Ministry of Climate Change, Environment and Energy

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Flora and Fauna Soil Assessment Report

Inside and in the vicinity of the ICZM by using remotely sensed data and field verification

Global Ocean Accounts Partnership

UNSW SYDNEY

THE MALDIVES NATIONAL UNIVERSITY

REKAM NUSANTARA FOUNDATION

Project: Consultancy Service for Development of Natural Capital Accounting with initiating pilot testing of the SEEA Ecosystem Accounting (SEEA EA) in Laamu Atoll

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Consultants:

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Contents

1. Executive summary

The Flora and Fauna soil assessment report conducted in and around the Integrated Coastal Zone Management (ICZM) was developed to support the initiation of pilot testing of the System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA) in Laamu Atoll. This report offers an initial assessment of (i) flora and fauna, and (ii) soil within the ICZM area of Laamu Atoll, using ground truth and remote sensing data. Flora assessment consisted of the classification of the ICZM areas by habitat or land cover, namely coral reef, seagrass, mangrove, coastal vegetation or crops utilizing GIS software in conjunction with remotely sensed data from satellite images. The fauna assessment relied on open access data and provided identified species within each protected area. The soil assessment was split into (1) subtidal / underwater areas and (2) land areas, classifying them by sand, rubble, hard substrate and sandy soils / muddy soils respectively.

The report includes:

- An outline of the data and data collection methods,
- Supporting maps and graphs delineating soils and substrate for each protected area and for the whole of Laamu Atoll.

2. Introduction

The Government of the Republic of the Maldives is developing natural capital accounts through pilot testing the SEEA Ecosystem Accounting (SEEA EA) framework in Laamu Atoll, an ecologically sensitive and economically important area in southern Maldives. The framework serves as a tool to promote sustainable developments and help ensure that the value of natural resources and the ecosystem in the Maldives, especially in Laamu Atoll, are fully accounted for in the decision-making process.

The report provides an assessment of flora and fauna, supported by field surveys and ground truthing. Flora was identified using remote sensing, to map the distribution and extent of different habitat types, track changes over time, and identify potential threats. The findings contained within this report support further data presented within the report, "Report of findings on habitat pattern of the ICZM" (submitted October 2023). Most of the fauna data were gathered using citizen science initiatives, namely iNaturalist. Citizen science is the involvement of volunteers in scientific research. It is an increasingly popular way to collect data on flora and fauna, as it allows researchers to cover large areas and collect data on a more frequent basis than would be possible with a dedicated team of scientists.

This report also provides a soil assessment within ICZM sites across Laamu Atoll. Subtidal soil assessments using remote sensing are a cost-effective way to monitor and assess the condition of the seabed. This is important for a variety of reasons, including:

- To ensure the health and productivity of marine ecosystems
- To manage coastal resources sustainably by monitoring changes,
- To identify and mitigate potential environmental hazards and impacts of human activity.

Soil types

The soils of the Maldives are young and consist mostly of un-weathered coral material. They are coarse in texture and shallow in depth, with a top layer of brown soil followed by coral reef limestone.[1] In some areas with human activity, deep soils with clay deposits can be found. In lagoon environments (called vilu), there may be substantial clay depth from accumulated marine and biological material. The soils have a weak structure and sometimes have a hard-pan layer preventing root penetration. They have poor water-holding capacity due to high porosity and infiltration rates. The soils are generally alkaline with pH values between 8.0 and 8.8, due to excess calcium. They are deficient in nitrogen, potassium, iron, manganese, zinc, and have high levels of unavailable phosphorus (trapped as calcium phosphorus).[2]

Protected Areas of Laamu Atoll

[1] FAO, 2007. Trees and shrubs of the Maldives. RAP Publication, (12).

[2] Ministry of Environment and Energy, 2015. Fifth national report to the United Nations Convention on Biological Diversity, pg. 19

Protected areas play a crucial role in preserving biodiversity and maintaining the health and resilience of ecosystems. They attempt to reduce human pressures on endangered species, promote ecosystem services, and contribute to scientific research and environmental education. Six sites of environmental significance at Laamu Atoll were declared protected in 2021 (Figure 1) under the Environment Protection and Preservation Act [(IUL)438-ENV/438/2021/371]. The sites include wetlands, reefs, lagoons, mangroves, seagrass meadows, and beaches and include:

- Bodu Finolhu and Vadinolhu Kandu Olhi Area (73.3685, 2.019181),
- Fushi Kan'du Area & Maabaidhoo Koaru Area (73.53068, 2.039574)
- Gan Boda Fengan'du Area (73.53376, 1.885685),
- Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area (73.44555, 1.821906),
- Gaadhoo – Hithadhoo Gan'du Area (73.43552, 1.805808), and
- Hithadhoo Wetland and Surrounding Marine Area (73.43552, 1.805808).

The protected areas are either marine or terrestrial and may be defined under six categories: Internationally recognized areas, Strict nature reserve, Wilderness Areas, National Park, Natural Monument, Habitat/Species Managed area, or Protected areas with sustainable use.

