The Maldives National University

Mangroves for the Future
INVESTING IN COASTAL ECOSYSTEMS

ENVIRONMENTAL VALUATION OF K. HURAA MANGROVE:

A case study of ecological, social and economic perspectives

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PREFACE

"Environment Valuation of Huraa mangrove: A case study of Ecological Social and Economic Perspectives" was developed with the assistance from MFF small grant support. The authors are indebted to MFF for providing funds to carry out this project. Appreciation is also extended to Hurra council for the support they provided during field visits to Hurra.

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A special mention must be given to Mariyam Nazviya, who dedicated many hours to proofread the book. And finally gratefulness is expressed to the layout designer Mariyam Yashfa, for her outstanding graphic design of the book.

project field work assistants, faculty of Science students and Huraa school students.

Mangrove ecosystems are rich in biodiversity, providing idle breeding grounds for many fish species and may function as a nursery ground to both marine and fresh water aquatic species. Mangroves provide habitats and nesting grounds for terrestrial and shorebirds. Mangroves also provide a wide range of ecological services including; carbon sequestration, navigational waterways, preventing coastal erosion, filtering water pollutants, in addition to being a resource for tourism & recreation activities.

At present, mangrove forests across the globe are declining at an alarming rate, due to the impact resulting from human activities. Most of these impacts are a result of resource dependence, such as over harvesting of timber, land reclamation for housing, farming and activities such as aquaculture12. The situation in Maldives is no exception. Today, most of the Maldivian mangroves are threatened with habitat loss and habitat degradation due to developmental projects that require mangrove reclamation.

Maldives, being a country threatened with climate change, ecosystems such as mangroves conservation is important as these habitats are proving to be important ecosystems that offer protection against natural hazards such as heavy winds, storms surges and floods.

In the year 2014 and 2015, United Nations Development Programme (UNDP) offered a small scale research grant project “Mangroves for Future (MFF)”. A two-year research study was conducted under this project to learn about biodiversity and economic value of one of the mangroves in the Maldives, namely the Huraa Mangrove, located in the island of Huraa in Kaafu Atoll. The findings of this research are presented in this report in the form of four different sections.

The first section will briefly look at mangroves in general with a main focus on mangrove characteristics, its ecosystem, functions of mangroves, and benefits from mangrove and threats faced. The part of the report resumes with a focus on the Maldivian mangroves, looking into the different types and characteristics of local mangroves and common mangrove species of the Maldives.

The second section of this report gives an overview of the fauna present in Huraa mangrove with an explanation of their ecological importance, with a main focus on the role of crabs as ecosystem engineers in Huraa. The third section of the report briefly explores why economics matter when it comes to natural resource management and resource conservation. This section will begin by presenting the concept of sustainable development, followed by introduction of basic environmental economics concepts and theories. Next section of the report will introduce valuation tools commonly used in environmental economics with some relevant examples and case studies related to Huraa. The Report concludes with a guide on the biodiversity of Huraa mangrove

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MANGROVE ECOSYSTEMS

Aminath Shazly

INTRODUCTION OF MANGROVE ECOSYSTEMS

The word "Mangrove" arises from 'mangue', which originated from West Africa, Senegal, Gambia and Guinea2. In the 15th century, the Portuguese were instrumental in taking the word across different countries and spreading it worldwide2. The Spaniards later used the words 'mangle' and 'mangler'. Hence, the word 'mangrove' is a derivative of either Portuguese or Spanish which means 'grove made of mangue'2 The Americans, the Spanish, and the Portuguese used the term 'Mangle' and 'Mangue' to refer trees and shrubs of the genus Rhizophora.2 Later, the term 'mangrove' was used for the individual plant, tidal forest or both and also used as 'Mangrove plants' or 'Mangrove ecosystem'2.

There are two types of mangrove species12:

(1) Major element of mangals (true mangroves) – which are completely dependable to the mangrove environment, and;

(2) Minor element of mangals (mangrove associates, earlier referred to as semi-mangroves) – not visible within the mangrove habitats, but prefer the peripheral habitats of mangrove regions

Hence the terms "true mangrove" and "semi-mangrove" were used until the term "mangrove associates" was created by a group of authors, to refer to those floras consisting of herbaceous, sub-woody and climber species growing on the border of the tidal periphery of the mangrove habitats1,4,11. Physical and biological component of mangrove ecosystem include mangroves, mangrove-associated microbes, flora and fauna, and abiotic factors.

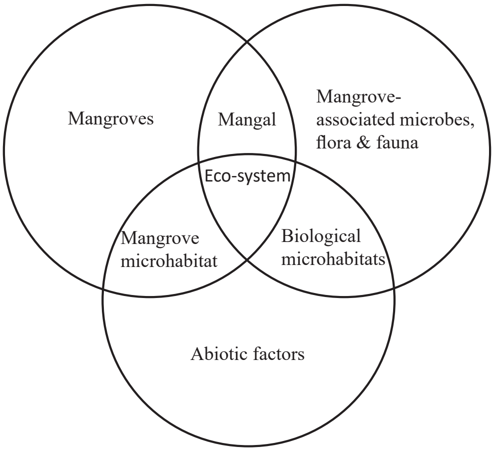


Fig 1: Physical and Biological components of mangrove ecosystem9

Mangrove trees with its associated microbes, plants and animals form the mangrove forest community or mangal. The mangal then with the associated abiotic factors forms the mangrove ecosystem as seen in Figure 19. "Mangroves include terrestrial angiosperms (flowering plants) as trees and shrubs, belonging to 12 genera11. The most dominant of the genera include; Rhizophora, Bruguiera and Avicenna.[9]

BIOLOGY OF MANGROVES

Mangroves are rooted in soft sediments of upper intertidal zone. They have aerial storage of biomass like saltmarshes, providing habitats for both terrestrial and marine species. Mangrove plants are euryhaline and are able to tolerate salinity levels from fully saline to that of estuaries7. Although mangroves are found in areas of low wave action, these ecosystems are strongly subject to high tidal action. The inflow and outflow of tides, assist in transporting nutrients into mangroves and materials out from them including marine organism such as different species of fish, shrimps etc.7 Mangrove associates or 'non-exclusive mangroves 'occur on the landward side of the mangrove and sometimes in non-mangrove areas such as rainforests, saltmarshes and lowland freshwater swamps.11

ECOLOGICAL DIVISIONS OF MANGROVES

Ecologically mangroves can be classified into the following three types: [7,4]

a) The above tide (above water) forest
b) The intertidal swamp
c) The sub-tidal zone

a) The above tide (above water) forest: An Arboreal environment formed by the trunk and leaf canopies of the mangrove plants. It is inhabited by terrestrial organisms such as birds, bats, lizards, snails, mangrove crabs, spiders and insects being most abundant.

b) The intertidal swamp: Supports a diverse group of marine organisms with many different substrates and microhabitats. Organism such as barnacles and oysters are found attached to the mangrove roots. Isopods bore into mangrove roots, Periwinkles and some worms are also associated with mangrove roots. Burrowing fiddler crabs and surface inhabiting sea cucumbers are found in the mud flats7. Leaf litter is a major source of nutrients and energy for this region, with many organisms in the area being detritivores.4

c) The sub-tidal zone: Consists of fine grained mud sediments high in organic content with patches of sand. Mangrove roots of this region support marine organism such as algae, sponges, tunicates, anemones, hydroids and bryozoans with very high levels of competition for space among these populations. Burrowing organism such as crabs, shrimps and worms help oxygen penetration through the mud.4, 7 The most abundant species in this region are the plankton feeding fish.

MANGROVE ADAPTATIONS TO ENVIRONMENT

There are many adaptations of the mangrove which makes it possible for the mangrove systems to carry out its functions in the ecosystem. These adaptations are detailed out below:

a) Root adaptation in waterlogged soil:

Root-like structures form the aerial part of the plant and this adaptive feature allows the plant to respire and taken in oxygen. In waterlogged soil, there is limited availability of oxygen, therefore anaerobic respiration takes place. Hence, oxygen diffusion to these waterlogged soils is low, and any oxygen present in these soils is used up by the aerobic soil bacteria.7 Therefore, anaerobic respiration takes place, resulting in the mangrove soil becoming anoxic. Mangrove trees have adapted to such surroundings. The aerial roots, which protrude from the branches or tree trunks above the ground are the most prominent of these adaptations. In Rhizophora, roots grow 2 metres above the soil from the main stem.7 The roots of the

Rhizophora are known as stilt roots.7 A shallow horizontal root that breaks the soil surface at intervals and submerges again, forming knee roots are observed in Bruguiera and Xylocarpus. Avicennia and Sonneratia have shallow horizontal roots which radiate outward to several metres, close to the soil surface.7 At 10 – 30 cm intervals, vertical structures known as pneumatophores (picture) of height 30 cm above the mud surface stand erect.7 Respiratory needs of roots in anoxic soil is supplied by the pneumatophores. Mangrove species Aegialitis & Excoecaria lack specialized respiratory roots. In these mangrove trees, the roots lie close to the sediment surface, in well oxygenated zones.7

Pneumatophores

b) Salt tolerance

Mangroves uses a variety of mechanisms to cope with its environment of high and varying salinity. The main methods include:

- Excluding salt by roots
- Having tissues which can tolerate high concentrations of salt
- Removing excess salt by secretion.[7]

In Rhizophora, the concentric layers (hypodermal & endodermal) of cells in the root afford a barrier. The hypodermis with tight rings of cells, having large vacuoles store high concentrations of Sodium (Na^+) and Chloride (Cl^-) ions. This can create a 'salt trap' & protect other tissues. Similar barriers have been found in Bruguiera and Avicennia.[7]

In mangrove species, such as Avicennia, Rhizophora, Sonneratia, and Xylocarpus, Sodium Chloride (NaCl) is deposited in the bark of stems and roots. Mangroves Xylocarpus and Excoecaria move excess salt into leaves which are shed by senescence, to prepare for the new growing and fruiting season. Mangrove species, Acanthus, Aegiceras, Aegialitis, and Avicennia, have salt glands on their leaves[7].

c) Reproductive adaptations of Mangroves

Pollination

Pollination is a very important step of plant reproduction. The method of pollination involved for any given species of plant can be concluded based on the morphology of both flower and the pollen[7]. Plant species producing large amounts of light powdery pollen, with tiny flowers that do not smell and have no nectar are wind-pollinated. But large flowers, with large size pollen grains, producing lots of nectar attract animals and so are vector-pollinated[7].

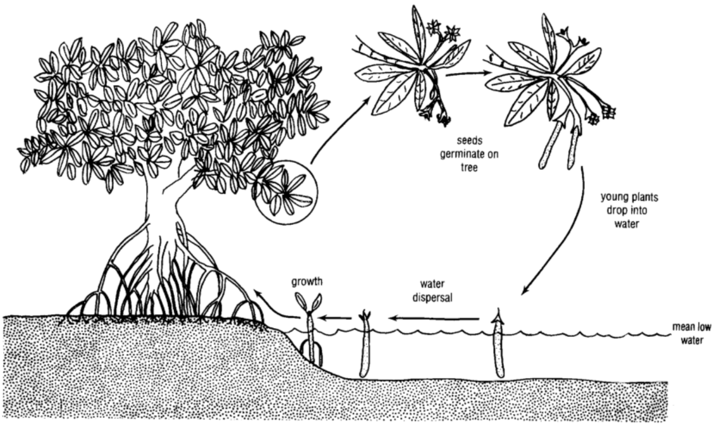
Table 1: Common pollinating methods for various mangrove species[7]

Mangrove species	Method of pollination
Rhizophora	*Wind, insects such as bees*
Sonneratia	*Bats , hawk moths, day-flying birds*
Bruguiera	*Birds and butterflies (small flowers)*
Acanthus	*Bees*
Aegiceras	*Bees*
Avicennia	*Bees*
Excoecaria	*Bees*
Xylocarpus	*Bees*
Nypa	*Small bees or flies of the family Drosophilididae*
Ceriops	Small insects
Kandelia	Small insects & wind

LIFE CYCLE OF VIVIPAROUS MANGROVE SPECIES [7]

All mangrove offspring are dispersed by water. The distinctive feature that allows the existence of such dispersal mechanisms are large propagating structures or propagules[7]. Mangroves are viviparous, referring to the fact that the growing embryo, formed after pollination remaining dependent on the parent tree for many months[7].

