



Mangrove Dieback in HA. Kelaa and HDh. Neykurandhoo  
Preliminary Mangrove Survey Report

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Ministry of Fisheries, Marine Resources and Agriculture

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## **Acknowledgment**

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## **Introduction**

The concerns regarding mangrove damage was first reported from HDh. Neykurendhoo, one of the largest mangrove habitats in the region. This region consists of *Bruguiera cylindrica* (small-leaved orange mangrove), locally known as *Kandoo* in the Maldives. Subsequently, reports were received from HA Kelaa island and N. Kendhikulhudhoo, regarding similar issues.

As this became a growing concern of the local communities of these islands, environmental NGOs and government authorities, the urgency to find the cause of the issue became crucial. Despite the restrictions and challenges posed by Covid-19, a team consisting of relevant technical staff from Environmental Protection Agency (EPA) and the Ministry of Fisheries, Marine Resources and Agriculture (MoFMRA) visited the islands of Neykurendhoo and Kelaa, in a collaborative effort.

Mangrove ecosystem is considered one of the most complex ecological niches. Abiotic factors such as salinity, temperature, rapid changes in water quality, and nutrient cycle could cause a large-scale issue akin to this. Alternatively, biotic factors such as predators, pathogens or invasive species could also alter the healthy balance of a mangrove habitat. Observations were made to discover the potential biotic and abiotic factors that might cause the issue. This report is a detailed account of the work done at the islands Kelaa and Neykurendhoo and preliminary analyses based on the data collected. However, investigation to find a conclusive cause is still in progress.

## **Objective of the visits**

In order to understand the cause of the sudden deaths of the mangroves, the staff began their investigation by;

- Exploring the history of affected areas and related historical events through in-person interviews
- Take relevant samples from the affected areas of both islands for further investigation

## **Method**

The Research team, consisting of staff from Hanimaadhoo Agriculture Center (HAC) and Environmental Protection Agency, visited the Kelaa study site on the 6-8<sup>th</sup> of July and to Neykurendhoo on the 11-13<sup>th</sup> of July to monitor and observe the mangrove sites. As species activities and symptoms were assumed to differ depending on the time, the samples taken from various parts of the study area were collected on alternating times of the day. Samples were taken from foliage, bark, trunk and roots for plants in selected areas in the affected sites. Additionally, samples of potential predatory insects observed from the sites were collected from infested plants. Random water samples were collected from both study sites to observe electrical conductivity and water salinity. Apart from mangrove visits, in-person interviews were conducted with the members of the community in both islands.

## **Data Analysis**

The water samples were tested for electrical conductivity and pH at the Hanimaadhoo Agriculture Center. Furthermore, data on insect observation and root samples were carefully tallied for each island. The insect samplings and root samplings were photographed and sent to experts from

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Kerala Forest Research Institute (KFRI) and Asia Pacific Forestry Invasive Species Network in order to identify the species.

### **Findings**

Neykurendhoo has a more dense and comparatively large affected area. In comparison, the affected area in Kelaa is in identifiable patches and more accessible. Tree logging practices have been regulated in both islands since the 1990's and the removal of *Bruguiera cylindrica* has been completely banned. For other species, the islanders must obtain a permit from the island council. In addition, both islands have reported that any other species of mangroves have never been imported into the island. There was no development within the mangrove area in Neykurendhoo, however in Kelaa, two walkways were constructed several years ago across the mangrove. It was reported that wells were dug within the mangrove habitat to introduce fish in Kelaa. Additionally, application of *Bacillus thuringiensis subspecies israelensis* (BTI) was carried out to control mosquitoes in Neykurendhoo.

Based on the observations, the issue started during the warmer months of the year when the water level was at a regular low. Both islands reported that the issue started in December 2019 and was at a peak during the warmer months (April, May) of the year 2020. The northern region receives on average less rainfall compared to central and southern region of the country. It is also important to note that during the December to April period of 2018 and 2019; it has been observed to be an irregularly drier period for the country.

The dieback has started from plants on the edge and mangrove that are nearer to the shore and progressed inward. It was also noted that the salinity of water was higher in the regions in which the trees were dying. Noticeably, both islands had a separate patch of mangrove from the main area, where it showed no sign of damage. As seen from Table 1 and Table 2, water samples tests conducted for Electrical Conductivity and pH show similar patterns in both mangrove habitats. However, some fluctuations in EC were observed in samples taken from Kelaa.

