



Ministry of Environment,
Climate Change
and Technology



ENDhERI



Report on historical analysis of the dynamic of the ecosystem and their services under current intervention management inside the ICZM



UNSW
SYDNEY



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THE MALDIVES NATIONAL
UNIVERSITY



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

Submitted: 31 July 2023

Image caption: Aerial view of atoll, Source: Nattu Adnan (CC4)

Consultants:

This report was prepared by the University of New South Wales (UNSW), with support from the Rekam Nusantara Foundation (RNF) and experts from the Maldives National University (MNU) per the Terms of Reference 438-ENV/438/2022/27.

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1. Executive summary

This report provides a baseline analysis of protected areas within Laamu Atoll, with specific attention to the extent of ecosystems present and the services they may provide. Data was gathered from multiple sources, including field visits and remote sensing to assess ecosystems for the years 2017 and 2020. The study focuses specifically on six protected areas, and the key ecosystems contained within them (mangrove, coral reef and seagrass, with supra-tidal (land) and sub-tidal (underwater) areas assessed separately).

The report details:

- Methods used to gather data,
- Maps of the protected areas and extent of ecosystems contained within them, Identification of ecosystem services present per ecosystem,
- Expected changes of ecosystems and their services, Management recommendations.

2. Introduction

2.1 Background

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 South Central 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.

This report focuses on six sites of environmental significance at Laamu Atoll, declared protected in 2021 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
- Fushi Kan'du Area & Maabaidhoo Koaru Area
- Gan Boda Fengan'du Area,
- Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area,
- Gaadhoo – Hithadhoo Gan'du Area, and
- Hithadhoo Wetland and Surrounding Marine Area.

This report assesses the ecosystems within each protected area, identifies ecosystem services provided, determines if they have changed in extent between 2017 and 2020. The protected areas were declared in 2021, and here we evaluate the potential implications of changes in protected status to the provision of ecosystem services, extrapolating from the change between 2017 and 2020. Future deliverables will attempt to access more recent data from 2021 and 2022.

2.2 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,
- Establish natural capital accounts based on the agreed scope in accordance with SEEA,
- 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.
- Analyze habitat pattern of the ICZM (species, habitat, mangroves, seagrass, diversity) using existing data and results and through site validation.
 - This report provides habitat patterns, and habitat coverage of mangroves and seagrass.
 - Species and biodiversity assessments will be provided in a separate report per the TOR.

3. Methodology

3.1 Remote Sensing

The utilization of remote sensing for marine benthic habitat classification has emerged as a valuable approach in recent years, revolutionizing the assessment and monitoring of coastal ecosystems. High-resolution satellite imagery, such as the SPOT6 platform, may provide detailed and comprehensive data on habitat distribution.

Multispectral imagery from SPOT6's sensors were used to distinguish six classes of marine ecosystems and benthic types:

- Coral / macroalgae (satellite cannot distinguish the dominant habitat),
- seagrass,
- rubble, and
- sand.

Data processing was carried out by interpreting satellite imagery to obtain an overview of objects observed during field surveys. Pre-processing of satellite imagery will be carried out before the imagery is used for the interpretation, which comprises radiometric, atmospheric, and sun glint corrections. Ground truthing was also performed (see below) and the resulting data were processed using ArcGIS Pro (v3, ESRI) and ENVI (v5.6, Harris Geospatial).

Supervised classification (i.e., use of ground truthing points and user input) was used to train a machine learning algorithm, which labelled each pixel in the satellite image with a known habitat class (e.g., forest, water, urban, agriculture). The algorithm used the ground truth points to associate spectral patterns and spatial relationships with each habitat class, enabling it to classify the remaining pixels in the image accordingly.

Note:

- While corals can be found at depths below 10 m, 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.

3.2 Field surveys

A field survey between 15 and 20 March 2023 was conducted to validate and improve the accuracy of satellite imagery interpretation to generate data on mangroves, seagrasses, coral reefs, and other substrates. The survey produced:

- Validation points for ecosystem classification,
- Data on the health of specific ecosystems (presented in the [preliminary field report](#)).

To measure the accuracy and validity of data obtained from remote sensing techniques, the direct observation and measurement of environmental variables through field surveys is critical. The field measurements were then compared with and used to calibrate or validate remote sensing data. An essential consideration in determining samples is looking at the differences in color tone and object characteristics on the satellite imagery and accessibility on land and sea during the ground truth for mangrove, seagrass, and coral reef objects.

For ground truthing, videos and underwater photos were taken for reference locations. Each photo and video was marked using GPS points.

For specific field survey methods for specific ecosystems, please see links in Annex.

4. Classifications

For ecosystem types, the study used the IUCN's Global Ecosystem Typology (GET), with further guidance specifically for the Maldives¹, to provide a standardized and consistent classification of ecosystems. The GET provides a hierarchical system for categorizing terrestrial, marine, and freshwater ecosystems based on their ecological characteristics and functions. The typology employs a robust set of criteria, considering biophysical attributes, species composition, and ecosystem dynamics, to classify ecosystems into distinct units and group them into broader categories. Categories included:

- Intertidal forests and shrublands – specifically, true mangroves (MFT1.2)
- Seagrass meadows (M1.1),
- Photic coral reefs (termed, ‘coral reef’ – M1.3),
- Rocky reefs (rubble was also included – M1.4),
- Sub-tidal sand beds (termed, ‘sand’ – M1.7),

The study used the Common International Classification of Ecosystem Services (CICES) as a standardized classification system for the identification of potential ecosystem services provided. The CICES provides a structured approach to categorize and organize the diverse range of benefits that ecosystems provide to human well-being, with three main categories - provisioning, regulating, and cultural - that are subdivided into specific classes. Only ecosystem services with a beneficiary were counted. For example, coastal protection from coral in areas where there were no residents or infrastructure was not assessed.