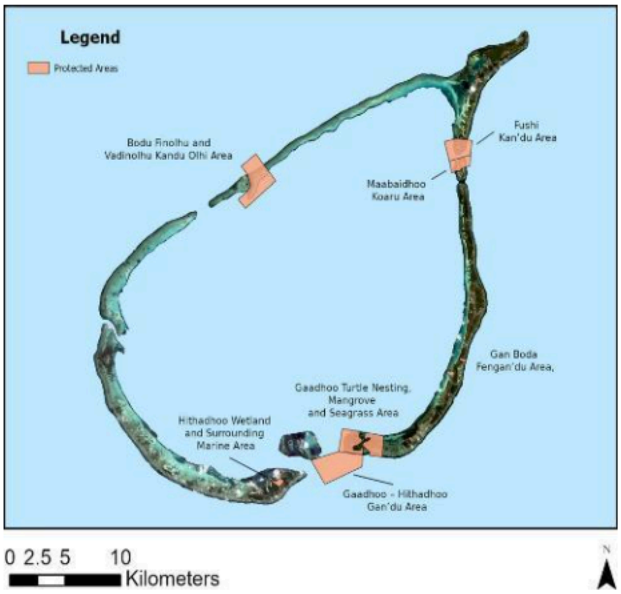

Figure 1: Protected areas within Laamu Atoll, established in 2021.

Objectives

This report furthers the objectives of the Terms of Reference (TOR, 438-ENV/438/2022/27) including to:

- Advance the knowledge agenda on Natural Capital Accounting, in particular ecosystem accounting, by initiating pilot testing of the SEEA Ecosystem Accounting (SEEA EA) in Laamu Atoll,
- Follow the developments (both biophysical modelling but also scenario analysis) in the Laamu pilot, with the view to extend this exercise to the whole Maldives.
- Analyse soil throughout the ICZM using existing data and results and through site validation.

3. Methodology

Soil / substrate assessment

Overview of the process

There are several methods to analysing soil and substrate, including:

- **Field soil sampling**: Collecting soil samples and conducting laboratory analysis,
- **Geological surveys**: to measure electrical conductivity, magnetic susceptibility, and density, and
- **Remote sensing**: Satellite or aircraft sensing to detect and map the distribution of different soil types across an atoll and monitor changes in soil properties over time.

Remote sensing was chosen as it most closely aligns with the processes required to strengthen Natural Capital Accounting within Laamu Atoll. Further, remote sensing could cover large areas quickly and efficiently, and include remote areas that were difficult to access.

Satellite imagery was used to support the mapping of substrate across Laamu Atoll. SPOT-6 and SPOT-7 satellites were used (operated by Airbus Defence and Space), which are twin optical imaging satellites that form a constellation that provides high-resolution, wide-swath imagery of the Earth. SPOT-6 and SPOT-7 have a resolution of 1.5 meters in the panchromatic band and 5.5 meters in the four multispectral bands (blue, green, red, and near-infrared).

The following process was conducted for mapping:

1. Define classification for soil and substrate features. A preliminary analysis was conducted, with limited classes based on visual interpretation, machine learning, and spectral analysis.
2. Classify the soil and substrate features. Classification was conducted using the supervised classification algorithms within ENVI (Harris Geospatial). The algorithm was trained using ground-truthing points.
3. Mapping. Once the classification was complete, maps were produced using ENVI and ArcGIS.

From preliminary analyses, it was clear that mapping was to be conducted separately for (i) subtidal / underwater and (ii) land areas, to enhance the ability of the algorithm for classification.

Classifications

Subtidal

The multispectral imagery from SPOT6/7's sensors were used to distinguish soil types (Figure 2), including:

- Sand - loose, non-cohesive granular material composed of small mineral grains. Sand grains are typically between 0.063 and 2 millimetres in diameter.
- Hard substrate - solid surfaces that are not easily deformed or eroded. Hard substrates can be natural, such as rocks or coral reefs, or man-made, such as concrete or metal.
- Rubble - a mixture of broken rocks, and other large debris. Rubble is found in a variety of marine habitats, including coral reefs and rocky shores. The rubble on Laamu Atoll is composed almost entirely of larger coral fragments and boulders.

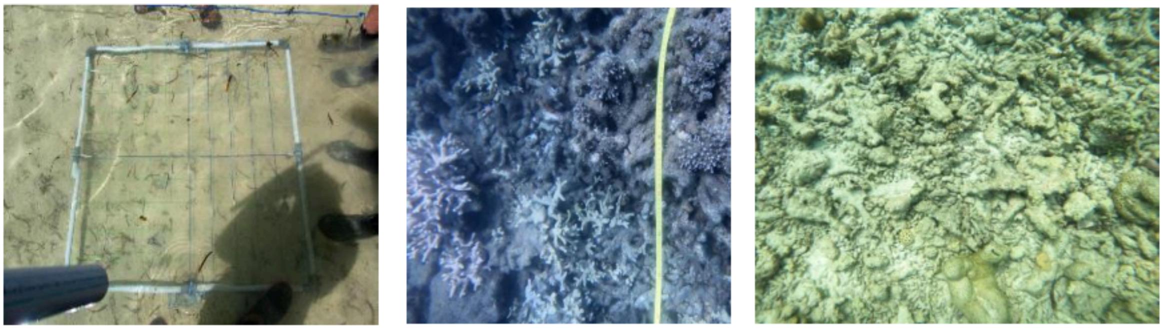

Figure 2. Ground truthing points for subtidal areas, classified into sand, hard substrate (coral) and rubble substrate.

