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The Adaptive Capacity of Mangrove Ecosystem in the Sub-District Sungai Apit, Siak Regency, Riau Province

Kapasitas Adaptasi Ekosistem Mangrove di Kecamatan Sungai Apit Kabupaten Siak Provinsi Riau

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Abstract

This research was conducted for five months from May to September 2022 which is located in Sungai Apit District by taking six (6) villages as sampling locations from the eight (8) existing villages. This research was conducted for five months from May to September 2022 which is located in Sungai Apit District by taking six (6) villages as sampling locations from eight (8) existing villages. The research objective was to calculate and assess the adaptive capacity of mangrove ecosystems in Siak District, Siak Regency. Measurement of the adaptive capacity of mangrove ecosystems is carried out by analyzing six parameters, namely Mangrove Dimension Index (IDMg), Dominant Mangrove Species, Mangrove Tree Density, Number of Mangrove Species, Substrate Type, Ecosystem Distance from Settlement. The value of the adaptive capacity of mangrove ecosystems is in the range of 0.0-1.0, with five capacity categories namely "very low, low, medium, high, and very high". The results showed that the number of mangrove species found growing on the coast of Sungai Apit District was 19 species belonging to 10 families and 12 genera, distributed in the "low" category with a mangrove dimension index (IDMg) value of 0.6 (0.4<IDMg <0.8).Dominant species from the Rhizophoraceae family with a density classified as "high". The adaptive capacity of the mangrove ecosystem at the study site is classified as ", high" with an adaptive capacity value of 0.67 ($0.6 \leq KPMg \leq 0.8$).

Keywords: Ecosystem, Mangrove, The Adaptive Capacity

Abstrak

Penelitian ini dilaksanakan selama lima bulan mulai Mei hingga September 2022 yang berlokasi di Kecamatan Sungai Apit dengan mengambil enam (6) desa sebagai lokasi pengambilan sampel dari delapan (8) desa yang ada. Penelitian ini dilaksanakan selama lima bulan mulai Mei hingga September 2022 yang berlokasi di Kecamatan Sungai Apit dengan mengambil enam (6) desa sebagai lokasi pengambilan sampel dari delapan (8) desa yang ada. Tujuan penelitian adalah menghitung dan mengkaji daya adaptasi ekosistem mangrove di Kecamatan Siak Kabupaten Siak. Pengukuran kapasitas adaptif ekosistem mangrove dilakukan dengan menganalisis enam parameter yaitu Mangrove Dimension Index (IDMg), Jenis Mangrove Dominan, Kerapatan Pohon Mangrove, Jumlah Jenis Mangrove, Jenis Substrat, Jarak Ekosistem dari Permukiman. Kapasitas adaptasi ekosistem mangrove berada pada kisaran 0,0-1,0, dengan lima kategori kapasitas yaitu “sangat rendah, rendah, sedang, tinggi dan sangat tinggi”. Hasil penelitian menunjukkan bahwa jumlah jenis mangrove yang ditemukan tumbuh di pesisir Kecamatan Sungai Apit sebanyak 19 jenis yang termasuk dalam 10 famili dan 12 marga, terdistribusi dalam kategori “rendah” dengan nilai indeks dimensi

mangrove (IDMg) sebesar 0,6 (0,4< IDMg <0.8). Spesies dominan dari famili Rhizophoraceae dengan kerapatan tergolong "tinggi". Kapasitas adaptif ekosistem mangrove di lokasi penelitian tergolong “, tinggi” dengan nilai kapasitas adaptif sebesar 0,67 (0,6 ≤ KPMg ≤ 0,8)

Kata Kunci: Ekosistem, Mangrove, Kapasitas Adaptif

1. Introduction

Mangrove forest is one of Indonesia's natural resources which is mostly found in coastal areas. Currently, mangrove ecosystems have been widely used to meet the needs of people's lives, such as settlements, aquaculture, industrial areas, ports, agriculture, and so on. On the other hand, mangrove ecosystems have many functions that are no less important, such as fisheries, coastal protection, recreation areas, and so on.

