Ministry of Environment,
Climate Change
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ENDhERI

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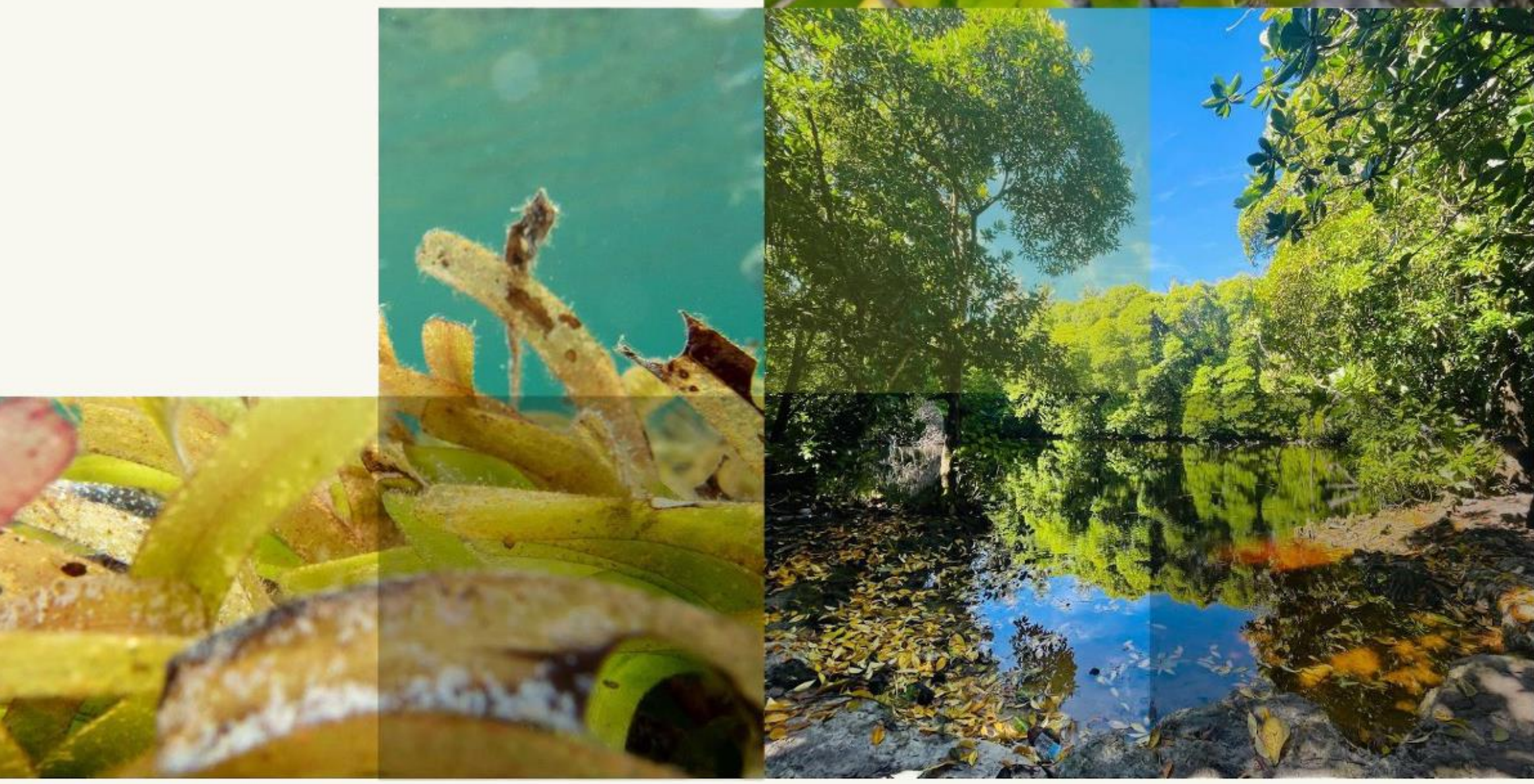
Preliminary survey of ecosytem extent and condition in Laamu Atoll, Maldives



Global Ocean Accounts Partnership

UNSW SYDNEY

THE MALDIVES NATIONAL UNIVERSITY

REKAM NUSANTARA FOUNDATION

Preliminary survey of ecosystem extent and condition in Laamu Atoll, Maldives

28 April 2023

Submitted to the Ministry of Environment, Climate Change and Technology (MECCT), Republic of the Maldives as part of the project, "*Development of Natural Capital Accounting with initiating pilot testing of the SEEA Ecosystem Accounting (SEEA EA) in Laamu Atoll*".

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Introduction

1.1 Background

The Maldives is an archipelagic country in the Indian Ocean. It comprises a chain of around 1,192 tiny islands that stretch from north to south with the islands being surrounded by the ocean. The country has a great diversity of marine life and various coastal ecosystems, such as coral reefs, seagrass beds, and mangrove forests. The coastal ecosystems are a hotspot for biodiversity and provide a habitat for a vast array of marine life and are home to over 1,100 species of fish, sea turtles, and other marine creatures, including sharks, rays, turtles, and birds. The Maldives' diverse and complex coastal ecosystems play a crucial role in maintaining the health of the ocean and the well-being of the Maldivian people.

The Government of the Republic of Maldives through the Ministry of Environment, Climate Change and Technology is implementing Enhancing National Development through Environmentally Resilient Islands (ENDhERI) project financed by Global Environment Facility (GEF) and assisted by United Nations Environment Program (UNEP) with the objective of enhancing reef protection, resilience and ecosystem recovery by reducing development impacts in Laamu atoll, enabled for replication nationally through public awareness and integrating the values of marine biodiversity and other natural capital in national development planning.

With the goal of assisting the government of the Maldives in its implementation of new environmental policies and transition towards national adoption of Green Growth atoll development and integrating Natural Capital accounting in to national planning, ENDhERI project 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 an essential tool to promote sustainable developments and help ensure that the value of natural resources and the ecosystem in the Maldives, especially in Laamu Atoll, is fully accounted for in the decision-making process. Hopefully, the pilot testing of the SEEA EA framework in Laamu Atoll will generate valuable information on the health and productivity of the region's ecosystems and how to contribute to the local economy and people's well-being. The research will provide the basis for a fit-for-purpose accounting system in line with the System of Environmental-Economic Accounting (SEEA) framework, particularly the SEEA Ecosystem Accounting (SEEA EA) framework.

The project initiative started with several activities, including a visit to Laamu Atoll. This visit also served as a preliminary survey to gather information on the availability of coastal ecosystem data in Laamu Atoll and ground truthing on the condition of the Mangrove ecosystem and Seagrass bed. This information was used to identify any potential issues or challenges that may need addressing before the project can proceed. Furthermore, the preliminary survey results are typically used to develop a more detailed plan or proposal for the project.

1.2 Objective

The objective of the site visit was to gather general information on the extent and condition of the seagrass and mangrove ecosystems in Laamu Atoll in the Maldives.

Methods

2.1 Ecosystem Extent

2.1.1 Data Collection

Data collection in the ecosystem extent study in Laamu Atoll was carried out in February-April 2023. The data used in this study came from digitization, field survey results, and satellite imagery (Table 1).

Table 1. Types and Sources of Data in the Extent Ecosystem Study in Laamu Atoll

Types of Data	Sources
Ground truth	Field survey results
Island Polygon	Digitization results
Sentinel-2 imagery	https://earthexplorer.usgs.gov/

2.1.2 Data Processing

Ecosystem extent data processing in this study adopted a remote sensing approach divided into two stages, i.e., pre-field and post-field surveys. Remote sensing is collecting and interpreting information from an object, area, and occurrence without physical contact with the object. Aircraft and satellites are the common platforms for remote sensing of the earth and its natural resources (Kairu, 1982). There are eight interpretation elements to be considered: size, shape, shadow, tone, color, texture, pattern, and association (Susanto, 1994).