¹ IUCN (2022) “Applying the IUCN Global Ecosystem Typology to the Maldives” : <https://www.environment.gov.mv/v2/en/download/14710>

5. Protected Areas

Six sites of environmental significance at Laamu Atoll were declared protected in 2021 under the Environment Protection and Preservation Act .

The protected areas are classified as either marine, or terrestrial. In terms of restrictions, there are also 6 protected area categories, described in Table X. A protected area may be zoned and classified as more than one category.

Table 1. Categories of protected areas

Category	Details of Protection
Internationally recognized areas	Areas of significance, proposed by the state or recognised by international communities.
Strict nature reserve,	Areas protected, for its significant biological diversity and for environmental protection. Taking, harming and removal of natural resources from these areas are prohibited, notwithstanding with prior approval from the Agency, research may be allowed in these areas. The objective of these areas is to conserve cultural and spiritual values associated with nature, and protected species threatened with extinction.
Wilderness Areas,	Areas that are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition. Any activity that may negatively affect the environment cannot be conducted in these areas.
National Park,	Natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities. The objective of protecting these areas are to protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation.
Natural Monument,	Areas set aside to protect a specific natural monument, which can be a landform, sea mount, and submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. The objective of protecting these areas is to protect specific outstanding natural features and their associated biodiversity and habitats. Activities that may not negatively affect the environment may be conducted in these areas.
Habitat/Species Managed area, or	Protected areas aiming to protect species or habitats and through its management. These areas aim to maintain, conserve, and restore species and habitats. Environmentally friendly economic activities may be carried out in these areas.
Protected areas with sustainable use.	Protected areas that conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area. The objective of protecting this area is for sustainable use of natural resources.

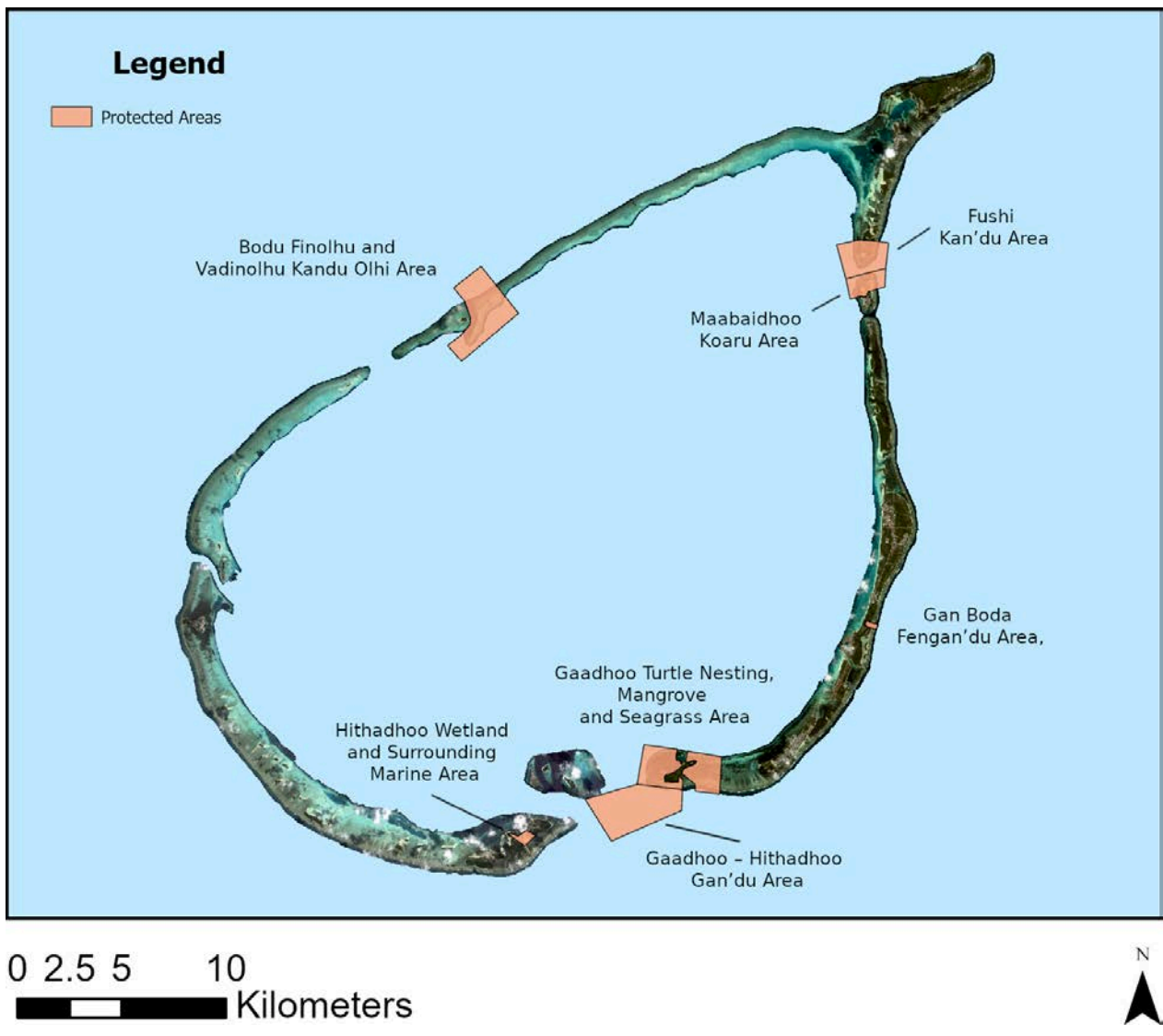


Figure caption: Protected areas within Laamu Atoll, since 2021.