A lack of knowledge and in-depth understanding of the importance of the role of mangroves in coastal ecosystems has encouraged unilateral exploitation. To avoid or minimize losses that may arise from such unilateral use, it is necessary to take into account the consequences of changes that occur, so that the utilization of mangroves can be carried out optimally and sustainably.In coastal ecosystems, mangrove forests have various roles, including as a producer of organic matter, shelter for various types of animals, spawning grounds for various types of shrimp, habitat for various gastropods, and a protector of the coast. Therefore, it is ideal if the utilization of mangrove forests is based on the principle of various uses, so that they can fulfill all or most of the existing interests. However, in an effort to use all kinds of data, it requires complete and detailed data and information.

Today, knowledge about mangrove ecosystems in Indonesia in general and in Siak District, in particular, is still far from being expected as a basis for formulating management policies and their alternatives. This is due to the limited information and data available, especially regarding the structure of the mangrove community itself, as well as the associated biota, especially aquatic biota.

Ecologically, mangrove forest ecosystems have a high risk of environmental pressure and are vulnerable to various activities and limited carrying capacity of the resources they contain. Every use or exploitation that is carried out will have an impact on the function of the mangrove ecosystem itself (Dahuri, 2003). Therefore, a basic study needs to be carried out on the mangrove ecosystem in Sungai Apit District, especially the study of adaptive capacity to disturbances that occur. This study aims to determine the adaptive capacity of mangrove ecosystems in Sungai Apit District, Siak Regency.

2. Material and Method

2.1. Research Location

This research was conducted from May to September 2022 in Sungai Apit District, Siak Regency.

2.2. Material and Tools

The tools used in this study included a tape measure, raffia rope for making line transects and plots (mapping), a 10 cm diameter PVC pipe for taking sediment samples, scissors or a knife for cutting twigs and branches of plants, label paper, a thermometer for measuring temperature, pH indicators to measure the acidity of water, soil testers (soil pH), aluminum foil, analytical balances, ovens, furnaces, desiccators, cups, multilevel filters to measure sediment fractions and organic matter and writing instruments (pencils, pens, markers) waterproof to record the data obtained

The materials used in this study were samples of mangrove leaves and mangrove fruit taken from a number of research stations that had been determined. The equipment used is a tape measure, raffia rope for making line transects and plots (plotting), a 10 cm diameter PVC pipe for taking sediment samples, scissors or a knife for cutting twigs and branches of plants, label paper, plastic bags for collecting samples of mangrove leaves and fruit.

2.3 Method

2.3.1. Determination of measurement stations and sampling

The method of determining stations at research locations was carried out by means of purposive sampling, which is based on a conceptual approach by looking at the possible distribution of mangrove characteristics. In this study, 6 villages were designated as observation stations, and mangrove sampling.

2.3.2. Observation of examples and sampling

Observation of the mangrove ecosystem using the line transect method refers to Bengen (2001) with the following procedure: 1) At each station a line transect is drawn from sea to land (perpendicular to the coastline

along the existing mangrove forest zoning). 2) In each mangrove forest zone along the line transect, 3 (three) square plots (plots) with a size of 10x10 m^2 are placed alternately. 3) Identification of mangrove species using (mangrove introduction guidebook by Rusila *et al*. (2006), and each sample plot that has been found, then calculating the number of individuals for each type of mangrove. 4) What was observed during the study were all individual mangrove tree stands at the tree level contained in the observation plots.

2.3.3. Data analysis

The assessment of the adaptive capacity of mangrove ecosystems found in the coastal areas of Sungai Apit District, Siak Regency was carried out by considering six parameters, namely; (1) calculation of mangrove dimension index (IDMg), (2) dominant mangrove species, (3) density (trees/ha), (4) number of genera, (5) substrate type, and (6) distance of mangrove ecosystem from settlements. Criteria for assessing the adaptive capacity of mangrove ecosystems are shown in Table 1 below

