

MODELING OF THE EFFECTIVENESS OF WETLAND VEGETATION AS EXTREME WAVE REMOVAL IN MANGROVE ECO-TOURISM AREA PAGATAN BESAR VILLAGE

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ABSTRACT

This study examines the effectiveness of mangroves in long distances to the beach in the Mangrove ecotourism area of Pagatan Besar Village. This study aims to determine the effectiveness of mangroves against extreme waves based on wave transformation before and after passing through mangrove vegetation. Data collection methods used are field research, literature and secondary data. The study was conducted by modeling the CMS Wave – SMS structure which predicts changes in height and deflection of extreme waves during the highest tide (Highest Astronomic Tide / HAT) that interacts with mangrove vegetation as a natural beach. The results obtained show that at stations overgrown with mangroves, the waves tend to be still high when approaching the mainland. This is different from Stations 2 and 3 which are overgrown with mangroves. The waves tend to decrease before approaching land. In Profile 1 (not overgrown with mangroves) and Profile 3 (covered with thin mangroves) the wave height is 75 meters from the shoreline (in front of the mangroves) the wave height is 0.31 m and at the back of the mangrove is still 0.01 m on the beach and the back of the mangroves. As for profile 2 (wide mangrove beach) at a distance of 150 m from the shoreline, the wave height has decreased to 0.26 m at the back of the mangrove. The wave height continues to decrease to 0.00 m or has run out.

Keywords: wave transformation, mangrove, effectiveness, HAT, Pagatan Besar

INTRODUCTION

Pagatan Besar Village Beach has mangrove vegetation that stretches for 1 km on the west coast. Growing well because the planting and care of mangroves are carried out gradually and continuously, so that it is currently known as a mangrove ecotourism area in South Kalimantan. With its various biophysical dynamics, it has the potential to change the landscape. This area has experienced a large enough abrasion to reach 150 - 200 meters from the coastline in 1997 - 2006.

This research is expected to be able to provide up-to-date information about the current mangrove vegetation, whether it is effective or not in reducing the threat of extreme waves. This is an effort to mitigate and reduce the risk of future coastal and marine disasters in the research area by looking at the wave transformation that occurs around the mangrove ecotourism area that occurs based on the direction of the wind that generates waves in the high seas towards the coast. Based on the results of this study, it is hoped that recommendations for mangrove ecosystem management can be formulated and involve all parties, especially the community in Pagatan Besar Village.

This research is also expected to be able to overcome strategic problems on a national scale in this case disaster management and disaster risk reduction, so this study aims to determine the effectiveness of mangroves against extreme waves based on wave transformation before and after passing through mangrove vegetation at the time of the highest tide.

THEORETICAL FRAMEWORK

Wetlands vegetation in Indonesia continues to be in the world's spotlight and is a serious concern for Indonesian stakeholders in improving their management. One of the types of wetlands in Indonesia is mangrove forest vegetation, with the largest area in the world 3.2 million hectares (Wetland International, 1999).

Physically, mangroves play a role in maintaining shoreline stability, protecting beaches from abrasion (non-structurally), as natural sediment traps, and buffer areas for seawater intrusion processes. Awareness of the function and role of mangrove forests for the stability of coastal areas is getting stronger after the tsunami incident on 26 December 2004.

The level of effectiveness of mangroves in reducing extreme waves is strongly influenced by the structure of the vegetation (vegetation width, density, diameter, tree height and the type of mangrove and its roots). In addition, coastal characteristics such as coastal morphology, slope, tidal type and basic water configuration (bathymetry) greatly determine the propagation pattern and wave energy formed (Ida et al., 2001; Dewi, 2004). Quartel et al. (2007) and Alongi (2008) state that the attenuation of wave energy depends on the structure of the mangrove forest, such as trunk configuration, roots and branch diameters Hiraishi and Harada (2003), Muliddin and Sugianto (2004), Tanaka et al. (2007, 2009, 2011), Onrizal et al. (2009), Yanagisawa et al. (2009a, 2009b, 2010). Onrizal and Mansor (2016) stated that dense mangrove forests are more effective in reducing extreme wave attenuation than mangroves with sparse density.

Harada and Imamura (2002) stated that coastal forest with a thickness of 200 meters, a density of 30 trees/100 m², and a tree diameter of 15 cm, can absorb 50% of the energy of a tsunami wave with a height of 3 m. Meanwhile, Hardianti (2014) got a wave reduction value of 59.72% - 85.01% for a mangrove thickness of 51.04 - 88.62 meters. Information to determine the effective mangrove width to reduce the danger of extreme waves is still very limited. However, Lekatompessy and Tutuhatunewa (2010) stated that the greater the density and thickness of the mangroves, the more the wave coefficient reflection (K_r) will be reduced.

