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Mangrove Forest of Roswar Island, in the National Park of Cenderawasih Bay, the Province of West Papua

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Research on mangrove vegetation on Rowsar Island, in the area of the National Park of Cenderawasih Bay, This research was conducted from March to April 2022[3]. West Papua Province conducted to identify and understand the condition of the mangrove forest. This research use quantitative methods by inventory with path plots. Based on the observations of mangrove vegetation on Roswar Island, 10 types of true mangroves identified, i.e Rhizopora mucronata,

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Rhizopora apiculata, Sonneratia alba, Xylocarpus granatum, Sonneratia caseolaris, Bruguiera gymnorrhiza, Avicennia marina, Avicennia rumphiana, Aegialitis annulata, dan Aegiceras floridum. The general mangroves found at every station are Rhizopora apiculata dan Rhizopora mucronata. Rhizopora apiculata grows in muddy, soft, deep, and waterlogged soil. Rhizopora apiculata does not like growing on harder substrates mixed with sand. The dominance rate can reach 90% of the vegetation growing in a location. Rhizopora mucronata grows in the same area as Rhizopora apiculata but more tolerant to hard substrates and sand. Mangrove forests on Roswar Island are still in good condition and extensive, the diversity of the mangrove plant species is relatively high and its natural regeneration is going well. The management of the mangrove forest areas requires coordination, integration, synchronization, and synergy across sectors, between many agencies and institutions.

Keywords: Mangrove forest; Roswar Island; The National Park of Cenderawasih Bay; The Province of West Papua.

1. INTRODUCTION

Mangrove ecosystems are essential resources of coastal wetlands becauese they provide life barrier systems that are a very high value of natural resources, therefore efforts are needed to protect, preserve, and use sustainably the resources for the welfare of the local communities [1-4]. This ecosystem is an integral part of coastal area management which is integrated with Watershed Management. Mangroves are specific littoral area plant formations. Mangroves usually grow on alluvial mud soils in coastal areas and river estuaries, which are influenced by salinity and tides, with a very distinctive zoning system. Mangrove ecosystem areas have a very important ecological role [5-11]. It's physical functions are to resist seawater abrasion, reduce CO_2 content in the air (Blue Carbon), withstand storms and salt-laden winds, and as a barrier to pollutants (toxins) in coastal waters. It's biological functions are as a place for marine life living, a source of food for marine life, a spawning place, and a care area for aquatic biota. Mangroves also have economic functions, such as attraction for tourism, source of wood materials, and source of medicines [12-16].

Based on the national mangrove map of the Ministry of Environment and Forestry, Directorate General of Watershed Control and Protection Forest of the Directorate of Land and Water Conservation (2020), the status of Indonesia's mangrove forest has a total area of 3.31 million hectares (20% of the world's total mangrove area). Based on the national mangrove map, the area of mangroves in West Papua Province (mostly in the Bird's Head Seascape area), has an area of 489,373.32 Ha. Several studies conducted in the Bird's Head Seascape area show that 39 types of mangroves have been found, consisting of 19 types of true mangroves and 20 types of associated mangroves (EcoNusa Foundation, 2019). The Bintuni Bay mangrove area consists of 13 types of true mangroves and 10 types of associated mangroves, while in the Raja Ampat area were found 10 true mangroves and 55 types of associated mangroves (Suharjono, 2013) and in Wondama Bay mangrove area there were 18 types of true mangroves (Dharmawan and Widyastuti, 2017). Several studies of fauna inventories of mangrove ecosystems in the Bird's Head Seascape, in Bintuni Bay, found that 27 species of reptiles and 9 species of amphibians (Pertamina, 2002; TNC, 2005), 27 species of birds, 12 species of mammals, and 14 species of invertebrates (TNC, 2005). At Oransbari District (South Manokwari) was found 13 types of mollusks consisting of 9 types of gastropods and 4 types of bivalves (Waran et. al., 2020). Mangrove areas of Indonesia based on monitoring results from the Center for International Forestry Research (CIFOR) are threatened by high degradation rates condition which reach 52,000 ha/year [17,18].