Table 1. Criteria for assessing the adaptive capacity of mangrove ecosystems

Parameter	weight	Scale/Score					Description
		1	2	3	4	5	
		Very low	Low	Currently	High	Very high	
Mangrove Dimension Index (IDMg)	5	0,0 ≤IDMg ≤0,4	0,4 ≤IDMg ≤0,8	0,8 ≤IDMg ≤1,2	1,2 ≤IDMg ≤1,6	1,6 ≤IDMg ≤2,0	Subur (2012)
Dominant Species	5	*Ceriop/Nypa*	*Bruguiera*	*Rhizopora*	*Soneratia*	*Avicenia*	Bengen,2003; Dahuri, 2003
Density (trees/ha)	3	<110	110 ≤ 330	330 ≤ 660	660 ≤ 880	≥ 880	Bakorsurtanal, 2011
Number of Genera	3	1-2	3-5	6-7	8-10	11-12	Bengen,2003; Dahuri, 2003
Substrate Type	1	Rocky Sand	Sand	Muddy Sand	Sandy Mud	Muddy	Modification Yulianda, 2007
Distance from Settlement (km)	1	< 0,5	> 0,5 - 1	> 1-4	> 4 – 5	> 5	Subur (2012)

2.3.4. Calculating Mangrove Dimension Index (IDMg)

To calculate the mangrove dimension index (IDMg) the first step is to measure the thickness and length dimensions of the mangrove ecosystem under study. These measurements are divided into segments that include certain dimensions of thickness and length. For each 10 m increase in thickness dimension, it will be followed by an increase in value of 0.01 and will reach a maximum value of 1.0 when the mangrove thickness dimension reaches ≥ 1,000 m. Furthermore, for each increase in the length dimension of 120 m at the same thickness dimension, the length dimension value will also increase by 0.01, and will reach a maximum value of 1.0 when the mangrove ecosystem reaches a length of ≥ 12,000 m.

After measurements have been made on the mangrove community which include the dimensions of thickness/width and length dimensions, then the index value of the dimensions of the mangrove community is calculated. The calculation uses the following equation (Subur *et al.*, 2011).

$$IDMg = \sum \left[\frac{NL}{SL}\right] + \sum \left[\frac{NP}{SP}\right]$$

Information :

IDMg : Mangrove Dimension Index
NL : The total number of all width dimension segment values
Sl : Total number of wide segments
NP : The total number of all long dimension segments
SP : The total number of long dimension segments

The Mangrove Dimensional Index (IDMg) values are in the range between 0.0 – 2.0 which are distributed into five categories namely, "Very Low (0.0 ≤IDMg≤0.4)", Low (0.4 ≤IDMg≤0.8)", "Medium (0.8≤IDMg≤1.2)", High (1.2≤IDMg≤1.6)", "Very High (1.6≤IDMg≤2.0)".

2.3.5. Dominant Species Analysis

The step taken to find out the dominant mangrove species is the process of direct identification in the field (in-situ). Then, all species found and observed were recorded and then the number of individuals of each species found in a certain unit area (10x10 m) was counted.

2.3.6. Mangrove Tree Density (trees/ha)

The calculation of the number of mangrove trees per hectare is carried out directly in the field (in situ) together with other data collection processes in the mangrove ecosystem. Furthermore, the results of the

calculation and analysis of the mangrove ecosystem are grouped into the category of mangrove tree density published by Bakorsurtanal (2011), as described in Table 2.

Table 2. Standard Criteria for Mangrove Ecosystems

Criteria	Density (Trees/ha)
Very low	< 110
Low	110-<330
Currently	330-<660
High	660-<880
Very High	>880

Source : SNI Bakosurtanal (2011).

2.3.7. Number of Genera

Calculation of the number of mangrove genera was carried out simultaneously after species identification in the field. After all species have been found, the species are grouped based on their respective genus.

2.3.8. Substrate Type Analysis

Substrate type observations were carried out simultaneously when other data were collected on mangrove ecosystems in the field (in-situ). Through visual observations, it was recorded, the tendency of the type of substrate that was grown by each species found at the study site.

2.3.9. The distance of the mangrove ecosystem from residential areas

Measuring the distance of the mangrove ecosystem from residential areas or community activities, was carried out using the GPS Map Garmin Tip 76 CSx. In addition, a spatial analysis or distribution of mangrove ecosystems was also carried out using a geographic information system (GIS).