Land areas

The SPOT6/7's sensors were used to distinguish soil types on land (Figure 3), including:

- Sand - loose, non-cohesive granular material composed of small mineral grains.
- Brown soil- Brown soil on coral atolls is a type of soil that is found on low-lying islands made up of coral reefs. It is typically shallow, alkaline, and coarse-textured, with a high content of calcium carbonate. The brown colour of the soil comes from the organic matter that has decomposed over time.

Figure 3. Examples of land areas classified into sand, and brown soil.

Data processing and classification

Satellite data from SPOT6/7 (accessed via Airbus platform) was acquired for the closest available year (2021). Due to cloud cover and other considerations, satellite imagery was captured in March, August and October and mosaiced together into one image for analysis. Prior to utilization, the satellite imagery underwent preprocessing, encompassing radiometric, atmospheric, and sun glint corrections.

Data processing involved the interpretation of satellite imagery to align with the field survey observations. Ground truthing data was used for the classification, requiring ArcGIS Pro (v3, ESRI) and ENVI (v5.6, Harris Geospatial).

The application of supervised classification, involving the utilization of ground truthing points and user input, facilitated the training of a machine learning algorithm. This algorithm assigned a specific habitat class label (e.g., brown soil, sand, rubble, etc.) to each pixel in the satellite image. Leveraging the ground truth points, the algorithm established associations between spectral patterns and spatial relationships with each habitat class.

Note:

- Analysis was limited to the 10 m depth due to remote sensing limitations related to light penetration.
- Habitats > 5 m in area were detected accurately,
- Land and sea were assessed separately, using the same analysis. 'Cloud' refers to areas masked by cloud cover.

Field surveys

Ground truthing surveys were conducted to enable remote sensing of soil and substrate variability across Laamu Atoll. Two field surveys were conducted, in March and August 2023, resulting in 357 ground truth points (Figure 4) and over 300 images / video transects. The survey produced the following outcomes:

- Validation points for soil type classification,
- Data on the extent of soil within specific ecosystems.

To enhance the precision and dependability of data obtained through remote sensing methods, in-person field surveys were conducted for validation purposes. The measurements gathered during these on-site surveys were then utilized to corroborate and validate the remote sensing data. An essential aspect of this validation process included assessing disparities in colour tones and object attributes discerned in satellite imagery in contrast to their real-world characteristics during ground truthing activities.

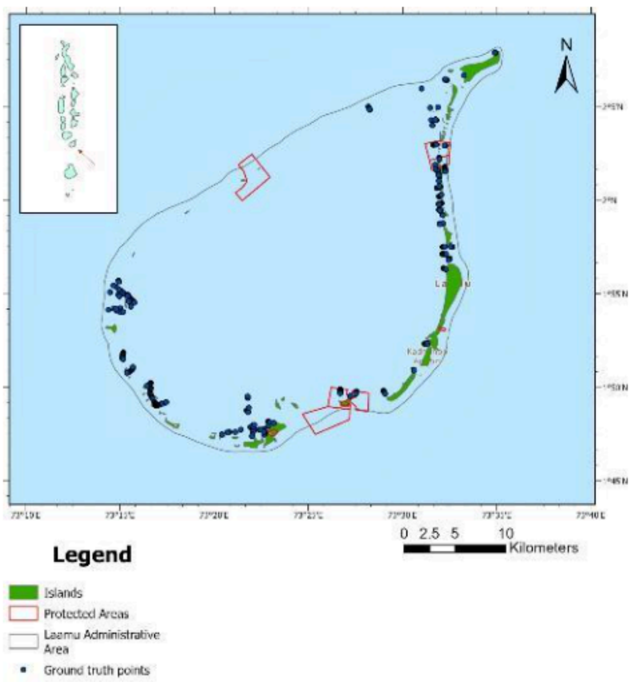

Figure 4. Map of ground truth points across Laamu Atoll.

4. Flora and Fauna

Seagrass and mangrove species were identified across all protected areas during the field surveys. Representative photos of species were also taken. A literature review was conducted to identify potential flora and fauna within the protected areas, beyond those identified through field surveys. The literature review involved searching for relevant scientific articles and reports that discussed species diversity and distribution with mention of Laamu Atoll. Databases such as Google Scholar, Web of Science, and Scopus were assessed to find relevant publications. Additionally, government documents related to the Convention on Biological Diversity, and other management reports were consulted. The review process noted the key species mentioned. Primary data on flora and fauna on Laamu Atoll was limited. Most work conducted has been based on habitat mapping of coastal vegetation, mangroves, seagrass and coral reefs.

iNaturalist

One source of data, which could be further encouraged and developed in the future, is iNaturalist. The platform is a social networking service and website for naturalists, citizen scientists, and biologists. It is built on the concept of mapping and sharing observations of biodiversity, where users can share photos and other information of their observation. Other users can then help to identify the organisms and provide feedback on the observations. There are two main ways that data is collected for iNaturalist:

- User observations: Users can submit observations of plants, animals, and fungi that they have seen in the wild. These observations can include photos, descriptions, and location information.
- Research-grade observations: A subset of user observations are designated as research-grade. These observations meet certain data quality standards, such as having high-quality photos and accurate location information. Research-grade observations are used by scientists to study biodiversity and conservation.

iNaturalist also collects data from other sources, such as:

- Museum collections: iNaturalist has partnerships with museums around the world to digitize their collections.
- Scientific literature: iNaturalist has partnered with several scientific databases to harvest data from published papers. This data includes information about the distribution and abundance of species.

iNaturalist data is used by scientists to study a wide range of biodiversity topics, including:

- Species distribution: iNaturalist data can be used to map the distribution of species across the globe. This information can be used to identify areas of high biodiversity and track changes in species distribution over time.
- Conservation: iNaturalist data can be used to identify threats to biodiversity and inform conservation efforts. For example, iNaturalist data has been used to identify areas where invasive species are spreading and to track the decline of endangered species.