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**Table 1. Water test results from HA. Kelaa mangrove**

Sample no.	Time	EC	pH	Date	GPS
1	11:37 am	16.65	6.15	06/07/2020	6°57'06.84N
	08:00 am	16.21	6.04	07/07/2020	73°13'03.6E
2	12:34 pm	8.5	6.73	06/07/2020	6°57'02.7N
	08:43 am	10.17	6.57	07/07/2020	73°13'01.0E
3	12:50 pm	6.53	6.71	06/07/2020	6°56'59.7N
	08:59 am	6.46	6.73	07/07/2020	73°13'00.1E
4	14:50 pm	14.65	7.17	06/07/2020	6°15'54.3N 73°12'56.0E
5	15:25 pm	18+	6.97	06/07/2020	6°57'26.9N
	07:21 am	18+	6.62	07/07/2020	73°13'16.9E
6	16:25 pm	18+	7.09	06/07/2020	6°57'21.4N
	07:43 am	18+	6.61	07/07/2020	73°13'16.8E
7	07:28 am	18+	6.45	07/07/2020	6°57'24.6N 73°13'16.6E
8	16:12 pm	2.32	6.93	07/07/2020	6°56'48.4N 73°13'03.0E

**Table 2. Water test results from HDh. Neykurendhoo mangrove**

Sample no.	Time	EC	pH	Date	GPS
1	9:32 am	18+	6.48	11/07/2020	6.54504500°N 72.98690833°E
2	10:30 am	18+	6.49	11/07/2020	6.54208667°N 72.98682833°E
3	11:20 am	16.16	6.17	11/07/2020	6.54026167°N 72.98468333°E
4	11:38 am	17.7	6.53	11/07/2020	6.53934333°N 72.98426833°E
5	12:36 pm	18+	6.26	11/07/2020	6.53787500°N 72.98026833°E
6	16:23 pm	18+	6.24	11/07/2020	6.54568335°N 72.9799424°E

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In both islands, the main affected plant species of the dieback was observed to be *Bruguiera cylindrica* (*Kandoo*). In Neykurendhoo, it is observed that almost all *Kandoo* plant patches within the inner mangrove was dead, leaving just the very few trees which were present at the edge of the mangrove and out of the water. Among the heavily infected patches, a notable number of dead *Bruguiera gymnorhiza* (*Bodavaki*) trees were also found.

Two distinct insects were observed in significant numbers in both islands. One of them is an insect larva that is singularly found on water surface and floating organic material. It was observed feeding on fallen outer skin of leaf tissue. Preliminary analyses have led us to believe that this belongs to an aquatic fly (Figure 1). However, the effort to grow the larvae to a full adult in laboratory conditions at Hanimaadhoo Agriculture Center did not yield much result.

Apart from that, a type of bark borer - a small larva (Figure 2 and 4), was seen in some affected plants between the layers of the bark. Along with these larvae, we sighted a small beetle in some areas inside the bark layers (Figure 3). This beetle is believed to be the adult form of the borer type larvae. Sighting of the pupal form and newly emerging larvae were also observed (Figure 4). This insect and the beetle were only seen from the bark and breathing roots of *Kandoo* and *Bodavaki* plants (Figure 6). In terms of age specificity, there are no differences observed in the level of presence between younger and larger plants. A key observation is that an unusual powdery bark was present at the base of the plant in areas where this borer and beetle were identified. The numbers of both insects were higher in Neykurendhoo mangrove than that of Kelaa's.

As seen from Table 3, in both islands, dead patches consist of large numbers of younger plants. Similarly, areas with low frequency of borer insect have a higher number of live young plants.



**Table 3. a compiled record on data collected on the two prominent insect species**

	<b>Total No. of trees</b>	<b>No. of live trees</b>	<b>No. of dead trees</b>	<b>Newly emerged beetles</b>	<b>Adult beetles</b>	<b>Pupa</b>	<b>Borer larvae</b>	<b>Water larvae</b>	<b>Remarks</b>
<b>HA. Kelaa</b>									
Sample Site 1									
6°57'21.4" N 73°13'16.7"E	546 plants	463 (1-2 feet) 50 (15 feet)	22 (1-2 feet) 11 (15 feet)	100 (0.18 average/tree)	50 (0.09 average / plant)	7	45 (0.08 average/plant)	5 (in water)	All plants were affected in this area. Samples site was selected randomly in a 10x10 feet. The borer Insect was seen from plant barks and air roots
Sample Site 2									
6°56'59.1" N 73°12'59.2" E	114 plants	38 (1 feet) 20 (5 feet)	50 (5 feet) 6 (20 feet)	No insects were found in this area					

