# Adaptation capacity of the mangrove ecosystem located in the Rawa Mekar Jaya Village, Siak Regency, Riau Province, Indonesia

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**Abstract**. This research was conducted for five months, from May to September 2021, in Rawa Mekar Jaya Village, Siak Regency, Riau Province. The purpose of the study was to calculate and assess the adaptive capacity of the mangrove ecosystem in Rawa Mekar Jaya Village, Siak Regency. The measurement of the adaptive capacity of mangrove ecosystems was carried out by analyzing six parameters: the Mangrove Dimension Index (IDMg), the dominant mangrove species, the mangrove tree density, the number of mangrove species, the substrate type and the ecosystem distance from settlement. The resulting value of the adaptive capacity index of the mangrove ecosystem was in the range 0.0-1.0, with five capacity categories, namely: "very low, low, medium, high and very high". The results showed that the mangrove ecosystems growing on the coast of Rawa Mekar Jaya Village comprised six species belonging to four families and five genera, distributed in the "very low" category. From the four families, the Rhizophoraceae family is the dominant species. The adaptive capacity of the mangrove ecosystem in the study area was classified as "medium" with an adaptation capacity value of 0.522 (0.4<KPMg<0.6).
**Key Words**: structure, community, ecosystem, mangrove, the adaptive capacity.

**Introduction**. Mangrove forests are one of Indonesia's natural resources that are widely found in the coastal areas. Currently, the mangrove ecosystem has been widely used to meet the needs of people's lives, such as settlements, aquaculture, industrial areas, ports, agriculture and others. On the other hand, the mangrove ecosystem has many functions that are no less important, such as fisheries, coastal protection, and recreation areas. Lack of knowledge and in-depth understanding of the importance of the role of mangroves in coastal ecosystems has encouraged unilateral use. To avoid or minimize losses that may arise from such unilateral use, it is necessary to take into account the 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, a shelter for various types of animals, a place for spawning various types of shrimp, habitat for various gastropods and as a beach protector (Bengen 2001). Therefore, the utilization of this mangrove forest should ideally be based on the principle of various uses, so that it can fulfill all or most of the existing interests. However, in an effort to use all kinds of things, it requires complete and detailed data and information.

Currently, knowledge about mangrove ecosystems, in Indonesia in general and in the Siak Regency in particular, is still far from what is expected as a basis for formulating management policies and their alternatives. This is due to the limited information and data available, especially related to the structure of the mangrove community itself, as well as the associated biota in it, especially the aquatic biota. Ecologically, the mangrove forest ecosystem has a high risk of environmental pressure and is vulnerable to various activities and the limited carrying capacity of the resources it contains. Every type of utilization or exploitation carried out will have an impact on the function of the mangrove ecosystem itself. According to Othman (1994), mangrove ecosystems with high capacity play an important role in reducing wave energy, trapping sediments and slowing down the process of coastal erosion. Furthermore, Smit & Pilifosova (2003) stated that adaptive capacity is the inherent character of a system to adapt and recover from a change. Therefore, a basic study needs to be carried out on the mangrove ecosystem in Rawa Mekar Jaya Village, especially on the study of adaptive capacity to disturbances that occur. Thus, the current study aimed to determine the adaptive capacity of the mangrove ecosystems in Rawa Mekar Jaya Village, Siak Regency, Riau Province, Indonesia.

## Material and Method

***Description of the study sites***. This research was carried out from May to September 2021, in Rawa Mekar Jaya Village, Siak Regency and Riau Province (Figure 1).

