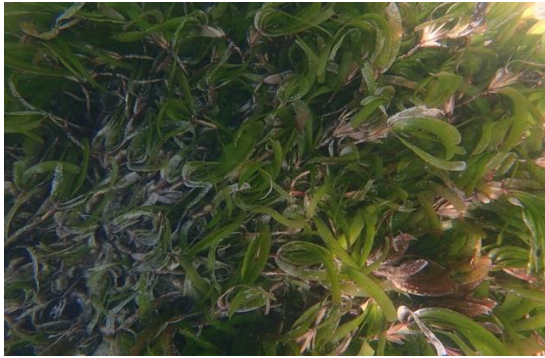


Mussidae – *Lobophyllia corymbosa*



Helioporidae – *Heliopora coerulea*

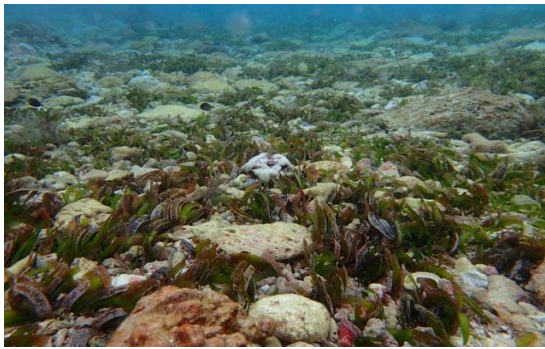
Seagrass and algae



Thalassondron ciliatum (fore reef)



Thalassondron ciliatum (fore reef)



Thalassondron ciliatum (fore reef)



Thalassia hemprichi (back reef)



Halimeda sp



Halimeda sp)

Trees and shrubs



Scaevola taccada (Sea Lettuce)



Cocos Nucifera (Coconut palm)



Cassytha filiformis (Love vine)



Morinda citrifolia (Cheese fruit)



Panicum repens (Victoria grass)



Pandanus tectoris (Wild screw pine)



Thespesia populnea (Tulip tree)



Guettarda speciosa (Nit pitcha)

Trees and shrubs



Hibiscus tilaceus (Sea hibiscus)



Turnera ulmifolia (Yellow alder)



Ochrosia oppositifolia (Cork wood)



Calophyllum inophyllum (Poon wood)



Pemphis acidula (Iron wood)



Tournefortia argentia (Beach heliotrope)



Ceriops tagal (Yellow mangrove)



Bruguiera gymnorhiza (oriental mangrove)

Inland water bodies (ponds)