The threat of damaging process of the mangrove ecosystems in Indonesia is caused by: land conversion into industry, settlements, and fish farms, pollution of domestic waste and other hazardous waste, illegal logging and over exploitation, and increasing abrasion rates of 1,950 Ha/year [19-23]. Based on the results of a study from Conservation International shows that the total mangrove carbon stock stored in Indonesia is 3.14 billion metric tons and equivalent to 2.2 billion motor vehicle emissions [24,25]. Mangroves have a very important role in anticipating and adapting to climate change, in which mangrove conservation can reduce 10

percent to 31 percent of the estimated annual emissions from the land use sector in Indonesia. Mangrove areas are land protectors from the rising of sea levels, abrasion, strong winds, tsunamis, and large waves due to climate change. In addition, mangrove areas can also store 800-1200 tons of C/Ha carbon (4-5 times terrestrial forests), and 80% of C is stored in the soil. Manokwari has a carbon storage potential of 234.88 MgC/ha - 302.4 MgC/ha (Hendri et al., 2005)

Roswar Island is one of the islands in the Cenderawasih Bay National Park area and located in the administrative area of Teluk Wondama Regency. Mangrove forests have been used by local communities traditionally for their daily livelihoods such as catching fish, shrimps and crabs. The utilization of fauna species in mangrove ecosystem areas, i.e one-tailed fish, nine-tailed fish, stonehead fish, congge fish, lasi fish, bubara fish, red snapper, sisip fish, shrimps, crabs, tambelo, clams / bia / snails. Various parts of flora in mangrove forest can be used by local communities for the needs of firewood, building materials, tools, handicraft materials, traditional boat equipment and the sources for traditional medicines. Several strategic areas have been used as mangrove ecotourism destinations, such as in Sorong (Klawalu Mangrove Tourism), Manokwari (Sin Beach Mangrove Tourism) and Raja Ampat (Blue Water Mangrove Tourism) and Bintuni Bay (Masina Village Ecotourism). The management of mangrove forest areas requires coordination, integration, synchronization and synergy across sectors, between many agencies and institutions.

2. MATERIALS AND METHODS

2.1 Data Collection

The procedure for collecting data and observing mangrove vegetation is in accordance with the method published by Bengen (2000; 2002; 2011). The procedure for observing mangrove forest ecosystems is as follows:

1. At each observation point, observation plots measuring 10 m x 10 m are determined. Tree-level observations were made on plots measuring 10 m x 10 m, for saplings on transects of 5 m x 5 m, while for seedlings the size of the observation plot was 2 m x 2 m.
2. In each existing plot, will be determined each type of existing mangrove plant and will be counted the number of each type of individual and the determinant of each type of mangrove plant that exists, calculated the number of individuals of each type, and measured the trunk circumference of each mangrove tree at chest level (about 1.3 meters).

Assessment of the condition of mangrove ecosystems is carried out by calculating the Important Value Index (IVI). This IVI provides an overview of the influence or the role of a type of mangrove plant in an area. Analysis of mangrove vegetation can be carried out by calculating:

a. The species density (Di) is the number of stands of the *i*-th species within an area

$$D_i = \frac{n_i}{A}$$

Where Di is the species density *i*-th, ni is the total number of stands of the species and A is the total area of sampling (total area of the sample plot in m^2)

b. Species Relative Density (RDi) (%) is the ratio between the number of stands of the i-th species and the number of stands of the whole species (∑n)

$$RD_i = \left(\frac{n_i}{\sum n}\right) \times 100$$

c. Species frequency (Fi) is the probability of finding the i-th species, in the observed example grid

$$F_i = \frac{p_i}{\sum p}$$

Where Fi is the frequency of species i, pi is the number of sample plots where species i is found, and ∑p is the total number of observed sample/plot plots.