5.1 Bodu Finolhu and Vadinolhu Kandu Olhi Area

Overview

The protected area (7.06 km²) covers a natural channel to the north of Laamu Atoll. The area contains two sand banks that are exposed at low tide. The windward area contains a coral reef, which leads to a rubble flat, and sand apron (deposits behind coral reefs). Coral reefs are found on both the windward and leeward sides and are the dominant key ecosystem within the area.

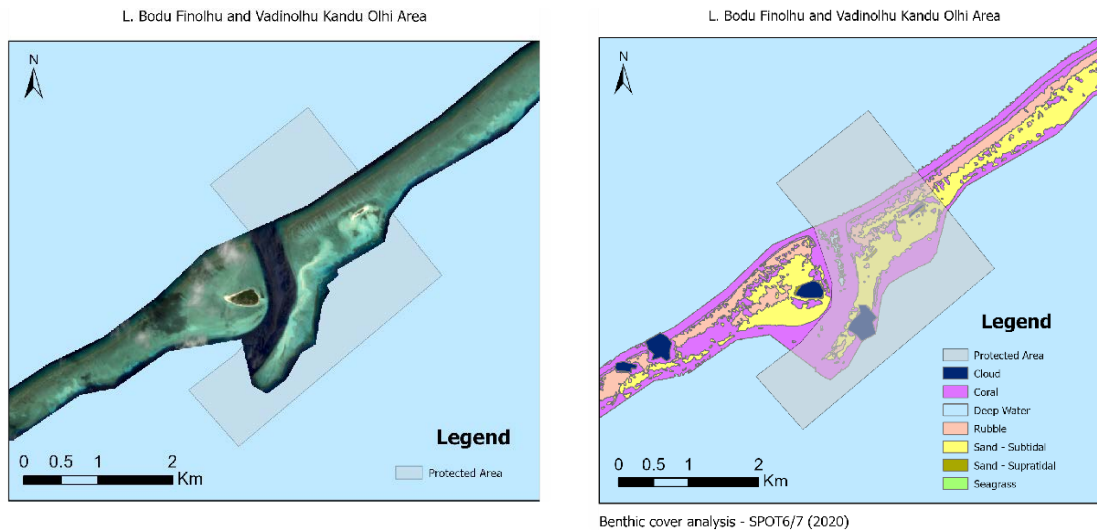


Figure caption: Satellite image of protected are (SPOT6/7 [2020]) and corresponding benthic habitat classification used to detect change. Different benthic covers coloured per the legend.

State and trend of key ecosystems within protected area

Please note errors due to cloud cover and satellite imagery processing.

Ecosystems	Year	Area (km ²)
Mangrove	-	No mangroves
Seagrass	-	No seagrass detected
Coral / macroalgae	2017	1.7418
Coral / macroalgae	2020	1.6398
Coral / macroalgae	Change	-0.1030 (decrease)

Ecosystem Services

Ecosystems	Ecosystem Services	Potential change	Reason
Coral / macroalgae	Food provisioning (Direct)	Decrease	As the area is now protected, fishing has been banned since 2021. This means no fish can be extracted from the area, limiting provisioning. The reputation for the area, and thus visitation, may increase due to its status as a protected area.
Coral / macroalgae	Nursery services	Increase	As fishing pressure has been reduced, there may be an increase in juvenile fish numbers, which may move to fishing areas as adults.
Coral / macroalgae	Coastal protection	None	There are no adjacent buildings or infrastructure to protect.
Coral / macroalgae	Recreational services	Stable (?)	The area contains a well-known dive spot, due to the large aggregation of fish. It is considered a channel dive for experienced divers due to strong currents. It has a maximum depth of ~35m. Visitation data is needed to determine change in the service.

5.2 Fushi Kan'du Area

Overview

The Fushi Kan'du and Maabaidhoo Koaru protected areas are found on the North-east side of the atoll, and span both the windward and leeward sides of the atoll. The Fushi Kan'du area (3.46 km²) is marine and contains coral reefs and seagrass, covering three vegetated but uninhabited islets. The area contains a well-known Manta Ray cleaning station and surf break, known as the "Machine".

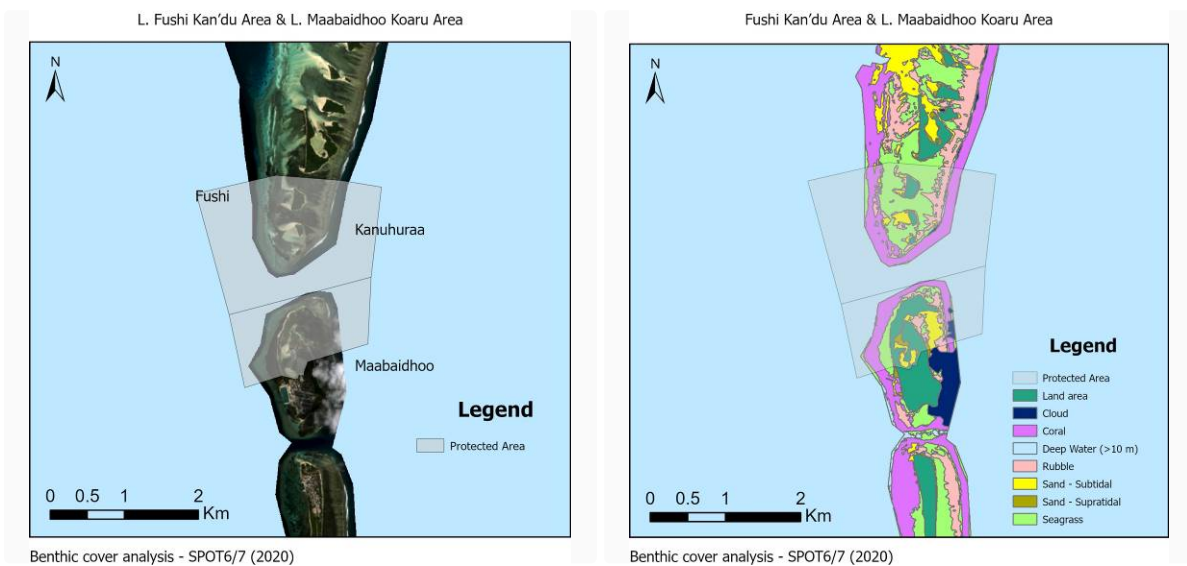


Figure caption: Satellite image of protected are (SPOT6/7 [2020]) and corresponding benthic habitat classification used to detect change. Different benthic covers coloured per the legend.