Pre-Field Survey Data Processing

Data processing was carried out by interpreting satellite imagery to obtain an overview of objects of mangroves, seagrasses, coral reefs, and other substrates 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. Radiometric and atmospheric corrections aim to correct the pixel values to match the ideal values by considering the atmospheric disturbance factor as the primary source of error (Lukiawan et al., 2019). The sun glint correction aims to subtract the glint radiance$T(\lambda)L_{glint}$ from the measured value L_{sensor}, leaving a corrected radiance that can then be processed further to remove other terms and leave L_{water} (Kay et al., 2009).

The next process following the corrections is the interpretation of satellite imagery, both digitally and visually. Digital interpretation uses software by creating training samples on the images to generate a categorical division of the object to be observed. This study adopted the ArcGIS software to perform the interpretation process through guided classification using the maximum likelihood method. Meanwhile, visual interpretation applies eight keys in interpreting satellite images.

Post-Field Survey Data Processing

Data processing was carried out by re-interpreting satellite imagery and comparing the data generated from pre-survey data processing and the information obtained from a field survey through points and photos taken and recorded during a survey.

2.1.3 Field Survey

A field survey was conducted to validate/test the correctness of the satellite imagery interpretation to generate data on mangroves, seagrasses, coral reefs, and other substrates. The expected information obtained from this field survey is location points that indicate objects at the location. These points will be used to test the correctness of the interpretation preceding the field survey.

The determination of sample points in this study employed a purposive sampling technique, which is a sampling technique with particular considerations according to the desired criteria to determine the number of samples to study (Sugiyono, 2018). The 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.

The field survey methods in this study included snorkeling and visual observation at the observation sites, taking pictures in four different cardinal directions, and recording the pictures.

2.2 Ecosystem Condition

2.2.1 Seagrass Ecosystem

Determination of Observation Sites

Determining observation sites in this study employed a purposive sampling technique and used basic data from satellite imagery. The initial mapping of the seagrass ecosystem in Laamu Atoll considered the differences in color tone and object characteristics on the satellite imagery. After that, survey locations were selected by taking into account several aspects, including the cardinal directions and wind direction (windward and leeward). Some other considerations in determining the survey locations included weather conditions and accessibility to the locations. In the preliminary survey, seagrass data collection in Laamu Atoll took place in six locations, i.e., South Hithadhoo, North Hithadhoo, East Maavah, Southwest Maavah, West Maabaidhoo, and Southeast Kalhaidhoo (Figure 1).

Figure 1. Survey locations for seagrass data collection

Data Collection Method

Seagrass observations employed the line transect method adopted from Seagrass Watch (modified) (McKenzie, 2003). The transect line was drawn perpendicular from the shoreline to the reef crest for a distance of 50 m to 150 m. The difference in the length of the transect line was adjusted to the seagrass ecosystem area that stretches from the shoreline to the reef crest. This way aimed to ensure the representation of the condition and species of seagrass found in the location. Furthermore, observations were made using a 1x1m squared transect placed systematically along the transect line with a distance of 5 m between transects. The quadratic transect was divided into 100 squares (10x10 cm) to facilitate observation and estimation of seagrass cover (Figure 2). The parameters observed included the type of substrate/sediment, cover percentage and name of seagrass species, seagrass canopy height, and macroalgae cover (Annex 1).

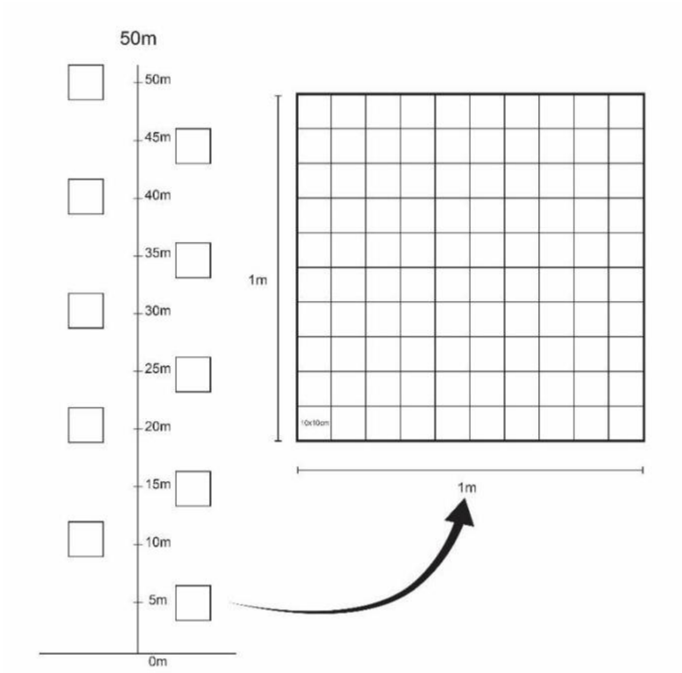


Figure 2. Illustration of seagrass data collection transects

Sediment type was determined by digging the top layer of the substrate on each quadratic transect using fingers and identifying the texture. Sediments can be categorized based on the size of the particles collected (e.g., coral rubble, sand, fine sand, silt, etc.). Seagrass cover percentage was taken in each squared transect using a visual estimation method based on Seagrass-Watch guidelines for standard seagrass cover percentage (McKenzie, 2003) (Annex 2). The percentage of cover taken was that of total seagrass cover and the cover of each seagrass species in the square (Figure 3). Seagrass species in quadratic transects were identified based on the Seagrass-Watch guidelines (McKenzie, 2003) (Annex 3).