d. Specific Relative Frequency (Rfi) (%) is the ratio between the frequency of species i (Fi) and the sum of frequencies for all types (∑F)

$$RF_i = \left(\frac{F_i}{\sum F}\right)$$

a. Species closure (Ci) is the area of species closure i within unit area

$$C_i = \frac{\sum BA}{A}$$

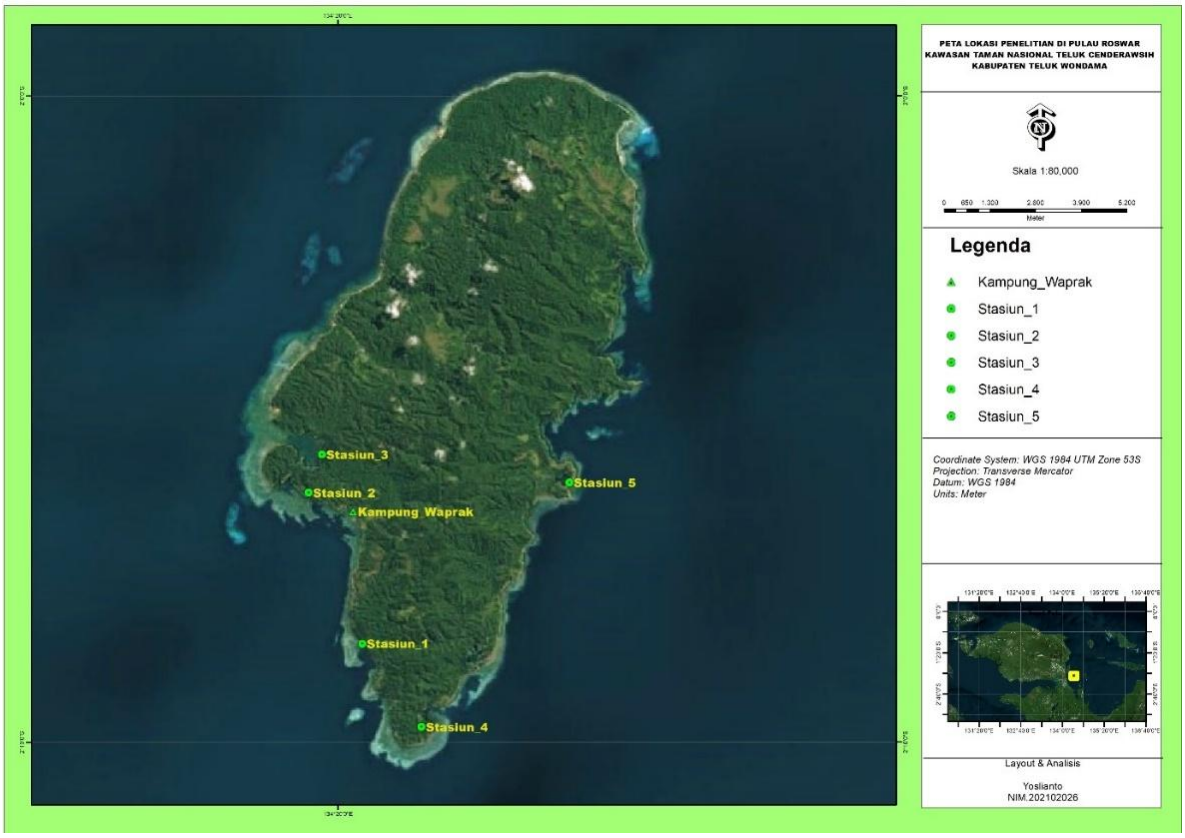

Fig. 1. Map of the Roswar island mangrove forest research location

Where $BA = \pi DBH^2/4$ (in cm2), π = (3.1416) is a constanta and DBH is the diameter of a tree of species i, A is the total area of sampling area (total area of the sample plot). DBH=CBH/ π, CBH is the magnitude of the tree circle.

b. Species Relative Closure (RCi) (%) is the ratio between the area of species i (Ci) closure area and the total area of closure area for all types

$$(\sum C)RC_i = \left(\frac{C_i}{\sum C}\right) \times 100$$

c. The sum of the values of the relative density of the species (RDi), the relative frequency of the species (RFi) and the relative closure of the species (Rci) indicate the Important Value Index (INP) for each species.

$$INP = RD_i + RF_i + RC_i$$

The importance value of a species ranges from 0-300. This index provides an overview of the influence or role of a type of mangrove plant in a community.