State and trend of key ecosystems within protected area

Please note errors due to cloud cover and satellite imagery.

L. Fushi Kan'du Area

Ecosystems	Year	Area (km ²)
Mangrove	-	None detected.
Seagrass	2017	0.4745
Seagrass	2020	0.5278
Seagrass	Change	0.0533 (increase)
Coral / macroalgae	2017	0.4786
Coral / macroalgae	2020	0.4612
Coral / macroalgae	Change	-0.0174 (decrease)

Ecosystem Services identified

Ecosystems	Ecosystem Services	Potential change	Reason
Coral / macroalgae	Food provisioning (Direct)	Decrease	As the area is now protected, fishing in the area has been banned since 2021.
Coral / macroalgae	Nursery services	Increase	As fishing pressure has been reduced, there may be an increase in juvenile fish numbers, which may move to fishing areas as adults.
Coral / macroalgae	Coastal protection	None	There are no buildings to protect on Fushi and Kanuhurra.
Coral / macroalgae	Recreational activities	Stable (?)	<p>The designation to a protected area will:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Stabilize or increase snorkelling and diving activities, and <input type="checkbox"/> Decreasing the potential for recreational fishing. <p>The area contains one of the most visited dive spots in Laamu Atoll, due to the channel's reputation as an aggregation for sharks, in addition to abundant sea turtles, snapper and trevally. Like most Kandu dives, it is recommended for experienced divers due to strong currents. It has a maximum depth of ~35m. Visitation data is needed to determine change in the service. The reputation for the area, and thus visitation, may increase due to its status as a protected area.</p>
Seagrass	Nursery services	Stable	The marginal change in seagrass should present no change in nursery services.
Seagrass	Coastal protection	None	There are no buildings to protect on Fushi and Kanuhurra.

Seagrass	Carbon sequestration and capture	Stable	There should be no major change in seagrass carbon sequestration.
Seagrass	Recreational services	Stable	During discussions with local stakeholders, there was no indication of direct snorkelling activity on the seagrass. It could, however, promote the aggregation of turtles and other megafauna that are important to tourism.

Maabaidhoo Koaru Area

The Maabaidhoo Koaru is a wetland protected area (1.74 km²) that covers the northern part of Maabaidhoo Island, which is predominantly a shallow inland lake / lagoon. The riparian zone of the lake (area between water and land) is mostly mangrove associates, although true mangroves have been introduced through planting near the football ground. The mangroves do not appear to have been present previously within Maabaidhoo. The sediments are sand dominated, making it unlikely for mangroves to expand and form a true forest without further manipulation of the environment. The northern area of the island appears to have been planted with rows of coconut trees.

The developed area of Maabaidhoo is estimated to contain 565 people (2022 census).² Infrastructure on the island includes an industrial processing area, jetty, powerhouse, and communications tower. The island also contains a health centre, school (Laamu Atoll School) and over 200 buildings (residential or commercial). The island also contains a football ground (~7000 m²).

State and trend of key ecosystems within protected area

Ecosystems	Year	Area (km ²)
Mangrove	-	Thirty-two individual saplings (< 0.5 m) and trees were identified during site visit.
Seagrass	2017	0.1970
Seagrass	2020	0.1783
Seagrass	Change	-0.0187 (decrease)
Coral / macroalgae	2017	0.2764
Coral / macroalgae	2020	0.2958
Coral / macroalgae	Change	0.0194 (increase)

Please note errors due to cloud cover and satellite imagery.

² Maldives Bureau of Statistics, Republic of Maldives.

Ecosystem Services identified

Ecosystems	Ecosystem Services	Potential change	Reason
Coral / macroalgae	Food provisioning (Direct)	Decrease	As the marine area is now protected, fishing in the area has been banned since 2021.
Coral / macroalgae	Nursery services	Increase	As fishing pressure has been reduced, there may be an increase in juvenile fish numbers, which may move to fishing areas as adults.
Coral / macroalgae	Coastal protection and erosion control	Stable	The corals within the protected area are part of the reef that encircles Maabaidhoo, although the area is not directly adjacent to urban and developed areas. The corals within the protected area, however, contribute to the stability of the island of Maabaidhoo. Due to the roughness and complexity of coral substrate, coral is responsible for most of the protection of the island from wave energy.
Coral / macroalgae	Recreational activities	Stable (?)	There was minimal change to coral detected, but further information is needed to identify changes to tourism visitation and use of the area. Recreational fishing may be impacted, decreasing the service. However, tourism through snorkelling and diving may remain stable.
Seagrass	Nursery services	Stable	The marginal change in seagrass should present no change in nursery services.
Seagrass	Coastal protection	Stable	As with the corals reefs, the seagrass within the protected areas are not adjacent to developed areas. They do, however, trap sediment and assist in reducing erosion to beaches and areas adjacent to developed areas. Seagrass contribute to coastal protection and erosion control, additional to coral reefs. Most protection, however, is reliant on coral reefs as opposed to seagrass meadows. Since the amount of seagrass is stable, it could be considered that the service has not changed over time.
Seagrass	Carbon sequestration and capture	Stable	As extent of seagrass remains the same, there is not estimated change in seagrass carbon sequestration.
Mangroves	Coastal protection	None	In L. Maabaidhoo Koaru Area, mangroves are not at a density to protect from wind energy. They are inland and therefore offer limited protection from waves.
Mangroves	Flood mitigation	None	The mangroves were predominantly saplings that were spaced apart. They are currently not at a density to reduce flooding from extreme rainfall events. The surrounding geomorphology of the area (shape), however, is a natural lake, which could assist in reducing flooding.
Mangroves	Carbon sequestration and capture	Increase	Young mangrove trees were identified in the field survey. They have been planted in the lake area. Growing mangrove trees will begin to increase sedimentation and trap more carbon. Their increase in number will sequester carbon, although they will first need to establish root systems.