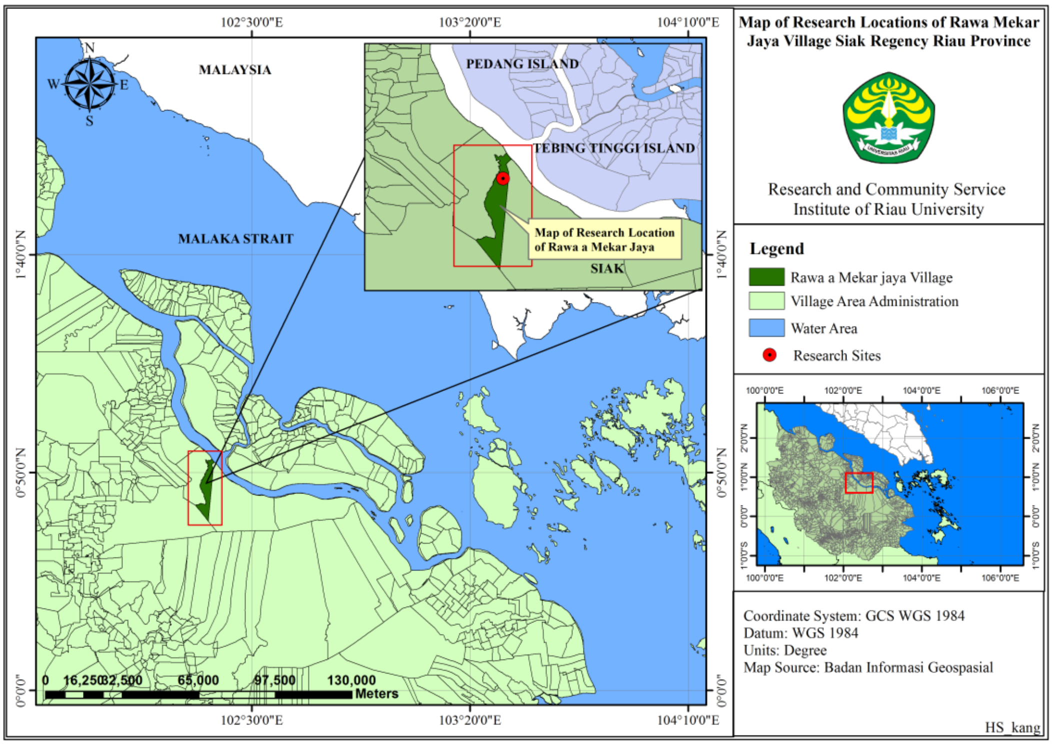

Figure 1. Sampling site.

***The design of the study***. The determination method at the research location was purposive sampling, based on the possible distribution of the mangrove characteristics. In this study, three observation and mangrove sampling stations were set. The location of each station was determined after a preliminary survey. The tools used included a meter, a raffia rope to make line transects and plots (map), a 10 cm diameter PVC pipe for sediment sampling, scissors or a knife to cut twigs and plant branches, label paper, thermometer to measure temperature, pH indicator for measuring the degree of acidity of water, soil tester (acidity of soil pH), aluminum foil, analytical balance, oven, furnace, desiccator, cup, multilevel filter to measure the fraction of sediment and organic matter, and waterproof stationery (pencils, pens, markers) to record the data obtained

The materials used in this study were samples of leaves and mangrove fruit taken from a number of predetermined research stations.

The observation of the mangrove ecosystem using the line transect method refers to Bengen (2001), with the following procedure:

- At each station, a line transect is drawn from the sea to the land (perpendicular to the coastline along with the mangrove forest zoning that occurs).
- At each mangrove forest zone located along the transect line, 3 alternating plots are placed by square of 10x10 $m^2$.

- The identification of mangrove species was performed (according to the guidebook of Rusila et al 2006), and for each sample plot that had been found, the number of individuals for each mangrove species was calculated.
- The retrieve data along the research are all individual tree-level mangrove stands in the observation plot.

***Data analysis***. The assessment of the adaptive capacity of the mangrove ecosystem found in the coastal area of Rawa Mekar Jaya Village, Siak Regency was carried out by considering six parameters, namely: (1) calculation of mangrove dimension index (IDMg), (2) dominant mangrove species, (3) density (trees $ha^{-1}$), (4) number of genera, (5) substrate type and (6) distance of mangrove ecosystem from residential areas. The criteria for assessing the adaptive capacity of mangrove ecosystems are shown in Table 1 below.