The coastal area of Pagatan Besar Village has a mangrove ecosystem of 276.58 ha spread along the coast and river mouths (Ponaru et al., 2017). There were 5 types of mangroves (Setiawan, 2017). Currently, a mangrove ecotourism area has been developed which stretches for 1 km on the west coast of Pagatan Besar Village. This ecotourism area has a mangrove area of ± 10 ha. The types of mangroves found in this location are dominated by *Avicennia alba* and *A. marina* species (Nursalam et al., 2019). The average diameter of a mangrove tree trunk is 9.19 – 11.19 cm (Akbar, 2019). Mangrove vegetation cover on ecotourism coastal areas only reached 13%. The shape of a straight coastline with a beach typology of muddy sand Mangroves that grow in this area have undergone various biophysical dynamics that have caused changes in the landscape. The current thickness of the mangroves growing is an average of 111.47 meters (Dewi et al., 2020).

This area used to experience severe abrasion in the period 1997 – 2006 to reach 200 meters. Naturally the waves are generated by the wind from the high seas to the coast. Given the importance of mangrove ecosystems on the coast, this research needs to be carried out to examine the physical role of mangroves whether or not they are effective or not in protecting beaches in the Pagatan Besar ecotourism area. The study was conducted using a CMS Wave – SMS modeling simulation which predicts changes in height and deflection of extreme wave

directions at the time of the highest tide (Highest Astronomic Tide/HAT) that interacts with mangrove vegetation as a coastal structure. From the modeling results, it is hoped that the level of effectiveness of mangrove vegetation in reducing extreme waves in Pagatan Besar will be known.

METHOD

The CMS-Wave module is used to see the pattern of wave transformation that occurs from the high seas to the coast which is dominated by mangrove vegetation in the waters of Pagatan Besar Village, Tanah Laut Regency, South Kalimantan Province. The data collection variables in this study were primary data and secondary data with various sources and relevant data collection techniques. The initial survey and data collection involved a number of students and alumni. Bathymetry data obtained by measurements in the field. The measurement results are corrected with tidal data to get the actual depth.

This research uses wave modeling CMS Wave – SMS (Surface water Modeling System). There are 3 stages carried out namely Pre Processing, Processing, and Post Processing. The data needed for model input are wave data, corrected depth data based on the HAT reference, tidal data and mangrove vegetation data. The beach with mangrove vegetation is simulated as far as 1.8 m from the top side to the north to the bottom side of the beach to the south, as many as 3 stations with different mangrove thicknesses with wave height data input of 2.5; 1.5; and 1 m while the wave period is 6.5; 5.5; and 5 s. of 3 data inputs on the CMS Wave model. The resulting output is the wave height parameter and wave propagation vector as well as wave interaction before and after passing the mangrove in Pagatan Besar Village.

DISCUSION

Mangrove Cover and Shoreline Shape

The shape of the coastline on the coast of the mangrove ecotourism area is straight. The shape of the beach like this is prone to erosion (abrasion) by currents along the coast or perpendicular to the coast. The mangrove ecotourism beach in Pagatan Besar Village based on the condition of the beach substrate is classified as a muddy sand beach. Map of mangrove cover at the study site is presented in Figure 1.

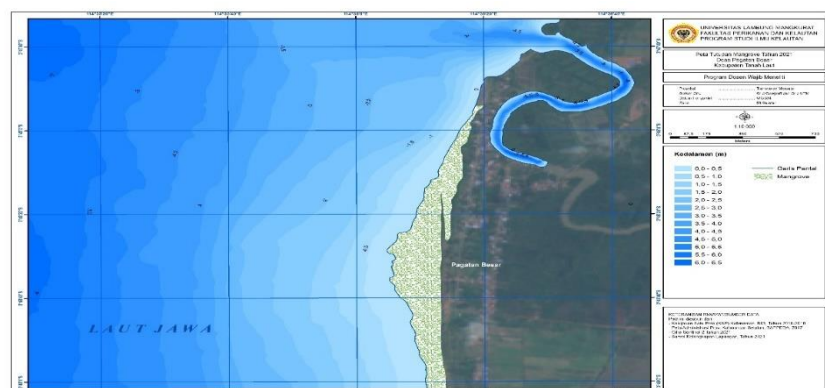


Figure 1. Map of Mangrove Cover

There are 4 types of mangrove found in the mangrove ecotourism area of Pagatan Besar Village, namely *Avicennia alba*, *Avicennia marina*, *Sonneratia caseolaris* and *Terminalia cattapa* L. (Table 1).