2.3.10. Mangrove Ecosystem Adaptive Capacity Analysis (KPMg)

After all data on mangrove ecosystems has been analyzed, the next process is to analyze adaptive capacity using the following equation (Subur *et al.,* 2011).

$$\text{KPMg} = \sum[\frac{Ni}{Nmaks}] \text{ x } 100\ \%$$

Description:

KPMg : The adaptive capacity of the mangrove ecosystem to i
Ni : The total parameter value of the measurement results
N_{max} : The maximum value of parameters in the mangrove ecosystem

The adaptive capacity value of the mangrove ecosystem is in the range between 0.0 – 1.0 with five categories namely: very low ($0.0 \leq \text{KPMg} \leq 0.2$), low ($0.2 \leq \text{KPMg} \leq 0.4$), moderate ($0.4 \leq \text{KPMg} \leq 0.6$), high ($0.6 \leq \text{KPMg} \leq 0.8$), and very high ($0.8 \leq \text{KPMg} \leq 1.0$).

3. Result and Discussion

3.1. General Condition of Research Area

Sungai Apit sub-district is generally located in the Siak River basin and in some places is a sloping beach facing Tebing Tinggi Island and Padang Island in the Bengkalis Regency. Sungai Apit District is located between 1014́ - 0034́ LS and 102003́ – 102053́ EL. The geography and shape of the Sungai Apit District area are 100% flat to undulating with an area of 1,346.33 km^2. The total population in 2020 is 29,506 people.

Sungai Apit sub-district consists of lowland units and hilly units, including river floods and swamps, and surface sediments. Sungai Apit District, whose central government position is in Sungai Apit Village, which is approximately 37 km straight from the district government center, and can be reached by land or river. As a coastal district, Sungai Apit District is overgrown with mangrove forests. The area of the mangrove forest in Sungai Apit District is around 511.4 hectares with the width of the mangrove ecosystem from the coast to the mainland ranging from 70-753 m. With the awareness of the local community, the mangrove ecosystem in this area has been well managed, which was once very damaged. The management activities carried out include planting mangroves of the *Rhizophora* sp species in areas that have been deforested and making regulations prohibiting the community from cutting down the mangrove trees. Currently the mangrove area in Sungai Apit District has been used as one of the Mangove Ecotourism Areas in Siak Regency.

3.2. Types of Mangrove Vegetation

The results of observations of mangrove vegetation in Sungai Apit Sub-district found that there were 19 types of mangroves consisting of 12 genera and 10 families. For more details can be seen in Table 3.

Table 3. Types of Mangrove Vegetation Identified at Research Locations

No	Family	Genus	Spesies
1	Rhizophoraceae	Rhizophora	*Rhizophora apiculata*
			Rhizophora mucronata
			Rhizophora stylosa
		Bruquiera	*Bruquiera sexangula*
			Bruguiera gymnorrhiza
			Bruguiera sylindrica
		Ceriops	*Ceriops decandra*
2	Meliaceae	Xylocarpus	*Xylocarpus granatum*
3	Avicenniaceae	Avicennia	*Avicennia marina*
			Avicennia rumphiana
4	Sonneratiaceae	Sonneratia	*Sonneratia ovata*
			Sonneratia alba
5	Combretaceae	Lumnitzera	*Lumnitzera racemosa*
			Lumnitzera littorea
6	Sterculiaceae Rubiaceae	Heritiera	*Heritiera littoralis*
7	Euphorbiaceae	Scyphiphora	*Scyphiphora hydrophyllacea*
8	Acanthaceae	Excoecaria	*Excoecaria agallocha*
9		Acanthus	*Acanthus ebracteatus*
10	Arecaceae	*Nypa*	*Nypa fruticans*

Source : Primary data

From Table 3 it can be seen that the most common types of mangrove vegetation found at the study site were from the Rhizopohoraceae family namely, there were 7 species, followed by the Avicenniaceae, Sonneratiaceae, and Combretaceae families, each with 2 species. The other 6 families only have 1 type. The dominance of mangroves from the Rhizophoraceae family is due to the fact that the substrate in this study is mud. This is in accordance with Rusila *et al.* (2006) stated that *Rhizophora apiculata* grows on muddy, fine, deep, and inundated soils during normal tides, while *R.stylosa* and *R.mucronata* can still grow on sand and rock/gravel substrates. In addition, the mangrove ecosystem in the study location has been replanting since 2009 with the species planted being from the genus Rhizophora.

