Mangrove Health Index and Carbon Potential of Mangrove Vegetation in Marine Tourism Area of Nusantara Dian Center, Molas Village, Bunaken District, North Sulawesi Province

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A B S T R A K

Tujuan dari penelitian ini untuk mengetahui kondisi kesehatan mangrove di Nusantara Dian Centre (NDC) Kelurahan Molas, Kecamatan Bunaken, Kota Manado, Provinsi Sulawesi Utara. Metode yang digunakan dalam kegiatan penelitian ini yaitu menggunakan metode garis transek petak/plot untuk mengambil data struktur komunitas dan metode hemisperichal photography untuk mengambil data persentase tutupan kanopi. Data yang didapat semuanya di input dan kemudian dianalisismenggunakan aplikasi MonManguntuk mengetahui mangrove healthy indeks (MHI). Dari hasil analisis menunjukan rata-rata kondisi kesehatan mangrove pada tiap stasiun masuk dalam kategori moderate/Sedang, serta kondisi tutupan kanopi mangrove masih masuk dalam kategori baik dengan nilai kerapatan dalam kategori sedang dan jarang berdasarkan Kepmen LH No 201 Tahun 2004 tentang kriteria kerusakan mangrove. Untuk potensi simpanan karbon vegetasi mangrove didapatkan total nilai rata-rata sebesar 32,91 ton C/ha atau 120,80 ton CO2/ha.

Keywords:
Mangrove Health Index
Vegetation Carbon
Mangroves
Bunaken

A B S T R A C T

The research aims at determining the health condition of mangroves in the Nusantara Dian Center (NDC) in Molas Village, Bunaken District, Manado City, North Sulawesi Province. The research method used the line transect plot method to collect community structure data and the hemisperichal photography method to collect canopy cover percentage data. The obtained data were entirely inputted and analyzed using the MonMang application to determine the mangrove healthy index (MHI). The analysis results showed that average health condition of the mangroves at each station was in the moderate category, and the condition of the mangrove canopy cover remained in the good category with the density value of medium and rare category based on the Minister of Environment Decree Number 201 of 2004 concerning the criteria for mangrove damage. For the potential carbon storage of mangrove vegetation, total average value reaches 32.91 tons C/ha or 120.80 tons CO2/ha.

Introduction

The potential of Indonesia's forest resources is very abundant, one of which is the mangrove forest. Mangrove forest is a type of forests that has a characteristic because it grows and develops along the coast or river estuaries due to tide influence (Kusmana, 2010 in Bachmid et al., 2020). Mangrove plant communities flourish in tropical areas and are able to adapt to extreme environmental conditions such as high temperatures, high salinity, extreme tides, high sedimentation, and substrate conditions with lack of oxygen or without any oxygen (Alongi, 2009 in Schaduw, 2018).

Indonesia's mangrove forest areas are the highest of totally 3,112,989 ha or 22.6% of the world's total mangrove areas if compared to other countries that have mangrove forests (Giri et al., 2011). However, unfortunately more than 30% of the mangrove forest areas in Indonesia has lost in the period of 1980 – 2005 (FAO, 2007). The degradation of mangrove forests in Indonesia is due to various factors, i.e. the conversion of mangrove forests into various development activities, such as residential growth areas, dock buildings and canals; agricultural and plantation areas as well as for oil and gas exploration activities. Myers & Patz (2009) have stated that the increasing need for and dependence on natural resources in coastal areas is a pressure for the sustainability of coastal ecosystems.

The decline quality and quantity of mangrove forests can affect the economic life of coastal communities, such as lower fish catches and fishermen's income (Mumby et al., 2004). Moreover, it can deteriorate the balance of ecosystems and habitats as well as the extinction of fish species, marine biota and coastal abrasion (Polidoro et al., 2010). High mangrove degradation is also due to the lack of strict law enforcement in Indonesia (Kathiresan & Bingham, 2001).