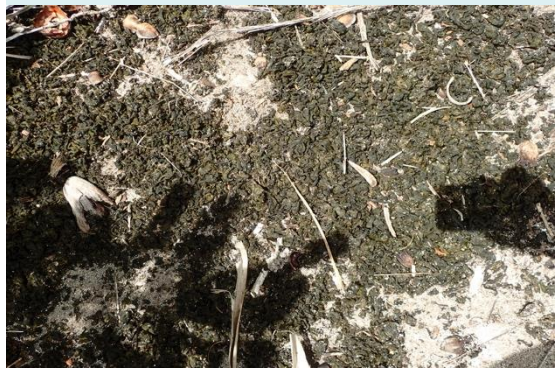
Pond 1



Pond 2



Pond 3



Pond 4

Appendix 4

Appendix 4 Fish Census

Family	Common Name	Scientific Name	R1	R2	R3	R4	R5	R6	R7	L8	L9	L10	L11	L12	L13	S11	S12	S13	S14
Acanthuridae	Convict Surgeonfish	<i>Acanthurus triostegus</i>	A	R	C	C	C	A	C						C	C			
Acanthuridae	Powder-blue Surgeonfish	<i>Acanthurus leucosternon</i>		C		C	C	A	C						C	C	C	A	A
Acanthuridae	Lieutenant Surgeonfish	<i>Acanthurus tennenti</i>		C												R			
Acanthuridae	Lined Surgeonfish	<i>Acanthurus lineatus</i>													R		C	A	
Acanthuridae	White-spotted Surgeonfish	<i>Acanthurus guttatus</i>													R	R			
Acanthuridae	Pale Surgeonfish	<i>Acanthurus mata</i>																	C
Acanthuridae	Two-coloured Parrotfish	<i>Cetoscarus bicolour</i>																	R
Acanthuridae	Spotted Unicornfish	<i>Naso brevisrostris</i>														R			
Acanthuridae	Big-nose unicornfish	<i>Naso Vlamingii</i>															R		
Acanthuridae	Sleek Unicornfish	<i>Naso hexacanthus</i>															A	C	
Atherinidae	Robust hardyhead	<i>Atherinomorus lacunousus</i>																A	
Balistidae	Stripped Triggerfish	<i>Balistapus undulatus</i>					R												
Balistidae	Picassa Triggerfish	<i>Rhinecanthus aculeatus</i>								R									
Balistidae	Titan Triggerfish	<i>Balistoides viridescens</i>															C		
Blennidae	Crested Sabretooth Blenny	<i>Petroscirtes mitratus</i>										R	C						
Blenniidae	Bearded Sabretooth Blenny	<i>Petroscirtes xestus</i>											C						
Caesionidae	Moon Fusilier	<i>Caesio lunaris</i>									R					C			
Caesionidae	Yellowback Fusilier	<i>Caesio xanthonota</i>														C		A	
Caesionidae	Gold-spot Emperor	<i>Gnathodentex aurolineatus</i>																	C
Caesionidae	Thin-lined Fusilier	<i>Caesia varilineata</i>																	A
Carangidae	Blue-fin Jack	<i>Caranx melampygus</i>														R	A		
Carcharhinidae	White-tip Reef Shark	<i>Triaenodon obesus</i>															C		R
Chaetodontidae	Black Pyramid Butterflyfish	<i>Hemotaurichthys zoster</i>		C															
Chaetodontidae	Yellow Butterflyfish	<i>Chaetodon andamanensis</i>			R								R						
Chaetodontidae	Eclipse Butterfly fish	<i>Chaetodon bennetti</i>					R												
Chaetodontidae	Head-band Butterfly fish	<i>Chaetodon collare</i>													R				
Chaetodontidae	Meyer's Butterfly fish	<i>Chaetodon meyeri</i>													R				
Chaetodontidae	Long-nose Butterfly fish	<i>Forcipiger Flavissimus</i>													R				
Chaetodontidae	Black Pyramid Butterflyfish	<i>Hemitaurichthys zoster</i>													R				
Cypraedae	Money Cowry	<i>Cypraea moneta</i>								R									
Dasyatidae	Pink whipray	<i>Himantura fai</i>															R		
Diodontidae	Blotched Porcupinefish	<i>Diodon litorosus</i>			R		R												
Ephippidae	Rounded Batfish	<i>Platax orbicularis</i>														R			
Ephippidae	Tall-fin Batfish	<i>Platax tiera</i>															R		
Gobiidae	Bandit Goby	<i>Gladiogobius rex</i>								C	R		A						
Gobiidae	Pretty lagoon Goby	<i>Oplopomus oplopomus</i>												R					
Haemulidae	Oriental Sweetlips	<i>Plectorhinchus vittatus</i>														R			
Holocentridae	Big-eyed Solderfish	<i>Myripristis pralinia</i>														R			
Holocentridae	Sabre Squirrelfish	<i>Sargocentron spineferum</i>																	R
Holothuriidae	Black Sea Cucumber	<i>Actinopyga miliaris</i>				C	R				R		R	C					
Labridae	Moon Wrasse	<i>Thalassoma lunare</i>			C						C	C							C
Labridae	Blue-lined wrasse	<i>Stethojulis albovittata</i>			C					C									
Labridae	Knife Wrasse	<i>Cymolutes praetextatus</i>				C		A											
Labridae	Blue-spot Wrasse	<i>Leptojulis cyanopleura</i>					R												
Labridae	Checkerboard Wrasse	<i>Hemitatutoga hortulanus</i>					R		R						R				
Labridae	Silver-streaked Wrasse	<i>Stethojulis stringiventer</i>						A				C	C		R				
Labridae	Ornate Leopard Wrasse	<i>Macropharyngodon ornatus</i>							R										
Labridae	Splendid Leopard Wrasse	<i>Macropharyngodon bipartitus</i>							R										
Labridae	Blue-lined wrasse	<i>Stethojulis albovittata</i>																A	
Labridae	Banded thick lip wrasse	<i>Hemigymnus fasciatus</i>										R							R
Labridae	Zigzag wrasse	<i>Hemitautoga scapularis</i>											C						
Labridae	Bird Wrasse	<i>Gomphosus caeruleus</i>											C		R				
Labridae	Six-bar Wrasse	<i>Thalassoma hardwicke</i>														C			
Labridae	Napoleon wrasse	<i>Cheilinus undulatus</i>														R		R	
Labridae	Banded Maori Wrasse	<i>Cheilinus fasciatus</i>														R			
Labridae	Oiental Maori Wrasse	<i>Cheillinus rhodochrous</i>																R	
Labridae	Thalassoma schwanen feldii	<i>Ribbon Wrasse</i>															A		
Labridae	Blue-streak cleaner Wrasse	<i>Labroides dimidiatus</i>															C	C	
Labridae	Two-tone Wrasse	<i>Thalassoma amblycephalum</i>																R	
Lethrinidae	Black-blothed Emperor	<i>Lethrinus harak</i>					C												