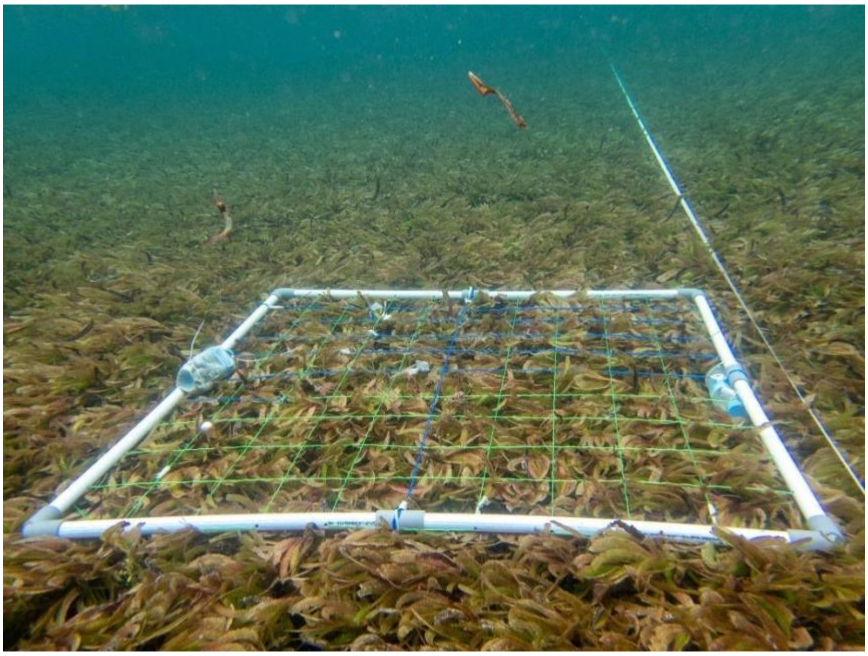
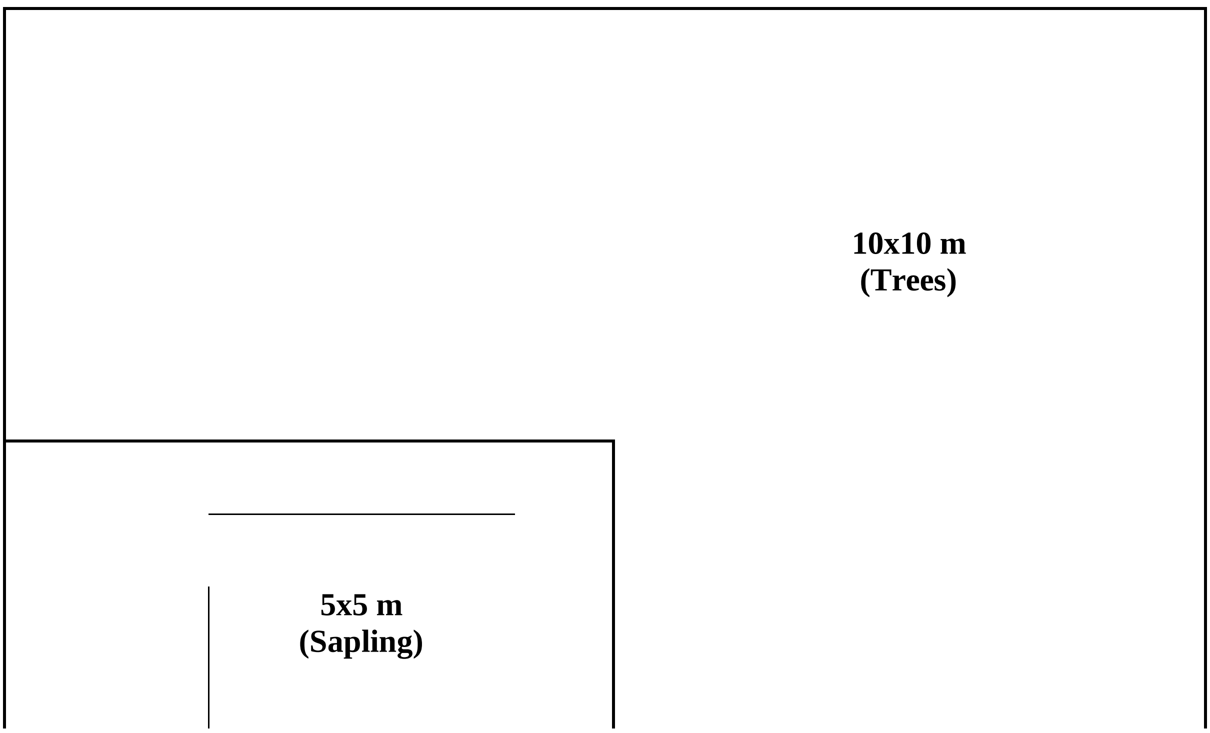


Figure 3. The transect used for seagrass data collection

2.2.2 Mangrove Ecosystem

Vegetation structure was measured using the Quarter plot sampling method to obtain baseline data for mangroves, including an analysis of the current condition of the mangrove community structure and assess the status of mangrove condition. Purposive sampling was carried out with the transect quadrat plot of 10 x 10 meters for mangrove trees, plot 5 x 5 meters for saplings, and plot 1 x 1 m for seedlings (Figure 4).

The method for collecting mangrove data in the research referred to the Manual for Mangrove Community Structure Monitoring in Indonesia-LIPI (Dharmawan et al., 2020). The purpose of vegetation structure measurement is to describe the current condition of the mangrove structure. Several data collected in the field, including species name, number of trees, diameter of tree, and height of tree in one plot. The plot was determined using purposive sampling method that referred to the Manual for Mangrove Community Structure Monitoring in Indonesia (Dharmawan et al., 2020). In this survey, mangrove data collection in Laamu Atoll took place in four locations, i.e., Hithadhoo A, Hithadhoo B, Maavah, and Maabaidhoo (Figure 5).



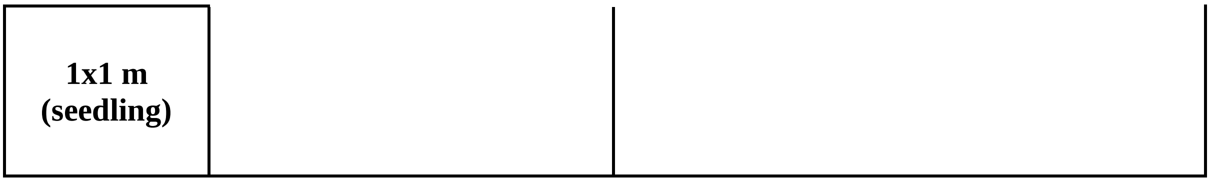


Figure 4. Sampling plot of mangrove ecosystem to measure vegetation structure

Figure 5. Survey locations for mangrove data collection

Results And Discussion

3.1 Ecosystem Extent

Laamu Atoll is one of the largest natural atolls in the world, comprising 88 islands, only 10 of which are inhabited. It is the second-largest atoll in the Maldives in terms of land area (McNamara et al., 2019). Its natural formation is characterized by its elongated shape, stretching over 48 kilometers from north to south and 28 kilometers from east to west. The atoll is surrounded by a shallow lagoon that varies in depth from just a few meters to over 50 meters, and is dotted with numerous coral reefs and sandbanks.

The ecosystem extent field survey in Laamu Atoll on 16-18 March 2023 aimed to validate the results of the satellite imagery interpretation. The field survey took place at three different locations in Laamu Atoll, covering 59 sample points, i.e., 28 sample points on Hithadhoo Island and its surroundings in the southern part, 19 points on Maava Island and its surroundings in the western part, and 12 points on Maabaidhoo-Kalhaidhoo Island and its surroundings in the northern part (Figure 6).

Figure 6. Locations of the Extent Ecosystem Field Survey in Laamu Atoll

The results of the interpretation and field survey at the three observation sites showed that the coastal ecosystems in Laamu Atoll comprised mangroves, seagrasses, coral reefs, and macroalgae. Seagrass dominated the areas between three class of coastal ecosystems in Laamu Atoll with an area of 4,128.77 ha; coral reefs, 3,121.21 ha; mangroves, 3.30 ha; and other substrates, 9,701.96 ha. The combined macroalgae and seagrass areas because macroalgae coexisted with seagrass and didn't have a large area. Another factor was the limitation of the satellite imagery in providing visual information to distinguish between seagrass and macroalgae (Figure 7).

Figure 7. Example of coexisting seagrass and macroalgae

Figure 8 shows the distribution of coastal ecosystems in Laamu Atoll, with seagrass dominating the island and the central part of the atoll. While other substrates dominated the outer edge of the atoll, coral reefs dominated the inner edge. We could also find small clusters of coral reefs and other substrates in the atoll's inner waters. Based on the satellite imagery analysis, mangroves were only detectable on Hithadhoo Island.