The overall health condition of the mangrove ecosystem can affect the condition of two other ecosystems in coastal areas, i.e. seagrass and coral reefs. The typical mangrove root system physically provides protection for seagrass and coral reefs from the dangers of sedimentation. Mangrove roots function to filter out large materials carried by rivers into the sea. This effort prevents the waters from becoming cloudy and therefore, there is no buildup and accumulation on the surface of seagrass and coral. Mangrove forests are ecologically a habitat for the growth of coral biota at certain phases of their lives. When the mangrove ecosystem is maintained, there are more choices for coastal communities in meeting the economic needs in an area. The research purpose was to determine the mangrove health condition and to estimate the potential vegetation carbon in the marine tourism area of Nusantara Dian Center (NDC).

Method

The research method used herein is the survey method of direct field observation to know the mangrove condition. The field observations will know the structure of the mangrove community with the line transect method by making a perpendicular line from the coast to the land in a kind of a map or plot (Cox in 1969 in Abrar et al., 2014). Taking pictures to determine the percentage of mangrove canopy coverage uses the hemisperichal photography method or techniques for canopy characteristics by using photographs to estimate solar radiation and plant characteristics through a remote viewing lens (Anderson, 1964). Moreover, the two parts are inputted and processed using the MonMang application.

Data collecting were carried out at 3 research stations with the station codes, i.e. M01, M02 and M03 (M = mangrove – 01 = serial number of the stations). At each station, 3 plots measuring 10x10 m2 were made (Figure 2). All individuals contained in the plot/plot are inputted for the number, type, and diameter of the tree trunk, as well as other supporting data such as number of seedling and sapling, tree height, amount of marine debris, tree felling, substrate types, and photos of canopy coverage are taken for further analysis to determine Mangrove Health Index / MHI (Mangrove Health Index) using the MonMang application.

Results and discussion

Based on the monitoring of mangrove forest condition in Nusantara Dian Center (NDC) presented in Table 3, it shows that Avicennia marina species dominates the dominant substrate type at each station, i.e. muddy sand because it is in accordance with the types of substrate located on Batanta and Salawati Islands, Raja Ampat Islands District, West Papua Province, where the types of substrate that dominates the Avicennia marina zoning is mud and muddy sand (Schaduw, 2019 and Schaduw, 2020c).

Table 1. Research Location and Subtrate Types

No	Stations	Coordinate		Substrate Types	Coverage Notes
		Longitude	Latitude		
1.	M01	124.837	1.52939	Muddy Sand	Good
2.	M02	124.838	1.52902	Muddy Sand	Good
3.	M03	124.838	1.52863	Muddy Sand	Good

Individuals and Types of Mangroves

The number of individuals and species of mangroves found at each research station is presented in Table 4 and Figure 4. These shows the number of species in M02 and M03. There are 3 types, i.e. Avicennia marina, Avicennia alba, and Sonneratia alba despite the number of the individuals is different, in M01 there are only 2 types, i.e. Avicennia marina and Sonneratia alba. The highest number of the individuals is in M01 as many as 36 ind/300 m2, while the lowest M02 is only 21 ind/300 m2. It is almost the same as the species found in Tongkaina Village, the mangrove species found here were R. Apiculata, Avicenia officinalis, and S. Alba (Sasauw et al, 2016; Tuwongkesong et al, 2018). Different from the case with Mantehage Island, the types of mangroves found at the two stations on Mantehage Island consist of 8 (eight) mangrove species, i.e. : R. mucronata, R. apiculata, R. stylosa, B. gymnorrhiza, B. cylindrical, C. tagal , S. alba, and L. littorea from 3 (three) families, i.e. : Rhizophoraceae, Sonneratiaceae, and Combretaceae (Lahabu et al, 2015; Schaduw 2015b)). In the protected marine area of Blongko Village, the mangrove vegetation consists of four families, with seven species. The mangrove families are Avicenniaceae, Meliaceae, Rhizophoraceae, and Sonneratiaceae. Meanwhile, the mangrove species in this village are Xylocarpus granatum, Avicennia lanata, Avicennia marina, Avicennia officinalis, Bruguiera gymnorrhiza, Rhizophora apiculata, and Sonneratia alba (Schaduw, 2015a and Schaduw, 2016a). In contrast to the species on Bunaken Island with five types of mangroves, i.e. Soneratia alba, Avicennia marina, Xylocarpus granatum, Rhizophora apiculata, and Bruguiera gymnorrhiza, which are divided into four families, i.e. Sonneratiaceae, Avicenniaceae, Meliaceae, and Rhizophoraceae (Schaduw, 2016b; Schaduw 2020a). Nain Island located in Bunaken National Park has two types of mangroves, i.e. Rhizophora apiculata and Avicennia marinna from the Avicenniaceae and Rhizophoraceae families, respectively, with a mangrove area of 4.40 ha, and an average distance between trees of 1.02 m (Schaduw, 2018). A research in Kupang Bay Nature Park from six stations where vegetation sampling was conducted, 16 species of mangrove were found: Acanthus ilicifolius, Aegialitis annullata, Avicenia alba, A. lanata, A. marina, Bruguiera cyndrica, B. parvifflora, Ceriops tagal, Excoecaria agallocha, Lumnitzera racemosa, Osbornia octodonta, Rhyzophora apiculata, R. mucronata, R. stylosa, Sonneratia alba, and Xylocarpus granatum. These species come from 9 families, i.e.: Acanthaceae, Avicenniaceae, Combretaceae, Euphorbiaceae, Meliaceae, Myrtaceae, Plumbaginaceae, Rhizopho-raceae and Sonneratiaceae (Bessie et al, 2013). It differs from the types of mangroves found on Morowali coast, from the three types of mangroves there were Rhizophora apiculata, Sonneratia alba and Rhizophora stylosa (Schaduw, 2020b). The difference in the number of mangrove species depends on the types of substrate, the input of fresh water, the duration of standing water at high tide, the topography, and the geographical and climatic conditions of each region.