3. RESULTS AND DISCUSSION

Based on the results of observations of mangrove vegetation on Roswar Island, 10 types of true mangrove vegetation have been identified, i.e *Rhizopora mucronata, Rhizopora apiculata, Sonneratia alba, Xylocarpus granatum, Sonneratia caseolaris, Bruguiera gymnorrhiza, Avicennia marina, Avicennia rumphiana, Aegialitis annulata, and Aegiceras floridum.* The species of mangrove found is a true mangrove, this is predictable because of the environmental conditions both of the substrate and the salinity which still can be tolerated by various types of mangrove plants. Roswar Island has heterogeneous mangrove conditions, but there are some stations where the mangrove conditions tend to be homogeneous.

The general mangroves found at every station are *Rhizopora apiculate* and *Rhizopora mucronata. Rhizopora apiculata* grows in muddy, soft, deep, and waterlogged soil at the normal tide. It does not like to grow on harder substrates mixed with sand. The dominance rate can reach 90% of the vegetation growing in an existing location. Favors tidal waters that have a

permanently strong freshwater input influence. *Rhizopora mucronata* grows in the same area as *Rhizopora apiculata* but is more tolerant of harder substrates and sand [26-29]. They generally grow in groups, near or on tidal river embankments, and at river mouths, rarely growing in areas far from tidal water. The dominance rate can reach 90% of the vegetation growing in a location. It favors growing at tidal waters which have a permanent influence of strong freshwater input. *Rhizopora mucronate* grows in the same area as *Rhizopora apiculata,* but it is more tolerant of harder substrates and sand [30-32]. It generally grows in groups, near or on tidal river embankments, and at river mouths, rarely growing in areas far from tidal water. Its optimal growth occurs in deeply flooded areas, as well as on soils rich in humus. *Rhizopora mucronata* is one of the most important and most widespread mangrove plant species (Noor, et.al. 1999).

3.1 Analysis of Mangrove Vegetation Species at the Tree Level

At station 1 found 6 species of mangroves, namely *Rhizopora mucronata, Rhizopora apiculata, Sonneratia alba, Xylocarpus granatum, Sonneratia caseolaris, and Bruguiera gymnorrhiza.* The highest density of mangrove species at the tree level at all observation stations is *Rhizopora apiculata* as many as 222 trees/ha (Station I), *Rhizopora mucronata* as many as 600 trees/ha (Station II), *Rhizopora mucronata* as many as 650 trees/ha (Station III), *Rhizopora mucronata* as many as 567 trees/ha (Station IV), and *Rhizopora mucronate* as many as 789 trees/ha (Station V).

At Station I, the smallest density values of *Sonneratia caseolaris* and *Bruguiera gymnorrhiza* were each 11 trees/ha. At Station II, the smallest density values are *Aegialitis annulata* and *Aegiceras floridum* each as many as 33 trees/ha. The type of *Rhizopora apiculate* has the smallest species density value at Station III with a density value of 417 trees/ha. The condition of mangroves at Station III tends to be homogeneous because only 2 types of mangroves are found, namely *Rhizopora mucronate* and *Rhizopora apiculata*. At station IV, the smallest density value is in the types of *Aegiceras floridum* and *Avicennia rumphiana* each as many as 11 trees/ha. *Avicennia marina* mangrove species is the type of mangrove with the smallest type density at Station V with a density value of 22 trees/ha.

Of all observation stations, the highest mangrove density value at the tree level is at Station V with a density value of 1,133 trees/ha, followed by Station III with a density value of 1,067 trees/ha, Station IV with a species density value of 1,011 trees/ha, Station II with a species density value of 800 trees/ha. The lowest density value is found at Station I with a density value of 567 trees/ha. According to the Decree of the State Minister of Environment Number 201 of 2004 concerning Standard Criteria and Guidelines for Determining Mangrove Damage, the status of mangrove conditions at Stations III, IV, and V is included in the good (medium) category, while at Stations I and Station II are included in the damaged category (rare).