The Rhizophora and other members of the family Rhizophoraceae shows the most advanced form of vivipary[7]. Following fertilization, the embryo develops within a small fruit. As the shoot elongates, it bursts through the fruit, developing into a spindle-shaped structure, which dwarfs the fruit. Remains of the fruit attach to the parent plant, the seedling develops chlorophyll and photosynthesizes. Raw materials such as water and nutrients are supplied by the parent plant[7]. Carbohydrates are also translocated from the parent. Salt concentrations decline in the fruit, preserving the tissues of the seedling from premature exposure to high levels of salt.[7]



MANGROVES OF THE WORLD

The 70 mangrove species of the world can be classified to 28 genera belonging to 20 families[15]. Out of 47 species as major components of mangroves, 38 belongs to only two families, Avicenniaceae and Rhizophoraceae which are dominant among all mangrove communities of the world. Mangroves are exclusively tropical[13], but they can tolerate low air temperatures of up to 5°C. However, the seedlings are intolerable to extreme low temperatures and frost. Their distribution is correlated to sea temperatures, where winter temperatures of 20°C limits their range. There has been a 35% decline in the world's mangroves since 1980.[4]

Family	Genus	Total number of species
Major components		
Arecaceae	*Nypa*	*1*
Avicenniaceae	*Avicennia*	*8*
Combretaceae	*Conocarpus*	*1*
	Laguncularia	*1*
	Lumnitzera	*3*
Meliaceae	*Aglaia*	*1*
	Xylocarpus	*2*
Rhizophoraceae	*Bruguiera*	*6*
	Ceriops	*2*
	Kandelia	*2*
	Rhizophora	*6*
Sonneratiaceae	*Sonneratia*	*9*
Minor components		
Acanthaceae	*Acanthus*	*2*
Bignoniaceae	*Dolichandrone*	*1*
	Tabebula	*1*
Bombacaceae	*Camptostemon*	*2*
Caesalpiniaceae	*Cynometra*	*1*
	Mora	*1*
Ebenaceae	*Diospyros*	*1*
Euphorbiaceae	*Excoecaria*	*2*
Lythraceae	*Pemphis*	*1*
Myrsinaceae	*Aegiceras*	*2*
Myrtaceae	*Osbornia*	*1*
Pellicieraceae	*Pelliciera*	*1*
Plumbaginaceae	*Aegialitis*	*2*
Pteridaceae	*Acrostichum*	*3*
Rubiaceae	*Scyphiphora*	*1*
Sterculaceae	*Heritiera*	*3*

MANGROVES IN THE MALDIVES

Very little is known about Maldivian mangroves and inland pond systems. Among the 1,190 islands of Maldives, only 150 contain mangroves. This means %12 of the islands represent mangrove ecosystem in Maldives as shown by (Table 14(1. Maldivian mangroves are not estuarine-based which is unique for these mangroves.

Table 2: key features of Maldivian mangroves.

Type of Mangrove		Key features
Closed mangrove system	Lake-based inland mangroves	A shallow brackish water pond (kulhi) encircles the mangrove. (Example: Found on the island of Fuvahmulah)
	Non-lake inland mangroves (Marsh-based mangrove)	Muddy substrate based mangrove, with no lake. Mangrove not subjected to regular flushing. (Example: Found in island of Keylakunu in Haa Dhaalu Atoll)
Open mangrove system	Coastal fringing mangroves	An uncommon mangrove to the Maldives. They are fully exposed to sea and are found on the shore. (Example: Seen in the island of Goidhoo)
	Embayment mangroves	Most common mangrove type in Maldives. A 'bay' is partially encircled by the mangrove and provides regular tidal flushes. Its vegetation has 'island-like' clumps

Mangroves are important sources of food, fuel wood, timber, medicines and also a great buffer for waves and so help in reducing erosion of islands. Mangroves contribute to the rich biodiversity of the Maldivian reefs, which the two main economic activities; fisheries and tourism, is dependent upon. However, Maldivian mangroves are also under threat from economic development projects resulting from urbanization.

CLASSIFICATION OF MANGROVES IN THE MALDIVES

The non-estuarine mangroves of the Maldives can be classified as in Figure 2. The mangroves are classified as either "open" or "closed" based on the systems exposure to the sea. Table 2 summarizes the key features of these mangroves

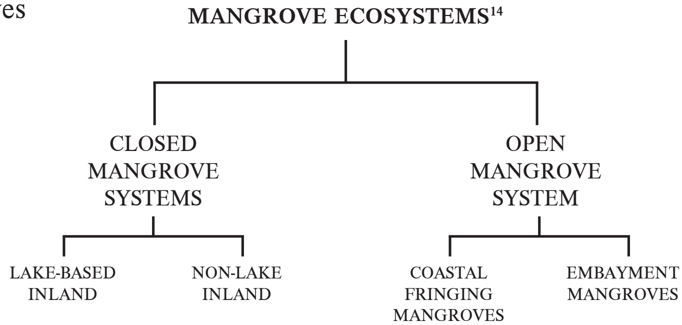


Figure 2: types of mangrove ecosystems found in the Maldives [14].

Table 2: Local names of mangroves found in the Maldives.

Botanical Name	Family	Common Name	Local Name
Avicennia marina	*Avicenniaceae*	*Mangrove*	*Baru*
**Brugueira cylindrica*	*Rhizophoraceae*	*Mangrove*	*Kandoo*
**Brugueira gymnorrhiza*	*Rhizophoraceae*	*Mangrove*	*Bodavaki*
Ceriops tagal	*Rhizophoraceae*	*Mangrove*	*Kharnana*
Derris heterophylla	*Fabaceae*	*Unknown*	*Unknown*
Excoecaria agallocha	*Euphorbiaceae*	*Unknown*	*Thella*
Heriteira littoralis	*Sterculiaceae*	*Unknown*	*Kaharuvah gas*
Lumnitzera racemosa	*Combreatceae*	*Black mangrove*	*Burevi*
**Rhizophora mucronata*	*Rhizophoraceae*	*Red mangrove*	*Randoo*
**Rhizophora apiculata*	*Rhizophoraceae*	*Tall-Stilted mangrove*	*Thakafathi*
Sonneratia caseolaris	*Sonneratiaceae*	*Crab apple mangrove*	*Kulhlhavah*
Xylocarpus moluccerisis	*Meliaceace*	*Cannonball tree*	*Marugas*

TERMINOLOGY IN THE LOCAL LANGUAGE- DHIVEHI

In Maldivian local Dhivehi language, mangroves are referred to as Kulhi, Faa and Chasbin. No single word has yet been created in Dhivehi for mangroves.

Kulhi - Mangroves enclosed or semi-enclosed in brackish water with standing water.
Chasbin – Muddy areas which lack standing water
Faa – enclosed or semi-enclosed brackish water mangroves or those with muddy areas with no standing water.

Since traditional times, mangroves have been used by people for various purposes. Some of these traditional uses of mangrove in the Maldives involved the following:

- Use of timber from Brugueira cylindrical, Brugueira gymnorrhiza and Rhizophora mucronata for boat building, firewood, making fishing poles and in construction work.
- Sonneratia caseolaris and Brugueira cylindrical was used as food by the locals
- Brugueira cylindrical was used to make dyes for coloring the fishing poles.
- The bark of Brugueira cylindrical was used to make indigenous medicine.

CASE STUDY:
HURAA MANGROVE ECOSYSTEMS

HURAA MANGROVE – AN INTRODUCTION

One of the most important landmark of Huraa island in the Maldives, is its beautiful mangrove area with diverse flora and fauna. The freehold land hosting the mangrove ecosystem is located on the western side of the island (Figure 3), covering an area of about 9 hectares.

Figure 3: Study Site: Huraa Mangrove.

The Huraa mangrove and the surrounding area are protected by the Environmental Protection and Preservation Act of Maldives (Act no. 4/1993) [3]. This Act was passed, due to the fact that Huraa mangrove is an important natural mangrove habitat, which contains species of particular conservation significance to the Maldives. The mangrove is an open mangrove which is easily accessible by land as it is close to the residential area and the less dense vegetation. Residential buildings are observed to be as near as 20 metres to the mangrove, which may in future lead to negative impact of human settlement on the mangrove.[8]

VEGETATION AND SOIL ASSESSMENT

One of the objectives of the study was to do an assessment of the whole vegetation of the mangrove. This was done to identify the number and type of mangrove species, as well as its associates found inside and within the near distance of the mangrove. A total of four true mangrove vegetation and six associates were identified from the study. Since Huraa Mangrove was a small area of about nine hectares, the vegetation study also included tagging and counting all the mature trees for each species of true mangrove. A combined total of more than 4,000 true mature mangrove trees were counted. Figure 4 shows a tagged tree used for counting.

Figure 4: A mangrove tree counted and tagged

Mature trees were identified based on its girth, those trees having a girth of more than 10 cm. To identify the position of each tree from a mangrove map, Global Positioning System (GPS) location of each were identified. For each of these trees the sediment depth was measured to identify the sediment depth inside the mangrove.

Based on the girth measurement, and species identification through tagging and counting the four main mangrove species were mapped to show the specific distribution of the true mangroves of the area. A basic mangrove sediment assessment of the mangrove was done. This included measurement of sediment depths, evaluation of sediment characteristics, measurement of salinity and pH. The sediment depths measured for each mangrove tree, was mapped separately. This showed that the different areas of the mangrove had different soil characteristics, based on its sediment depths. It also showed how these sediment depths varied from one area of the mangrove to the other. To identify the factors which could be affecting the distribution of these mangroves, both the salinity and pH of water and the soil near each species was measured, thereby doing a sediment assessment of the mangrove.

METHODS USED IN THE ASSESSMENTS

A – VEGETATION ASSESSMENT

In relation to evaluating the true mangrove vegetation, four different measurements were taken as data. These four measurements include:

1. Position of the trees: measured using handheld Global Positioning System (GPS).

2. Identification of plant species: The plant species were identified using the Species Identification Guide published by [WHO]. "Features that were initially observed for the trees' taxonomic identification were its fruit, the flower or leaf. If neither the fruit nor the flower was visible, the tree species was then identified by observing its leaves, roots and by the texture of its bark.

3. Measurement of girth: To measure the girth of the tree, a measuring tape was put around the trunk at chest height. If the tree was multi-trunked the girth was measured from the largest trunk, as the clump was counted as one single tree. The trees having a girth greater than 10 cm were measured.

Figure 5: School students measuring tree girth and position of the tree

4. Measurement of height of the trees: To measure the height of the tree, a clinometer was used to calculate angle of elevation and using the angle the height of the tree was calculated as shown in Figure 6. The vertical distance between the base of the tree and the highest shoot at the top of the tree was measured using the measuring tape and clinometer.

Figure 6: Measuring height of tree using Clinometer.

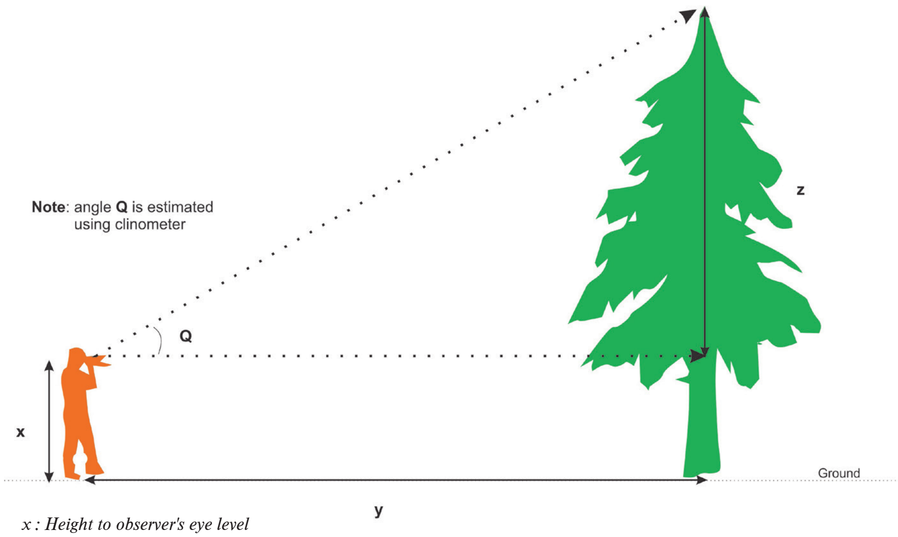
The field assistant, stood at a constant horizontal distance of 5 metre from the tree and the angle to the top of the tree was measured using the clinometer.

The height of the tree can be estimated using either measurements taken at surveyor's eye level or using measurement at shoulder level. Thus the tree height was estimated using one of the formulae below, depending on the method of angle measurement:

(Horizontal distance (i.e. 5 m) x tangent Θ) + Height up to eye level = tree height

Or

(Horizontal distance (i.e. 5 m) x tangent Θ) + Height up to the shoulder = tree height



x : Height to observer's eye level
Q : Angle of elevation, from eye level of observer, standing from tree to 5m
y: Distance from tree to observer (5m)
z: height of the need to find using TanQ

TanQ = z/y

Height of the tree = z+x

Figure 7: Estimation of height of a tree

B – SEDIMENT ASSESSMENT

The sediment assessment was done by measuring three different measurements. The three measurements include measurement of sediment depth, salinity and pH:

1. Sediment depth:

A measuring device was made by using a 1 m long PVC pipe of diameter 1.27 cm. This pole was embedded into a 5 kg bed of cement mixture, poured into containers made from empty plastic bottles of 5 litre as shown in Figure 8. This allowed the measuring device to be carried by a single field person, and so allowed that person to do the sediment measuring itself.