Table 1

Criteria for assessment of adaptive capacity of mangrove ecosystem

| *Parameter* | *Weight* | *Scale/Score* | | | | | *References* |
|---|---|---|---|---|---|---|---|
| | | *1* | *2* | *3* | *4* | *5* | |
| | | *Very low* | *Low* | *Medium* | *Height* | *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 (ind $ha^{-1}$) | 3 | <110 | >110 and ≤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 | Yulianda 2007 |
| Distance from people settlement (km) | 1 | <0.05 | >0.5 and <1 | >1-4 | >4-5 | >5 | Subur 2012 |

***Calculating mangrove dimensional index (IDMg)***. To calculate the mangrove dimension index (IDMg), the first step is to measure the thickness and length dimensions of the studied mangrove ecosystem. The measurement is divided into segments that include thickness dimensions and certain length dimensions. Subur et al (2011) stated that every increase of 10 m mangrove in the thickness dimension will be followed by an increase of 0.01 and will reach a maximum value of 1.0 when the mangrove thickness dimension reaches 1,000 m. Furthermore, for every increase in the length dimension of 120 m mangrove 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 the measurements were carried out on the mangrove community, including the dimensions of thickness/width as well as the dimensions of length, then the calculation of the dimension index of the mangrove community was carried out. The calculation used the following equation (Subur et al 2011):

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

Where:
IDMg - mangrove dimension index;
NL - the total sum of all the values of the width dimension segment;
SL - total number of width segments;
NP - the total number of all length dimension segments;
SP - total number of length dimension segments.

The value of the IDMg was in the range between 0.0–2.0, 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).

***Dominant species analysis***. The step taken to determine the dominant mangrove species was the direct identification process in the field (in situ). Then all the species found and observed were recorded and the number of individuals of each species found by an area of 10x10 m was counted.

***Mangrove tree density (ind ha$^{-1}$)***. The calculation of the number of mangrove trees per hectare was carried out directly in the field (in situ) along with other data collection processes. Furthermore, the results of the calculation and analysis of the mangrove ecosystem were grouped according to Bakorsurtanal (2011), as described in Table 1.

***Number of genera***. The calculation of the number of mangrove genera was carried out simultaneously, after the species identification in the field. All species were determined and grouped according to their respective genera.

***Analysis of substrate type***. Substrate type observations were carried out at the same time as other data collection on mangrove ecosystems in the field (in situ), through visual observations, then the overgrowing tendency of each species by substrate type found at the study site was recorded.

***The distance of the mangrove ecosystem from residential areas***. Measurement of 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 analysis of the mangrove ecosystem was also carried out using a geographic information system (GIS).

***Mangrove ecosystem adaptive capacity analysis (KPMg)***. After all the data on the mangrove ecosystem has been analyzed, the next process was to analyze the adaptive capacity using the following equation (Subur et al 2011):

$$KPMg = \sum \left[ \frac{Ni}{N_{max}} \right] x100\%$$

Where:
KPMg - adaptive capacity of the mangrove ecosystem to several parameters;
Ni - observation value for the i$^{th}$ parameter;
N max - maximum parameter value in mangrove ecosystem.

The value of the adaptive capacity of mangrove ecosystems was in the range between 0.0 and 1.0 with five categories: very low (0.0<KPMg<0.2), low (0.2<KPMg<0.4), moderate (0.4<KPMg<0.6), high (0.6<KPMg<0.8), and very high (0.8<KPMg<1.0).

**Results**

***General condition of research site***. Rawa Mekar Jaya Village is one of the villages in Sungai Apit District, Siak Regency, Riau Province, which is located on the edge of the Rawa River. The area of this village is around 16,803 ha, with a population of 1,010 people, in 2018. It is located at an altitude of 5 m above sea level. As a coastal area, Rawa Mekar Jaya Village is affected by tides, where the highest tide can reach 3.1 m and the lowest 0.3 m (Statistics of Rawa Mekar Jaya Village 2019). As a coastal village, Rawa Mekar Jaya Village is overgrown by mangrove forests. The area of the mangrove forest in Rawa Mekar Jaya Village is about 25 ha with the width of the mangrove ecosystem from the riverbank to the mainland ranging from 50-75 m. With the awareness of the local community, the mangrove ecosystem in this area, which was once very damaged, has been managed well. The management activities carried out include planting mangroves of the *Rhizophora* sp. species in deforested locations and making rules prohibiting the community from cutting down the mangrove trees. Currently, the mangrove area in Rawa Mekar Jaya Village has been used as one of the Mangrove Ecotourism Areas in Siak Regency, under the name "Mangrove Ecotourism House of Mangrove Nature". However, in the recent period, the facilities built for mangrove ecotourism activities were not properly maintained.