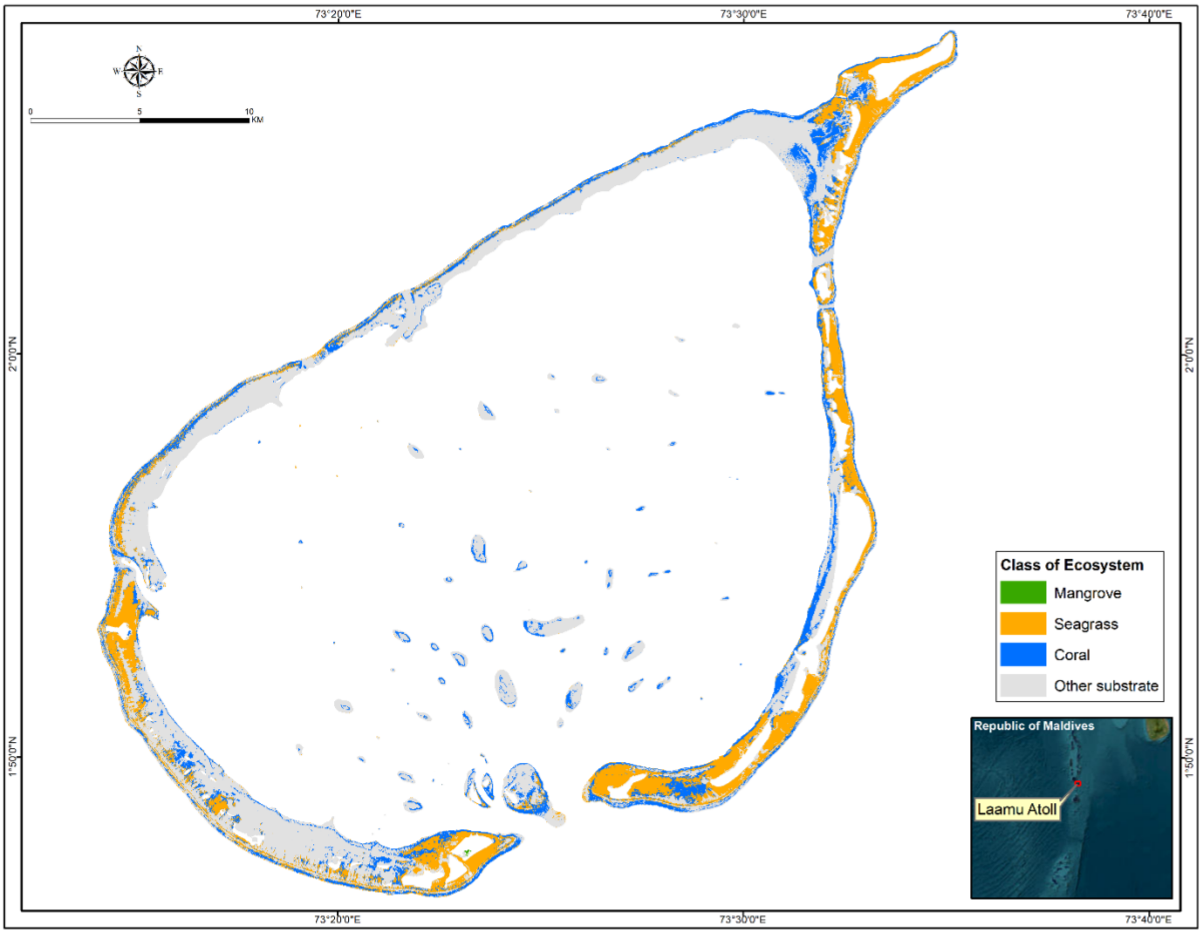


Figure 8. Distribution of coastal ecosystems in Laamu Atoll

3.2 Ecosystem Condition

3.2.1 Seagrass Ecosystem

The observations at six sites in Laamu Atoll showed that the seagrass vegetation was composed of multiple species per community. The field observations identified four seagrass species across sites:

- *Thalassia hemprichii* (Th),
- *Thalasadendron ciliatum* (Tc),
- *Syringodium isoetifolium* (Si), and
- *Cymodocea rotundata* (Cr) (Table 2).

Thalassia hemprichii and *Cymodocea rotundata* were the most common species at five of the six observation sites. Of all the observation sites, Southwest Maawah had the highest species variation. At least four seagrass species were found in the location (Figure 9).

Figure 9. Distribution of seagrass species diversity at each observation site

The study of MUI (Maldives Underwater Initiative) in 2019 and 2020 at other locations in Laamu Atoll (Six sense Laamu) found six seagrass species, i.e., Thalassia hemprichii (Th), Thalassodendron ciliatum (Tc), Halodule pinofilia (Hp), Syringodium isoetifolium (Si), Cymodocea rotundata (Cr), and Halophila ovalis (Ho) (Roe, 2020).

Table 2. Seagrass species found during observations in Laamu Atoll

Locations	Th	Tc	Si	Cr
South Hithadhoo	v	v		
North Hithadhoo	v		v	v
East Maavah			v	v
Southwest Maavah	v	v	v	v
West Maabaidhoo	v	v		v
Southeast Kalhaidhoo	v			v

a. *Thalassia hemprichii*

Thalassia hemprichii has *strap-like* and curved leaves and dark green in color, 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).

(a) (b)

Figure 10. Seagrass of *Thalassia hemprichii* species at the time of observation (a) and its illustrations (Source: Seagrass-Watch (McKenzie, 2003)) (b)

b. *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).

(a) (b)

Figure 11. Seagrass of *Thalassodendron ciliatum* species at the time of observation (a) and its illustrations (Source: Seagrass-Watch (McKenzie, 2003)) (b)

c. ***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 12. Seagrass of *Syringodium isoetifolium* species at the time of observation

d. ***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 13. Illustration of *Cymodocea rotundata* seagrass (McKenzie, 2003)

Seagrass cover and Composition

Seagrass cover can serve as an indicator of seagrass condition and health and provide information on biodiversity in an area (Hemminga & Duarte, 2000). Fahruddin et al., (2017) stated that the higher the seagrass cover, the better the seagrass ecosystem health. Information on seagrass cover can be obtained from the estimated percentage of seagrass cover that grows at the observation sites.

Seagrass cover at the observation sites ranged from 35.79% to 89.71%, with an average of 62.14%. The highest percentage of seagrass cover was found in Southeast Kalhaidhoo at 89.71%, followed by West Maabaidhoo at 83.23%. The location with the lowest seagrass cover was South Hithadhoo at 35.79% (Figure 14).