Data was extracted for protected areas and the entirety of Laamu Atoll.

5. Results

Soil and substrate per Protected Area

Subtidal

Mapping for subtidal habitats above 10 m depth identified a total area for Laamu Atoll of:

- 71.2 km^2 of hard substrate,
- 29.8 km^2 of rubble, and
- 42.5 km^2 of sand.

The cover per Protected Area is presented in Table 1. Coverage is mapped in Figure 5

Table 1. Coverage of subtidal substrate (in km2) by protected area.

Protected Area	Hard substrate	Rubble	Sand	Grand Total
L. Bodu Finolhu and Vadinolhu Kandu Olhi Area	0.45	0.76	0.66	1.87
L. Fushi Kan'du Area	0.89	0.09	0.22	1.20
L. Gaadhoo – Hithadhoo Kan'du Area	0.22	0.01	0.05	0.28
L. Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area	2.55	1.48	0.62	4.65
L. Gan Boda Fengan'du Area	0.08	-	0.01	0.09
L. Hithadhoo Wetland and Surrounding Marine Area	0.09	0.00	0.04	0.14
L. Maabaidhoo Koaru Area	0.45	0.00	0.09	0.55

For depths greater than 10 m, hard substrate was dominant due to the coverage of coral reefs and associated geomorphology (e.g., reef slope, reef flat). These areas are developed through physical, biological and chemical processes, including:

- Coral growth: Corals are the primary builders of hard substrate on coral reefs. They secrete a calcium carbonate skeleton that builds up over time, creating a hard surface on which other organisms can settle.
- Erosion: Erosion can also play a role in the formation of hard substrate on coral reefs. Erosion can remove loose sediment and expose the underlying coral skeleton. This can create a hard surface on which other organisms can settle.

- Cementation: Cementation is a process by which calcium carbonate is deposited on the surface of coral reefs. This can occur through the precipitation of calcium carbonate from seawater or through the activities of certain algae and bacteria.

Waves, storm surges and strong currents can detach coral from hard substrate and form rubble. These areas were located behind the reef crest across Laamu Atoll. Sand is the result of weathering and erosion of larger coral pieces, through processes including:

- Coral erosion: Coral reefs are constantly being eroded by waves and currents. This erosion produces small fragments of coral, which are gradually broken down into sand- sized particles.

- Biological erosion: Many marine organisms, such as parrotfish and sea urchins, feed on coral. These organisms grind up the coral with their teeth or beaks, producing sand-sized particles.

The sand produced by these processes is then transported by waves and currents around Laamu Atoll. Some of the sand may be deposited on the beaches of the atoll, while other sand may be transported to deeper waters.

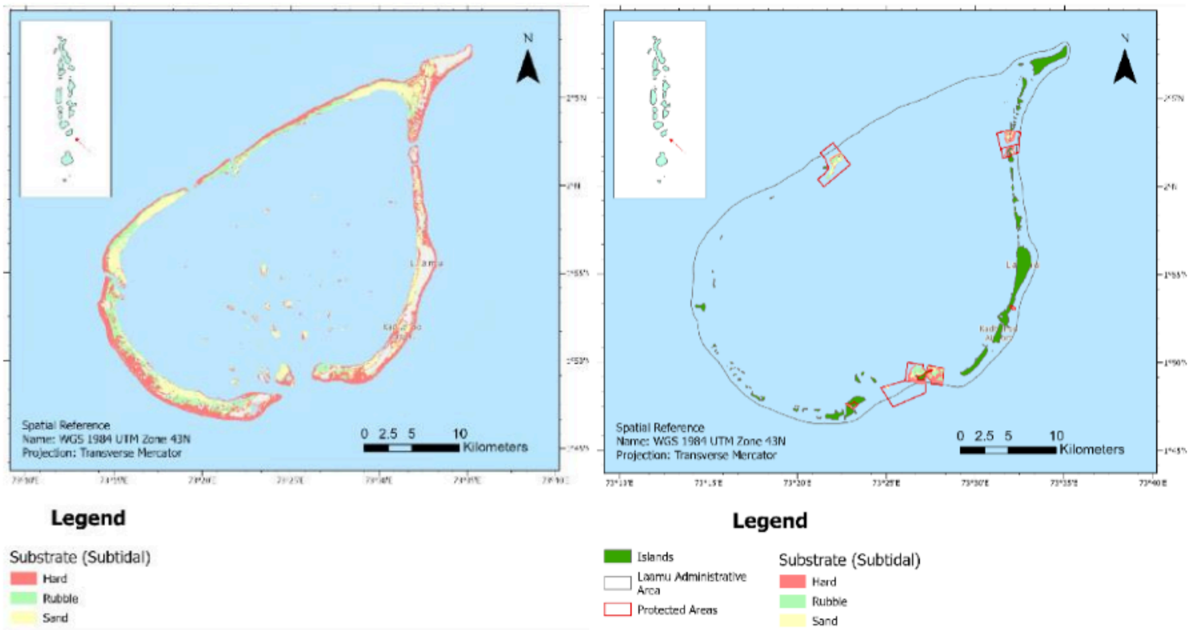

Figure 5. Map of subtidal substrate across (left) Laamu Atoll and (right) for specific protected areas. Depths greater than 10 m were not covered in the analysis.