Table 2. Types of Mangrove at Each Research Station

No	TYPES OF MANGROVES	M01	M02	M03
1.	*Avicennia marina*	✓	✓	✓
2.	*Avicennia alba*	-	✓	✓
3.	*Sonneratia alba*	✓	✓	✓

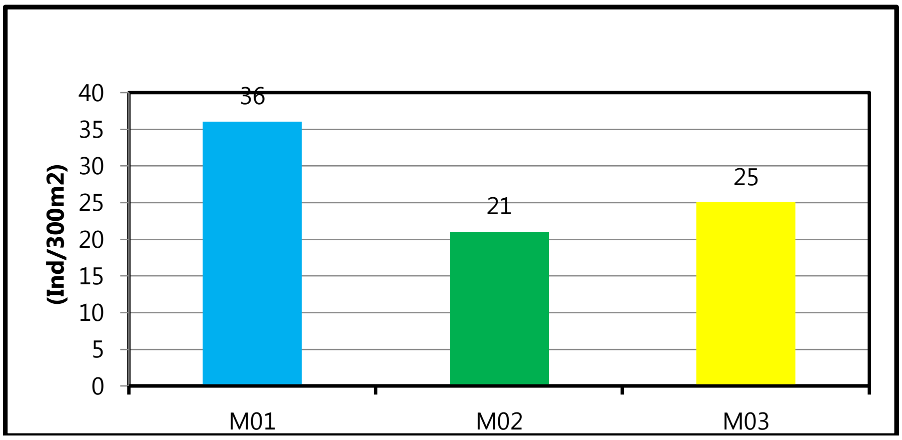

Figure 1. Diagram of total individuals per station

Percentage of Canopy Coverage and Mangrove Density

From the analysis results (Table 5), it can be shown that average percentage of mangrove canopy cover at each station is different. The highest percentage of the coverage is in M01 totaling 78.90 ± 1.47% and the lowest percentage is at M03 with 57.61 ± 4, 71%. From these analysis results when considered from Minister of Environment Decree No. 201 of 2004 concerning the criteria for mangrove damage, M01 is in the good category with a canopy coverage value of >75% and M03 is in the damaged category because it only has a canopy coverage value of <50% . For the density value, it can be shown that M01 has the highest density value of 1200 ind/ha which is in the medium category, while the lowest is M02 which is only 700 ind/ha which is in the rare category. This research is in line with the previous researches where the value of mangrove canopy coverage in Meras Village amounts to 82.78% and Molas Village 61.24%. However, if it is viewed from Minister of Environment Decree No. 201 of 2004 concerning the criteria for mangrove damage, it includes the very dense category with medium/moderate canopy coverage. The highest species density value was seen in Tiwoho Village for R. mucronata species totaling 0.133 ind/m2 and the relative density value was 76.92%, while the lowest value was in Tongkaian/Bahowo Village for B.gymnorrhiza and R.mucronata species totaling 0.003 ind/m2. and the relative density value was 3.333%. Furthermore, the highest species diversity index value was in Tongkaian Village with a value of 1.203 and the lowest value in Molas Village was 0.562, while the highest evenness index value was in Tongkaina Bahowo Village with a value of 11.14 and the lowest value in Molas Village was 3.474 (Anthoni et al, 2017).