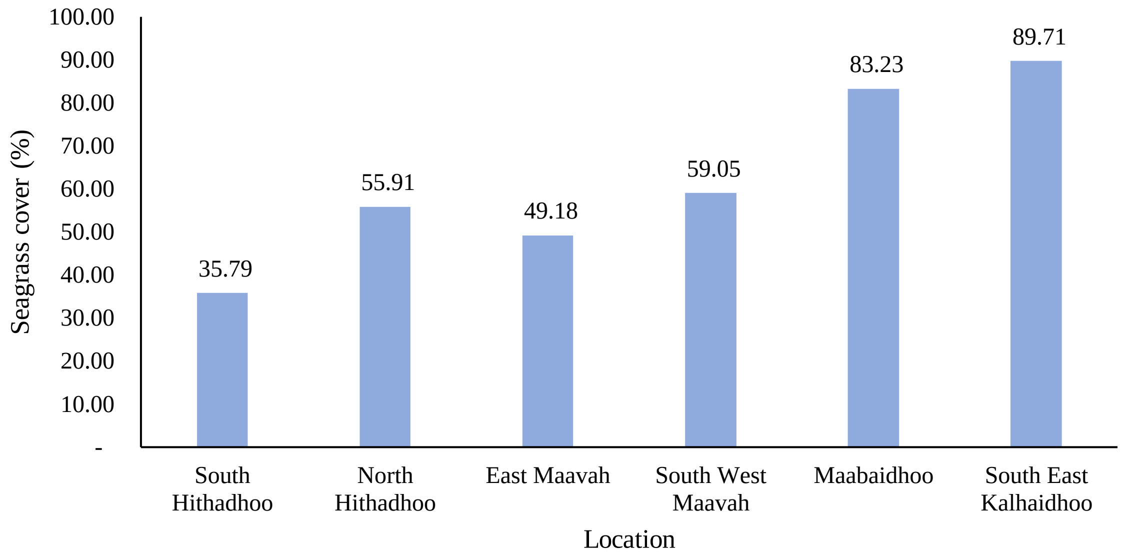


Figure 14. Percentage of seagrass cover at observation sites in Laamu Atoll

Seagrass cover per species for each observation site is presented in Figure 15. Two seagrass species were found in Southeast Kalhaidhoo, i.e., *Thalassia hemprichii* and *Cymodocea rotundata*, with the former being dominant. *Thalassia hemprichii* has large and wide leaves. According to Gosari & Haris (2012), large seagrasses have thicker, wider, and longer leaves allowing them to have a greater percentage of cover and photosynthetic capacity than other species. Apart from that, *Thalassia hemprichii* can live on various substrate types, ranging from smooth to coral rubble substrates, and will grow and dominate on coarse substrates where the sediment grain size is relatively large and coarse so that it can form monospecific vegetation on coarse sand with relatively shallow waters (Hartog, 1970; Tupan & Uneputty, 2018).

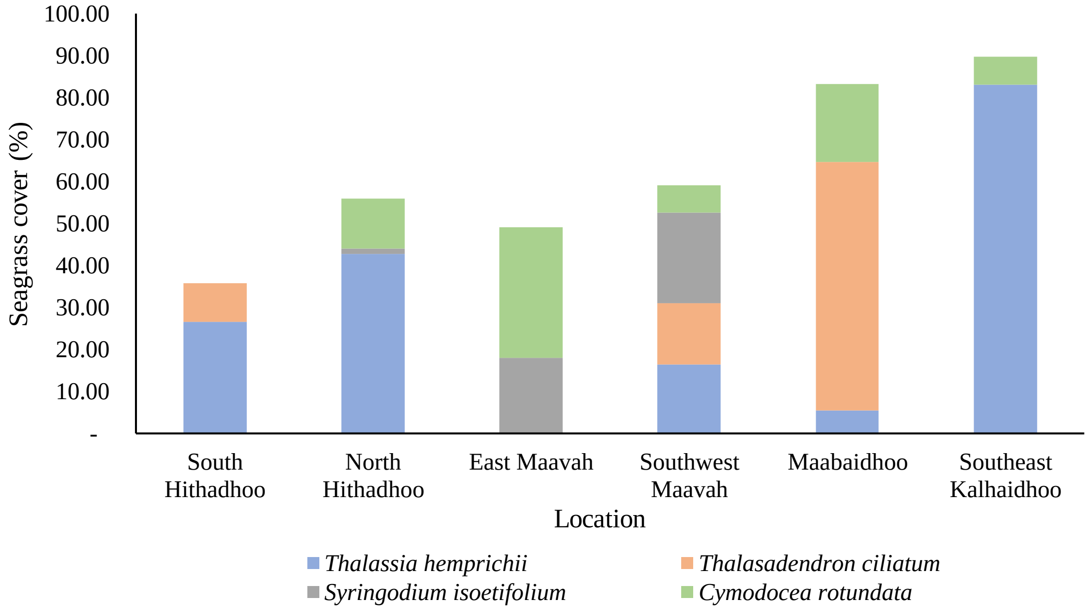
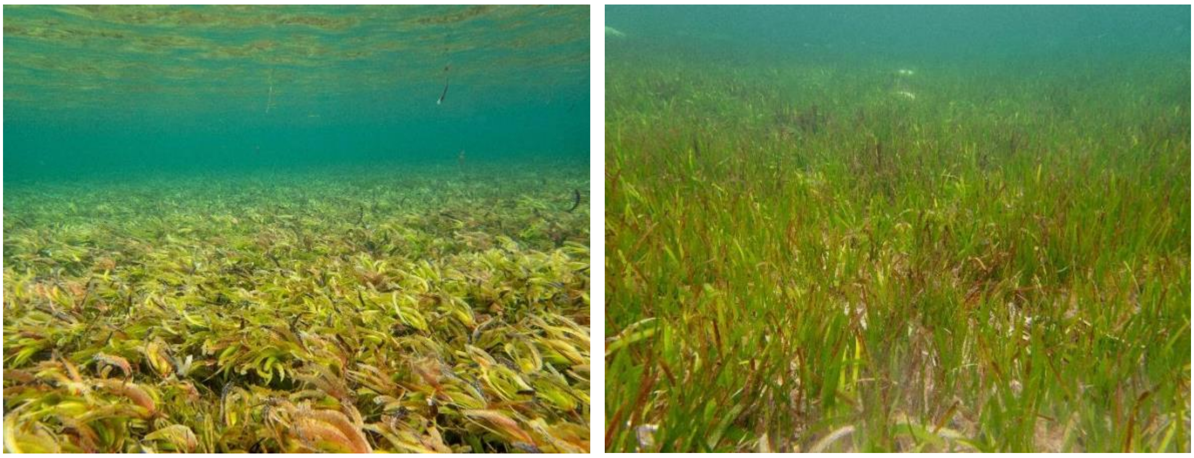


Figure 15. Seagrass cover per species at each observation site in Laamu Atoll

Figure 16. Seagrass cover in Southeast Kalhaidhoo

The location with the second-highest seagrass cover was West Maabaidhoo, where three seagrass species were found, i.e., *Thalassia hemprichii, Thalassodendron ciliatum*, and *Syringodium isoetifolium*. In contrast to Southeast Kalhaidhoo, *Thalassodendron ciliatum* predominated seagrasses in West Maabaidhoo. While *Thalassodendron ciliatum* was found to grow as a single species on the transect close to the shore (Figure 17a), *Thalassia hemprichii* and *Cymodocea rotundata* predominated the transect close to the coasts (Figure 17b). *Thalassodendron ciliatum* is a dominant seagrass species but has a limited distribution. It is commonly found growing to form monospecific communities which are dominant on sand, rubble, and especially hard substrates (coral), with strong waves and currents (Rani et al., 2020; Verheij & Erftemeijer, 1993).



a b

Figure 17. Seagrass cover of *Thalassodendron ciliatum* (a) and *Thalassia hemprichii* and *Cymodocea rotundata* (b) in West Maabaidhoo

South Hithadhoo had the lowest seagrass cover. Two seagrass species were found in this location, i.e., *Thalassia hemprichii* and *Thalassodendron ciliatum*, with the former being dominant. This location is in shallow waters, where seagrass will be exposed when the sea water is at its lowest tide. This condition affects the condition of seagrass cover in this location.

Figure 18. Seagrass cover condition in South Hithadhoo

3.2.2 Mangrove Ecosystem

The observations at four sites in Laamu Atoll showed that the mangrove ecosystem present in small area such as in Hithadhoo, Maavah, Maabaidhoo, and Gan. In Hithadhoo the observations using Quadrat plot method, meanwhile Maavah and Maabaidhoo due to the mangrove area are small the observation didn't use the quadrat plot. There are six genera of mangrove in Those area: *Rhizophora*, *Ceriops*, *Lumnitzera*, *Sonnerati*, *Bruguiera*, and *Pemphis acidula*.