5.3 Gan Boda Fengan'du Area

Historical Overview

The Gan Boda Fengan'du protected area is 0.15 km² and is both wetland and terrestrial. Gan in Laamu Atoll is the largest inhabited island in the Maldives with an area of approximately 633 ha and with 3,080 residents. The population density is the lowest in Laamu Atoll, with 4.6 persons/ha. The area contains Pari Fengan'du, a wetland frequently visited by local people and associated with several local legends. The area is mostly coastal vegetation and mangrove associates (sea hibiscus and screw pine) and coconuts trees, although there were few true mangrove trees identified during the field visit (*Brugeria spp.*).



Figure caption: Bodu Fengan'du, or Pari Fengan'du at L. Gan (Photo/Salt and Sunny)

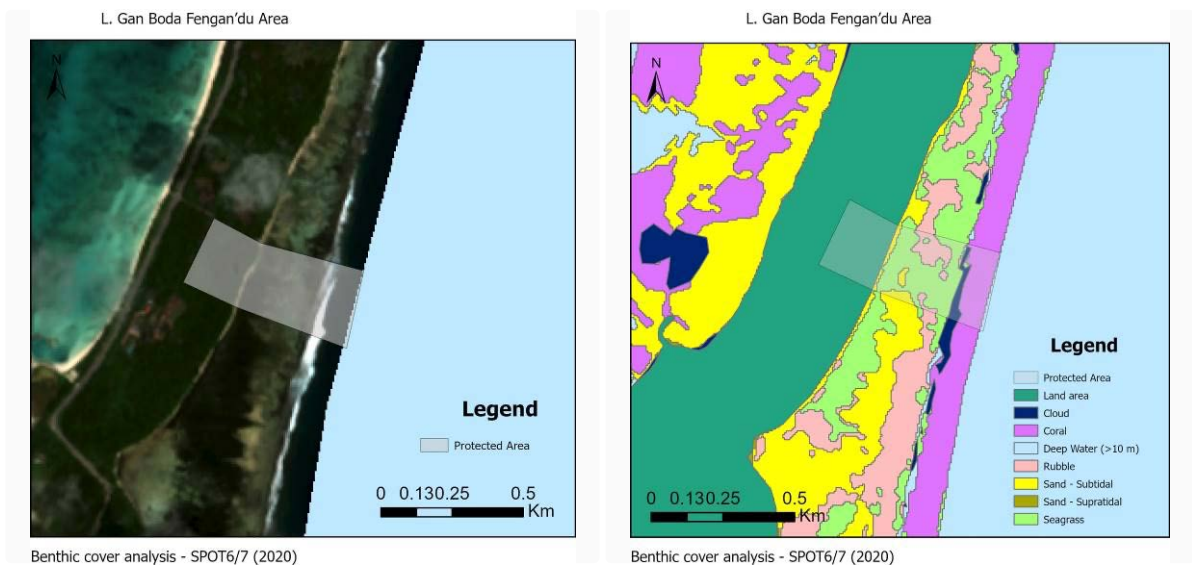


Figure caption: Satellite image of protected are (SPOT6/7 [2020]) and corresponding benthic habitat classification used to detect change. Different benthic covers coloured per the legend.

State and trend of key ecosystems within protected area

Please note errors due to cloud cover and satellite imagery.

Ecosystem	Year	Area (km ²)
Mangrove	-	Could not be detected with satellite imagery.
Seagrass	2017	0.0946
Seagrass	2020	0.1117
Seagrass	Change	0.0171 (increase)
Coral / macroalgae	2017	0.0279
Coral / macroalgae	2020	0.0274
Coral / macroalgae	Change	-0.0005 (decrease)

Ecosystem Services

Ecosystem	Ecosystem Services	Potential change	Reason
Coral / macroalgae	Food provisioning (Direct)	Reduced	As the area is now protected, fishing in the area has been banned since 2021. It is unlikely, however, that fishing was conducted directly over the shallow corals (reef crest) that are now within the protected area.
Coral / macroalgae	Nursery services	Stable	The same level of nursery services is expected.
Coral / macroalgae	Coastal protection and erosion control	Stable	There are no buildings to protect. Coral reefs, however, prevent further erosion of the narrow beach near the road through reducing wave energy.
Seagrass	Nursery services	Stable	The marginal increase in seagrass may lead to further fish habitat.
Seagrass	Erosion control	Stable	Seagrass contribute to coastal protection and erosion control, additional to coral reefs. Most protection, however, is reliant on coral reefs as opposed to seagrass meadows. Since the amount of seagrass is stable, it could be considered that the service has not changed over time.
Seagrass	Carbon sequestration and capture	Stable or increasing	The marginal increase in seagrass may lead to further carbon sequestration.
Mangroves	Flood mitigation	None	As an inland water body, the area may contribute to flood mitigation from extreme rainfall, in carrying water away from developed areas. In the Gan Bodu Area, mangroves may not be at a density to contribute significantly to flood reduction. Most of these services could be contributed instead to mangrove affiliates, including screw pine (<i>Pandanus tectorius</i>) and box-fruit tree (<i>Barringtonia asiatica</i>).