There are more types of mangroves in Sungai Apit Subdistrict when compared to the results of Fakhrizal (2007) in the mangrove forest area in the northern part of Bengkalis Island which includes the villages of Jangkang, Bantan Tua and Selat Baru, found 10 species belonging to 8 families whose basic substrates are also in the form of muddy sand. There are more types of mangroves in Sungai Apit Subdistrict when compared to the results of Fakhrizal (2007) in the mangrove forest area in the northern part of Bengkalis Island which includes the villages of Jangkang, Bantan Tua and Selat Baru, found 10 species belonging to 8 families whose basic substrates are also in the form of muddy sand.

3.3. Mangrove Ecosystem Dimension Index

Measurement of the mangrove dimension index is very useful to determine the extent of mangrove distribution in an area. In addition, the dimension index can also indicate that an area or region of an island has a wide distribution of mangrove ecosystems or vice versa. The results of measurement and analysis of the dimension index of mangroves in Sungai Apit District show that the dimension index in that area is 0.607. This means that the dimension index value is in the range of $0.4 \leq IDMg \leq 0.8$. This shows that mangroves in Sungai Apit District are distributed in the "low" category. Dahuri (2003); Bengen (2003) states that mangroves can grow well in calm waters and are protected from strong tidal currents. In addition, Dahuri (2003) states that the survival and growth of mangroves are determined by three main factors, namely: supply of fresh water and salinity, nutrient supply, and substrate stability.

3.4. Dominant Species

Based on observations of mangrove vegetation at the tree level (trees) at each research station in Sungai Apit District, Siak Regency, 19 types of mangrove vegetation were found consisting of 10 families (Table 3). The most common types of mangrove vegetation found were the Rhizopohoraceae family, namely 7 species (*R.apiculata, R. mucronata, R. stylosa, Bruquiera sexangula, B. Gymnorrhiza, B. sylindrica, Ceriops decandra*). The genus Rhizophora was found growing and dominant in most of the observation stations. This is in accordance with the opinion of Khairijon (1998) who said that in general the largest structure of mangroves in Indonesia is filled by *Rhizopohora* sp. Furthermore Nybakken (1992) stated that the specific life cycle of *Rhizopohora* sp with seeds that can germinate when they are still on the mother plant greatly supports the process of wide distribution of this species in the mangrove ecosystem.

3.5. Mangrove Tree Density

To determine the density of mangrove trees in an area, it is necessary to calculate the number of trees per hectare. The higher the density of mangrove trees, it will increase the value of its role in coastal ecosystems and conversely the lower the density of trees, the lower the value of the role of the ecosystem. Based on the research results, it was obtained data that the density of mangroves in Sungai Apit District was an average of 1,379 trees/ha. Thus it can be concluded that the density of mangroves in Sungai Apit District, Siak Regency is classified as "very high" (> 880 trees/ha). This is in accordance with the criteria issued by Bakosurtanal (2011), where there are five categories of density levels of mangrove trees per hectare, namely density < 110 trees/ha are categorized as "very low", density of 110 ≤ 330 trees/ha is categorized as "low", density of 330 ≤ 660 trees/ha is categorized as "medium", 660 ≤ 880 trees/ha are categorized as "high" and ≥ 880 trees/ha is categorized as "very high".

The density level of mangrove trees in Sungai Apit District is currently in the "very high" category. This is due to the emergence of public awareness to protect mangroves, namely the formation of mangrove conservation groups in every village/village since 2009. In addition to protecting mangroves from illegal logging, the community also replants in collaboration with various elements.