Table 3. General information of mangrove ecosystem in sites survey

No	Site Name	Genus	Species	Common Name	Divehi Name
1	Hithadhoo	*Rhizophora*	*R. mucronata*	Red Mangrove	Randoo
		Ceriops	*C. tagal*	Yellow Mangrove	Karamana
		Lumnitcera	*L. Racemosa*	Black Magrove	Burevi
		Derris	*D. trifoliata*	Mangrove Vine	Thelaviyo
2	Maavah	*Sonneratia*	*S. caseolaris*	Mangrove Apple	Kulhavah
		Rhizophora	*R. mucronata*	Red Mangrove	Randoo
		Brugueira	*B. cylindrica*	Small-leafed Orange mangrove	Kan'doo
		Lumnitcera	*L. Racemosa*	Black Magrove	Burevi
3	Maabaidhoo	*Ceriops*	*C. tagal*	Yellow Mangrove	Karamana
		Rhizophora	*R. mucronata*	Red Mangrove	Randoo
		Phempis	*P. acidula*	Shrubby Coral	Kuredhi
4	Gan	*Brugueira*	*B. ghymnorrhiza*	Large-leafed Orange Mangrove	Bodavaki

Table 4. General information of mangrove associated/coastal vegetation in sites survey.

No	Mangrove Association		Present in Sites			
	Botanical Name	**Divehi Name**	**Hittadhoo**	**Maavah**	**Maabaidhoo**	**Gan**
1	*Scaevola Taccada*	Magoo	√	√	√	√
2	*Baringtonia asiatica*	Kinbi	√	√	√	√
3	*Pandanus sp.*	Kashikeyo	√	√	√	√
4	*Hibiscus tilliaceus*	Dhiggaa	√	√	√	√
5	*Phempis acidula*	Kuredhi	√	√	√	√
6	*Thespesia Populnea*	Hirundhu	√	√	√	√

Sampling took place in the middle of March 2023. The present study focuses on at four sites Hithadhoo, Mavaah, Mabaidhoo & Gan in Laamu Atoll, Maldives. Hithadhoo Island is an inhabited island located in the southern region of the atoll and hosts a large region of semi-enclosed mangroves at the southern corner of the island. Rhizophora mucronata dominate in the center of mangrove area, interspersed by C. tagal. While L.. racemosa and D. trifoliata were observed at the edge of mangrove area near the mainland. We took two plot sampling mangrove, one plot with high density category and another with rare density category. Qualitative analysis between two plots can be observed at Table 5.

Table 5. Qualitative analysis between two plots of mangrove sampling

PLOT	Species Mangrove	Number of Seeding	Number of Sapling	Number of Tree	Average Trees high (m)	Basal Area (cm²)	Species density (Ind/Ha)
Hithadhoo A	*R. mucronata*	2	8	22	6	800	2200
	C. tagal	-	-	2	3	49	200
Hithadhoo B	*R. mucronata*	-	-	5	3,3	208	500
	C. tagal	2	2	16	2,5	1045	1600
Average of tree per plot				**22,5**			
Average of tree heigh per plot					**3,7**		
Average of Basal area per plot						**1051**	

Maabaidhoo Island is an inhabited island located in the northeastern part of the atoll and hosts a large semi-enclosed mangrove area known as Maabaidhoo Koaru. Native mangrove associated *Pemphis acidula* is dominant along the island. Any 24 saplings and 54 seedling of *R. mucronata* still exist. Besides that, 5 trees of *Ceriops tagal* with height 0,5-1,5 meter survive to growth. Depend on local information, they were introduced/planted in 2017, which the propagule came from Hithadhoo island.

At Mavaah only 8 mangrove trees were found: one (1) *Sonneratia Caseolaris, one* (1*) Rhizopora, four (4) Brugueira cylindrica* and *two (2) Lumnitcera racemosa*. Mangrove area was drought and then planted with banana, coconut, taro, corn, chili etc. by local people (potentially farmers). The remaining vegetation was only mangrove-associated along the coast.

Mangrove vegetation at Gan Island concentrated at Boda Fengandu/Paree fenganda. *Brugueira gymnorrizha* very dominant at this area. Small brackish water lake surrounding with the heavy density of *B. gymnorrhiza*, height tress average moreless 30 meters. So many mangroves seedling and sapling was found under the giantic trees of *B. ghymnorrhiza*.
Canopy cover

Canopy cover

Canopy cover of mangrove in Laamu Atoll calculate by measuring the percentage of the forest floor that is covered by tree canopy. The canopy cover measured use ground -based method to estimate the canopy cover of mangrove. A hemispherical camera used to capture the image of the sky and vegetation from the fixed position. And then the images were uploaded to software program to analyse the canopy percentage.

Table 6. General information of canopy cover

No	Site Name	Stratification	Average of canopy (%)
1	Hithadhoo A	High density	72.12
2	Hithadhoo B	Low density	14.16