Figure 8: Measuring the sediment depth using PVC pipe

To measure the sediment, the tip of the PVC pipe was placed in the soil, and without any force, but by the weight of the 5 kg cement base, the pipe was allowed to sink into the soil. Using a measuring tape, the depth was measured from the tip of the pipe, to where the sediment mark remained on the pipe.

Figure 9: Sedimentation in the mangrove

2. Soil salinity

To measure soil salinity, a conductivity meter was used. To get the salinity reading, conductivity meter's pole was randomly inserted into the mangrove sediment near the mangrove vegetation. The reading displayed on the monitor was recorded, along with the GPS location of the tree.

Figure 10: Students using the conductivity probe to measure conductivity

3. Soil pH

To measure pH, a pH meter was used. By randomly inserting the pole of the pH meter into the sediment near mangrove vegetation, the reading displayed on the monitor was recorded, along with the GPS location of the tree.

C- MAPPING USING GIS

To develop a Geographical Information System (GIS) map, data was collected using a handheld (Global Positioning System (GPS) receiver. These GPS units receives signal from satellites and computes its position. These positions are stored as coordinates. Data received were stored as points or lines depending on the data type selected prior to collection.
Points are best used for individual feature with only one geographic location. Points were used for collection of individual tree data during the survey.

Track logs or lines are best used for linear features. Water body and mangrove perimeter was collected as line data during the survey.
All the data collected were exported to Microsoft Excel to sort out the data by type. For every tree position, its girth, height and sediment depth near the tree were recorded. The collected data were sorted out by girth, height and sediment depth.
A GIS geodatabase was created for the project to which final Excel file was imported to create the mangrove map.
Aerial photo sourced from Google Earth was imported to GIS and was geo referenced to the data collected. All the layers were overlaid on the photo to make sure the data collected represents the survey area.
Maps were then exported in PDF format with the selected layers.

Limitations

For the best result, a GPS must have a clear view of sky from horizon to horizon. The satellite signal weakens when they penetrate the leaves of tree canopy. During the survey several data points were collected under the tree canopy which may not give high accuracy results. However, to ensure the data collected are well within the survey area, satellite images (aerial images) of the area were overlaid on the data during data processing and map development. Any points that were outside the mapping area was not used.

RESULTS OF THE ASSESSMENTS

The results of the vegetation assessment and sedimentation assessment done for Huraa Mangrove are illustrated in the form of maps and graphs below:

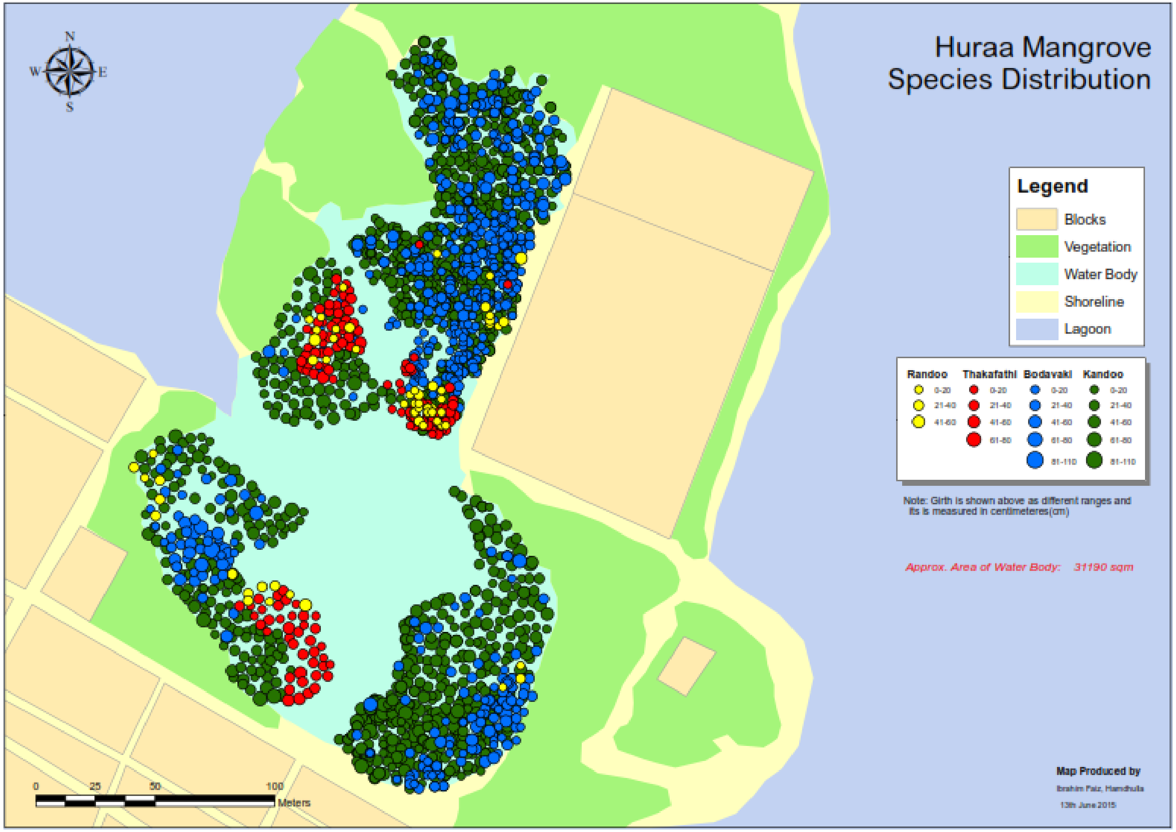


Figure 11: The distribution of mangrove vegetation in Huraa.

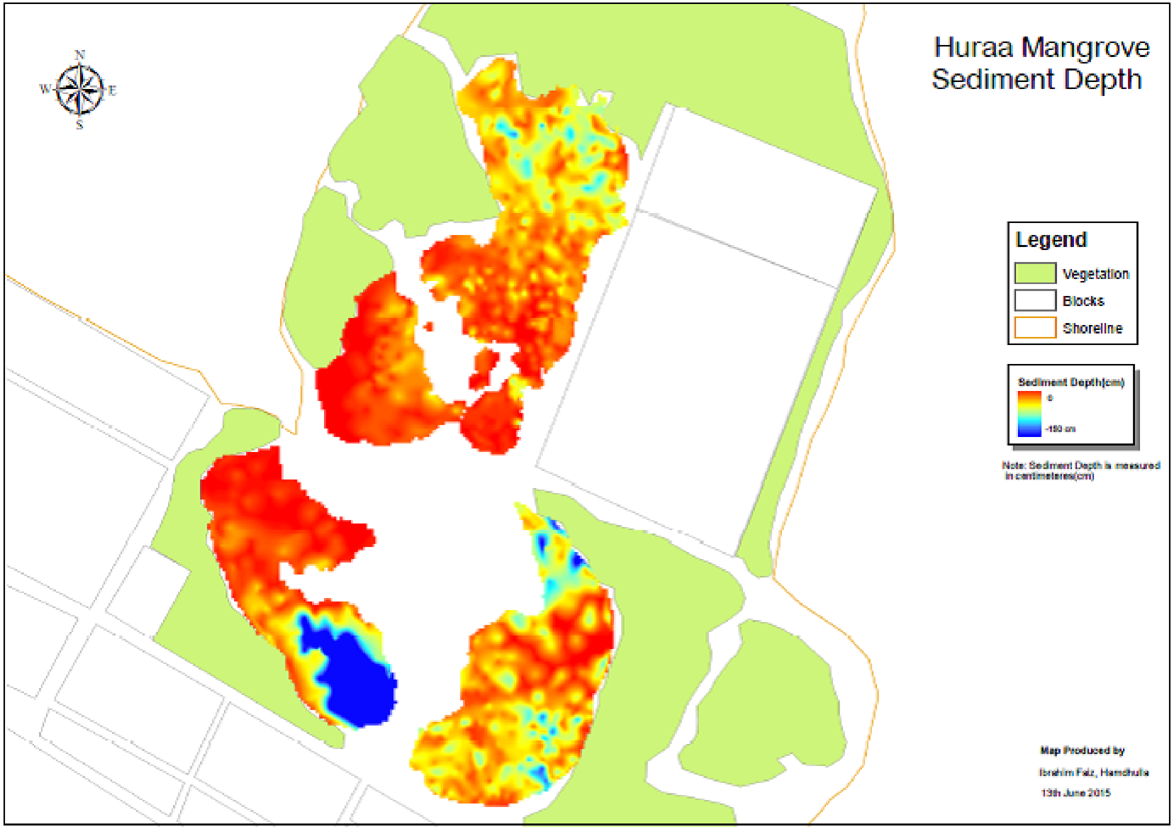


Figure 12: The distribution of sediment depth.

Figure 11 shows the distribution of mangrove vegetation and figure 12 shows the distribution of sediment in the mangrove. According to the Figure 11, the most abundant species present in Huraa was Kandoo. The second most abundant species found was Bodavaki.

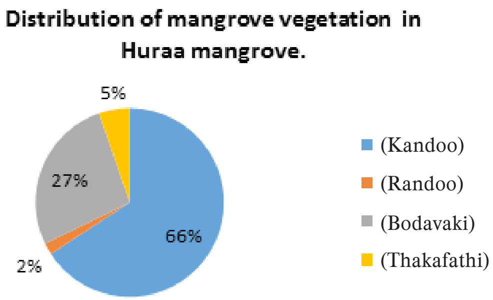


Figure 13: Distribution of mangrove vegetation in Huraa.

According to figure 13, 66% of mangrove vegetation is Kandoo, 27% of vegetation is Bodavaki, 5% of vegetation is Thakafathi and only 5% of veg-etation is Bodavaki.

From Figure 11, it can be seen that Kandoo which was the most abundant species found in Huraa mangrove were distributed throughout the mangrove while the second most abundant species, Bodavaki was more distributed away from the water body towards the periphery of the outer mangrove. Figure 11 also shows the area of mangrove opening, (where the mangrove meets the lagoon). It is found that this mangrove opening has Kandoo as the most dominant species amongst the mangrove vegetation.

Figure 12 shows that most of the sediment was deposited for a depth of 150cm. When the vegetation map (Figure 11) and sediment map (Figure 12) is compared, it was noted that Thakafathi was more abundant at depth of 150cm sedimentation.

DISCUSSION

Huraa mangrove consisted mainly of 4 different mangrove species. Among these species, Kandoo (Bruguiera Cylindrica) was found to be the most common species while Randoo (Rhizophora mucronata) was found to be the least common.

Fig 14: Rhizophora mucronata (Randoo)

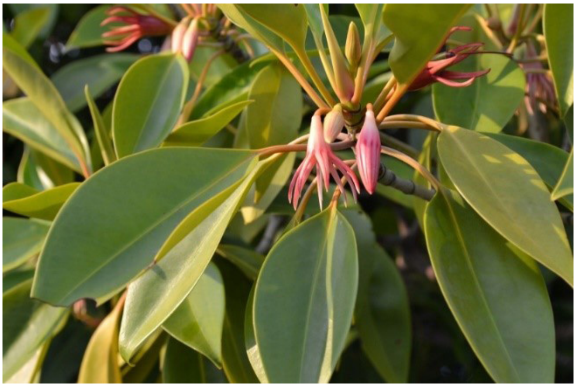


Fig 15: Bruguiera cylindrical (Bodavaki)

Fig 16: Bruguiera cylindrical (Bodavaki) flowers blooming

According to the species distribution (Figure 11), Bodavaki were distributed throughout the mangrove, but with majority of its mature trees being located in northeast and southeast of the mangrove. Whereas the mature trees of Bodavaki, is mostly found on the northeast side. Randoo, the least in number is sparsely distributed on northeast, southeast and southwest of the mangrove and appears to be concentrated on the northeast side towards the central part of the mangroves water body.

The conditions of soil were found by measuring the salinity and pH near random trees of different mangrove species. The average pH of soil at the shoreline of the mangrove was at 7.2 while at inland the average pH was at 7.5. At the mangrove where Randoo is most abundant, the pH was slightly alkaline at 7.84. This is the perfect range for mangrove vegetation and is one of the reasons why Randoo flourished in this region.

The sediment depth was a measurement taken for each and every plant counted, within the mangrove. These sediment depths were mapped (Figure 12) to show how the sediment depth varied within the mangrove. As seen from the Figure 12, the southwest side of the mangrove has an area of highest sediment depth reaching above 500cm in depth.

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2

MANGROVE FAUNA

A Riyaz Jauharee

INTRODUCTION TO MANGROVE FAUNA

Huraa mangrove supports hundreds of thousands of crabs, birds and fish. Fiddler crabs and mangrove crabs are abundant on the mangrove floor. While several species of fish are found living inside the mangrove, others enter the mangrove searching for food. Both migratory birds and birds residing in the Maldives use the mangrove for food and as a resting place. Organisms such as crabs and bees living in the mangrove provide important ecosystem services to sustain the mangrove.

