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Identification of Mangrove Zonation in Sondaken Village, Bunaken National Park Area

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Abstract. Sondaken Village has three mangrove zones, each with its type of plant. The first zone, facing directly towards the sea, is dominated by *Avicennia* sp. The second zone, in the middle, is characterized by *Rhizophora* sp. The third zone, closer to the land, is predominantly *Bruguiera* sp. Mangroves have different levels of growth, including seedling level, stake level, pole level, and tree level. The purpose of this study was to determine the types and growth levels of mangroves within its zonation in Sondaken Village, which is part of Bunaken National Park Area. This was done using exploratory and descriptive survey methods, by creating 3 plots in each zone from the edge to the center, with sizes of 10 x 10 m^2, 5 x 5 m^2, and 2 x 2 m^2. The research found that mangrove in Sondaken Village consists of *Avicennia* sp, *Rhizophora* sp, and *Bruguiera* sp, with the number of individuals per species being 124, 133, and 113 individuals respectively. Each type of mangrove has different growth levels and numbers. The research was conducted in July-August 2022, in the Sondaken Village Bunaken National Park area.

Keywords: *Avicennia, Bruguiera, Mangrove, Rhizophora, Zonation*

I. INTRODUCTION

Indonesia, located in the tropics, boasts of being the largest archipelago in the world, with a massive mangrove area. Due to its archipelagic nature, Indonesia boasts an 81,000-kilometer coastline that comprises 17,508 islands. It is estimated that 60-75 percent of the tropical seashores around the world are covered by mangroves [1], with about 27 percent of the world's 15.9 million hectares of mangroves found in Indonesia. Mangrove forests are typically found in tropical and subtropical areas near the sea or river mouths that experience tidal waters [2]. Coastal areas with large river mouths and muddy or delta water are ideal for mangrove growths, as they protect against waves. Conversely, coastal areas without an estuary, where the growth of mangrove vegetation is not optimum, can be challenging to grow mangroves due to the need for siltation [3]. Mangroves typically grow in four zones, namely the open areas (*Avicennia-Sonneratia* Zone), middle areas (*Rhizophora* Zone), areas with less water (*Bruguiera* Zone), and areas closer to land (*Ceriop* Zone) [4], and the species composition depends on their adaptability to growing conditions. The zonation of mangrove forests is determined by soil conditions, salinity, inundation, tides, rates of deposition and erosion, and the relative height of land and water. Sondaken Village, situated within the Bunaken National Park Area, was the focus of this study, which aimed to determine the types and levels of mangrove zonation in the area.

II. METHODS

The research was conducted in Sondaken Village within the Bunaken National Park Area, from July 2022 to August 2022. An exploratory and descriptive survey method was utilized in the study [5]. Several tools and instruments were employed, including a photo camera, a measuring instrument (meter) for determining the time of sampling in the field, an identification reference book, the Mangrove Recognition Guide in Indonesia [6], stationery, and label paper for recording data in the field. Stakes and ropes were also used to create transect lines and measuring plots (blocks) for observations. Google Earth and a Garmin III+ GPS device were used to determine the location of sampling points while cutting tools (cutter) were used to cut ropes.

To collect mangrove zonation information, exploratory and descriptive qualitative field survey procedures were employed. The following steps were taken :

1). Three plots were created for each zonation, from the edge to the center. Information on mangrove vegetation was gathered from each plot, with a plot size of 10 x 10 m^2 for tree and mast, 5 x 5 m^2 for stake, and 2 x 2 m^2 for seedlings.
2). The number of genera was counted, and unidentified genera were identified using the Guide to Mangrove Recognition [6].
3). Any information collected and identified was recorded immediately in the observation table (tabulation).

III. RESULTS AND DISCUSSION

Results

Total Mangrove Levels Found in Each Zonation

The exploratory and descriptive survey conducted in Sondaken Village, Bunaken National Park, North Sulawesi, revealed the presence of three types of mangroves and four levels for each type in the entire zonation. The data collected regarding the number of mangroves in each zonation can be seen in Table 1.

According to Table 1, the total number of mangroves comprising *Avicennia*, *Rhizophora*, and *Bruguiera* species were 124, 133, and 113, respectively and the total number of mangroves comprising Seedling, Stake, Mast, and Tree species were 154, 104, 75, and 37, respectively.