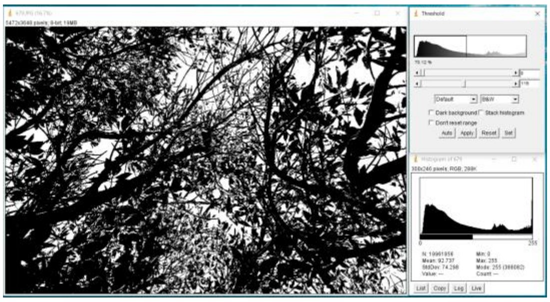
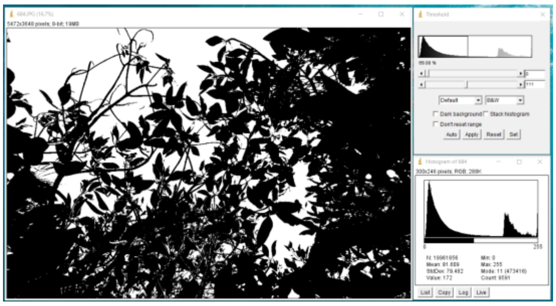
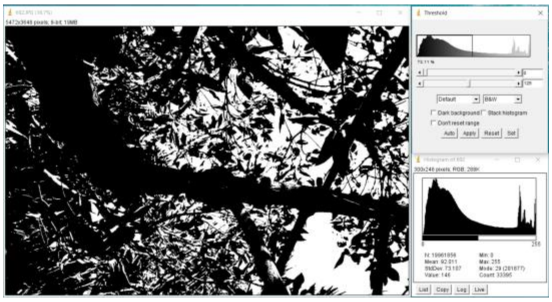
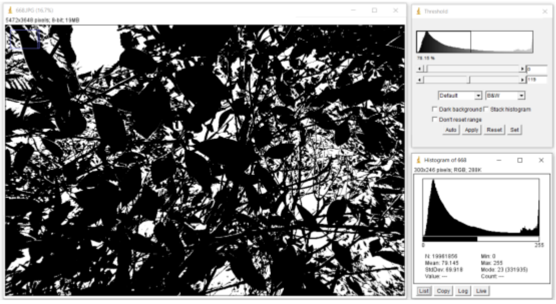
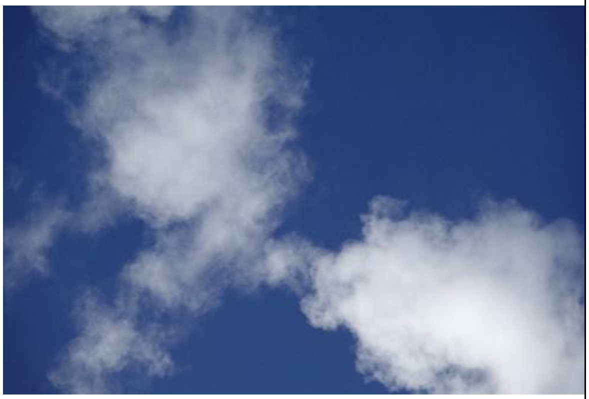
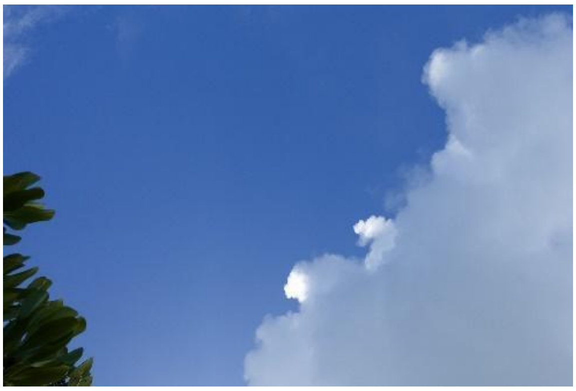
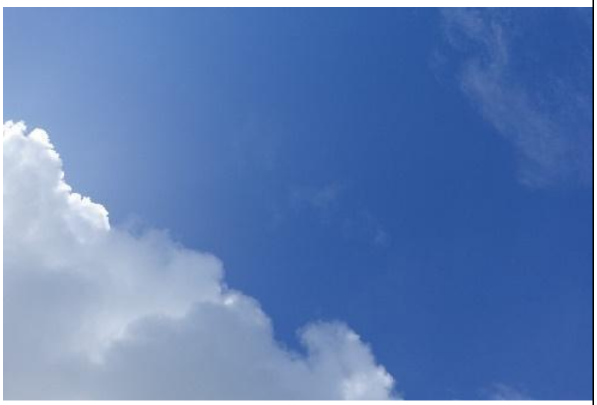
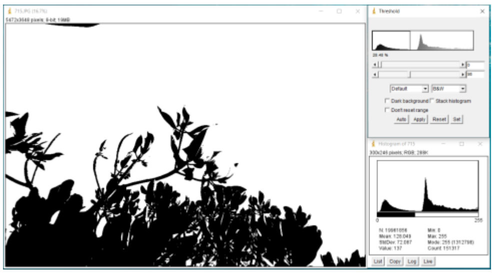
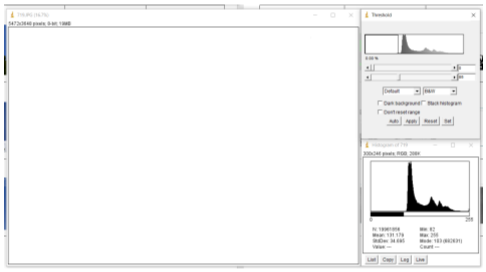
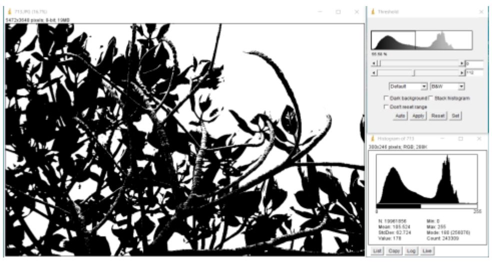
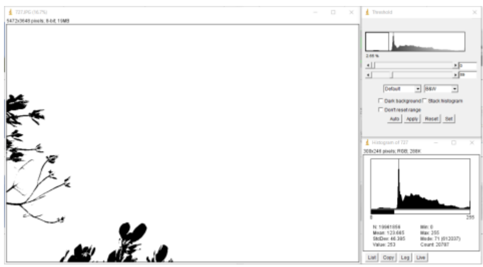
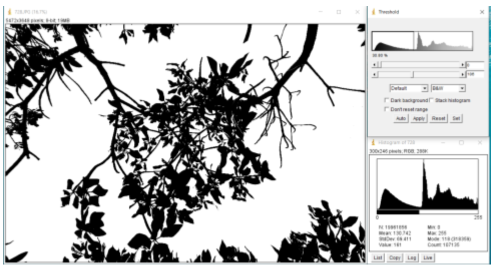
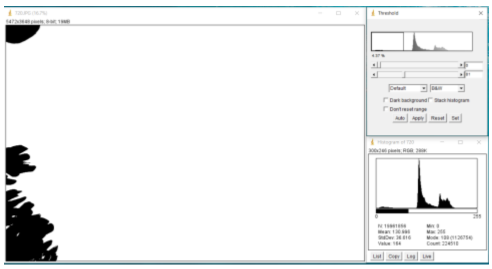
683	**684**
	
692	**668**
	
683 Percentage of canopy = 70.12	**684 Percentage of canopy = 69.08**
	
692 Percentage of canopy = 73.11%	**668 Percentage of canopy = 78.15%**
	

Figure 19. The results of the image processing analysis of the mangrove canopy with the highest percent cover at Hittado from the field image and the processed image.

715	**739**
	
713	**727**
	
728	**720**
	
726	**723**

	
719	
	
715 Percentage of canopy	**Percentage of canopy 739**
	
Percentage of canopy 713	**Percentage of canopy 727**
	
Percentage of canopy 728	**Percentage of canopy 720**
	

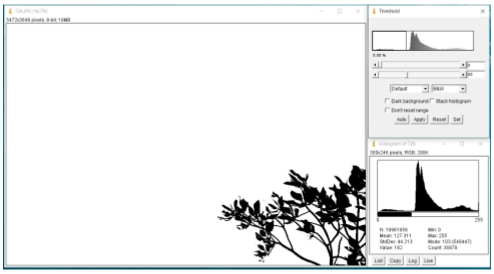
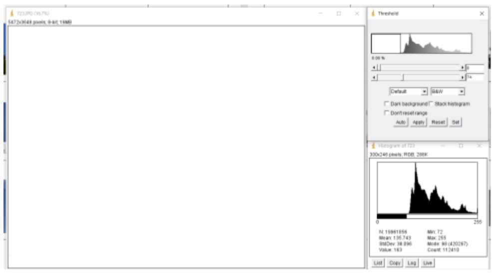
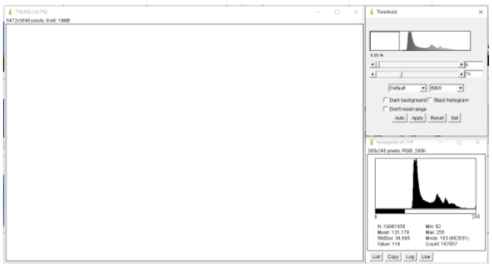
Percentage of canopy 726	Percentage of canopy 723
	
Percentage of canopy 719	
	

Figure 20. The results of the image processing analysis of the mangrove canopy with the lowest percent cover at Hittado B from the field image and the processed image.

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Annexes

Annex 1. Form Data of Seagrass (McKenzie, 2003)

SEAGRASS-WATCH MONITORING

ONE OF THESE SHEETS IS TO BE FILLED OUT FOR EACH TRANSECT YOU SURVEY

OBSERVER: .... DATE: ..... / ..... / .....

LOCATION: ....

SITE no.: .... TRANSECT no: ....

Start TIME: .... End TIME: ....