Mangrove Health Index

Based on the analysis results using the MonMang application presented in Table 5, it can be shown that the mangrove health condition based on the Mangrove Health Index (MHI) shows M02 with average highest MHI percentage value of 69.79%, and M03 as the lowest of only 48 ,66%. From these results, there are several indicators that determine the good or bad condition of mangrove health, such as garbage. It can be shown due to the high amount or percentage of waste coverage on M03 and therefore, the MHI percentage value at this station is low. Marine debris is one of the most influential indicators. It can interfere the growth and regeneration and death of mangroves. This is in line with the response of Hartoni and Agusalim, 2013 in Djohar et al., 2020, that waster entering the mangrove ecosystem will have a negative impact on mangroves and the associated biota therein. Djaguna et al, (2019) have stated that the types of marine debris commonly found at the research sites at Tongkaina Beach and Talawaan Bajo, such as plastic, rubber, metal, glass, and wood debris. However, the most common type of debris is plastic debris. The total amount of macro-debris and meso-debris collected on the twelve observation transects was 481 species/items with a total weight of 1433, 38 gr/m2. A research on marine debris on the coast has been carried in the research of Schaduw et al (2021). The research results show that on the mainland there are 9 types of debris groups from 14 types of debris groups, i.e. glass; aluminum; paper, cardboard and wood; medical/personal device; paper plastic; foam plastic; plastic sheet and foam; rubber; ropes and wires are not for fishing. On the other hand, marine debris includes 7 types of glass debris groups; aluminum; paper, cardboard and wood; medical/personal device; paper plastic; foam plastic; plastic sheet and foam. Land debris has a higher total weight than that from marine debris. The debrus source definitely comes from from waste or human activities that are not processed or not disposed of in its place. The researcg of Kahar et al, (2020) have found that the density of inorganic debris in the Talawaan Bajo coastal mangrove ecosystem as a whole reaches 162 pots/900m2 (1,800 Pots/Ha) with a weight of 4392.11 grams/m2 (48,801.2 grams/ha). Moreover, the most dominating types of marine debris is plastic debris with total number of 132 pots/900m2 (1,466 Pots/Ha) and total weight of 3131.55 grams/900m2 (34,795 grams.ha) and the highest waste. It is found at station 3, i.e. 62 pots/ha with a weight of 1608.73 grams/m2 (17.874.7 grams/ha).

Table 3. Table of Mangrove Health Index

St	Spec	%cover	Tre (m)	Diameter (cm)	Density (ind/ha)	Important Value Index (IVI)		NuM of Seedling (ind/m2)	Cut-Wood Occurence (%)	Garbage Coverage (%)	Mangrove Healthy Indeks (%)
						Min	Max				
M01	2 (Sa;Am)	78,90 ± 1,47	12.5	17.14	1200 ± 346,41	Sa: 132,02	Am: 300,00	7	0	25	63,93 (MODERATE)
M02	3 (Aa; Am; Sa)	75,94 ± 4,85	10.3	21.39	700 ± 200	Aa: 62,83	Am: 200,58	4	0	25	69,79 (MODERATE)
M03	3 (Aa; Am; Sa)	57,61 ± 4,71	10.8	18.72	833,33 ± 115,47	Aa: 60,28	Sa: 213,38	8	0	33	48,66 (MODERATE)