FISH

Mangroves are often linked to coastal ecosystems and play an important role for the sustenance of diversity among the communities across these coastal ecosystems. Mangrove habitats are important feeding sites for several species of fish and provide protection for others. It also serves as an important nursery ground hence in many countries mangroves are protected due to their importance to fisheries. There are several species of fish found in Huraa mangrove. Some of these regularly visit the mangrove during high tide while others spend most of their life in the mangrove.

Fishing inside the mangrove is a recreation activity for many young children living on the island. In the past fish from the mangrove was an important source of protein for the local community. Small fish found within the mangrove is also an important source of food for birds and other larger predators.

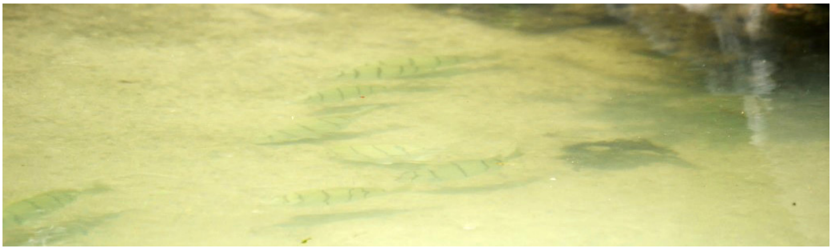

Fig 1: Some of the fish found in mangroves

Table 1: Some fish species sighted inside the mangrove

Dhivehi name	English name	Species
Narunagoo madi	Whiptail stingray	*Himantura fai*
Raabulhaa	Convict surgeonfish	*Acanthurus striostegus*
Ori	Rabbit fish	*Siganus argenteus*
Filolhu	Blackspot snapper	*Lutjanus fulviflamma*
Lahfilolhu	Block spot emperor	*Lethrinus harak*
Uniya	Longtail silverbiddy	*Gerres longirostris*
Maa kalhuoh	Dash-dot goatfish	*Parupeneus barberinus*
Guruva	Sweetlips	*Plectorhinchus*
Black-tip reef shark	Falhu miyaru	*Carcharhinus melanopterus*

Several herbivorous fish take shelter inside the mangrove feeding on the algae growing on the bottom of mangrove floor and drifting in the water column as shown figure 2. During low tide, these small fish take shelter in pools of water within the mangrove that have not dried out. The small fish is also a good source of food for the birds and other organisms that feed on them.

Figure 2: Algae on the mangrove floor exposed during low tide

Figure 3: black tip reef shark found in Huraa mangrove.

A frequent visitor to the Huraa mangrove. The sharks enter the mangrove through the opening linking the mangrove and the shallow lagoon. As the tide rise the sharks (˜ TL = 50cm-) enter the mangrove and exits when the tide recedes. During data collection in January 2014 – in a 1 hour observation period 22 such sharks approached the opening linking the mangrove to the lagoon and 16 sharks entered the mangrove as it got flooded. Sharks use of Huraa mangrove is yet to be studied but many believe some sharks use mangroves for easily ambushing their prey while others use mangroves for breeding too.

CRABS

In Huraa mangrove, thousands of crabs were seen on the mangrove floor during low tide. They all have a very important role in the mangrove ecosystems and are a rich source of food for birds and fish that frequently visit it. Hundreds of thousands of crabs continuously repair its burrows and this process helps aerate the muddy mangrove floor.

Figure 4: Fiddler crabs actively repairing their burrow and feeding during low tide.

Crabs affect the sediment structure and influence other organisms living in the mangroves through their activities. Feeding and burrowing by crabs helps nourish the soil. Construction of burrows and their continued maintenance affect sediment cycle and topography having a significant engineering effect on their surrounding habitats. It creates space for bacteria which provides nutrients for primary production. It also enhances the distribution of nutrients to coastal zones. Burrowing helps easy flow of water into the sediments and mixing of sediments.

There are several species of crabs found in and around the Huraa mangrove. Two species that are common include:

1. Fiddler crab
2. Mangrove crab

Fiddler crab (Uca rapax)

Fiddler crabs occupy muddy environments and scavenge on dead plant matter, bacteria and worms found on the muddy mangrove floor. These crabs made their burrow in the mud and do not wonder too far from their burrow since they have to quickly retreat back into their burrow with even the slightest sign of danger.

Figure 5. : Male fiddler crabs

Fiddler crabs are brightly coloured and have the ability to change its colour. They change colour during courtship and for camouflage too. The male fiddler crab has a very large claw which they use for attracting females by waving it.

Figure 6: Female fiddle crab

Unlike male crabs, female fiddler crabs have two small claws which are used for feeding on organic matter. This makes the female crabs more efficient at feeding than the male fiddler crabs which has one large claw and a single small feeding claw. This large claw in males cannot be used for feeding or burrowing but is used during breeding to attract females. Like many other invertebrates fiddler crabs also has the ability to regrow its limbs. Whenever a claw is lost it can regrow a new claw.

Mangrove crab (Cardisoma carnifex)

Mangrove crab is the largest species of crab found in Huraa mangrove. They make burrows in the muddy mangrove floor and the adjacent areas. They also take shelter among the branches and logs on the mangrove floor. Many mangrove crabs climb the trees inside the mangrove during high tide as it gets flooded.

Mangrove crabs feed on leaf litter produce by the trees helping degradation of leaves on the mangrove floor making it easily available to the meiofauna.

Mangrove crabs burrow can be several feet deep and are continually maintained. Continuous burrowing helps aerate the mangrove floor and mix the sediments. These crabs also take several leaves into their burrow where nutrients from the decaying leaves seep into the ground making them available for the micro-organisms in the sediments.

Figure 7: Mangrove crabs repairing its burrow and scavenging.

Mangrove crabs are popular among the tourists visiting Huraa Island. It is important to ensure sustainable exploitation of mangrove crab resources to preserve the mangrove ecosystems and other organisms within the ecosystem. Over exploitation could lead to total depletion of mangrove crabs from Huraa mangrove which could even lead to complete collapse of the ecosystem finally destroying a beautiful and important mangrove very close to Male' which is visited by hundreds of students every year.

Figure 8: Other crabs sighted in and around Huraa mangrove

BIRDS

There are several birds using Huraa mangrove for feeding, breeding and shelter. The number of birds and types of birds visiting the mangrove varied during the day and also during the two monsoons. In the northeast monsoon there was more variety of birds using the mangrove.

Table 2: Some bird species sighted inside the mangrove

Dhivehi name	English name	Species
Maakana	Grey heron	*Ardea cinereo*
Iruvaahudhu	Cattle egret	*Bubulcus ibis*
Laganaa	Great egret	*Casmerodius albus*
Dhivehi kanbili	Maldivian white hen	*Amaurornis phoenicurus maldivus*
Dhivehi koveli	Asian koel	*Eudynamys scolopacea*
Raabondhi	Black crowned night heron	*Nycticorax nycticorax*
Kaalhu	House crow	*Corvus splendens*

More birds were also sighted during the early morning and later evening hours before sunset. There were more birds during period of low tide when the schools of small fish were concentrated and trapped in the small pools of water formed as the tide receded inside the mangrove.

Figure 9: Birds spotted in Hurra mangrove.

OTHER ORGANISMS SIGHTED IN HURAA MANGROVE

Polychaete worm

Found usually buried within the mangrove floor. Some use this worm as bait for fishing.

Figure 10: Polychaete worm spotted in Hurra mangrove.

Shrimps

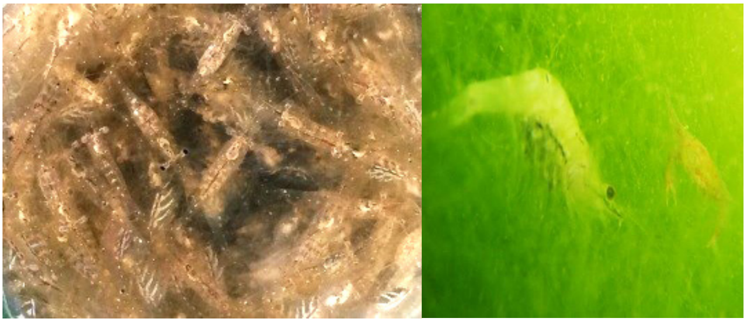

Figure 11: Shrimps spotted in Hurra mangrove.

Tiny transparent shrimps were taking shelter among the sea weed and the mangrove floor. Some locals collect and use it in preparing various dishes.

Sting ray

Figure 12: Sting rays regularly enter the mangrove looking for food.

CASE STUDY:
ESTIMATION OF CRABS AT HURAA MANGROVE

Mangroves help sustain complex ecosystems and influence species distribution and their abundance[9]. The complex roots of the plants provide protection to several marine organism[6,10] including fish, snails, crabs, shrimps and jelly fish found within the water column and on the mangrove floor. Readily available food sources, low predator pressure and the complex structure support the benthic fauna in the mangrove[9,11]. Many of these organisms spend their whole life in the mangrove while others are seasonal visitors to the mangrove.

Figure 13: Complex roots of mangroves where many organisms take shelter.

Crabs are abundant in mangroves across the Maldives. They provide important ecological services. While making their burrows, they make thousands of holes on the floor improving the infiltration of water which helps to remove excessive salt form the soil[12]. Burrowing also helps increase the levels of oxygen in the anoxic-sediment floor[12,13,14]. In addition, the burrows also provide shelter for organisms such as molluscs, fish and worms[15].

Figure 14: Crabs next to their burrows – Huraa mangrove

Lifecycle of crabs

Crabs begin their life as a larva (zoea) hatched from an egg. Zoea do not have limbs are drifts with the plankton in the water. Zoea moults several times to transform into a megalopa which has functional claws which then moult into juvenile crab. These processes take several days. The juvenile crab which is very similar to the adult settles in sheltered areas such as mangroves.

Similar to many other crustaceans, crabs found in Huraa mangrove have exoskeletons. These skeletons provide protection from predators as well as from changes in environmental conditions. During growth the crab leaves (cast off) its rigid exoskeleton and regrows a new skeleton. During this moulting process the crabs are vulnerable and can be an easy prey for many other species. To increase body size, crabs take in water into its muscular tissue and expand before a new exoskeleton is formed.

Adaptation of crabs

Several organisms living in the mangrove have specific adaptations that helps to survive in this ecosystem. To prevent the organisms from getting carried away by the current organisms such as crabs, snails and starfish have special appendages that help them anchor or attach to various objects in the mangrove. Many hide in burrows and in the complex network of roots. To escape from the hot sun and to prevent desiccation during low tides many burry themselves in the mud.

figure 15: Crabs on mangrove trees – Huraa mangrove

During low tide crabs and shrimps also hide under rocks and fallen branches while the small fish take shelter in tidal pools. Some also climb the mangrove trees to escape from predators. In addition, many organisms can camouflage to blend with the natural environment to avoid predation. The hard exoskeleton and shells on crabs and snails respectively also deter predators.

Many organisms in the mangrove, including crabs, snails and several fish can also graze on the algae and feed on the detritus on the mangrove floor. Some crabs use their claws to slice and directly feed on mangrove litter such as leaves while others use its claws for attracting partners.

Figurew 16: Large claws of crabs found in Huraa mangrove

Ecosystem Services

Crabs affect the sediment structure and influence other organisms living in the mangroves through their activities. Feeding and burrowing by crabs helps nourish the soil. Construction of burrows and their continued maintenance affect sediment cycle and topography having a significant engineering effect on their surrounding habitats. It creates space for bacteria which provides nutrients for primary production. It also enhances the distribution of nutrients to coastal zones. Burrowing helps aeration of the sediments and easy flow of water into the sediments.

The mangrove system has several different species as explained above, it is deemed as important to estimate the number of the species within the ecosystem. However, given the limitation of the time, one such species, crabs were taken into consideration and the population of crabs in Huraa Mangrove were estimated. The details pertaining to the crab estimation study are given below.

OBJECTIVES OF THE STUDY

There are several mangroves across the Maldives. Many of these mangroves have economically important species including crabs. Due to difficulty in accessing mangroves it has always been a challenge to estimate these species and its value. This is the first attempt to estimate the total number of crabs found in such a mangrove in the Maldives. The purpose of this study is to estimate the crab population in Huraa mangrove towards valuing its economic importance to the community and the important services provided to the ecosystem.

METHODOLOGY

Two common methods for rapidly assessing the abundance of crabs are trapping and burrow counting methods. In this study burrow counting method was used to estimate the crab population as trapping is more difficult and time consuming to implement in Huraa mangrove. Mangrove gets flooded during high tide and reef fish are able to enter the mangrove through an opening linking the mangrove to the shallow lagoon. During extreme low tide the water drains out and most of mangrove floor is exposed. The crabs take shelter in the muddy bottom of the mangrove shaded by the mangrove plants. During high tide the small fiddler crabs take shelter in their burrows while many other larger crab species were seen on the branches and trunks of mangrove trees.