START of transect (GPS reading)

Latitude: .....°.....'S Longitude: .....°.....'E

Quadrat (metres from transect origin)	Sediment (eg. mud/sand/shell)	Comments (eg 10x gastropods, 4x crab holes, dugong feeding trails, herbarium specimen taken)	(✓)	% Seagrass coverage	% Seagrass species composition (must total 100%)							Canopy height (cm)	% Algae cover	% Epi-cover
					Th	Tc	Hp	Si	Cr	Ho				
1 (0m)														
2 (5m)			☐											
3 (10m)														
4 (15m)														
5 (20m)														
6 (25m)			☐											
7 (30m)														
8 (35m)														
9 (40m)														
10 (45m)			☐											
11 (50m)														

END of transect (GPS reading)

atitude: .....°.....'S Longitude: .....°.....'E

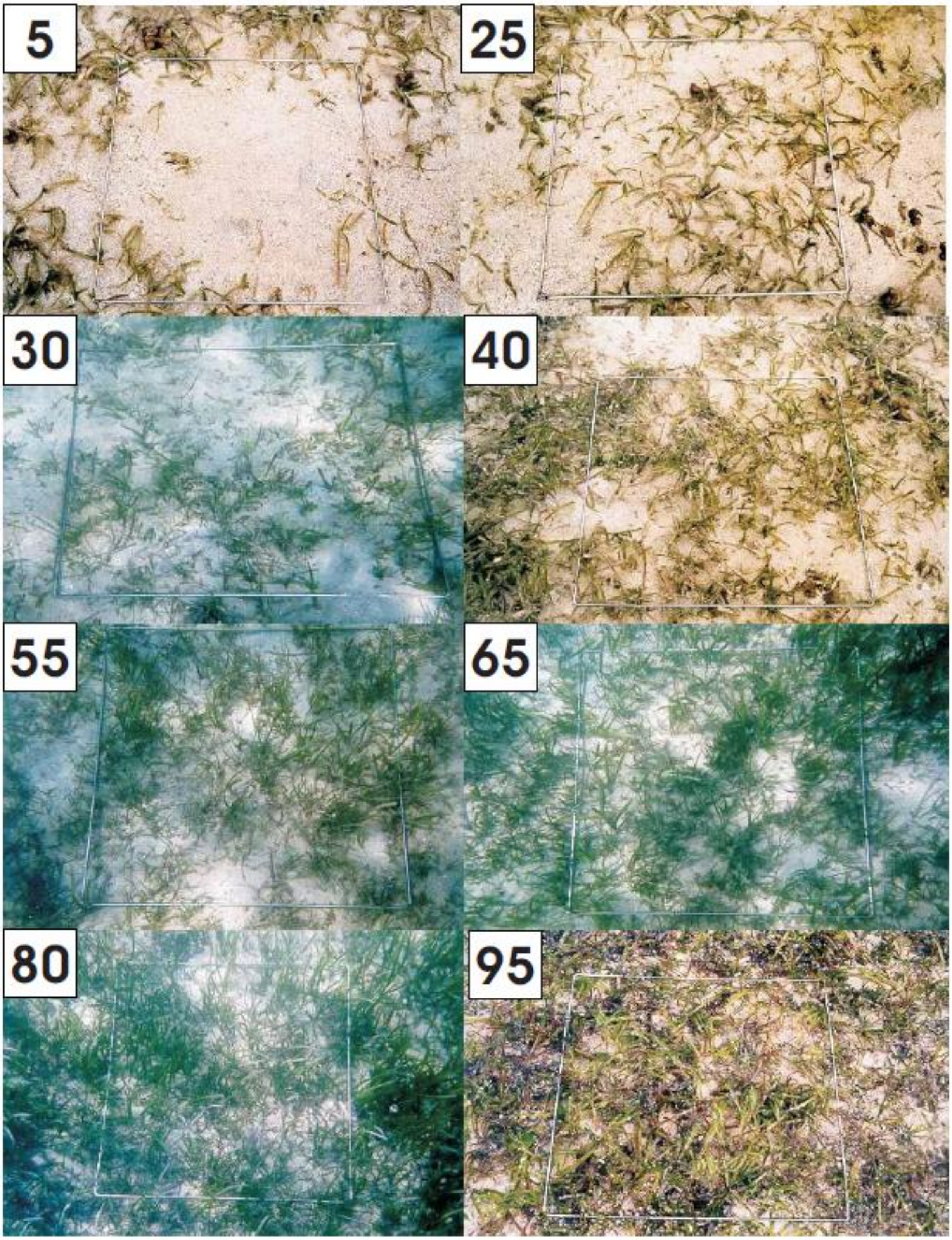
Note:

Th (Thalassia hemprichii); Tc (Thalasadendron ciliatum); Hp (Halodule pinofilia); Si (Syringodium isoetifolium); Cr (Cymodocea rotundata); Ho (Halophila ovalis)

Seagrass-Watch, Townsville, 28th January 2006

Annex 2. Seagrass percent cover standards (McKenzie, 2003)

Seagrass Percentage Cover



Annex 3. Seagrass identification sheets & key (McKenzie, 2003)

SEAGRASS SPECIES CODES

Cs *Cymodocea serrulata*

- Serrated leaf tip
- Wide leaf blade (5-9mm wide)
- Leaves 6-15cm long
- 13-17 longitudinal veins

Cr *Cymodocea rotundata*

- Rounded leaf tip
- Narrow leaf blade (2-4mm wide)
- Leaves 7-15 cm long
- 9-15 longitudinal veins
- Well developed leaf sheath

Ea *Enhalus acoroides*

- Very long ribbon-like leaves with inrolled leaf margins
- Thick rhizome with long black bristles and cord-like roots
- Leaves 30-150 cm long

Th *Thalassia hemprichii*

- Short black bars of tannin cells on leaf
- Thick rhizome with scars between shoots
- "Sickle" shaped leaves
- Leaves 10-40 cm long

Hu *Halodule uninervis*

- trident leaf tip
- 1 central vein
- Usually pale rhizome, with clean black leaf scars

Hp *Halodule pinifolia*

- rounded leaf tip
- 1 central vein
- Usually pale rhizome, with clean black leaf scars

Hx

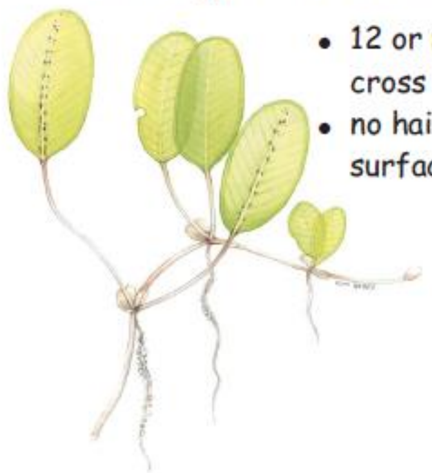
Hu or **Hp** species cannot be distinguished (i.e., not sure of the ID)

Compiled by the Marine Plant Ecology Group, Northern Fisheries Centre CAIRNS, AUSTRALIA July 2002

SEAGRASS SPECIES CODES

Ho

Halophila ovalis



- 12 or more cross veins
- no hairs on leaf surface

Hm

Halophila minor

- Less than 12 pairs of cross veins
- Small oval leaf blade

Hy

Ho or **Hm** species cannot be distinguished (i.e., not sure of the ID)

Si *Syringodium isoetifolium*

- Cylindrical in cross section
- leaf tip tapers to a point
- Leaves 7-30cm long

Hd *Halophila decipiens*

- Small oval leaf blade 1-2.5cm long
- 6-8 cross veins
- Leaf hairs on both sides

Tc *Thalassodendron ciliatum*

- cluster of leaves on elongate shoot
- "Sickle" shaped leaves with serrated tip
- ligule present
- rhizome "woody"

Compiled by the Marine Plant Ecology Group, Northern Fisheries Centre CAIRNS, AUSTRALIA July 2002

Preliminary survey of ecosytem extent and condition in Laamu Atoll, Maldives