***Mangrove vegetation type***. Mangrove trees in Rawa Mekar Jaya Village comprise six species consisting of four families (Table 2).

Table 2

Types of mangrove vegetation identified at the research site

| *No* | *Family* | *Genus* | *Species* |
|---|---|---|---|
| 1 | Rhizophoraceae | Rhizophora | *Rhizophora apiculata* |
| | | | *Rhizophora mucronata* |
| | | Bruquiera | *Bruquiera sexangula* |
| 2 | Avicenniaceae | Avicennia | *Avicennia marina* |
| 3 | Sonneratiaceae | Sonneratia | *Sonneratia ovata* |
| 4 | Arecaceae | Nypa | *Nypa fruticans* |

***Mangrove ecosystem dimension index***. To determine the adaptive capacity of the mangrove ecosystem in the Rawa Mekar Jaya Village, Siak Regency, the parameters affecting the capacity of the mangrove ecosystem were determined in several steps: (1) measuring the dimensional index, (2) identifying the dominant mangrove species in the studied area, (3) calculating the density of mangrove trees per hectare, (4) calculating the number of genera, (5) observing the substrate type for mangrove growth and (6) measuring the distance of the mangrove ecosystem from human activities or human settlements (Subur 2012). The results of the measurement and analysis of the mangrove dimension index in Rawa Mekar Jaya Village show that the dimension index in the area is 0.134 ($0<IDMg\leq 0.4$). This shows that the mangroves in Rawa Mekar Jaya Village are distributed in the “very low” category.

***Dominant species***. Based on observations of the mangrove mature trees at each research station in the village of Rawa Mekar Jaya Siak, six species of were found, consisting of four families (Table 2). The most common type of mangrove vegetation found was the Rhizopohoraceae family, which consisted of 3 species (*R. apiculata*, *R. mucronata* and *Bruquiera sexangula*).

***Mangrove tree density***. To determine the density of mangrove trees in an area, it is necessary to calculate the number of trees per hectare. Based on the results of the study, the density of mangroves in Rawa Mekar Jaya Village was of an average of 1,555 trees $ha^{-1}$. Thus, it can be concluded that the mangrove density in Rawa Mekar Jaya Village, Siak Regency is classified as "very high" (>880 trees $ha^{-1}$), in accordance with the criteria issued by Bakosurtanal (2011).

***Number of genera***. Based on the observation of the mature trees at each research station in the village of Rawa Mekar Jaya Siak, 5 genera *Rhizophora* mangrove vegetation species were identified: *Bruquiera*, *Avicennia*, *Sonneratia* and *Nypa*.

***Substrate type***. The substrate type is one of the important parameters for the growth and development of mangrove vegetation in an area. Based on the results of a research conducted simultaneously with observations of other parameters in the mangrove ecosystem, it was found that the dominant type of substrate where mangroves grow and develop on the coast of Rawa Mekar Jaya Village is mud.

***Distance of mangrove ecosystem from residential settlement***. Based on the measurements and analysis in this study, it resulted that the mangrove ecosystem that grows on the coast of Rawa Mekar Jaya Village, Siak Regency is located at about 40-350 m (<0.5 km) from the residential areas.

***Mangrove ecosystem adaptation capacity***. Based on the description of some of the parameters above, a summary of the measurement results of these parameters and the calculation of the value of mangrove adaptation capacity is provided in Table 3 below.