Mangroves	Carbon sequestration and capture	Stable	The mangroves within the Gan Bodu Area are mature and will contribute to carbon sequestration. Further data is needed to determine if trees have been lost over time, impacting carbon sequestration.
Mangroves	Recreational and cultural services	Stable	The Gan Bodu Area, also known as Parea Fengandu, is a well-known recreation spot for the inhabitants of Laamu Atoll, and the area is also associated with several cultural stories / myths. The reputation for the area, and thus visitation, may increase due to its status as a protected area.

5.4 Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area

Overview

The L. Gaadhoo Turtle Nesting Area, Mangrove and Seagrass Area (6.14 km²) is both terrestrial and marine. Gaadhoo Island is identified as a significant nesting site for turtles, specifically for the Green turtle (*Chelonia mydas*). In 2006, legislation banned egg harvesting from Gaadhoo island, which was recognized alongside 14 other islands in the Maldives. A 2016 study by The [Maldives Marine Research Institute](#) identified Gaadhoo as having the highest percentage of turtle nesting (44%) and 71 true nests in a 6-month period. An estimated 178 females used the area. The residents of Gaadhoo were moved in 2015, meaning there are no permanent residents on the island.

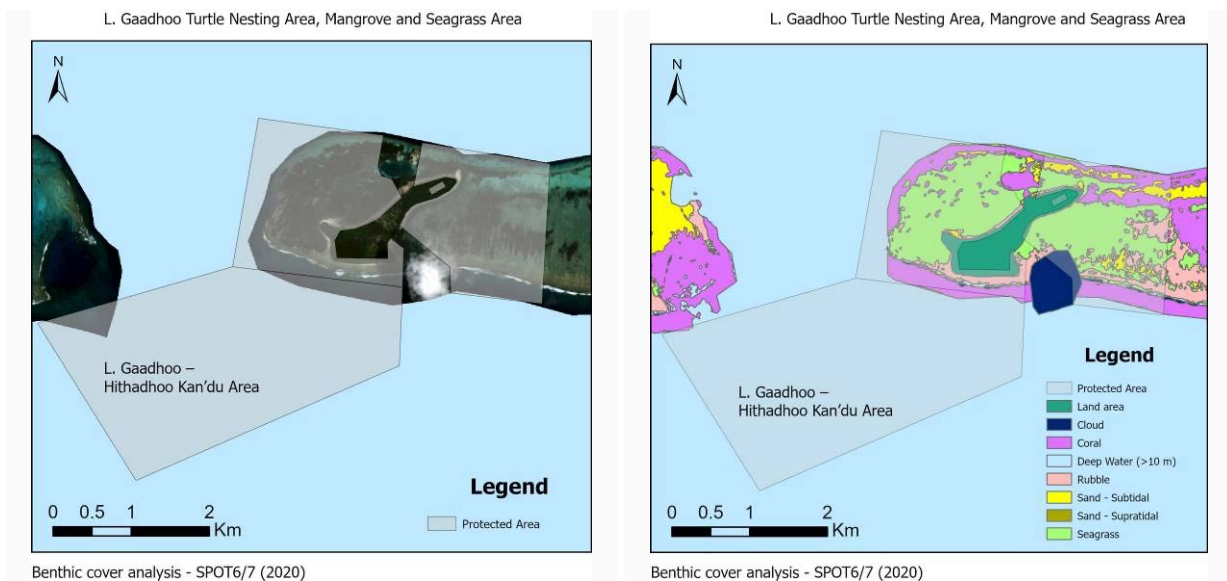


Figure caption: Satellite image of protected are (SPOT6/7 [2020]) and corresponding benthic habitat classification used to detect change. Different benthic covers coloured per the legend.

State and trend of key ecosystems within protected area

Please note errors due to cloud cover and satellite imagery processing.

Ecosystems	Year	Area (km2)
Mangrove	-	Could not be detected with satellite imagery.
Seagrass	2017	0.0946
Seagrass	2020	0.1117
Seagrass	Change	0.0171 (increase)
Coral / macroalgae	2017	1.3768
Coral / macroalgae	2020	1.2967
Coral / macroalgae	Change	-0.0801 (decrease)

Ecosystem Services

Ecosystems	Ecosystem Services	Potential change	Reason
Coral / macroalgae	Food provisioning (Direct)	Decrease	As the surrounding area is protected, fishing is banned. Thus, there is an expected decrease in the service. Further data, however, are needed to monitor the enforcement of the protected area.
Coral / macroalgae	Nursery services	Stable / Increase	As human activity has been significantly decreased and coral extent remains unchanged, the survival of juveniles is expected to increase.
Coral / macroalgae	Coastal protection and erosion control	Stable	Buildings have been vacated and are not managed within the residential zone. As an agricultural island, cultivated land is protected from erosion and saltwater intrusion by the coral reef.
Seagrass	Nursery services	Increase	As human activity has been significantly decreased and coral extent remains unchanged, the survival of juveniles is expected to increase.
Seagrass	Coastal protection	Stable	Buildings have been vacated and are not managed within the residential zone. The seagrass reduces the potential for erosion on beaches, which is an important barrier between the ocean and agricultural land.
Seagrass	Carbon sequestration and capture	Stable / Increase	The estimated increase in seagrass may lead to further carbon sequestration.
Mangrove	Flood mitigation	None	Mangroves were not at a density to reduce flooding impacts. Most of these services could be contributed instead to mangrove affiliates, including screw pine (<i>Pandanus tectorius</i>) and box-fruit tree (<i>Barringtonia asiatica</i>).
Mangrove	Carbon sequestration and capture	Could not be determined	Further field trips are needed to identify mangrove locations for mapping using remote sensing.