Table 1. Types of Mangroves in the Ecotourism Area of Pagatan Besar Village

No	Local Name	Scientific name	Family	Description
1	Api-api	<i>Avicennia alba</i>	Avicenniaceae	Mangrove mayor
2	Api-api	<i>Avicennia marina</i>	Avicenniaceae	Mangrove mayor
3	Rambai	<i>Sonneratia caseolaris</i>	Sonneratiaceae	Mangrove mayor
4	Ketapang	<i>Terminalia cattapa</i> L	Combretaceae	Mangrove asosiasi

Authority : Observation Results (2021)



Figure 2. The condition of mangroves in Pagatan Besar

Mangrove Height

Mangrove thickness was obtained by measuring the width of the mangrove perpendicular to the coastline in 3 segments, from the north to the south. In each segment, there are differences in the average height of mangrove trees. The middle segment is a point that has a higher tree height than the other segments (Table 2). The measurement results show that the thickness of mangroves in ecotourism areas is 0.5 – 5 meters.

Table 2. Mangrove Height in Ecotourism Area of Pagatan Besar Village

Segment	Height (m)	Description
1	0,5 – 3,5	Northern side
2	1 – 5	Middle side
3	0,5 – 2	South side
Average	0,5 – 5	

authority: Observation Results (2021)

Mangrove Thickness

Mangrove thickness was obtained by measuring the width of the mangrove perpendicular to the coastline in 3 segments, from the north to the south. The measurement results show that the average mangrove height in the ecotourism area is 111.47 meters (Table 3).

Table 3. Thickness of the Mangrove in the Ecotourism Area of Pagatan Besar Village

Segment	Width (m)	Description
1	110,20	Northern side
2	149,93	Middle side
3	74,27	South side
Average	111,47	

authority: Observation Results (2021)

Tides

The tidal pattern at the study site is strongly influenced by tidal propagation from the waters of the Java Sea and the influence of the entry of the Sea Strait water mass, besides that the amplitude and phase are also influenced by the flow of river discharge found in this area. Tidal data was obtained from the measurement results (Figure 3) and predictions for 15 days (17 – 31 July 2021) with an interval of every 60 minutes (Figure 4). Tide measurements in the field are carried out when bathymetry data is taken every 5 minutes with a benchmark time of GMT +08.00. The data is then analyzed using the Admiralty method to obtain the harmonic constants.