Table 3

Measurement results of several parameters in determining the adaptation capacity of mangrove ecosystems in Rawa Mekar Jaya Village, Siak Regency

| *Parameter* | *Value/Scale* |
|---|---|
| Mangrove dimension index | (0.0≤IDMg≤0.4) |
| Dominant species | *Rhizophora* sp. |
| Mangrove density | > 850 trees $ha^{-1}$ |
| Number of genera | (Rh, Br, Av, Sn, Ny) |
| Substrate type | Sandy mud |
| Distance from settlement | <0.5 km |
| Adaptation capacity | 0.522 |

Rh-Rhozophora; Br-Bruguiera; Av-Avicenia; Sn-Sonneratia; Ny-Nypa.

From Table 3, it can be seen that the value of the adaptive capacity of mangroves in Rawa Mekar Jaya Village, Siak Regency is 0.522. This value is in the range of 0.4<KPMg<0.6 or the "medium" category. This means that the role of the mangrove ecosystem at the study site as a coastal protector, to reduce wave energy, trap sediment and slow down the process of coastal erosion, is also in the "medium" category.

**Discussion**

***Mangrove vegetation type***. The most common types of mangrove vegetation found at the study site were from the Rhizophoraceae family, which had 3 species, while the other 3 families only had 1 species. 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), who stated that *R. apiculata* grows on muddy, smooth, deep soil and is flooded during normal tides, while *R. stylosa* and *R. mucronata* can still grow on sand and rock/gravel substrates. In addition, the mangrove ecosystem at the study site has had replanting activities since 2009, with the planted species from the genus *Rhizophora*.

The frequency of this type of mangrove in Rawa Mekar Jaya Village is lower when compared to the results of Adriman (2020) in Mengkap Village, Sungai Apit District or compare the mangrove forest area in the northern part of Bengkalis Island, which includes the villages of Jangkang, Bantan Tua and Selat Baru. In Mengkap Village, 9 species of mangroves were found, belonging to 6 families, while in Bengkalis Island, 10 species were found, belonging to 8 families. But the similarity is the basic substrate, in the form of muddy sand.

***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 dimensional index can also indicate that the region or area of an island has a wide distribution of mangrove ecosystems or vice versa (Subur 2012). Based on the Mangrove Ecosystem Dimension Index, the distribution of mangroves in the study area is classified as "very low". The very low distribution of mangroves in the study area is probably caused by many factors, including past exploitation, the existence of a replanting program by community groups comprising only the genus *Rhizophora*, and other environmental factors. This is in accordance with the opinion of Dahuri (2003) and Bengen (2003), who stated that mangroves can grow well in calm waters and are protected from strong tidal currents. In addition, Dahuri (2003) stated that the survival and growth of mangroves are determined by three factors: freshwater supply and salinity, nutrient supply and substrate stability.

***Dominant species***. The most common type of mangrove vegetation found was the Rhizopohoraceae family, which consisted of 3 species (*R. apiculata*, *R. mucronata* and *B. sexangula*). 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 stated that in general the largest structures of mangroves in Indonesia are filled by *Rhizopohora* sp. Furthermore, Nybakken (1992) stated that the special life cycle of *Rhizopohora* sp, with seeds that can germinate while still in the mother plant, is very supportive of the process of a wide distribution of this species in the mangrove ecosystem. According to Gardner et al (1991), factors that affect growth include soil and climate. Climatic factors include, among others: light, temperature, water, day length and wind, soil factors: texture, structure, organic matter, cation exchange capacity, pH and other chemical properties such as C, N, P, and K. According to Hutahaean (1999), a good height of growth of *R*. *mucronata* was obtained at 0-15 ppt salinity. Kusmana (2014) stated that the salinity range for *R. mucronata* was 12-30 ppt, while in *B.* gymnorrhiza tillers a good height of growth was obtained at 0-15 ppt salinity. Salinity at the study site ranged from 0–26 ppt.

***Mangrove tree density***. The density level of mangrove trees in Rawa Mekar Jaya Village is currently in the "very high" category. This is due to the emergence of public awareness to protect mangroves, namely the formation of a mangrove conservation group in Rawa Mekar Jaya Village, in 2009. In addition to protecting mangroves from illegal logging, the community also carries out replanting. In addition, the density of mangroves is also determined by the content of organic matter contained in the substrate. The average organic matter content of the sediment at the study site ranges from 11.09 to 12.93. This is in accordance with the results of the research by Lestaru et al (2018), on the Pannikiang Island, Balusu District, Barru Regency, which found a significant relationship between the organic matter content of the sediment and the density of mangrove species.