5.5 Gaadhoo – Hithadhoo Kan’du Area

Overview

The Gaadhoo – Hithadhoo Kan’du Area (7.77 km²) is the largest protected area on Laamu Atoll. It is a marine protected area, with a benthic habitat composed of coral reefs, sand and rubble. Due to site depth, benthic cover mapping and estimates could not be performed.

The area has several dive spots and are a known Manta Ray cleaning station. It has also been noted as a Grouper aggregation spot.

Ecosystem Services

Ecosystem	Ecosystem Services	Potential change	Reason
Coral / macroalgae	Food provisioning (Direct)	Decrease	As the area is now protected, fishing in the area has been banned since 2021.
Coral / macroalgae	Nursery services	Stable	The same level of nursery services is expected
Coral / macroalgae	Coastal protection and erosion control	Stable	There are no buildings to protect. Coral reefs, however, prevent further erosion of the narrow beach near the road
Coral / macroalgae	Recreational activities	Stable (?)	The area contains dive sites (Gaadhoo Kandu, shark point), but further information is needed to identify changes to visitation.

5.6 Hithadhoo Wetland and Surrounding Marine Area

Overview

The Hithadhoo Wetland and Surrounding Marine Area protects wetland (mangrove) and marine areas, spanning 0.43 km². The Hithadhoo mangrove wetland is the only clearly identifiable true mangrove forest using remote sensing on Laamu Atoll. The forest is visited by locals for raw materials and medicinal uses.

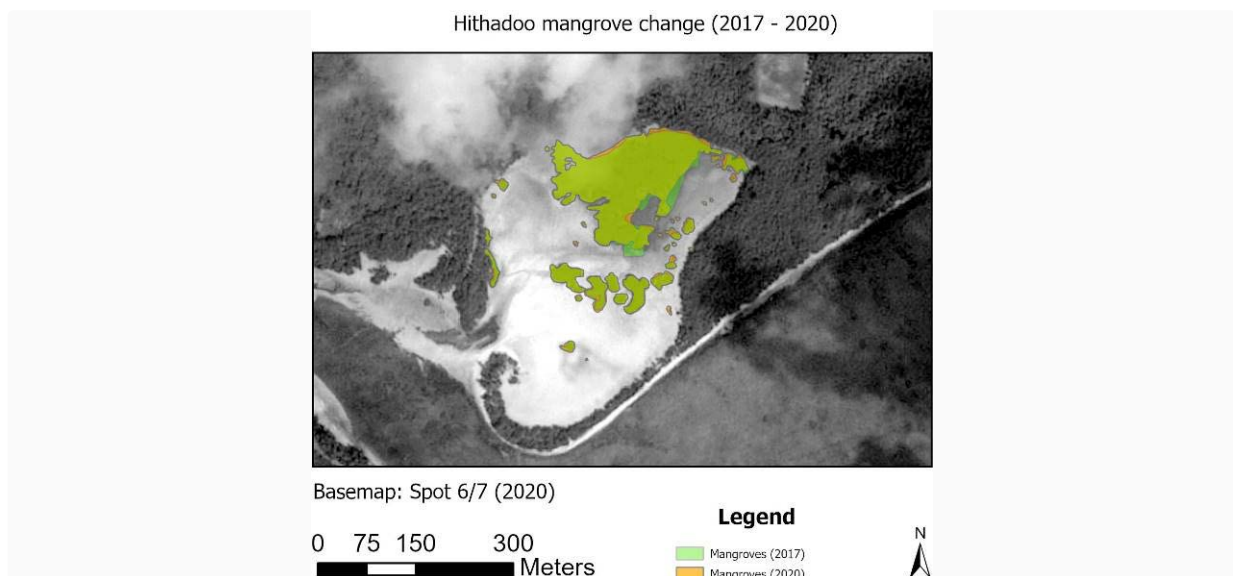


Figure caption: Aerial view of the mangrove change in extent.

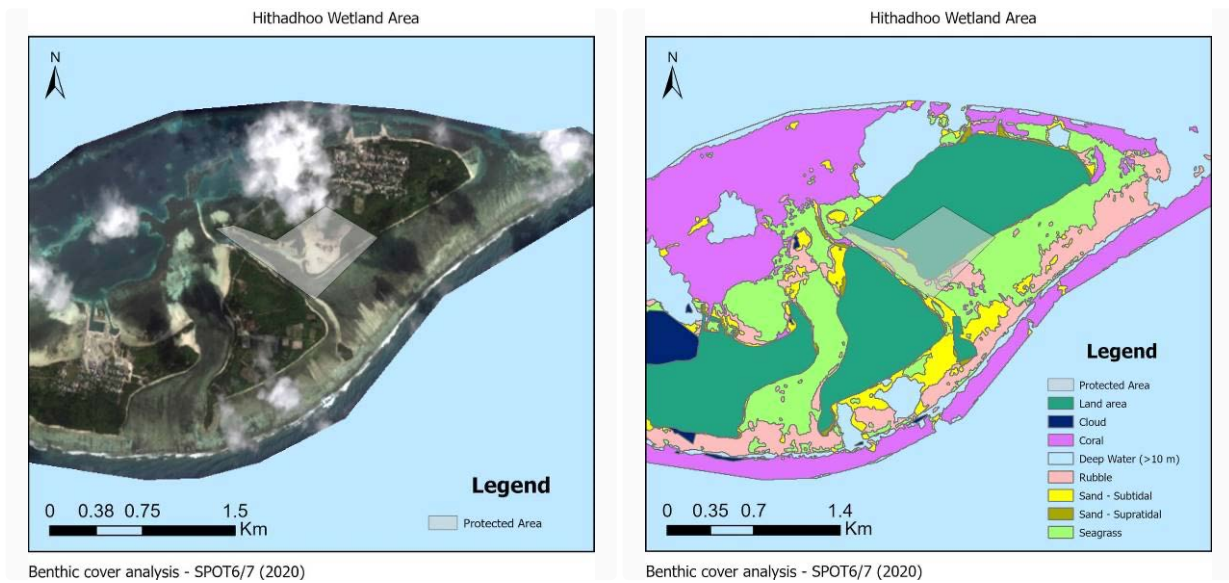


Figure caption: Satellite image of protected are (SPOT6/7 [2020]) and corresponding benthic habitat classification used to detect change. Different benthic covers coloured per the legend.