**HDh. Neykurendhoo**

Sample Site 1

6.545045 <sup>0</sup> N 72.98690833 <sup>0</sup> E	523 trees	3 trees (1 feet) 1 tree (2 feet)	449 (2 feet)  65 trees (7 feet) 5 trees (20 feet)	0	93 (in bark) 0.18 average / plant		1260 (in bark) 2.41 average /plant	2619 (in water)	10x10 feet plot randomly selected for sample collection. The species found from the bark are from the 70 trees of 20 feet and 7 feet height. This was a completely dead patch
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Sample Site 2

6.54216500 <sup>0</sup> N 72.98692833 <sup>0</sup> E	214 plants	120 (1 feet)  13 (3 feet)	57 (1 feet)  13 (3 feet)  11 (20 feet)	0	16 (in bark) 0.07 average / plant		299 (in bark) 1.01 average/ plant	2784 (in water)	10x10 feet plot randomly selected for sample collection. The species found in bark were from the 11 dead trees that are of 20 feet. A dying patch.
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It is noted that there was a rotting odor coming from the dead tree parts, especially from the roots of the plants in Kelaa (figure 7 and 8). This could be a result of bacterial or fungal damage. Moreover, the damaged roots of these plants, both at the surface level and under water, were observed to be soft and hollow.

Additionally, in Kelaa, the area where the trees first started to die from now show regrowth of smaller plants from propagules. These new areas have no symptoms of damage. Some larger trees that showed symptoms of damage have seemingly grown back by generating new roots above water level. The insect populations in these newly grown areas are also found to be low.

## **Discussion**

In Neykurendhoo, reduced propagule collecting activities and overall interaction has resulted in a more compacted and high competition tree growth. In Kelaa, the main mangrove area is more accessible than in Neykurendhoo, based on the structure of the mangrove as whole. However, some healthy patches in deeper mangrove seem to be very compact, resulting in non-uniform growth. In a healthy setting, compaction might not become a big issue. However, when the environment becomes challenging due to growth inhibition factors, such as high temperature, limited fresh water, reduced fresh air supply, lack of nutrients and sunlight, could lead the plants to die from suffocation.

The powdery base of the tree trunks is a good indicator of the feeding behavior of the borer insect. Bark borers have the capacity to cut off the nutrient supply to the upper part of the plants, causing progressive weakening of the plant. Since this insect was observed in all of its lifecycle, it is assumed to be well established and has been present in the habitat for a while. Their prevalent presence in *Bruguiera spp* (*kandoo* and *bodavaki*) plants indicates that it might be host specific. Moreover, the absence of these insects in the areas that are already dead indicates that it is moving to viable hosts. It could be argued that the sudden surge of this insect might be due to the low water level during the Dec- April period, enabling more access to the lower, more fragile part of the plants for an extended period of time.

The potential larvae of the aquatic fly that was observed from the water surface are more likely to increase in number with the amount of fallen leaf matter. This is supported by the lack of its

presence in Kelaa where there is less foliage over water surface compared to Neykurendhoo. The main reason for the increase in the number of the larvae may attribute to the large amount of leaf matter on the water surface due to dieback. However, as the organic matter sink deeper due to decomposition, the number of larvae is reduced. As with many similar water larvae, it has gills in the posterior end, indicating its sole reliance on water at this stage. This also explains its complete absence in the parts of trees that are above water. This could be a common insect in mangrove habitats acting as an early decomposer. The significantly high number of this insect in Neykurendhoo might be due to low water level with reduced water movement enabling stable environment for its survival. Hence, despite its alarmingly high number, there is no evidence to suggest that this insect has a direct role in the issue under investigation.

Electrical conductivity (EC) of water samples taken from the Neykurendhoo mangrove was high and similar in all sample locations. In the case of the Kelaa mangrove, some variations were observed among samples taken. Many factors contribute to the EC level of a location. Some of these factors include; water salinity and movement, nutrient circulation, fresh water input and connectivity to external water sources. Neykurendhoo mangrove has more frequent water exchanges with the coastal waters. This may be the reason for its high yet uniform salinity levels across the sampled locations.

High salinity in suspended waters might cause significant harm to mangroves. Even though some mangroves are found in coastal areas, salinity level does not decrease below the nearest water body average. However, in still water, salinity level may increase significantly due to the lack of fresh water input aided by increased evapotranspiration. Additionally, high temperature for an extended period might limit the biological activities of the rhizosphere and water body in general, thereby leading to imbalances in decomposition, water uptake and nutrient circulation. This is supported by the large number of tree death in areas where water level was low with few exchanges. However, further supporting research is required to place this evidence as the major conclusive cause of the mangrove dieback.