Total Number of Mangroves Found in Each Zonation

According to Table 2, the front zonation of 10 x 10 m^2 showed that there were 2 *Avicennia* trees, 4 *Rhizophora* trees, and 1 *Bruguiera* tree at the tree level. At the pole level, there were 5 *Avicennia* trees, 3 *Rhizophora* trees, and 5 *Bruguiera* trees. The sapling level obtained 7 *Avicennia* trees, 5 *Rhizophora* trees, and 8 *Bruguiera* trees. Lastly, the seedling level had 15 *Avicennia* trees, 10 *Rhizophora* trees, and 10 *Bruguiera* trees. In the plot size of 5 x 5 m^2, there was only 1 *Avicennia* tree found at the tree level and no *Rhizophora* or *Bruguiera* trees.

The pole level had 5 *Avicennia* trees, 3 *Rhizophora* trees, and 1 *Bruguiera* tree. The sapling level obtained 2 *Avicennia* trees, 4 *Rhizophora* trees, and 3 *Bruguiera* trees. Lastly, the seedling level had 8 *Avicennia* trees, 7 *Rhizophora* trees, and 4 *Bruguiera* trees. In the plot size of 2 x 2 m^2, there were no trees of any species found. The pole level had 1 *Avicennia* tree and no *Rhizophora* or *Bruguiera* trees. The sapling level obtained 1 *Avicennia* tree, 3 *Rhizophora* trees, and 4 *Bruguiera* trees. Lastly, the seedling level had 2 *Avicennia* trees and 2 *Rhizophora* trees, but no *Bruguiera* trees.

TABEL 1.
TOTAL NUMBER OF MANGROVES IN ALL ZONES

Types of Mangroves	Total Mangroves by level			
	Seedlings	Stake	Mast	Tree
Avicennia	53	30	31	10
Rhizophora	56	37	23	17
Bruguiera	45	37	21	10
Total	154	104	75	37

TABLE 2.
TOTAL NUMBER OF MANGROVES IN THE FRONT ZONATION

Size Plot	Types of Mangroves	Total mangrove levels by type				Total
		Tree	Mast	Stake	Seedlings	
10 x 10 m^2	*Avicennia*	2	5	7	15	29
	Rhizophora	4	3	5	10	22
	Bruguiera	1	5	8	10	24
Total		7	13	20	35	
5 x 5 m^2	*Avicennia*	1	5	2	8	16
	Rhizophora	0	3	4	7	14
	Bruguiera	0	1	3	4	8
Total		1	9	9	19	
2 x 2 m^2	*Avicennia*	0	1	1	2	4
	Rhizophora	0	0	3	2	5
	Bruguiera	0	0	4	0	4
Total		0	1	8	4	

TABLE 3.
TOTAL NUMBER OF MANGROVES IN THE MIDDLE ZONATION

Size Plot	Types of Mangroves	Total mangrove levels by type				Total
		Tree	Mast	Stake	Seedlings	
10 x 10 m^2	*Avicennia*	5	9	8	14	36
	Rhizophora	4	5	13	18	42
	Bruguiera	1	3	3	2	9
Total		10	17	24	34	
5 x 5 m^2	*Avicennia*	2	6	5	8	21
	Rhizophora	2	8	5	11	26
	Bruguiera	0	0	2	3	5
Total		4	14	12	22	
2 x 2 m^2	*Avicennia*	0	1	0	4	5
	Rhizophora	1	0	1	4	6
	Bruguiera	0	0	0	2	2
Total		1	1	1	10	

Table 3 shows that in the middle zonation with a plot size of 10 x 10 m^2, 5 *Avicennia* trees, 4 *Rhizophora* trees, and 1 *Bruguiera* tree were found at the tree level. At the pole level, 9 *Avicennia* trees, 5 *Rhizophora* trees, and 3 *Bruguiera* trees were observed. The number of sapling levels obtained were 8 *Avicennia* trees, 13 *Rhizophora* trees, and 3 *Bruguiera* trees. Additionally, at the seedling level, 14 *Avicennia* trees, 18 *Rhizophora* trees, and 2 *Bruguiera* trees were found. For the plot size of 5 x 5 m^2, 2 *Avicennia* trees, 2 *Rhizophora* trees, and 0 *Bruguiera* trees were observed at the tree level. At the pole level, 6 *Avicennia* trees and 8 *Rhizophora* trees were found, but no *Bruguiera* trees were observed. The number of sapling levels obtained were 5 *Avicennia* trees, 5 *Rhizophora* trees, and 2 *Bruguiera* trees. At the seedling level, 8 *Avicennia* trees, 11 *Rhizophora* trees, and 3 *Bruguiera* trees were observed. In the plot size of 2 x 2 m^2, no *Avicennia* or *Bruguiera* trees were found, only 1 *Rhizophora* tree at the pole level. At the sapling level, 1 *Rhizophora* tree was found. The number of seedling levels obtained were 4 *Avicennia* trees, 4 *Rhizophora* trees, and 2 *Bruguiera* trees.