Land area

Classification on islands identified urban areas, crops / cleared areas, vegetation and sand. Note that Bodu Finolhu and Vadinolhu Kandu Olhi Protected Area and Gaadhoo – Hithadhoo Kan'du Area were completely subtidal and not analysed. Further, for soil analysis, urban areas were omitted. Each class total for Laamu Atoll is presented in Table 2, below.

Table 2. Coverage by sediment type within each protected area (km²).

Class	Area
Airport	0.31
Crop / Manip	6.03
Sand	0.75
Unclassified	0.21
Urban	7.15
Vegetation	10.12

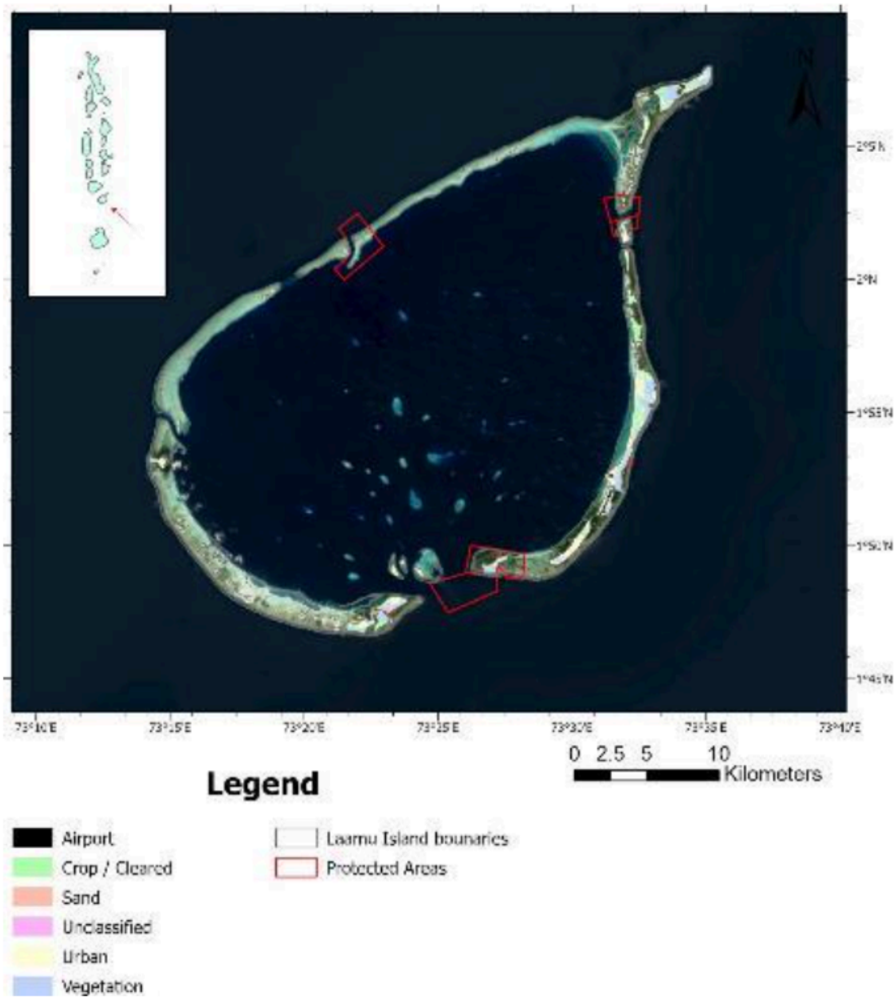

Figure 6. Map of land class across Laamu Atoll, highlighting protected areas.

Crop and vegetated areas were considered brown soil, where a layer of organic matter is present. In total, soils for Laamu Atoll were estimated at:

- 16.14 km2 of brown soil, and
- 0.75 km2 of unvegetated sand.

Coverage per protected area is mapped in Table 3.

Table 3. Coverage by sediment type within each protected area (km^2).

Name	Brown soil	Sand
L. Bodu Finolhu and Vadinolhu Kandu Olhi Area	-	0.0034
L. Fushi Kan'du Area	0.0399	0.0010
L. Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area	0.1966	0.0136
L. Gan Boda Fengan'du Area	0.0425	-
L. Hithadhoo Wetland and Surrounding Marine Area	0.1521	0.0826
L. Maabaidhoo Koaru Area	0.1681	0.0134

Flora and fauna

The following section provides an overview of the mangrove and seagrass species, identified within each protected area. An in-depth assessment of mangrove and seagrass extent and condition within each ICZM is presented within "Report of findings on habitat pattern of the ICZM using data and through site validation".

Mangrove assessment per Protected Area

Mangroves were identified in only three protected areas, namely:

- L. Maabaidhoo Koaru Area,
- L. Gan Boda Fengan'du Area, and
- L. Hithadhoo Wetland and Surrounding Marine Area.