Family	Common Name	Scientific Name	R1	R2	R3	R4	R5	R6	R7	L8	L9	L10	L11	L12	L13	SI1	SI2	SI3	SI4
Mullidae	Round-spot goatfish	<i>Parupeneus pleurostigma</i>	C										R						
Mullidae	Long-barbel Goatfish	<i>Parupeneus macronema</i>					R		R										
Mullidae	Schooling Goatfish	<i>Upeneus taeniopterus</i>						A											
Ostraciidae	Yellow Boxfish	<i>Ostracion cubicus</i>		R															
Pinguipedidae	Maldivian Grubfish	<i>Parapercis signata</i>										R							
Pomacanthidae	Regal Angelfish	<i>Pygoplites diacanthus</i>														R	C	C	
Pomacentridae	Blue-yellow Damsel	<i>Pomacentrus caeruleus (juvenile)</i>		R			C												
Pomacentridae	Indian Damsel	<i>Pomacentrus indicus (juvenile)</i>		R					C		C	C							
Pomacentridae	Green Sergeant	<i>Amblyglyphidodon batunai</i>		C															
Pomacentridae	White band Damsel	<i>Plectroglyphidodon leucozonus</i>				R													
Pomacentridae	Sharp eye Damsel	<i>Plectroglyphidodon imparipennis</i>				R													
Pomacentridae	Scribbled Damsel	<i>Pomacentrus nagasakiensis</i>					R		R										
Pomacentridae	White tailed Damsel	<i>Pomacentrus chrysurus</i>										C							
Pomacentridae	Blue-yellow Damsel	<i>Pomacentrus caeruleus (juvenile)</i>													C				
Pomacentridae	Azure Damsel	<i>Pomacentrus pavo (juvenile)</i>													C				
Pomacentridae	Green Puller	<i>Chromis viridis</i>		R			C		R							C			
Pomacentridae	Jewel Damsel	<i>Plectroglyphidon lacrymatus</i>															C		
Pomacentridae	Sergeant Major	<i>Abudefduf vaigiensis</i>																	C
Scaridae	Five-saddle parrotfish	<i>Scarus scaber</i>	C															C	C
Scaridae	Spinytooth Parrotfish	<i>Calotomus spinidens</i>						A											
Scaridae	Two-coloured Parrotfish	<i>Cetascarus bicolour</i>													R	R			R
Scaridae	Shabby Parrotfish	<i>Chlororus sordidus (juvenile)</i>													C	R			C
Scaridae	Sheep headed Parrotfish	<i>Chkirurus strongylocephalus</i>													R		C		
Scaridae	Ember Parrotfish	<i>Scarus rubroviolaceous</i>																C	C
Scaridae	Fine-lined Bristletooth	<i>Ctenochaetus striatus</i>																	C
Serranidae	Squaretail coral grouper	<i>Plectropomus areolatus (juvenile)</i>	R		C											R	C		
Serranidae	Four saddle Grouper	<i>Epinephelus spilotoceps</i>	R				R								R		C		
Serranidae	Vermillion Rock Cod	<i>Cephalopholis miniata</i>													R				
Serranidae	Peacock Rock Cod	<i>Cephalopholis argus</i>																	R
Serranidae	Threadfin Basslet	<i>Nemanthias carberryi</i>																A	
Synodontidae	Variegated Lizardfish	<i>Synodus variegatus</i>			R							R						R	
Tetraodontidae	Saddled Pufferfish (juvenile)	<i>Canthigaster valentini</i>		R								C							
Tetraodontidae	Bennett's Pufferfish	<i>Canthigaster bennetti</i>											R						