Due to the sudden onset and prolonged effect of the dieback issue, much of the mangrove areas of both islands have received large quantities of decomposing matter. Anaerobic decomposition is slow and produces ammonia that is not easily taken up by plants without ammonia nitrification bacteria. The nitrification process can be hindered by low water quality, high salinity and high-

water temperature thus prolonging anaerobic conditions. The rotting odor in root samples taken from Kelaa mangrove could be due to an infection of either bacterial or fungal origin escalated by the heavy application of BTI. BTI, being a biological pesticide requires a healthy environment to be active. In poor conditions, it could contaminate the water and deteriorate growth promoting factors. However, there is no direct indication that this is the primary reason for the onset of the rot. It is well known that poor water quality coupled with high temperature is an escalating factor for water based fungal or bacterial pathogens. This is supported by the fact that this odor and associated root rot samples were not present in Neykurendhoo mangrove where BTI was not reported. Due to the irregularity of root rot samples observed, this infection might be a secondary factor that takes advantage of the large number of dead plants rather than the main cause of plant death.

### **Recommendation**

It is important to clear areas of the mangrove where large number of dead and decaying matter is observed. Especially for Kelaa, an organized plant removal effort might be beneficial to promote growth of regenerating plants. This is also to limit further spread of root rot and reduce the introduction of potential predatory or pathogenic species.

In addition to the above-mentioned recommendation, replanting activities could be carried out during the rainy seasons. Priority should be given to plant *Bruiguiera spp.* Walk ways or access path could also be constructed within an organized plan so that the changes to the mangrove can be easily observed.

A proper island level mangrove management plan could be useful. In future, planned propagule collection and replanting might be organized under this plan.

Additionally, a periodic water sampling could be carried out so that the data can be used to understand the health of the mangrove, over time. These data could be very useful in diagnosing such issues in the future.

## **Conclusion**

As in most ecological scenarios, sudden collapse of a habitat is usually based on many causes rather than a single one. As such, the primary reason for the onset of this issue is likely due to the persistent drier conditions reported in the northern region for December to April for the years 2019-2020, and especially during the prior 2018-2019 period. This resulted in low fresh water input to the mangroves. This coupled with high temperatures and sporadic swell surges might have contributed to high salinity conditions with limited periodic water exchanges. The symptoms observed in both mangroves could be a direct result of progressive worsening of the water quality in both the mangroves. The two main insects identified in both the islands are likely the result of hindered plant defenses due to reduced biological activity. It is likely that both the organisms have been in the habitat as part of the species pool and has spread with heavy antagonistic potential due to the sudden change in ecosystem parameters. If the situation persists, the borer pest is likely to spread further. However, if these conditions hold true, t we may then observe a gradual improvement in the coming months as the season will change with cooler average temperatures and high rainfall.

Even so, further investigations through expert communications and literature review is in progress. A final consensus could be reached in coming days. As of now, communications have been shared with the best likely experts in the region and beyond. These experts are from Kerala Forest Research Institute (KFRI), Asia Pacific Forestry Invasive Species Network (APFISN) and Forestry Research group in Wageningen University, Netherlands



Figure 1: Larvae found in water (likely aquatic fly)



Figure 2: Larvae found in bark (borer insect)



Figure 4: Beetles in tree bark

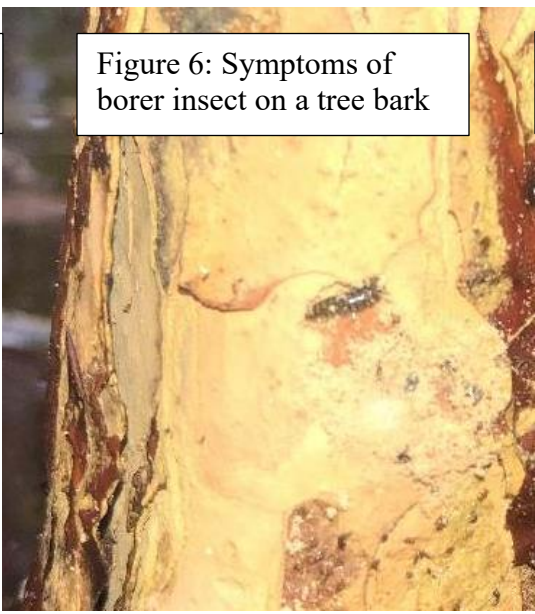


Figure 6: Symptoms of borer insect on a tree bark



Figure 5: Borer Larvae in the tree bark



Figure 7: Symptoms of root rot in *Bruguiera cylindrica* – Kelaa



Figure 8: Symptoms of root rot in *Bruguiera cylindrica* – Kelaa