The Hithadoo Wetland contains the only pure stand areas on Laamu Atoll, where mangrove coverage is > 80% of trees within the area. From local consultation, the observed mangroves within the Maabaidhoo Koaru Area were planted in the last 3 - 5 years. Evidence for plantation includes the straight row of 5 *Ceriops tagal* trees and the presence of *Rhizophora mucronata* deep within the lagoon, where natural transference of the mangrove seedling from other areas (e.g., Hithadoo wetland area) would be unlikely. Extent is presented in Table 4, while species per protected area is presented in Table 5. Representative photos of mangroves from Hithadoo Wetland provided in Figure 7.

Table 4. Mangrove coverage per protected area in 2020.

Site Name	Area
Maabaidhoo Koaru Area	32 individuals (5 were trees, 27 were saplings < 1 m in height)
Gan Boda Fengan'du Area	7 - 12 trees
Hithadhoo Wetland	0.0324 km2

Table 5. Mangrove species per protected area.

Site Name	Genus	Common Name	Divehi Name	Estimated individuals within Protected Area
Hithadhoo Wetland	*Rhizophora mucronata*	Red Mangrove	Randoo	>6800 trees
Hithadhoo Wetland	*Ceriops tagal*	Yellow Mangrove	Karamana	>1600 trees
Hithadhoo Wetland	*Lumnitzera racemosa*	Black Mangrove	Burevi	Unknown
Hithadhoo Wetland	*Derris trifoliata*	Mangrove Vine	Thelaviyo	Unknown
Hithadhoo Wetland	*Sonneratia caseolaris*	Mangrove Apple	Kulhavah	Unknown
Maabaidhoo Koaru Area	*Rhizophora mucronata*	Red Mangrove	Randoo	24 **saplings**
Maabaidhoo Koaru Area	*Phempis acidula*	Shrubby Coral	Kuredhi	31 **saplings**
Maabaidhoo Koaru Area	*Ceriops tagal*	Yellow Mangrove	Karamana	5 trees
Gan Boda Fengan'du Area	*Brugueira ghymnorrhiza*	Large-leafed Orange Mangrove	Bodavaki	12 trees

Figure 7. Mangrove species identification survey within Hithadoo wetland protected area, showcasing *Cerips tagal* (left) and dense *Rhizophora mucronata* (right).

Seagrass assessment per Protected Area

Seagrass were identified in all protected areas except the Bodu Finolhu and Vadinolhu Kandu Olhi Protected Area and Gaadhoo – Hithadhoo Kan'du Area. Of the seven identified seagrass species within the Maldives, six were identified on Laamu Atoll:

- *Thalassia hemprichii* (Th),
- *Thalasadendron ciliatum* (Tc),
- *Syringodium isoetifolium* (Si),
- *Cymodocea rotundata* (Cr),
- *Halodule pinofilia* (Hp), and
- *Halodule uninervis* (Hu).

Their presence and extent in each protected area is recorded in Table 6. The distribution of the number of seagrass species can be seen in Figure 8, with extent in Table 6.

Table 6. Seagrass species and coverage (in 2020) per protected area.

Site Name	Total area (km^2)	Th	Tc	Si	Cr	Hu	Hp
Maabaidhoo Koaru Area	0.1783	X	X		X		
L. Fushi Kan'du Area	0.5278	X	X		X		
Gan Boda Fengan'du Area	0.1117	X			X		X
Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area	2.5076	X	X	X	X		
Hithadhoo Wetland and Surrounding Marine Area	0.0324	X			X		

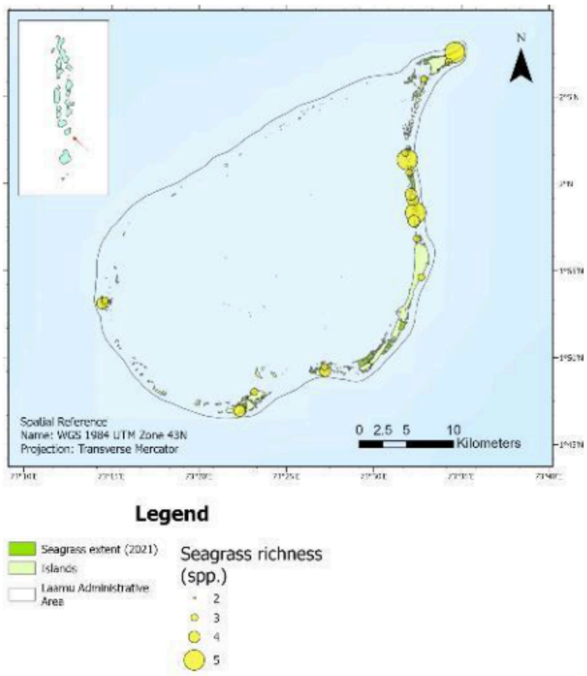

Figure 8. Map of Laamu Atoll showing biodiversity hotspots for seagrass species

Literature Review

Despite harsh environmental conditions, the Maldives has 260 species of vascular plants that grow in the wild and are either native or naturalized, while an additional 323 are cultivated.