TABLE 4.
TOTAL NUMBER OF MANGROVES IN THE REAR ZONE

Size Plot	Types of Mangroves	Total mangrove levels by type				Total
		Tree	Mast	Stake	Seedlings	
10 x 10 m^2	*Avicennia*	0	4	3	0	7
	Rhizophora	2	3	3	4	12
	Bruguiera	4	6	10	12	32
Total		6	13	16	16	
5 x 5 m^2	*Avicennia*	0	0	4	1	5
	Rhizophora	2	1	3	0	6
	Bruguiera	3	3	7	9	22
Total		5	4	14	10	
2 x 2 m^2	*Avicennia*	0	0	0	1	1
	Rhizophora	0	0	0	0	0
	Bruguiera	1	3	0	3	7
Total		1	3	0	4	

According to Table 4, the middle zonation with a plot size of 10 x 10 m^2 had 5 *Avicennia* trees, 4 *Rhizophora* trees, and 1 *Bruguiera* tree at the tree level. At the pole level, there were 9 *Avicennia* trees, 5 *Rhizophora* trees, and 3 *Bruguiera* trees. For sapling levels, there were 8 *Avicennia* trees, 13 *Rhizophora* trees, and 3 *Bruguiera* trees, and at the seedling level, there were 14 *Avicennia* trees, 18 *Rhizophora* trees, and 2 *Bruguiera* trees.

In the plot size of 5 x 5 m^2, there were 2 *Avicennia* trees, 2 *Rhizophora* trees, and 0 *Bruguiera* trees at the tree level. At the pole level, there were 6 *Avicennia* trees, 8 *Rhizophora* trees, and 0 *Bruguiera* trees. For sapling levels, there were 5 *Avicennia* trees, 5 *Rhizophora* trees, and 2 *Bruguiera* trees, and at the seedling level, there were 8 *Avicennia* trees, 11 *Rhizophora* trees, and 3 *Bruguiera* trees.

In the plot size of 2 x 2 m^2, there were no *Avicennia* trees, 1 *Rhizophora* tree, and 0 *Bruguiera* trees at the tree level. At the pole level, there were 1 *Avicennia* tree, 0 *Rhizophora* trees, and 0 *Bruguiera* trees. For sapling

levels, there were no *Avicennia* trees, 1 *Rhizophora* tree, and 0 *Bruguiera* trees, and at the seedling level, there were 4 *Avicennia* trees, 4 *Rhizophora* trees, and 2 *Bruguiera* trees.

For the rear zonation with a plot size of 10 x 10 m^2, there were no *Avicennia* trees, 2 *Rhizophora* trees, and 4 *Bruguiera* trees at the tree level. At the pole level, there were 4 *Avicennia* trees, 3 *Rhizophora* trees, and 6 *Bruguiera* trees. For sapling levels, there were 3 *Avicennia* trees, 3 *Rhizophora* trees, and 10 *Bruguiera* trees, and at the seedling level, there were no *Avicennia* trees, 4 *Rhizophora* trees, and 12 *Bruguiera* trees.

In the plot size of 5 x 5 m^2, there were no *Avicennia* trees, 2 *Rhizophora* trees, and 3 *Bruguiera* trees at the tree level. At the pole level, there were no *Avicennia* trees, 1 *Rhizophora* tree, and 3 *Bruguiera* trees. For sapling levels, there were 4 *Avicennia* trees, 3 *Rhizophora* trees, and 7 *Bruguiera* trees, and at the seedling level, there was 1 *Avicennia* tree, 0 *Rhizophora* trees, and 9 *Bruguiera* trees.

In the plot size of 2 x 2 m^2, there were no *Avicennia* trees, 0 *Rhizophora* trees, and 1 *Bruguiera* tree at the tree level. At the pole level, there were no *Avicennia* trees, 0 *Rhizophora* trees, and 3 *Bruguiera* trees. For sapling levels, there were no *Avicennia* trees, 0 *Rhizophora* trees, and 0 and 0 *Bruguiera* trees. The number of seedling levels obtained was 1 *Avicennia* tree, 0 *Rhizophora* tree, and 3 *Bruguiera* tree.