Figure 17: Exposed mangrove floor during low tide – Huraa mangrove

Figure 18: Flooded mangrove during high tide – Huraa mangrove

Figure 19: The passage connecting the inside of the mangrove to the shallow lagoon during low tide – Huraa mangrove

DATA COLLECTION

Since the site (Huraa mangrove) was close to Male' and there were regular ferry services, it was easier for the field assistants to travel to Huraa and conduct the study during weekends and holidays. Data on the crab populations were obtained from the 3 sites (A, B and C). The total area of the 3 sites combines together was 30000 square meters or 3 hectares.

Figure 20: Mangrove area showing where the sampling was conducted. (photo: Google earth)

Sampling activities to study the abundance of crabs were carried out during periods of extreme low tides (spring tides) which occur every lunar month around full moon and new moon periods. This period was selected since most parts of the mangrove floor was exposed during low tide and the crabs are out foraging and repairing their burrows then.

The field assistants worked together to collect data under the supervision of Field specialist. There were some challenges in getting enough field assistants with the right skills to conduct the sampling.

Figure 21: Field Assistants helping in data collection work.

In order to identify the sampling area for data collection, transect lines from the edge of the mangrove (where the mangrove meets the island) to the edge of the water at low tide was laid at 5m intervals between lines.
Along each line, 1m by 1m quadrats were placed at alternative intervals. The following data was obtained from each quadrat.

1. Random selection of 25 crab holes within each quadrat.
2. Diameter of the largest and the smallest crab hole.
3. Sediment depth.

Some parts of the mangrove were thick and were difficult to access as the roots were too close to each other.
Sediment depth was measured by placing a weight (2kg) on a 1m plastic pipe (diameter: 0.5 inches). How far the pipe sank into the ground was recorded as sediment depth.

The transect lines were laid using 50m long measuring tapes and the diameter of the crab holes were measured using a simple rule having a cm scale. In addition, position (latitude and longitude) of the transect lines were collected using a hand held GPS.

Observing the behaviour of the crabs was difficult as they quickly go into their burrows and hide as samplers approach them. Sometimes the crabs did come out unless the samplers stood very still for a while, but this was very difficult. Hence GoPro cameras were fixed near their burrows and their behaviour was filmed and analysed later.

Figure 22: Equipment for measuring sediment depth.

Field assistants collecting data on crabs.

Figure 23: Field assistants collecting data on crabs.

Figure 24: GoPro camera used for recording the behavior of the crabs

RESULTS

Along 36 transect lines , 358 quadrats were counted and diameter of 2578 crab holes were measured. More than 50% of the crab holes measured were less than 2cm in diameter.

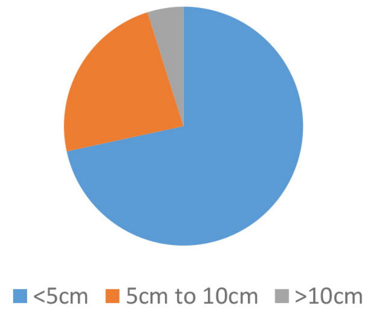

Figure 25: Diameter of the crab holes in Huraa Mangrove

Only 20 holes were above 15cm in diameter. Nearly one third of the crab holes found in the mangrove were small (<5cm) and only 126 crab holes had a diameter larger than 10cm.

Figure 26: Small burrows made by tiny fiddler crabs

The largest hole had a diameter of 21cm while the smallest was only 0.5cm. There were 415 holes with a diameter less than 1cm. Most of the small crab burrows measured were occupied by fiddler crabs.

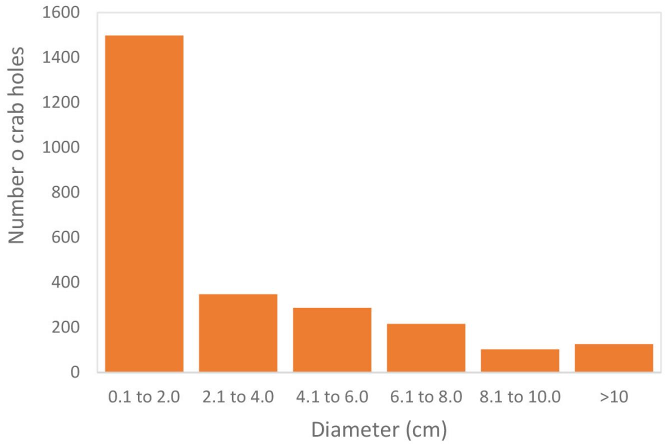

Figure 27: Majority of the crab holes had a diameter less than 2cm and only 126 holes had a diameter bigger than 10cm.

Total area sampled were 358 quadrats (358m^2). Each quadrat was 1m by 1m. It took 12 samplers 9 days to collect data. Total area of the 3 sites sampled were about 30,000m^2 (3 hectares). The total area of the Huraa mangrove is 90,000m^2 (9 hectares).

DISCUSSION OF FINDINGS

CRAB HOLES – SIZE

The sampling was done during spring tides and all the crab holes in the sampling area gets flooded during this period.

Figure 28: Fiddler crab removing sand from the burrow during low tide. The balls of sand are the sand taken out of the burrow.

During the low tide crabs continuously repair and maintain their burrows [1]. Hence it was assumed that the holes observed along the transect line were occupied by at least one crab when the sampling was done during low tide.

Figure 29: Crabs repairing their burrow during low tide

The size of the hole reflected the size of the crab and diameter of the mouth of the burrow was used to reflect the size of the crab. From visual observations made during the sampling, it was very obvious that most of the small burrows were occupied by fiddler crabs.

Figure 30: Large crabs found in Huraa mangrove

Along the 36 transact lines laid across the 3 sites (A, B and C *photo: Google earth*) in the mangrove 358 quadrats were counted. In these 358 quadrats the size and the number of crab holes varied. The smallest holes had a diameter of 5mm while the largest was 21cm. More than 50% of the crab holes measured were less than 2cm in diameter and were occupied by fiddler crabs. Only 20 holes were above 15cm in diameter and were occupied by mangrove crabs. The largest burrow had a diameter of 21cm while 126 burrows had a diameter greater than 10cm.

Figure 31: Several large crabs taking shelter inside the mangrove

CRAB ESTIMATES

There were 2578 crab holes counted covering an area of 358m^2 (358 quadrats – 1m x 1m). The total area of the Huraa mangrove was about 90,000m^2 (9 hectares) but the area under the mangrove vegetation (where most of the crabs were found) covered about 30,000m^2 (3 hectares). It is estimated that about 216,033 crabs (of all species) live in the sampled area of the mangrove.

Population of Crabs in mangrove =

(Mangrove Area X Number of crab holes) / Quadrat area

$= (30{,}000\ m^2 \times 2578) / 358\ m^2$

In the sample area there were 732 crabs which had a burrow diameter larger than 5cm while only 126 burrows had a diameter greater than 10cm. The larger crabs are exploited by the local communities as they can be sold to the tourists visiting the island. The present estimates for the larger edible crabs (10>5cm) is about 61,000 crabs but those occupying a burrow exceeding 10cm is only around 10,000. Crabs are collected by the locals and sold to the Chinese tourists visiting the island. There have been some requests made from other nearby islands to buy the crabs to sell to the guests on those islands.

ECOLOGICAL IMPORTANCE

Crabs provide number of ecological services to the mangrove ecosystem. It plays a major role in processing litter [1] that fall onto the mangrove floor, aerate the soil and also helps mixing of sediments. These crabs are active during low tide and return to their burrows taking shelter from predators during high tide. The burrowing effect of crabs has a significant effect on their surroundings and other organisms in the mangrove [2]. Thousands of crabs making burrows in the mangrove helps improve aeration of the mangrove floor, help create habitat for micro-organisms while contributing to nutrient release and mangrove productivity [3,4,5].

TWO SPECIES OF CRAB ABUNDANT IN HURAA MANGROVE

Fiddler crab

Kingdom	Animalia
Phylum	Arthropoda
Class	Crustacea
Order	Decapoda
Family	Ocypodidae
Genus	Uca

Figure 32: Male – has a large claw
Female – has two small feeding claws

Mangrove crab

Kingdom	Animalia
Phylum	Arthropoda
Class	Crustacea
Order	Decapoda
Family	Gecarcinidae
Genus	Cardisoma

GENERAL OBSERVATIONS – THE HABITAT

The Huraa mangrove was initially looked after by the Huraa Council and the community. But it since 14TH June 2006 has been declared as a protected area (PA) by Ministry of Environment and Energy. Before it was declared a PA, the community had access to the mangrove and since they used the mangrove for various purposes, the community took the responsibility of looking after the mangrove and planted trees to ensure the mangrove stayed healthy. But since the mangrove was declared a PA, the community no longer had access to it like before, the caring to the mangrove from the community stopped and slowly the condition of the habitat had deteriorated. More trees had died and the thickness of the mangrove has declined.

In addition, over the years the mangrove has become shallow and sand has entered the mangrove and this has narrowed the opening between the mangrove and the lagoon reducing the exchange (flow) of water between the mangrove and the lagoon. This has affected the number of reef fish entering the mangrove.

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3

ECONOMIC VALUATION OF HURAA MANGROVE.

Fathmath Shadiya

INTRODUCTION TO ECONOMIC VALUATION

Natural resources such as mangroves, rivers and forests are important resources for livelihood activities. When natural resources such as land, forests and wetlands are degraded, the environmental damage has a direct impact on the lives of the people who depend on these resources.

Many poor people directly depend on natural resources for their livelihood. When natural resources are destroyed or degraded, their opportunities for livelihood activities get reduced and as a result, the conditions of the poor become worse and they get trapped in a vicious circle of poverty. Poverty and social inequality very much affect how we manage our natural resources. Poverty decreases people's capacity to use resources in a sustainable manner. When people overexploit natural resources for short term gains, the consequences are long term losses such as loss of livelihood activities and economic loss.[5]

THE CASE OF GROUPER FISHERY IN THE MALDIVES DURING THE 1990s

Grouper fishery which started in the central atolls of the Maldives during the 1990s spread quickly to different atolls of the Maldives due to very high demand from overseas market. As a result of over exploitation, the grouper stock in the reefs started to decline rapidly due to their limited stock size.[6]

According to Marine Research Centre[6], the average sizes of groupers caught for commercial fishery have reduced compared to size estimate made in the 1980s and 1990s. Recent survey from the Research Centre showed that 43% of groupers caught in the fishery were immature groupers. [/12]

To protect the Grouper fish stock, the Marine Research Centre has developed a grouper management plan which recommends regulation of grouper fishing by introducing measures such as setting up species quotas, setting of minimum size of landings, identifying areas for grouper spawning and protecting these areas from fishing.

If Groupers are not protected today, their population may diminish in the future and this will result in economic losses for fishermen whose livelihood depends on grouper fishery. Overexploitation of natural resources such as grouper in the long run leads to more economic losses than short term economic benefits. Groupers are important for healthy functioning of the coral reef ecosystem. Even though coral reefs are rich in variety of species, they are poor in abundance. As a result, reef fish such as grouper become vulnerable to over exploitation, and in the long run, they cannot support large scale commercial fisheries.

SUSTAINABLE DEVELOPMENT

The concept of sustainable development was introduced in 1987 by World Commission on Environment and Development (WCED) in a report called "Our common future".

Sustainable development can be defined based on three common principles.

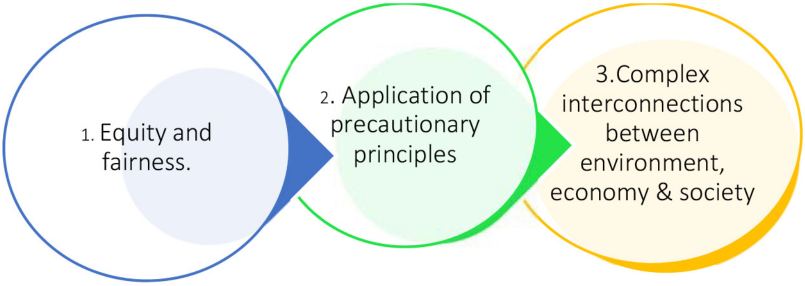

Figure 1: Three main principles of sustainable development.

Primary goal of any development project must be to alleviate poverty by improving the lives of the poor in the society. To address the issues of inequality, "equity and fairness" is the first principle of sustainable development. Equity and fairness means during development process, the poor people in the community must not be marginalized from development projects, their livelihood must be protected and they should not be excluded from any prosperity development brings. In addition, the development also should protect the rights of the future generations too. This concept of development is referred to as Intergenerational equity (equity between generations) and intra-generational equity (equity between different communities in any generation). [/2]

The second principal of sustainable development is the application of precautionary principles. Precautionary principle is a guiding framework that anticipates how our actions and decisions will affect the environment and wellbeing of the society including future generations. For example, if there is a threat to an environmental resource such as a river or a wetland, even though there is no guiding scientific knowledge to solve the problem, immediate cost effective measures should be applied to save the resource as effectively as possible.[2]

The third principal emphasizes inter connections between environment, economy and the society.[2] By interconnection, it means that society, environment and the economy are all interwoven into a system that cannot be separated from each other. For example, the society will need raw materials from nature for livelihood activities. The livelihood activities are a part of an economic system, societies have developed over time, and this system determines the socio-economic conditions of the people. Thus poverty and inequality are social issues that results from unequal distribution of wealth within the society.