The islands of the Maldives can, in general, be divided into three zones namely, i) the foreshore or lower beach, ii) the beach crest (beach top) and iii) the inner island (Figure 9). The foreshore can be further divided into high tide and high-storm levels. The high tide level is normally located at an elevation of 0.5 m above mean sea level and high storm level, which is beyond the reach of normal tides, is located at about 0.8 to 0.9 m. The storm level is affected by storm waves and is composed of gravel or shingle. The average elevation of the beach crest is about 1.2 m, and the inner islands are at about 1.45 m above mean sea level (Morner *et al.*, 2003). Each of these zones provides relatively uniform environment with its own associated plant community.

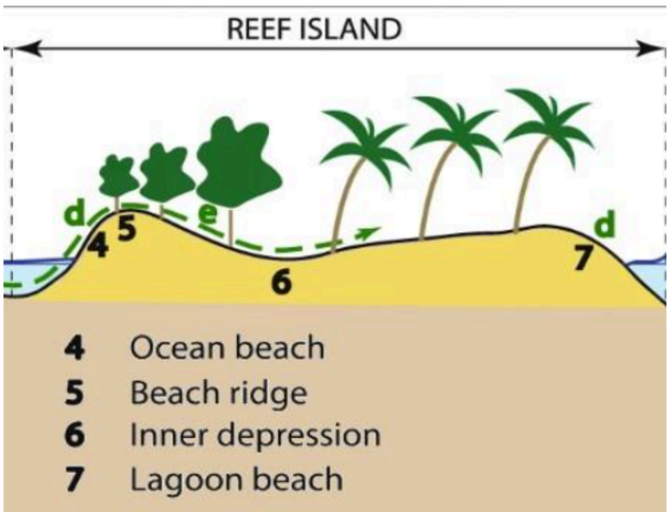

Figure 9. Conceptual diagram of atoll island natural dynamics showing sections of the reef island. Adapted from Duvat & Magnan (2019).

Foreshore or lower beach

The foreshore can be further divided into two levels: high tide (~0.5 m above sea level) and high-storm levels (~0.8 m above sea level). The environmental drivers of flora and fauna are exposure to wind and wave action and salinity due to salt spray. The dynamic nature of the lower beach and movement of sediments results in limited vegetation. Creeping plants in this zone have been observed across the Maldives, including *Ipomoea littoralis,* and *Ipomoea biloba, Launaea pinnatifida* and *Portulaca alata (*Figure 10).

Figure 10. Photos of *Ipomoea littoralis (left) and Launaea pinnatifida (right).*

Beach crest

The beach crest has an average elevation of 1.2 meters and consists of the area above the high tide line to the adjacent and stable beach frontage. The zone is exposed to winds and salt spray and may occasionally be inundated during storm surges and spring tides. Some beach crest zones may extend up to 20 m inland. Vegetation consists mostly of strand plant communities, although the zone may also include trees and shrubs and herbaceous plants (Figure 11). These plant communities include:

1. Scaevola taccada scrub community is commonly found on the beach crests of the Maldives and is a windbreak. It may reach heights of approximately 3 to 4 meters above spring tide level. It thrives on sandy or rubble-dominated soils.
2. The Pemphis acidula scrub community is often found on elevated reef rock and beach rockin open sites above the high tide level. In sandy areas, Pemphis acidula can also be found growing alongside Suriana maritime. In some cases, there may be coral rock just below the surface in these areas.

Other tree species within Laamu Atoll associated with the zone include *Pandanus tectorius, Pisonia grandis* and *Cordia subcordata* (local names in Table 7).

Figure 11. Photos of *Scaevola taccada (left) and Pandanus tectorius (right)*

Table 7. Beach crest tree species and local names

Species	Dhivehi name
Pandanus tectorius	Maakashikeyo (includes other Pandanus species)
Pisonia grandis	Kaani, kauni
Cordia subcordata	Funa

Inner island

The inner section of an island can vary between 1.5 and 3 m above sea level and consists of a microclimate formed by the protection of beach-crest communities. Vegetation in the inner island could be composed of pure stands (at least 80% of the canopy is of a single species) or mixed forests.

Where extensive coconut plantations are not present mixed species forest is the most common vegetation type found next to beach-crest scrub community. Principal tree species (and their local names) are provided in Table 8.

In many islands the original distribution of trees and shrubs has been greatly disturbed by the establishment of extensive coconut plantations (e.g., Hithadoo Island, adjacent to the mangrove area). Some islands in Laamu Atoll contain coconut plantations immediately adjacent to the beach-crest vegetation, which in turn provide shelter for species such as *Morinda citrifolia* and *Guettarda speciosa.* In particularly moist areas of the inner island, small pure stands of *Cordia subcordata* and *Barringtonia asiatica* may be present.

Table 8. Inner island tree species and local names

Species	Dhivehi name
Barringtonia asiatica	Kim'bi, Kin'bi
Cordia subcordata	Kaani, kauni
Calophyllum inophyllum	Funa
Adenanthera pavonina	Madhoshi
Guettarda speciosa	Uni
Pandanus spp.	Maakashikeyo

iNaturalist observations (Flora and fauna)

The number of species recorded across Laamu Atoll using the iNaturalist platform and species identified within the protected areas are provided in Tables 9 and 10. The full list can be found here.

Table 9. Number of species observed within Laamu Atoll reported on iNaturalist from 447 observations between 2011 and 2023.