3.6. Number of Genera

Based on observations of mangrove vegetation at the tree level at each research station in Sungai Apit District, Siak Regency, 12 genera of mangrove vegetation were found, namely Rhizophora, Bruquiera, Ceriops, Xylocarpus, Avicennia, Sonneratia, Lumnitzera, Heritiera, Scyphiphora, Excoecaria, Acanthus, and Nypa. The types of mangrove vegetation found above are generally found on the coast of Siak Regency and Sungai Apit District in particular. This is in accordance with the opinion of Odum (1993) that the dominant plant group in mangrove forests is the Rhizophoraceae family of the Rhizophora genus. This was also reinforced by Khairijon *in* Subur (2012) said that in general the largest structures of mangroves in Indonesia are filled by *Rhizophora* sp.

3.7. Substrate Type

Substrate type is an important parameter for the growth and development of mangrove vegetation in an area. Based on the results of research conducted concurrently with observations of other parameters in the mangrove ecosystem, it was found that in general the type of substrate on which mangroves grow and develop on the coast of Sungai Apit District is mud type.

3.8. Distance of Mangrove Ecosystem from Residential Settlements

According to Algar *et al*. *in* Subur (2012) that a resource that is closer to the center of community activity or residential areas, the more vulnerable this resource will be. Conversely, the farther a resource is from the center of community activity or residential areas, the more sustainable the resource will be. Based on the results of measurements and analysis in this study, it is known that the mangrove ecosystem that grows on the coast of Sungai Apit District, Siak Regency is about 40–350 m (<0.5 km) from residential areas.

3.9. Mangrove Ecosystem Adaptation Capacity

Based on the description of some of the parameters above, a summary of the results of measuring these parameters and calculating the value of the mangrove adaptation capacity is obtained as shown in Table 4.

Table 4. Measurement Results of Several Parameters in Determining the Adaptive Capacity of Mangrove Ecosystems in Sungai Apit District, Siak Regency

No	Parameter	Value/Scale
1.	Mangrove Dimension Index	(0,4 ≤IDMg≤0,8)
2.	Dominant Species	*Rhizophora* sp
3.	Mangrove Density	> 880 pohon/ha
4.	Number of Genera	(Rh, Br, Ce, Xy, Av,Sn, ,Lu, He, Sc, Ex, Ac, Ny)
5.	Substrate Type	Mud
6.	Distance From Settlement	< 0,5 km
	Adaptability	0,67

From Table 4 it can be seen that after doing the calculations, the value of the mangrove adaptation capacity in Sungai Apit District, Siak Regency is 0.67. This value is in the range of 0.6 ≤ KPMg ≤ 0.8 or the "high" category. This means that the role of the mangrove ecosystem in the study location as a protector of the coastal area to reduce wave energy, trap sediment and slow down the process of coastal erosion is also in the "high" category.

The value of the capacity of the mangrove ecosystem can show its role in protecting a coastal area, so that the lower the capacity value of the mangrove, the lower the role. Vice versa, the higher the capacity value, the greater its role in increasing adaptive capacity in an area. According to Othman *in* Subur (2012) that mangrove ecosystems with high capacity play an important role in reducing wave energy, trapping sediment, and slowing down the beach

erosion process. Furthermore, Mazda *et al.* (2007) added that mangroves with high density are able to protect the land of an island and act as a natural protector from tsunamis.

4. Conclusion

Twelve genera of mangrove vegetation were found namely Rhizophora, Bruqiera, Avicennia, Sonneratia, and Nypa with six species namely *R.apiculata*, *R.mucronata*, *R.stylosa*, *B.sexangula*, *B.gymnorrhiza*, *B.sylindrica*, *C.decandra*, *X.granatum*, *A.rumphiana*, *A.marina*, *S.ovata*, *S.alba*, *L.racemosa*, *L.littorea*, *H.littoralis*, *S.hydrophyllacea*, *E.agallocha*, *A.ebracteatus*, and *N.fruticans*. The dominant species is *Rhizophora* sp. The average density value for the entire mangrove area in the research location is 1,379 trees/ha. The adaptive capacity of the mangrove ecosystem in Sungai Apit Subdistrict, Siak Regency is classified as high, where the adaptive capacity value is 0.67 or around $0.6 \leq \text{KPMg} \leq 0.8$.

5. Suggestion

Considering that research is only limited to adaptive capacity, further research is needed, especially research on the sustainability of mangrove forest management in Sungai Apit District in the future.

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