Discussion

This study shows that there are 3 types of mangroves found in Sondaken Village: *Avicennia*, *Rhizophora*, and *Bruguiera*, which show 4 levels of growth: seedling level, stake level, pole level, and tree level. The seedling level is characterized by a height of less than 1,5m, the stake level by a height of more than 1,5m and a diameter of more than 10cm, the pole level by a diameter ranging from 10cm to 20cm, and the tree level by a diameter above 20cm. The information retrieval was aimed at establishing the abundance and distribution of these mangrove species in the 3 zonations [7].

Fig.1. Seedling Level Mangroves

Fig.2. Stake Level Mangroves

Fig.3. Mast Level Mangroves

Fig.4. Tree Level Mangroves

In general, the observations showed that there were 124 *Avicennia* trees, 133 *Rhizophora* trees, and 113 *Bruguiera* trees. There were a total of 154 trees at the seedling level, 104 trees at the stake level, 75 trees at the pole level, and 37 trees at the tree level. The most abundant species was *Rhizophora* with 133 trees, and the seedling level had the highest number of trees with 154 in total.

In the front zonation, *Avicennia* was the most abundant species with 49 trees, and the seedling level had the highest number of trees with 58 in total. In the middle zonation, *Rhizophora* was the most abundant species with 74 trees, and the seedling level had the highest number of trees with 66 in total. In the back zonation, *Bruguiera* was the most abundant species with 61 trees, and the sapling and seedling levels had the highest number of trees with 30 in total.

The mangrove zonation in Sondaken Village can be categorized into three types, which are open zonation or outer zonation, middle zonation, and the zones closer to

land or back zonation. The outermost area of mangroves is the open zonation, which is strongly affected by seawater and is characterized by having the largest pool of water compared to the other zones. In plot 1 of Sondaken Village, with sizes of 10 x 10 m^2, 5 x 5 m^2, and 2 x 2 m^2, the *Avicennia* species dominates the open or outer zonation. The middle zone, on the other hand, is located slightly farther from the coast and is not as waterlogged as the open zone. In plot 2, with sizes of 10 x 10 m^2, 5 x 5 m^2, and 2 x 2 m^2, the middle zonation in Sondaken Village has deep mud and is dominated by the *Rhizophora* species. Finally, the zonation closer to the mainland or back zonation is characterized by being located near the mainland with a lower salt concentration than the open zonation or front zonation. In Sondaken Village, the back zonation is located in plot 2 with sizes of 10 x 10 m^2, 5 x 5 m^2, and 2 x 2 m^2 and is dominated by *Bruguiera* mangrove genera. Meanwhile, *Avicennia* mangroves are found in the open or front zonation, which is located close to the sea and on very thick soil and deep mud [8]. *Rhizophora*, on the other hand, grows in the middle zonation, which is located on muddy soil. It can be observed that each type of mangrove not only grows in a specific zone but is also strongly influenced by the type of substrate containing mud [9]. Thus, zonation plays a significant role in the physical and ecological functions of mangroves. It is evident that zonation significantly affects the growth and distribution of mangrove species [9]. Each type of mangrove prefers specific environmental conditions that are available in a particular zone. Moreover, the type of substrate containing mud is a crucial factor that affects the growth of mangroves. Therefore, the zoning system plays an essential role in maintaining the ecological balance of the mangrove ecosystem [10]

Mangrove areas in Sondaken are therefore clearly categorized into various zonations that are dominated by different vegetation types. The zonation pattern observed in mangrove ecosystems is the result of a succession process that occurs due to external environmental factors [11]. This phenomenon is attributed to the ability of mangrove plant species to adapt to the coastal environment. The varied pattern of plant zonation within the mangrove component is a reflection of the diverse environmental conditions in each research location.

IV. CONCLUSIONS

The research found three distinct zones in the mangrove area of Sondaken Village in the Bunaken National Park, namely the open zone or front zone, middle zone, and back zone or zone closer to the mainland. The mangrove area comprises three types of mangroves, which are *Avicennia* sp, *Rhizophora* sp, and *Bruguiera* sp. The mangrove vegetation exhibits a zonation pattern that is characterized by four levels of mangroves, including seedling, stake, pole, and tree levels.

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