Based on observations from all observation stations, looking from the type of mangrove species, the highest mangrove density value at the tree level on Roswar Island is *Rhizopora mucronata* as many as 2,750 trees/ha and the lowest is *Avicennia marina* as many as 22 trees/ha. The results of the analysis of the relative density of species (RDi), the relative frequency of species (RFi), and the relative closure of species (RCi) obtained the importance value of a species of mangrove found on Roswar Island, at the tree level at Station I, the type of mangrove vegetation found to be the most important role at the observation location was *Rhizopora apiculata* with an Important Value Index (IVI) of 117.79.

The results of observations at station 1, found 5 species of mangroves, namely *Avicennia rumphiana, Rhizopora mucronata, Rhizopora apiculata, Aegialitis annulata, and Aegiceras floridum*. Based on the results of mangrove vegetation analysis at station II, the relative density of species (RDi), the relative frequency of species (RFi), and the relative closure of species (RCi) obtained the importance of a type of mangrove at the tree level, the type of mangrove vegetation found to be the most important role at station II was *Rhizopora mucronata* with an important value index (IVI) of 154.13.

Based on the results of observations of mangrove vegetation at station III, 2 species of mangroves were found, namely *Rhizopora mucronata* and *Rhizopora apiculata*. The results of the analysis of the relative density of species (RDi), the relative frequency of species (RFi), and the relative closure of species (RCi) obtained the importance of a type of mangrove at the tree level, the species of mangrove vegetation that has the most important value in station III

is *Rhizopora mucronata* with an important value index (IVI) value of 152.20.

The results of observations of mangrove vegetation on Roswar Island at station IV found 7 species of mangroves, namely *Aegiceras floridum, Avicennia rumphiana, Bruguiera gymnorrhiza, Rhizopora apiculata, Rhizopora mucronata, Sonneratia alba, and Xylocarpus granatum*. The results of the analysis of the relative density of species (RDi), the relative frequency of species (RFi), and the relative closure of species (RCi) obtained the importance of a species of mangrove at the tree level, the species of mangrove vegetation that has the most important value in its role at station IV is *Rhizopora mucronata* with an important value index (IVI) of 141.36.

The results of mangrove vegetation observations at station V found 5 species of mangroves, namely *Aegialitis annulata, Aegiceras floridum, Avicennia marina, Rhizopora mucronata, and Sonneratia caseolaris*. The results of the analysis of the relative density of species (RDi), the relative frequency of species (RFi), and the relative closure of species (RCi) obtained the importance of a species of mangrove at the tree level, the species of mangrove vegetation that has the most important value of its role at station V is *Rhizopora mucronata* with an important value index (IVI) of 209.23. The results of Relative Frequency, Relative Density, Relative Dominance and Important Value Index of Tree-Level Mangrove Plant Species is presented in Table 1.

3.2 Analysis of Mangrove Vegetation Types at the Stake Level

Observations of mangrove vegetation conducted on Roswar Island at the stake level, found 5 species of mangroves, namely *Bruguiera gymnorrhiza, Rhizopora apiculata, Rhizopora mucronata, Nipa fruticans, and Xylocarpus granatum.* The highest density values of the sapling level are *Rhizopora apiculata* as many as 1,467 individuals/ha (Station I), *Rhizopora mucronata* as many as 1,067 individuals/ha (Station III), *Bruguiera gymnorrhiza* as many as 178 individuals/ha (Station IV), and *Rhizopora mucronata* as many as 267 individuals/ha (Station V). While at Station II only 1 species of mangrove at the stake level is *Rhizopora mucronata* with a typical density value of 400 individuals/ha.

Of all observation stations, the highest density value of mangrove species at the stake level is found at Station I with a density value of 2,000 individuals/ha, followed by Station III with a density value of 1,733 individuals/ha, and Station II with a density value of 400 individuals/ha. The lowest density values at the stake level are found at Stations IV and V with density values of 311 individuals/ha each. Based on observations from all observation stations, judging from the type of mangrove species, the highest density value of mangrove species at the stake level on Roswar Island is *Rhizopora apiculata* as many as 2,267 individuals/ha and the lowest is *Nipa fruticans* as many as 89 individuals/ha.