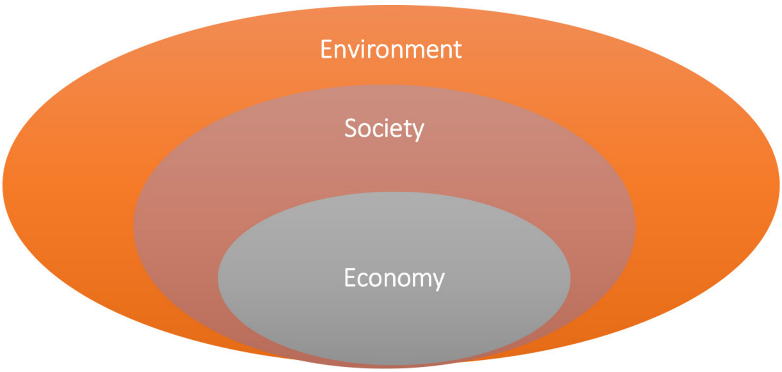

Figure 2: The concept of sustainable development.

Poverty can only be reduced when development strategies align with the principles of sustainable development. Policy makers should acknowledge the interconnections between environment, society and economy when they make policies for development. However, in many instances, development strategies fail to acknowledge these interconnections.

Economic development creates opportunities for people to earn income so that they can move out of poverty. However, when development only concentrates on gaining economic benefits, the outcome may be social inequality and environmental degradation. In many cases, societies compromise their natural resources for immediate benefits. For example, in Maldives, land reclamation is a common practice for development. A land reclamation project may provide immediate land for urbanization. However, the long term consequences of such activities could be; beach erosion and coral reef degradation, which will impact fisheries and tourism industry in the long run.

Figure 3: Lagoon reclamation for urban development.

The sustainable development concept gives a framework for developers to work in a holistic context that balances the social, economic and environment dimension. The main policy objectives of sustainable development according to Brundtland report are:

Table 1: main policy objectives of sustainable development

1) Encouragement of economic growth.
2) Changing the quality of life.
3) Meeting the needs for jobs, food, energy, water and sanitation.
4) Ensuring a sustainable level of population.
5) Conservation and enhancement of resources.
6) Reorienting technology and managing risks.
7) Merging environment and economics in decision making process.

During conservation of natural resources, we should always take into account the role of the community and their socio-economic status. If the communities are poor and if they do not get sufficient income from natural resources, it will be difficult for the communities to bear the cost of conservation of natural resources, since they can use the same money for other uses. Therefore, success of conservation programs very much will depend on the knowledge, attitude and perception of the people within the community regarding natural resources.3

DOES ECONOMICS MATTER?

Economics is a social science that tries to explain how and why people make decisions about use and distribution of valuable resources.[1] the main principle of economics lies in the concept of scarcity. Scarcity tries to explain the tension between limited resources and unlimited wants of people. While resources are limited in supply, our wants are unlimited, and as a result we have to make decisions regarding what resources we can have and what resources we should forgo. In simpler terms we can say economics is a social science that tries to explain how societies use scarce resources to produce valuable goods and services and how these scarce resources are distributed to meet needs and wants of people in a society.[1]

Economic activity is based on markets. When people find value in goods and services, markets are created. From an economic point of view markets are seen as a tool of exchange of valuable goods. The values of goods in economic terms are expressed as price. Market price is an efficient tool to measure the wants and needs of the society.

The behavioral foundations of economics can be summed up as follows. People respond to incentives such as price, they try to balance out the costs and at the same time try to see if they could get any benefits by taking risks. People also act in their own best interests.[11]

An important feature of interaction between economic and environment systems is the concept of co-evolution.[3] The evolution of the sub economic system over time depends on the changing conditions of the environment systems and vice versa. However, it should be noted that Environmental resources are scarce resources with an opportunity cost. Opportunity cost is the value of satisfaction of a good or service a person gives up, when that person chooses another alternative.[11] In other words it is the next best alternative forgone.

Conservation measures such as environmental protection also have opportunity costs. In conservation, this opportunity cost means, the cost inquired to protect natural resources that can be allocated for another use. For example, if a government decides to spend additional money on public transport to reduce air pollution, it also means the government will have less money to spend on other sectors of the country such as education and health.[3]

THE RELATIONSHIP BETWEEN ENVIRONMENT AND ECONOMIC SYSTEM

Environment provides the economic systems with inputs of raw materials and energy resources such as minerals, metals and food. In return, the economic system converts the raw materials into outputs that the consumers demand. For example, wood from forests may be converted into paper and oil from fossil fuel may be converted to petrol. The raw materials or inputs are derived from natural environment and the outputs or consumer goods are produced by utilizing the inputs from nature.
Environment provides four types of services to the economic system.[3] The services are:

1) **Raw materials:** The environment acts as a source of input of raw materials to the economic system.
2) **Waste Sink:** The environment acts as a waste sink (eg: waste are dumped in rivers).
3) **Global Life Support System:** Provider of global life support system.

While the economic system needs the environment to provide all the raw materials for economic production, the economic system also uses the environment as a waste sink.[3] Figure five shows how the economy and the environment interact with each other.

Sustainable development is not an easy concept to apply in the real life context. Developmental agencies face enormous challenges when they try to bring a balance between social, economic and environmental issues in a society. Poverty elevation is absolutely necessary for resource conservation and management. However, with the advancement in technology, modification of natural resources for development is more drastic and alarming as the rate of destruction precedes natural recovery. However, it is impossible to preserve all of the ecosystems in the world, therefore during the course of development, many habitats such as forest, mangroves, lagoons and rivers would be modified. Nevertheless, if environmental resources such as forests and fish stocks are used within the limit of regeneration and natural growth, they will not be exhausted and some of the natural resources will always be left for the next generation to utilize.

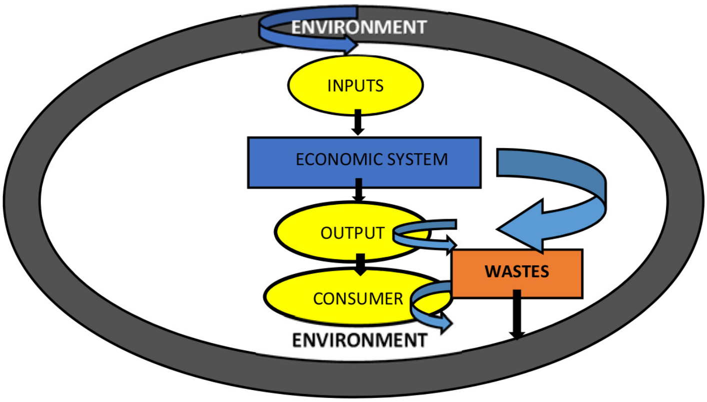

Figure 5: Interaction between Economy and Environment.

Waste may be originated during the production phase of the goods or waste may also be generated during the consumption phase of the good as shown in figure five.

The interrelation between environment and the economic system means environment and the economic system cannot be separated. Resources such as minerals, metals and food are important raw materials for economic systems to function properly. If the economy unsustainably increases its demand for natural resources, the environment cannot keep supplying the raw materials infinitely as raw materials are limited in supply.

However, the problem with nature is that natural resources such as forests, wetlands and seas are open access resources that are not sold in the market.[4] An open access resource is a resource or a facility that is accessible to individuals who wish to use the resource. [1] When a resource is open access, there is no way of ensuring the rate of resource utilization.4 A classic example of an open access resource is ocean fishery where anyone who wants to fish can catch as many fish as possible. In the absence of a market to regulate open access resources, resource over- exploitation occurs. Today, resource over-exploitation and habitat modification are two main threats faced by mangroves in many parts of the world.

Figure 6: Photo of a mangrove habitat modified to a shrimp farm.

Source: (Sebastien Blanc/AFP/Getty Images): http://e360.yale.edu/slideshow/shrimp_farmings_dirty_legacy_is_target_of_certification_drive/1/110/

ENVIRONMENTAL VALUATION

The emergence of environmental economics as a separate discipline during the last couple of decades had very much influenced economic reasoning to move from traditional economic approaches to more environmentally sound approaches. Environmental valuation has gain enormous popularity among researchers over the last few decades as a tool to estimate a marketable price for the quality of services natural ecosystems provide in the absence of a market. The main purpose of environmental valuation is to find best alternative that provides highest benefit to human wellbeing.[10] There are two main approaches for environmental valuation. In the first approach market information is used to assign a value for goods and services obtained from the natural resources. In the second approach a hypothetical method is applied to generate a value for environmental goods and services. [10]

THE USE OF ECONOMIC VALAUTION METHODS IN WETLAND ECOSYSTEMS.

The concept of ecosystem services is becoming a useful concept in linking functions of ecosystems and human welfare. Ecosystem services provided by mangroves are services that are directly or indirectly beneficial to humans.[10] The services provided by wetlands can be grouped into three categories. They are:

1) **Hydrological services:** wetlands ability to adjust water and sediments.
2) **Biogeochemical services:** conversion and storage of materials that can have important effects on the quality of the environment.
3) **Ecological services:** maintenance of habitats where organism lives.

Valuation of the above mentioned services are based on market based and non-market based methods. Market based valuation methods are based on existing market behavior and market transactions are used as the basis for economic valuation.[10] However many services provided by wetlands are not traded in the market, as a result; there is no known price for these services provided by the wetland ecosystems.

Economists try both direct and indirect methods of valuation to capture the worth of ecosystem services provided by the wetlands using tools such as valuation methods. Economic valuation methods provide a framework which helps to prioritize investment decisions for decision makers during development projects. The most common economic valuation framework used to understand full economic value of natural resources such as wetlands is the Total Economic Value (TEV) frame work[9] shown in figure eight.

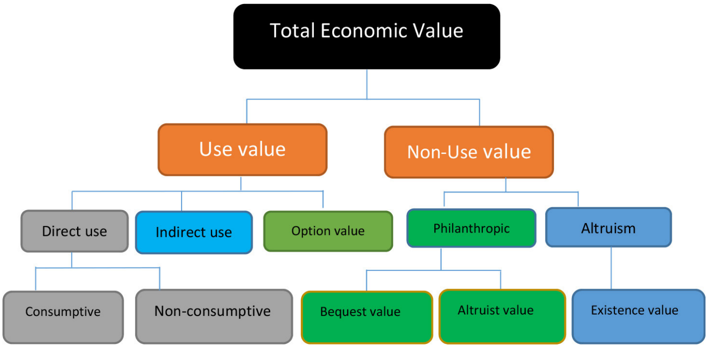

Figure 7: Total Economic value framework adopted from TEEB

Total Economic value can be grouped into two broad categories known as Use values and Non-use Values. Use values can be further categorized into direct use, indirect use and optional Values. [14]

Direct values can be categorized into consumptive and non-consumptive values. Indirect values refers to regulatory services provided by the ecosystem such as local climate and air quality, carbon sequestration and storage, moderation of extreme events, erosion prevention. Option value refers to the importance that people give to the future availability of the ecosystem services for personal benefit. [9]

Similarly, Non-use values can be categorized into Bequest value, Altruist Value and Existence Value. A bequest value is the value of satisfaction attached by individuals knowing that future generation will also have access to the benefit from that ecosystem that is conserved.

Altruist value means the satisfaction people get when they know that others also can enjoy good and services ecosystem provides.

Existence value refers to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist. [9]

In recent years, environmental valuation has become a useful tool because valuation tools provides information that is useful for

a) Designing policies for the sustainable use of environmental resources.[3]

b) Making informed investment choices. [3]

Case study

A study about mangrove storm protection function conducted by Das during 1999 in Kendrapada district (present in the state of Orissa in India) showed that, in places where mangrove vegetation was thick, actual death of human casualties were few compared to places where mangrove was modified. Such studies show that mangroves play an important role in disaster reduction by acting as natural barriers against storm winds.

Similar to the findings of Das (1999), a study done by Barbier (2006) indicates that in the event of disasters (such as storms and cyclones), the damage cost to the properties and loss of human lives is very much less in areas where there is dense mangrove vegetation, However, in areas where mangrove is considerably degraded, damage to properties and loss of human lives are more significant. (Barbier,2006)

In the wake of 2004 Asian Tsunami, many researchers found that mangroves play an important role in protecting coastal habitats from destructive events such as storms, cyclones, and flooding.
Disaster management in developing countries is an expensive procedure due to inadequate finance and limited resources. Installing new technologies and developing innovative know-hows is costly and time consuming in poor countries. As a result, adequate planning and preparation against natural hazards are not done effectively in many developing countries. The extent of damage to properties and human casualties in an event of a disaster is much more in number when compared to developed countries. However, if governments recognize the importance of mangroves and their role as a

natural barrier against storms, cyclones, flooding and tsunamis, there may be more effective policies implemented to protect these natural habitats. Preserving existing natural habitats is as important as introducing new innovative conservation strategies.