State and trend of key ecosystems within protected area

Please note errors due to cloud cover and satellite imagery.

Ecosystem	Year	Area (km ²)
Mangrove	2017	0.0321
Mangrove	2020	0.0324
Mangrove	Change	0.0003 (increase)
Seagrass	2017	0.0946
Seagrass	2020	0.1117
Seagrass	Change	0.0171 (increase)

Ecosystem Services

Ecosystem	Ecosystem Services	Potential change	Reason
Seagrass	Nursery services	Stable / Increase	The estimated increase in seagrass may lead to further habitat for important species.
Seagrass	Erosion control	Stable	While the developed areas
Seagrass	Carbon sequestration and capture	Stable / Increase	The estimated increase in seagrass may lead to further carbon sequestration.
Mangroves	Raw materials / local medicines	Stable	Locals spoke of the use of medicinal ingredients from the mangroves during the field survey.
Mangroves	Coastal protection & flood mitigation	Stable	There are no buildings immediately adjacent to the mangroves. There are, however, planted coconuts which are an important source of food and raw materials, which are protected by the mangroves. The mangroves may also serve to capture excessive rainfall, reducing the amount which may have entered developed areas.
Mangroves	Carbon sequestration and capture	Stable	The minimal change in mangroves suggests stable carbon sequestration.
Mangroves	Recreational services	Stable	Locals spoke of visitation to the mangroves for recreational and cultural practices.

5.7 Plans for tourism ecosystem services research

This preliminary assessment identified key data gaps for ecosystem services, which could be addressed by targeted surveys and access of further data. Lacking data could be organized into (i) the use of ecosystems by specific tourism-related activity and (ii) the value of tourism related activities.

In terms of ecosystem use, further data is needed to identify the proportion of tourists that (i) directly engage with marine ecosystems through activities such as snorkelling and diving, or (ii) visit specific the Maldives and specific atolls due to the reputation of Maldives' marine ecosystems. Relevant data could be gathered through the [Maldives Tourism Survey](#), where 59% of respondents stated that their reason for visiting was Maldives' underwater beauty and 30% identified Maldives' reputation as another factor. Respondents also identified snorkelling (17%) and diving (9%) as key purposes for the visit. Further financial data on tourism expenditure should be captured. The project will attempt to develop methods and analyses linking tourism visitation and activities within Laamu Atoll to specific ecosystem services.

In terms of valuing tourism-related activities, further efforts are needed to disaggregate those specifically related to the environment. A first step in identifying such activities is through the International Standard Industrial Classification (ISIC) codes, which further assist in the production of a Tourism Satellite Account (TSA). A TSA was produced by the [Maldives Bureau of Statistics in 2017](#), containing the value of tourism products and activities, such as:

- Accommodation,
- Food and beverage services,
- Land, air, and water passenger transport,
- Travel and reservation agencies, and
- Cultural, sports and recreational services.

The proportion of cultural, sports and recreational services related to marine ecosystems could be estimated through targeted surveys and interviews. This could determine the frequency of tourists and amount spent on diving and snorkelling activities.

5.8 Conclusion

In conclusion, this report has provided an assessment of the changes in ecosystems extent and the resultant potential changes in the provision of ecosystem services within six protected areas across Laamu Atoll. The analysis accounts for whether services are present, based on recipients / beneficiaries and the potential trend due to the change in protected status. Satellite data enabled a preliminary assessment of changes in the extent of key ecosystems (mangrove, coral reef, and seagrass), with ground truthing providing an understanding of local conditions and changes.

The report also identified further plans to gather data for ecosystem services, especially those related to recreation and tourism.

The analysis provides a means to:

- Assess changes in the extent of ecosystems within the protected areas over time,
- Assess potential changes to ecosystem services, and
- Provides considerations for the alteration or extension of managed areas.

Annex

Seagrass methods:



<http://maldivesresilientreefs.com/resources/MaldivesSeagrassMonitoringMethods.pdf>
<http://maldivesresilientreefs.com/resources/MaldivesSeagrassMonitoringMethods.pdf>

Mangrove methods:



Draft_Module 1_Ecosystem Condition Survey.pdf
<https://drive.google.com/file/d/12va5d7uDcBgwQKmwT3AgnMq60Len-QV/view?usp=sharing>
https://drive.google.com/file/d/12va5d7uDcBgwQKmwT3AgnMq60Len-QV/view?usp=sharing&usp=embed_facebook

Coordinates of protected areas on Laamu Atoll

Name	Date of Protection	Area (km ²)	Coordinates (X, Y)
L. Gan Boda Fengandu Area	23/12/2021	0.15	73.53376, 1.885685
L. Maabaidhoo Koaraai Fushi kandu sarahadhdu	23/12/2021	3.46	73.53068, 2.039574
L. Bodu Finolhu adhi Vadinolhu Kandu Olhi sarahadhdu	23/12/2021	7.06	73.3685, 2.019181
L. Gaadhoo key biodiversity areas	23/12/2021	6.14	73.44555, 1.821906
L. Gaadhoo Hithadhoo Kandu	23/12/2021	7.77	73.43552, 1.805808
L. Hithadhoo Kulhi aai vashaigenvaa sarahadhdu	23/12/2021	0.43	73.3855, 1.792731