***Number of genera***. The number of genera found in the study area was only 5, namely *Rhizophora*, *Bruquiera*, *Avicennia*, *Sonneratia* and *Nypa*. The mangrove species found in the coastal villages of Siak Regency, such as Mengapan Village, Rawa Village, and other coastal villages are in accordance with the opinion of Odum (1993), stating that the dominant plant group in mangrove forests is the Rhizophoraceae family of the *Rhizophora* genus. This is also reinforced by Khairijon (1998) and Subur (2012) who affirmed that in general the largest structures of mangroves in Indonesia are filled by *Rhizophora* sp.

***Substrate type***. The type of substrate for the mangrove ecosystem at the study site is mud. This mud substrate comes from suspended particulates carried by water flows into the mangrove ecosystem, especially at high tide. Based on the results of the study, the measured concentration of total suspended solids (TSS) averaged 26-34 mg $L^{-1}$. Over time, the TSS will settle and will become a substrate in the mangrove ecosystem. The rate of sediment transport in the mangrove ecosystem is strongly influenced by the density of mangrove stands. A very high mangrove density (1,555 trees $ha^{-1}$) at the study site will affect the rate of sediment transport to the substrate of the mangrove ecosystem. This is in accordance with the results of Siregar et al (2016), who conducted a research in the coastal area of Pulau Sembilan Village, Langkat Regency, North Sumatra. From the results of his research, it is known that there is a relationship between mangrove density and sediment transport rate (negatively correlated), where the higher the mangrove density, the lower the sediment transport rate (floating). This is because the sediment carried by the water has been trapped by the mangrove roots.

The mangrove root system can reduce the speed of water flowing on the forest floor, thus providing an opportunity for soil colloidal particles to settle on the forest floor. Wolanski et al (1997) suggested that mangroves play a role in regulating sediment movement by reducing the erosive power of water currents, enriching clay deposits, and reducing the resuspension power of clay deposits so that mangroves can improve water quality and primary productivity by the abundance of phytoplankton.

***Distance of mangrove ecosystem from residential settlement***. According to Subur (2012), resources located closer to the center of community activity or residential areas are more vulnerable. Based on observations and research in the field, it was found that there were activities of residents who cleared land for oil palm plantations, especially land adjacent to settlements adjacent to the mangrove ecosystem. This has the potential to disrupt the sustainability of the mangrove ecosystem in the future.

***Mangrove ecosystem adaptation capacity***. The mangrove ecosystem has a role in the protection of a coastal area and in increasing its adaptive capacity. According to Subur (2012), mangrove ecosystems with high capacity play an important role in reducing the wave energy, trapping the sediments and slowing down the process of coastal erosion. Furthermore, Mazda et al (2007) added that mangroves with a high density can protect the mainland of an island and act as a natural protector from tsunamis. Harada & Kawata (2004) reported that coastal forest, consisting of mangrove, sago, casuarina and coconut tree stands, with a density of 3,000 trees $ha^{-1}$ with an average trunk diameter of 15 cm and a forest width of about 200 m can reduce the tsunami wave height by approx. 50-60% and the tsunami flow velocity by around 40-60%.

**Conclusions**. Five genera of mangrove vegetation were found: Rhizophora, Bruqiera, Avicennia, Sonneratia and Nypa, with six species, namely: *R. apiculata*, *R. mucronata*, *B. sexangula*, *Avicennia rumphiana*, *Avicennia marina*, *S. ovata* and *N. fruticans*. The adaptive capacity of the mangrove ecosystem in Rawa Mekar Jaya Village, Siak Regency, is classified as moderate, where the value of the adaptive capacity is 0.522 ($0.4<KPMg<0.6$).

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**Conflict of interest**. The authors declare no conflict of interest.

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