CASE STUDY: ECONOMIC VALUATION OF HURAA MANGROVE

INTRODUCTION

Mangrove ecosystems are complex ecosystems with numerous ecological functions. Some of these functions are

1. Shoreline protection where mangroves acts as natural barrier against destructive waves.
2. Reduction of the impacts from hurricane, cyclones, and Tsunami and storm surges.
3. Stabilization of fine sediments near the shore. (The stabilizing effect reduces coastal erosion)
4. Act as breeding grounds for many organisms.
5. Act as a nursery ground for juvenile marine organisms such as sharks, rays, shrimps and many species of fishes.

Even though mangroves provide numerous ecological services, they are threatened by anthropogenic activities. Today in many parts of the world, mangroves swaps are rapidly converted into salt evaporation ponds or shrimps farms or they are modified for urban development projects such as infrastructure development.[7]

Figure 8: Addu convention center developed for 17 SAARC Summit.
The convention centre was developed by modifying surrounding marshland. Source: Haveeru online English edition Oct 23rd 2011

Wetlands are dynamic ecosystems continuously undergoing natural changes due to fluctuating conditions of the environment surrounding them.[7]

In the past, wetlands are seen as waste lands by many people. As a result, a lot of wetlands were converted to intensive agricultural lands, or aquaculture farms such as shrimp farms. In addition, many wetlands became sites for waste disposal which degraded the fragile ecology of wetland ecosystems. Table two adopted from a study done by Barbier, Acreman & Knowlerb (1997) shows the percentage loss of wetland during 1980s and 1990s.

Country	Period	% loss of wetland
Netherland	1985-1950	55
France	1993-1900	67
Germany	1985-1950	57
Spain	1990-1948	60
Italy	1984-1938	66
Greece	1991-1920	63

Table 2: wetland loss from Europe between 1950 to 1991 [/11]

The alarming rate of wetlands loss was brought to the attention of world leaders by Ramsar Convention in 1971. Ramsar Convention was the first inter-government treaty that provides the framework for international cooperation for the conservation of wetlands. Ramsar Convention has 168 member countries as of May 2015, all working together to conserve wetland ecosystem in different parts of the world. Through agreements, the member countries are obliged to develop national wetland policies, to promote conservation of wetlands through establishment of nature reserve, promotion of research and training in the field of wetland management, to give consultation with other member countries regarding trans-boundary wetland issues and to include important national wetlands in the "list of wetlands of International Importance".[11]

There are many mangroves in the Maldives. Unique mangroves such as Huraa mangrove have been protected by environmental protection agency as stated by Ramsar Convention. However, declaration of a mangrove as a protected area does not protect the mangrove unless the community takes an active part in the conservation measures. In the case of Huraa mangrove, keystone species such as giant mangrove crabs are being over exploited for their meat by the local community and as a result, the health of Huraa mangrove is at risk as crabs are important species to maintain the health of the mangrove ecosystem. [15]

When crabs dug burrows to live in the mangrove soil, the burrowing action causes alteration of soil chemistry and sediment structure of the mangrove soil. This is because water, dissolved nutrients and air is flushed deep into the anaerobic layer of the soil. As a result of this aeration and mixing of water, physical, chemical and biological changes are brought to the mangrove environment in a process called bioturbation15. This process is important for maintaining the health of the mangrove ecosystem. However, the process of bioturbation can only be possible, if there is a healthy population of mangrove crabs in the ecosystem.

Figure 9: Burrow of a giant mangrove crab.

With the introduction of local tourism in Huraa, there is a growing demand for giant mangrove crabs by the Chinese tourists who visit the island. Mangrove crabs are hunted for their meat and in restaurants they are served as a special dish for tourists who visit the island.

Figure 10: Crabs form the mangrove prepared for tourists

Giant mangrove crab's meat is a favorite dish among the Chinese tourists who visits the island. Crabs are cooked and served for tourists in restaurants at a price of $6. Due to high demand for crab meat by chines tourists who visits the island, there is fear of over exploitation of giant mangrove crabs in Huraa.

Environmental resources are scarce resources with opportunity costs. [10] In the case of natural resources, the concept of opportunity cost is useful because, the idea of value of a particular resource use can be measured in terms of sacrifice people are willing to make to have it. Environment can have economic value, in-terms of both indirect and direct values, even if it has no market value or price.

The concept of total economic value tries to address the direct and indirect values of natural ecosystem such as wetlands. In a wetland ecosystem the use value may be the direct benefits people get from the mangrove such as fishing, hunting and bird watching. Use values in this case can be consumptive such as fishing and hunting. The other types of values associated with wetlands are non-use value. None use values are values that are not associated with actual use. [10]

Economic valuation tools are powerful tools that can be used for the management of wetland resources. In the case of Huraa, it is hoped that through application of valuation methods, the mangrove might be better managed by the local community and the regulatory bodies in the future, with this hope in mind, the purpose of this study is to capture the value of Huraa mangrove using the concept of economic valuation. [15]

METHODOLOGY

There are many economic valuation methods that can be applied to value ecosystems and ecosystem services. The method applied for this study was market price method. Market price method is used to estimate the economic value of the ecosystem in terms of ecosystem products that can be bought and sold in commercial markets. In order to determine which products from Huraa mangrove are sold in the market, a series of focus group interviews were conducted with the council, local community and business men who are involved in local tourism.

RESULTS

Interviewers who participated in the focus group interviews session highlighted that giant mangrove crabs are high in demand by the Chinese tourists who visit the island. In addition, they also pointed out those tourists from nearby resorts pay a huge fee to watch reef sharks that lives in the surrounding waters of Huraa mangrove. (Hurra mangrove is a nursery habitat for many reef sharks.) One member of the focus group discussion explained that, Kandoo, mangrove vegetation found in Huraa is also a valuable product to build boats. In addition, due to the location of Hurra mangrove, the mangrove is an important site for schools visits from nearby

islands, especially from the capital city Male'.
One contributing factor highlighted by members of focus group interview session were the indication of a market value for species such as giant mangrove crab, Kandoo trees, and reef sharks that resides in the mangrove. In addition, the aesthetic beauty and the geographical location of the mangrove also make the mangrove an important destination for school visits by school children from the capital city.
Mangrove crabs lives in deep burrows, the size of the burrow hole depends on the size of the crab.

Market price estimation of Giant mangrove crabs.

Figure 11: A giant mangrove crab (Cardisoma Carnifex) retrieving into its burrow.

Giant mangrove crabs can be found between shoreline and mangrove periphery. Mature crabs (crabs with a diameter of 10cm or more) lives in larger burrows while smaller crabs (crabs with a diameter less than 10 cm) live in smaller burrows. It was assumed that only one crab lives in a burrow at a given time. To estimate the population of mature crabs, crab holes greater than 5 cm were counted during the quadrate sampling. In the sampled area there were 858 crab holes exceeding 5 cm.

Figure 12: Students measuring distance between two lines transact.

Figure 13: Students measuring the diameter of the crab burrow using a ruler.

To estimate the total population of giant mangrove crabs, the following formula was applied.

(Mangrove Area X Number of crab holes exceeding 5 cm) / Quadrant area

= (30,000 m2 X 732) / 358 m2 =61,341

Figure 14: Steps to estimate the total population of giant mangrove crabs residing in Huraa mangrove.

Based on the calculation, estimated total population of giant mangrove crabs is equal to 71899 crabs per m^2

After finding the total crab population, the next step was to find out the market value of the crab population.

To determine the market value of this crab population, the total crab population was multiplied to the market price of the crab as shown below.

Market valuation

*(Edible giant mangrove crab population) * (market price)*

=

61340 × 5$ = $306,700

Figure 15: steps to calculate the market price of giant mangrove crabs.

Market price estimation of Kandoo.

In the past, Kandoo trees were used as timber for boat building. Even today, in some islands, Kandoo tree logs are used to build boats. According to interviews carried out among dhoni (boat) builders, it was found that in the market a Kandoo tree log with more than 9 inches in diameter can be sold at a price of MVR 500 to build boats.

To calculate the market value of Kandoo tree suitable for boat building, first, mature kandoo tree population was estimated. A kandoo tree is considered mature, if the tree has a girth more than 10 cm. Before counting, the trees were tagged and their GPS location was recorded to avoid double counting of the same tree. A total of 2025 mature Kandoo trees with a circumference larger than 9 inches were counted in the mangrove.

To estimate the value of Kandoo stock that is suitable for boat building, kandoo population exceeding diameter of 9 inches were multiplied by the market price as shown below.

*Kandoo trees exceeding 9 inches in diameter * the market price*

2025 ×$32 = MVR 64,800.

Figure 16: steps to calculate the market price of mature Kandoo trees present in Hurra mangrove.

According to the calculation, the value of kandoo stock as timber for boat building is MVR 1012500 which is equal to $65,661.

Market price estimation of black tip baby shark.

During each field visit on average, 16 Black Tip Baby Reef Sharks (Farumathi Dhon Miyaru) were spotted on go pro camera for a period of four hours during the field visits. Shark watching is one of the preferred activities among divers. Conferring to divers nearby resorts, tourists pay $250 for shark watching alone. Each week dive Centre nearby Huraa arranges a shark watching dive excursion for tourists who are interested to watch sharks. Black Tip Shark is one common shark spotted in the reefs near Huraa. Since $250 is paid by tourists to watch a live shark each week, it can be said that the value of 16 live baby Black Tip Sharks in Huraa mangrove estimated for a year will be (16 times $250 into 52 weeks) which is equivalent to $208000.

Market price estimation of school visits to the mangrove.

The unique aesthetic beauty of Huraa mangrove makes the mangrove an idle place for school visits. From interview sessions conducted to the members of island council, it was found that on average, 50 field trips are conducted annually by schools. On average 60 students are accommodated into these visits. In each school visits about $10 is spent for each student as field trip fees.

Summing up, table 3 provides estimates of Huraa mangrove’s worth in terms of mangrove crabs, Kandoo trees, baby black tip sharks and school visits.

Type	Quantity	Market Value
Mangrove crabs	71000	$368,046
Kandoo trees (with a circumference more than 9 inches)	2025	$65,661
Black tip reef baby sharks.	16	$208000
School field trips (for 60 students with a rate of $10)	50	$30000
Total price in $		$644,707
Total price in MVR		MVR 9,941382

Result table 3: Value of Huraa mangrove.

DISCUSSIONS

From the result table 3, it can be said that the value of Huraa mangrove in terms of mangrove crabs, Kandoo trees, black tip reef sharks and educational trips is worth \$ 644,707 which is equivalent to MVR 9,941382. It should be noted that the calculated figure is a rough estimate of very few marketable species found in Huraa mangrove. However, a thorough detailed study is suggested as a future study to capture the value of Huraa mangrove.

From the social research conducted among the local community, Resource management and conflict was one major issue identified by the participants of the focus group interview. According to respondents of the focus group interview, one of the biggest challenges the local community face was the unclear nature of protected area model applied in Huraa mangrove by EPA. The respondents said they were not clear on exactly what roles and responsibilities they should play in conservation of Huraa mangrove. In addition, the local community showed concerns that the current conservation model applied in Huraa mangrove makes them feel isolated as they are not allowed to use any natural resource from the mangrove. One of the respondents said:

"The mangrove belongs to the people of Huraa, but they are not allowed to touch it"

As the mangrove was highly threatened by habitat destruction and habitat degradation, EPA declared Huraa mangrove as a protected area on 14th July 2006. Even though the mangrove was declared as a protected area, success of the protected area model applied by the government is at question, because from the study it was found that, the local community feels a sense of isolation from the mangrove as they are not allowed to consume resources from the mangrove. According to island council, the local community feels that if they were allowed to utilize mangrove for their livelihood activities, they would feel more responsible for conserving the natural resources in the mangrove. However Environment protection agency fears that if the mangrove is not protected, over exploitation of mangrove resources may destroy the mangrove ecosystem.

It was also interesting to note that even though Huraa mangrove is declared as a protected area, exploitation of crabs was taking place as there was a demand for mangrove giant crabs by the Chinese tourists who visits the island. However what was surprising was from the discussion with restaurant owners and guest house owners who hunt crabs to sell to Chinese market; the level of awareness they had about over-exploitation of mangrove crabs was much higher than expected. The business owners showed concern that over-exploitation of crabs may eventually reduce their crab supply to the market which in turn will affect their business negatively.

To conserve mature crabs, the business men have their own rules for conservation. One such rule is giving discount prices to tourists who bring their own crabs for eating in the restaurant. This activity was included in the local tourism package where the tourists are given the opportunity to eat crab meal at $12 rate or $10 rate. The $10 rate applies to tourists who choose to join crab hunting activities where the tourists are given the opportunity to hunt two crabs on their own. This is a fun activity that is becoming popular among tourists who visits the island.

When asked why the restaurant and guest house owners think this strategy will help in crab conservation, the business owners said that the tourists do not know where the mature crabs live, so they usually hunt the smaller ones. By this way, the mature ones are protected from over exploitation and will get a chance to breed to maintain their future generations.