At each station, the highest IVI values for the stake level were *Rhizopora apiculata* at 117.78 (Station I), *Rhizopora mucronata* at 111.54 (Station III), *Bruguiera gymnorrhiza* at 117.14 (Station IV), and *Rhizopora mucronata* at 135.71 (Station V). While at Station II only 1 type of mangrove was found, namely *Rhizopora mucronata* with an IVI value of 200. The results of Relative Frequency, Relative Density, Relative Dominance and Important Value Index of Tree-Level Mangrove Plant types at Sapling Level is presented in Table 2.

3.3 Analysis of Mangrove Vegetation Types at the Seedling Level

Observations of mangrove vegetation conducted on Roswar Island at the seedling level found 7 species of mangroves, namely *Rhizophora apiculata, Rhizopora mucronata, Xylocarpus granatum, Avicennia rumphiana, Bruguiera gymnorrhiza, Avicennia marina, and Aegiceras floridum.* The highest density values at seedling levels are *Rhizopora apiculata* as many as 35,833 individuals/ha (Station I), *Avicennia rumphiana* as many as 30,000 individuals/ha (Station II), *Rhizopora mucronata* as many as 8,333 individuals/ha (Station III), *Rhizopora apiculata* as many as 8,333 individuals/ha (Station IV), and *Rhizopora mucronata* as many as 17,500 individuals/ha.

Of all observation stations, the highest density value of mangrove species at the stake level is found at Station I with a density value of 44,167 individuals/ha, followed by Station II with a density value of 38,333 individuals/ha, Station IV with density value of 33,333 individuals/ha, and Station V with a density value of 33,056 individuals/ha. The lowest

density value at the sapling level is found at Station III with a density value of 15,000 individuals/ha. Based on observations from all observation stations, judging from the type of mangrove species, the highest density value of mangrove species at the seedling level on Roswar Island is *Rhizopora apiculata* as many as 68,333 individuals/ha and the lowest is *Aegiceras floridum* as many as 278 individuals/ha.

At each station, the highest IVI values for seedling levels were *Rhizopora apiculata* at 135.68 (Station I), *Avicennia rumphiana* at 128.26 (Station II), *Rhizopora mucronata* at 122.22 (Station III), *Bruguiera gymnorrhiza* at 104.17 (Station IV), and *Rhizopora mucronata* at 115.44 (Station V). Relative Density, Relative Dominance and Important Value Index of Tree-Level Mangrove Plant types at at seedling level is presented in Table 3.

Table 1. Relative frequency, relative density, relative dominance and important value index of tree-level mangrove plant species

Station	No	Name of species	Rdi (%)	Rfi (%)	Rci (%)	IVI
I	1	*Rhizopora mucronata*	25.49	16.67	28.50	70.66
	2	*Rhizopora apiculata*	39.22	38.89	39.68	117.79
	3	*Sonneratia alba*	3.92	11.11	1.79	16.82
	4	*Xylocarpus granatum*	27.45	22.22	28.03	77.71
	5	*Sonneratia caseolaris*	1.96	5.56	0.39	7.91
	6	*Bruguiera gymnorrhiza*	1.96	5.56	1.60	9.12
II	1	*Avicennia rumphiana*	8.33	12.5	49.78	70.62
	2	*Rhizopora mucronata*	75.00	37.5	41.63	154.13
	3	*Rhizopora apiculata*	8.33	25	3.63	36.96
	4	*Aegialitis annulata*	4.17	12.5	1.45	18.12
	5	*Aegiceras floridum*	4.17	12.5	3.51	20.17
III	1	*Rhizopora mucronata*	60.94	50	41.2621	152.20
	2	*Rhizopora apiculata*	39.06	50	58.7379	147.80
IV	1	*Aegiceras floridum*	1.10	4.7619	0.2294	6.09
	2	*Avicennia rumphiana*	1.10	4.7619	5.06747	10.93
	3	*Bruguiera gymnorrhiza*	7.69	14.2857	12.3703	34.35
	4	*Rhizopora apiculata*	25.27	28.5714	24.6028	78.45
	5	*Rhizopora mucronata*	56.04	38.0952	47.2218	141.36
	6	*Sonneratia alba*	3.30	4.7619	10.1466	18.21
	7	*Xylocarpus granatum*	5.49	4.7619	0.36159	10.62
V	1	*Aegialitis annulata*	2.94	7.69231	3.2696	13.90
	2	*Aegiceras floridum*	22.55	23.0769	6.75954	52.39
	3	*Avicennia marina*	1.96	7.69231	2.05937	11.71
	4	*Rhizopora mucronata*	69.61	53.8462	85.7762	209.23
	5	*Sonneratia caseolaris*	2.94	7.69231	2.13527	12.77