Potential Carbon

From the analysis results of the potential carbon presented in Table 6 and Figure 5, it can be shown that average highest carbon storage of mangrove tree stands is in M01, which is 59.28 tons C/ha, while the lowest is M03, which is 15.52 tons C. /Ha. The obtained results are higher if compared to those from Bachmid et al,. 2020 for the mangrove forest in Sarawet Village, East Likupang Sub-District, North Minahasa District totaling 52.90 tons C/ha. However, it is lower than the research results of Restuhadi et al., (2013) in Indragiri Hilir District totaling 159.46 tons C/ha. Moreover, mangrove sediments also have the potential to store carbon. The research of Verisandria et al (2018) has stated that average value of carbon content per depth in mangrove ecosystem sediments in the North Coast of Bunaken National Park differs. At the front and middle points of the mangrove forest, average highest carbon content in a depth layer of 60-100 cm reaches 160.37 Mg ha-1 and 178.26 Mg ha-1 respectively. Average carbon content value at the back point has the highest value in the 0-30 cm depth layer totaling 124.21 Mg ha-1.

The carbon stock is directly proportional to the biomass content. The greater the biomass content, the greater the carbon stock. Therefore, the amount of carbon storage in a vegetation depends on the amount of biomass contained in trees, soil fertility and the absorption capacity of the vegetation. Moreover, the value of tree biomass is directly proportional to its carbon value. It is because the carbon content of an organic material amounts to 47% of the total biomass (IPCC, 2006 in Bachmid et al., 2020).

The carbon content in plants describes how much the plants can bind CO2 from the air. Some of the carbon will be used as energy for plant physiological processes and some will enter the plant structure and become part of the plant, for example cellulose stored in stems, roots, twigs and leaves (Bismark, et al. 2008 in Bachmid et al., 2020).

Table 4. Results of Estimated Potential Carbon in Mangrove Trees

Station	Biomassa (ton/ha)	Carbon (ton/ha)	Absorption CO2 (ton/ha)
M01	126.14	59.28	217.57
M02	50.94	23.94	87.87
M03	33.01	15.52	56.94

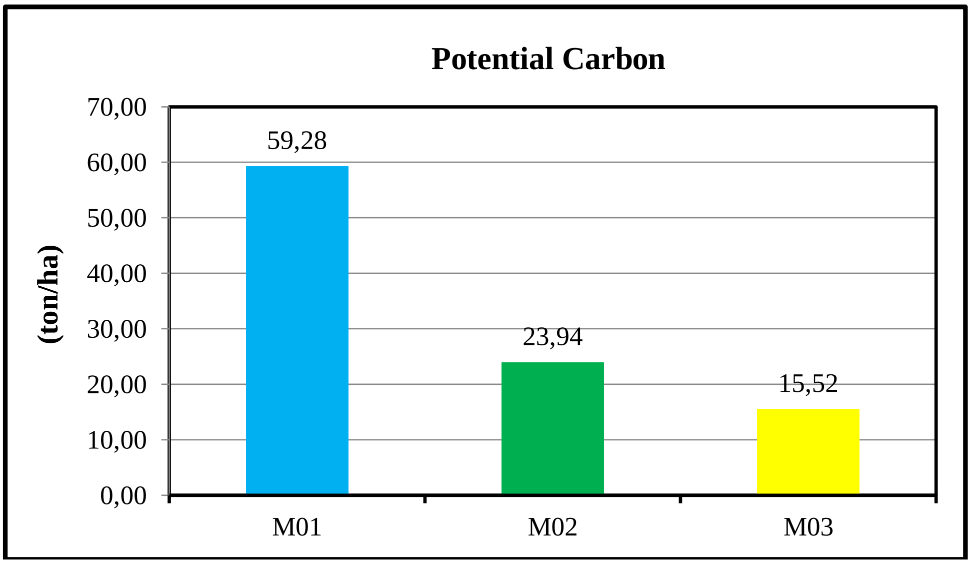

Figure 2. Diagram of Average Potential Carbon Storage Value at Each Station

Conclusion

From the analysis results of the Mangrove Health Index (MHI) it shows that average mangrove health condition at each station is in the moderate category, and the mangrove canopy coverage is in the good category with the mangrove density value of medium and rare category. It bases on the Minister of Environment Decree Number 201 Year 2004 regarding the criteria for mangrove damage. For the potential carbon storage of mangrove vegetation, moreover, average total value amounts to 32.91 tons C/ha or 120.80 tons CO2/ha.

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