From the interview it was also found that since the introduction of the local tourism in Huraa, locals have become more aware about the direct and indirect benefits of the mangrove. When the community feels they get direct benefits from natural resources they tend to value the resource more.

From the social research conducted on valuation, it was found that, a participatory conservation model is very much needed for Huraa mangrove. Because the current model does not define the roles and responsibilities of the local community in conserving the mangrove. When the community is separated from the natural resource they feel it is not their responsibility to conserve the area. As a result, the sustainability of the protected area often is at risk.

Figure 17: Meeting with council members

In some countries, aesthetic beauty of the mangrove is used to promote eco- tourism activities such as bird watching, nature photography, and nature walk. All of these activities provides valuable source of income to the tourism industry. With the recent introduction of local tourism in Huraa, aesthetic beauty of Huraa mangrove has become an important tourist attraction. Tourist operators in the island promote Huraa mangrove in their local tourism promotional packages to attract tourists for their local tourism business.

SUMMARY

Mangrove ecosystems are rich in biodiversity, providing idle breeding grounds for many fish species and may function as a nursery ground for both marine and fresh water aquatic species. Mangroves provide habitats and nesting grounds for terrestrial and shorebirds. Mangroves also provide a wide range of ecological services including; carbon sequestration, navigational waterways, preventing coastal erosion, filtering water pollutants, in addition to being a resource for tourism & recreation activities.

At present, mangrove forests across the globe are declining at an alarming rate, due to the impact resulting from human activities. Most of these impacts are a result of resource dependence, such as over harvesting of timber, land reclamation for housing, farming and activities such as aquaculture. The situation in Maldives is no exception. Today, most of the Maldivian mangroves are threatened with habitat loss and habitat degradation due to developmental projects that require mangrove reclamation.

Huraa mangrove found in the Maldives is a unique mangrove. Even though the mangrove is protected, the mangrove is still facing threats such as over exploitation of keystone species such as mangrove crabs and habitat modification. Huraa mangrove is an important natural mangrove habitat, which contains species of particular conservation significance to the Maldives. The mangrove is an open mangrove which is easily accessible by land as it is close to the residential area and the less dense vegetation. Huraa mangrove consisted mainly of 4 different mangrove species.

The results of the study showed that, among the four vegetation species found in Huraa , Kandoo (Bruguiera Cylindrica) was found to be the most common species while Randoo (Rhizophora mucronata) was found to be the least common. Bodavaki were distributed throughout the mangrove, but with majority of its mature trees being located in northeast and southeast of the mangrove. Randoo, the least in number is sparsely distributed on northeast, southeast and southwest of the mangrove and appears to be concentrated on the northeast side towards the central part of the mangroves water body.

Results of the abiotic study showed that, the average pH of soil at the shoreline of the mangrove was at 7.2 while at inland the average pH was at 7.5. At the mangrove where Randoo is most abundant, the pH was slightly alkaline at 7.84. This is the perfect range for mangrove vegetation and is one of the reasons why Randoo flourished in this region.

Mangroves are often linked to coastal ecosystems and play an important role for the sustenance of diversity among the communities across these coastal ecosystems. Mangrove habitats are important feeding sites for several species of fish and provide protection for others. It also serves as an important nursery ground, hence in many countries mangroves are protected due to their importance to fisheries. There are several species of fish found in Huraa mangrove. Some of these regularly visit the mangrove during high tide while others spend most of their life in the mangrove.

In Huraa mangrove, thousands of crabs were seen on the mangrove floor during low tide. They all have a very important role in the mangrove ecosystems and are a rich source of food for birds and fish that frequently visit it. Hundreds of thousands of crabs continuously repair its burrows and this process helps aerate the muddy mangrove floor.

Crabs affect the sediment structure and influence other organisms living in the mangroves through their activities. Feeding and burrowing by crabs helps nourish the soil. Construction of burrows and their continued maintenance affect sediment cycle and topography having a significant engineering effect on their surrounding habitats. It creates space for bacteria which provides nutrients for primary production. It also enhances the distribution of nutrients to coastal zones. Burrowing helps easy flow of water into the sediments and mixing of sediments. There are several species of crabs found in and around the Huraa mangrove. Two species that are common include fiddler crab and mangrove crab.

Mangrove crabs are popular among the tourists visiting Huraa Island. It is important to ensure sustainable exploitation of mangrove crab resources to preserve the mangrove ecosystems and other organisms within the ecosystem. Over exploitation could lead to total depletion of mangrove crabs from Huraa mangrove which could even lead to complete collapse of the ecosystem finally destroying a beautiful and important mangrove very close to Male' which is visited by hundreds of students every year.

Over the last few decades, environmental valuation has become a useful tool for designing policies for sustainable use of environmental resources.

The emergence of environmental economics as a separate discipline during the last couple of decades had very much influenced economic reasoning to move from traditional economic approaches to more environmentally sound approaches. Environmental valuation has gain enormous popularity among researchers over the last few decades as a tool to estimate a marketable price for the quality of services natural ecosystems provide in the absence of a market. The main purpose of environmental valuation is to find best alternative that provides highest benefit to human wellbeing.

There are two main approaches for environmental valuation. In the first approach market information is used to assign a value for goods and services obtained from the natural resources. In the second approach a hypothetical method is applied to generate a value for environmental goods and services.

There are many economic valuation methods that can be applied to value ecosystems and ecosystem services. The method applied for this study was market price method. Market price method is used to estimate the economic value of the ecosystem in terms of ecosystem products that can be bought and sold in commercial markets. In order to determine which products from Huraa mangrove are sold in the market, a series of focus group interviews were conducted with the council, local community and business men who are involved in local tourism. From the interview session it was found that there is a growing market for giant mangrove crabs by the Chinese tourists who visit the island. Kandoo logs with the diameter more than 9 inches can still be sold in the market for MVR 500 to build boats. Black tip baby reef sharks which is often spotted in Huraa mangrove also have a market value as tourists who comes to the nearby resorts pay $250 to watch black tip reefs sharks in their diving excursions.

Annually on average, 50 field trips are conducted to Huraa by schools from Capital city. In such trips, each student spend about $10 as field trip fees to visit the island.

In summary it can be said that the value of Huraa mangrove based on the market price of the few species taken in to account, can be equivalent to $644,707 (six hundred and forty four thousand seven hundred and seven dollars), when converted to Maldivian Ruffiya, this amount is equal to MVR9,941,382 (nine million nine hundred and forty one thousand, three hundred and eighty two Ruffiya).

Even though market price is one way to estimate value of the mangrove, there are many other methods that can be applied as a valuation tool to calculate value of mangroves. Some common economic valuation tools used by researches are found in Appendix 2.

Social research findings suggest that local community does not have a clear idea of the current protected area model applied in Huraa mangrove and they feel that they are excluded from their own natural resources. An inclusive participatory model where economic, social, and environment dimensions are considered is very much needed to ensure future sustainability of Huraa mangrove.

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GLOSSARY OF TERMS

Sustainable development: development that meets the needs of the present without compromising the ability of future generation to meet their own needs.

Economics: is a social science that tries to explain how and why people make decisions about use and distribution of valuable resources.

Ecosystem services: services provided by wetlands that are directly or indirectly beneficial to humans.

Scarcity: tries to explain the tension between limited resources and unlimited wants of people.

Opportunity cost: is the value of satisfaction of a good or a service a person gives up when the person choses another alternative.

Open access resources: resource or a facility that is accessible to individuals who wish to use the resource.

Economic valuation tools: tools that can be used for the management of global wetland resources.

Ramsar convention: the first inter-government treaty that provides the framework for international cooperation for the conservation of wetlands.

Indirect values: environmental services provided by the ecosystem.

Option value: refers to the importance that people give to the future availability of the ecosystem services for personal benefit.

Bequest values: are values attached by individuals to the fact that future generation will also have access to the benefit from ecosystem.

Altruist value: means value other people from the present generation have access to the benefits provided by ecosystems.

Existence value: refers to the satisfaction that individuals derive from the mere knowledge that species and ecosystems continue to exist.

APPENDIX – 1 – Interview Guide

INTERVIEW GUIDE FOR COUNCIL MEMBERS

1.How long have you been in the council?

2.Can you explain how the council is responsible for protecting Huraa mangrove?

3.How often do you regulate the mangrove area?

4.What are the common threats to the mangrove that you have noticed?

5.What are the measures you take to minimize these threats?

6.How do the local community perceive Huraa mangrove as a protected area?

7.Do you support the idea of Huraa mangrove as a protected area? Explain your views.

8.Which resources in the mangrove are exploited most?

9.Are any mangrove resources being over-exploited?

10.What is your future expectation towards Huraa mangrove in the future?

INTERVIEW GUIDE FOR CRAB HUNTERS

1.How long have you been in the business of crab hunting?
2.Who are your customers?
3.How much demand is there for mangrove crabs from your customers?
4.Which species of mangrove crabs are sold to the customers?
5.At what prices are the crabs sold to the market?
6.On a monthly basis how much do you get as profit from selling crabs?
7.Do you think you get enough supply of mangrove crabs throughout the year?
8.What about the size of the crabs, does price vary according to the size?
9.Do you think that if more people start to sell more mangrove crabs, the crabs might be over exploited?
10.Will this affect your business? If so how?
11.Do you have any conservation measures applied to maintain the stock of the crabs? If so, could you explain these methods?
12.What do you think of the current protected area model applied in Huraa mangrove by EPA?

APPENDIX – 2 : ECONOMIC VALUATION TOOLS

Method	Application	Importance	Constraints and Limitations.
Market price method	Direct Use values can be applied to wetlands products.	The value is estimated using prices in the commercial markets.	Market imperfection such as subsidies, lack of transparency.
Damage Cost Avoided, Replacement Cost or Substitute Cost Method.	Indirect Use Values such as: Coastal protection Avoided erosion Pollution control	Example of substitute cost. The value of organic pollutant's removal can be estimated from the cost of building and running water treatment plant. This cost inquired for running the system is known as substitute cost. Damage cost avoided or Replacement cost. The value of flood control can be estimated from the damage caused by flooding.	The key assumption when applying cost of avoided damage or substitute is that the cost of avoided damage matches the original benefit. But due to external unpredicted circumstances, the original expected benefit may change, as a result the method might give a under or over estimates.
Travel Cost Method.	Recreation and Tourism	The recreational value of a site is estimated from the amount of money people spend on to reach the site.	This method only gives an estimate. There is a high chance of making over estimates as the site may not be the only reason for travelling to that area.
Hedonic Pricing Method	Some aspects of Indirect Use, Future Use-and Non-Use Values.	This method is used when wetland values influence the price of market goods. For examples houses near the wetland vegetation may have a higher price due to their aesthetic view.	This method only gives an estimated value of people's willingness to pay for perceived benefits.
Contingent Valuation Method.	Tourism and Non-Use values.	This method asks people directly how much they would be willing to pay for specific environmental services.	Bias might arise due to interviewing techniques used. In addition there is controversy over whether people would actually pay

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6th December 2016

Mangroves for the Future
INVESTING IN COASTAL ECOSYSTEMS

About Mangrove for the Future

A mangrove for the Future (MFF) is a unique partner-led initiative to promote investment in coastal ecosystem conservation for sustainable development. Co-chaired by IUCN and UNDP, MFF provides a platform for collaboration among the many different agencies, sectors and countries which are addressing challenges to coastal ecosystem and livelihood issues. The goal is to promote an integrated ocean-wide approach to coastal management and to building the resilience of ecosystem-dependent coastal communities

MFF builds on a history of coastal management interventions before and after the 2004 Indian Ocean tsunami. It initially focused on the countries that were worst affected by the tsunami -- India, Indonesia, Maldives, Myanmar, Seychelles, Sri Lanka and Thailand. More recently it has expanded to include Bangladesh, Cambodia, Pakistan and Viet Nam.

Mangroves are the flagship of the initiative, but MFF is inclusive of all types of coastal ecosystem, such as coral reefs, estuaries, lagoons, sandy beaches, sea grasses and wetlands.

The MFF grants facility offers small, medium and regional grants to support initiatives that provide practical, hands-on demonstrations of effective coastal management in action. Each country manages its own MFF Programme through a National Coordinating Body which includes representation from government, NGOs and the private sector.

MFF addresses priorities for long-term sustainable coastal ecosystem management which include, among others: climate change adaptation and mitigation, disaster risk reduction, promotion of ecosystem health, development of sustainable livelihoods, and active engagement of the private sector in developing sustainable business practices. The emphasis is on generating knowledge, empowering local communities and advocating for policy solutions that will support best practice in integrated coastal management.

Moving forward, MFF will increasingly focus on building resilience of ecosystem dependent coastal communities by promoting nature based solutions and by showcasing the climate change adaptation and mitigation benefits that can be achieved with healthy mangrove forests and other types of coastal vegetation.

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Learn more at: www.mangrovesforthefuture.org

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