Table 2. Relative frequency, relative density, relative dominance and important value index of mangrove plant types at sapling level

Station	No	Name of Species	Sum	Di (Ind/ha)	Rdi (%)	Rfi (%)	IVI
I	1	*Rhizopora mucronata*	7	311	15.56	22.2222	37.78
	2	*Rhizopora apiculata*	33	1,467	73.33	44.4444	117.78
	3	*Xylocarpus granatum*	3	133	6.67	22.2222	28.89
	4	*Nipa fruticans*	2	89	4.44	11.1111	15.56
II	1	*Rhizopora mucronata*	3	400	100.00	100	200.00
III	1	*Rhizopora mucronata*	8	1,067	61.54	50	111.54
	2	*Rhizopora apiculata*	5	667	38.46	50	88.46
IV	1	*Rhizopora apiculata*	2	89	28.57	20	48.57
	2	*Rhizopora mucronata*	1	44	14.29	20	34.29
	3	*Bruguiera gymnorrhiza*	4	178	57.14	60	117.14
V	1	*Rhizopora apiculata*	1	44	14.29	50	64.29
	2	*Rhizopora mucronata*	6	267	85.71	50	135.71

Table 3. Relative frequency, relative density, relative dominance and important value index of mangrove plant types at seedling level

Station	No	Name of Species	Sum	Di (Ind/ha)	Rdi (%)	Rfi (%)	IVI
I	1	*Rhizopora mucronata*	13	3,611	8.18	36.3636	44.54
	2	*Rhizopora apiculata*	129	35,833	81.13	54.5455	135.68
	3	*Xylocarpus granatum*	17	4,722	10.69	9.09091	19.78
II	1	*Avicennia rumphiana*	36	30,000	78.26	50	128.26
	2	*Rhizopora mucronata*	10	8,333	21.74	50	71.74
III	1	*Rhizopora mucronata*	20	8,333	55.56	66.6667	122.22
	2	*Rhizopora apiculata*	16	6,667	44.44	33.3333	77.78
IV	1	*Rhizopora apiculata*	63	17,500	52.50	20	72.50
	2	*Bruguiera gymnorrhiza*	53	14,722	44.17	60	104.17
	3	*Rhizopora mucronata*	4	1,111	3.33	20	23.33
V	1	*Rhizopora mucronata*	63	17,500	52.94	62.5	115.44
	2	*Avicennia marina*	25	6,944	21.01	12.5	33.51
	3	*Aegiceras floridum*	1	278	0.84	12.5	13.34
	4	*Rhizopora apiculata*	30	8,333	25.21	12.5	37.71

4. CONCLUSION

1. Based on the results of observations of mangrove vegetation on Roswar Island, 10 types of true mangrove vegetation have been identified, namely *Rhizopora mucronata, Rhizopora apiculata, Sonneratia alba, Xylocarpus granatum, Sonneratia caseolaris, Bruguiera gymnorrhiza, Avicennia marina, Avicennia rumphiana, Aegialitis annulata, and Aegiceras floridum.* The most common types of mangroves found at each station are *Rhizopora apiculata* and *Rhizopora mucronata*. *Rhizopora apiculata* grows on muddy, smooth, deep, and flooded soils at normal high tide. They do not like to grow on harder substrates mixed with sand. The dominance rate can reach 90% of the vegetation growing in a location. *Rhizopora mucronata* grows in the same area as *Rhizopora apiculata* but is more tolerant of harder substrates and sand.
2. Mangrove forests on Roswar Island are still in good condition and extensive, the diversity of mangrove plant species is quite high and natural regeneration is going well.

5. RECOMMENDATIONS

1. Management of mangrove forest areas requires coordination, integration, synchronization, and synergy across sectors, between agencies and institutions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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