Taxon	Count of species
Actinopterygii (Bony fish)	146
Animalia	132
Arachnida	5
Aves (Birds)	4
Fungi	4
Insecta	7
Mammalia	1
Mollusca	31
Plantae	27
Reptilia	4
Grand Total	361

Table 10. Species identified within Laamu Atoll protected areas. [1]Phylum and class identified via NCMI taxonomy browser.

Protected Area	Phylum / Class[1]	Scientific name	Common name
L. Maabaidhoo Koaru Area	Chordata / Chondrichthyes	Pateobatis fai	Pink Whipray
L. Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area	Mollusca / Gastropoda	Drupa morum	Mulberry Drupe
	Annelida / Polychaeta	Eurythoe	Polychaete
	Arthropoda / Malacostraca	Alpheidae	Snapping Shrimps
	Arthropoda / Malacostraca	Eriphia sebana	Smooth, Red-eyed Crab
	Arthropoda / Malacostraca	Zosimus aeneus	Killer Crab
	Porifera / Demospongiae	Phyllospongia foliascens	Sea sponge
L. Fushi Kan'du Area	Chordata / Actinopteri	Cephalopholis miniata	Coral Grouper
	Chordata / Actinopteri	Pomacanthus xanthometopon	Blueface Angelfish
	Chordata / Actinopteri	Myripristis adusta	Shadowfin Soldierfish
	Chordata / Actinopteri	Solenostomus paradoxus	Ornate Ghostpipefish
	Chordata / Chondrichthyes	Aetobatus ocellatus	Whitespotted Eagle Ray
	Chordata / Actinopteri	Cirrhitichthys oxycephalus	Pixy Hawkfish
	Annelida / Polychaeta	Spirobranchus	Christmas Tree Worms
	Chordata / Actinopteri	Cephalopholis nigripinnis	Darkfin Hind
	Chordata / Actinopteri	Plectropomus laevis	Blacksaddle Coral grouper
L. Gan Boda Fengan'du Area	Chordata / Actinopteri	Geograpsus grayi	Little Nipper
	Streptophyta / Magnoliosida	Barringtonia asiatica	Fish Poison Tree
L. Hithadhoo Wetland and Surrounding Marine Area	Arthropoda / Malacostraca	Cardisoma carnifex	Brown Land Crab
	Arthropoda / Malacostraca	Gelasiminae	Broad-fronted and Indo-west Pacific Fiddler Crabs

6. Conclusion

In conclusion, the report provides an overview of the flora and fauna found in the Maldives, specifically focusing on the subtidal substrate and protected areas within Laamu Atoll. The study highlights the unique plant biodiversity of the Maldives and the different zones within the islands, including the foreshore or lower beach, beach crest, and inner island. The report also discusses the plant communities and species found within each zone. Additionally, the report presents data from iNaturalist observations, showcasing the diversity of species within Laamu Atoll. Overall, the report provides valuable information on the plant and animal communities in the Maldives, contributing to our understanding of the biodiversity in Laamu Atoll.

7. References

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8. Appendix

Seagrass species identified.

1. *Thalassia hemprichii*

   Thalassia hemprichii has strap-like and curved leaves and dark green in colour, with 2–5 leaves in one stand. The leaves are around 10-40 cm long and have small black spots. It has thick rhizomes about 2-4 mm in diameter, which are brownish white. This seagrass species can grow on all substrate types ranging from sand, muddy sand, and coral rubble. This species can also grow from the highest tide to the low tide and sometimes emerges to the water surface during the lowest tide (Hernawan et al., 2017; Wagey, 2013).

Figure A1. Seagrass of Thalassia hemprichii species at (a) the time of observation and (b) illustration (Source: Seagrass-Watch (McKenzie, 2003))

2. *Thalassodendron ciliatum*

   Thalassodendron ciliatum has sickle-shaped leaves with rounded and jagged edges. The leaf sheath forms a triangular structure with pink stripes at the base. This species is characterized by the leaves at the ends of the elongated stems, with the long stands of the stems reaching 10-65 cm. The rhizomes are hard and woody, enabling them to live on various substrate types, including around chunks of coral rocks (McKenzie, 2003).

Figure A2. Seagrass of Thalassodendron ciliatum species at the time of observation (a) and its illustrations (Source: Seagrass-Watch (McKenzie, 2003)) (b)

3. Syringodium isoetifolium

Syringodium isoetifolium, commonly known as noodle seagrass, has a round leaf shape resembling noodles (cylindrical), with a leaf diameter of around 2 mm. This species can grow to 50 cm long in single species stands but may only reach 5 to 10 cm when growing with other seagrass species. Unlike other seagrasses which are flat in shape, this species has a circular shape with a cross section. The leaves have a smooth pointed tip. The rhizomes are unbranched, and each stalk consists of 2-3 leaves. Noodle seagrass is commonly found in waters with a bottom substrate of muddy sand mixed with gravel or coral rubble (Wild Singapore, 2023)

Figure A3. Seagrass of Syringodium isoetifolium species at the time of observation

4. Cymodocea rotundata

Cymodocea rotundata has long flat leaves with rounded tips, about 6-15 cm long and 2-4 mm wide. The leaves are not narrowed to the end. The rhizomes are unbranched and have no root hairs, and each stalk consists of 2-5 leaves. Cymodocea rotundata lives on muddy sand substrates and sand substrates accompanied by dead coral fragments (Kuo et al., 1996).

Figure A4. Illustration of Cymodocea rotundata seagrass (McKenzie, 2003)