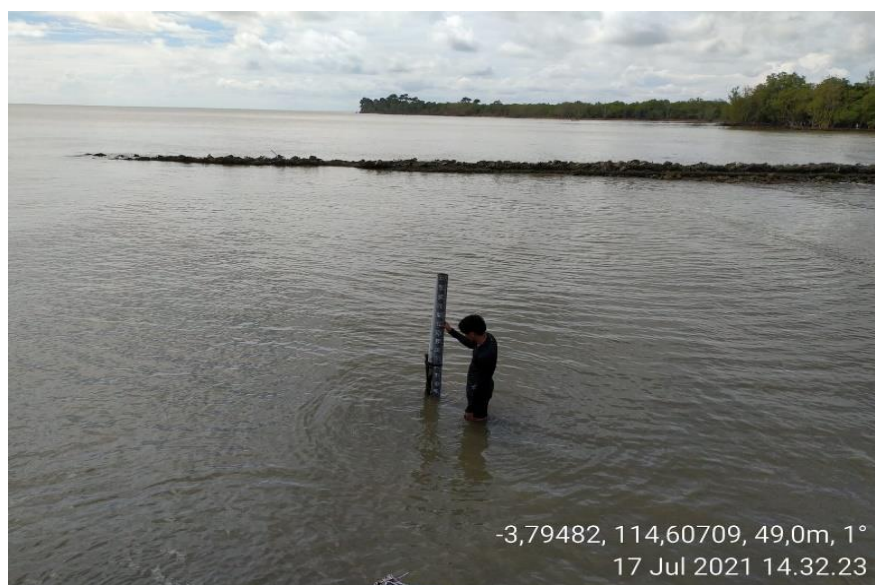


Figure 3. Observation of Tidal Data in Pagatan Besar Village

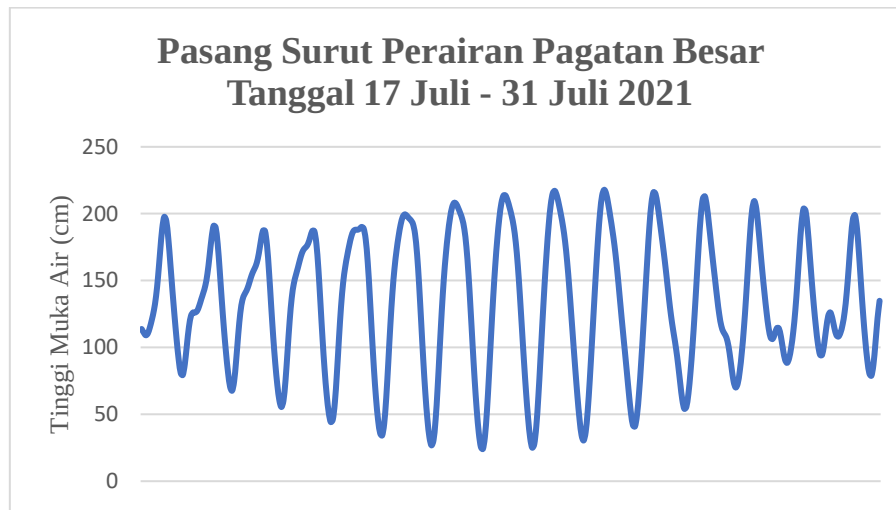


Figure 4. Tidal Patterns in Pagatan Besar Waters 17 – 31 July 2021

The tides in the waters around the study area are generally classified as mixed tide prevailing diurnal. This is based on an analysis using the admiralty method of measurement data that the amplitude of the main daily tidal components (K1 and O1) is greater than that of the main double tidal components (M2 and S2), namely 45.66 cm and 34.66 compared to 14, 83 cm and 22.83 cm, so that the Formzahl number (F) is 2.13. This value is based on the criteria of courtier range including mixed tide prevailing diurnal.

The value of the spring tide, at the average high tide (MHHWS) is 277.9 cm or 80.3 cm above MSL and the low water at low tide (MLLWS) is 11, 37 cm or –80.3 cm below MSL. For the value of high tide at neap tide, the average high tide (MHHWN) is 208.6 cm or 11.0 cm above MSL, while for low water at low tide (MLLWN) by 186.6 cm or –11.0 cm below the MSL. The highest high water value at high tide (HAT) is 315.6 cm or 118.0 above MSL and the lowest low water value at high tide (LAT) is 79.6 cm or –118.0 below MSL. The value of the tidal ride between MHHWS and MLLWS (tidal range) is 160.6 cm (Table 4).

Table 4. Tide tides for mixed tide prevailing semi diurnal types based on MSL and tidal palm references

Tidal Characteristics	Formula (Iwagaki dan Sawaragi 1979; Beer 1997 in Baharuddin 2006)	Reference	
		MSL (cm)	Tidal Staff (cm)
HAT	$= LAT + 2 (AK_1 + AO_1 + AS_2 + AM_2)$	118,0	315,6
MHHWS	$= LAT + 2 (AK_1 + AO_1) + AS_2 + AM_2$	80,3	277,9
MHHWN	$= LAT + 2 AK_1 + AS_2 + AM_2$	11,0	208,6
MSL	$= So$		197,6
MLLWN	$= LAT + 2 AO_1 + AS_2 + AM_2$	-11,0	186,6
MLLWS	$= LAT + AS_2 + AM_2$	-80,3	117,3
LAT	$= MSL - AK_1 - AO_1 - AS_2 - AM_2$	-118,0	79,6
Tidal Range	$= MHHWS - MLLWS$		160,6

authority: Observation Results (2021)

The sea waters around the study area are generally shallow and have gentle gradations. The depth of the sea waters around the study area is 0 - 6.5 meters. The bathymetric map presented in Figure 5 is the result of the analysis of the results of the interpolation of field measurement data.

The depth profile in Pagatan Besar waters is strongly influenced by sedimentation and erosion processes. This process is highly dependent on hydro-osenographic dynamics from both the sea and the river. As a result of this process, the depth profile in these waters is irregular, where there are many irregular sand dunes as a result of the influence of waves. In addition, the bathymetric profile is also strongly influenced by the pattern of sediment distribution from the sea and land which causes sedimentation to settle in calm areas around the mangroves (in areas with very weak currents).

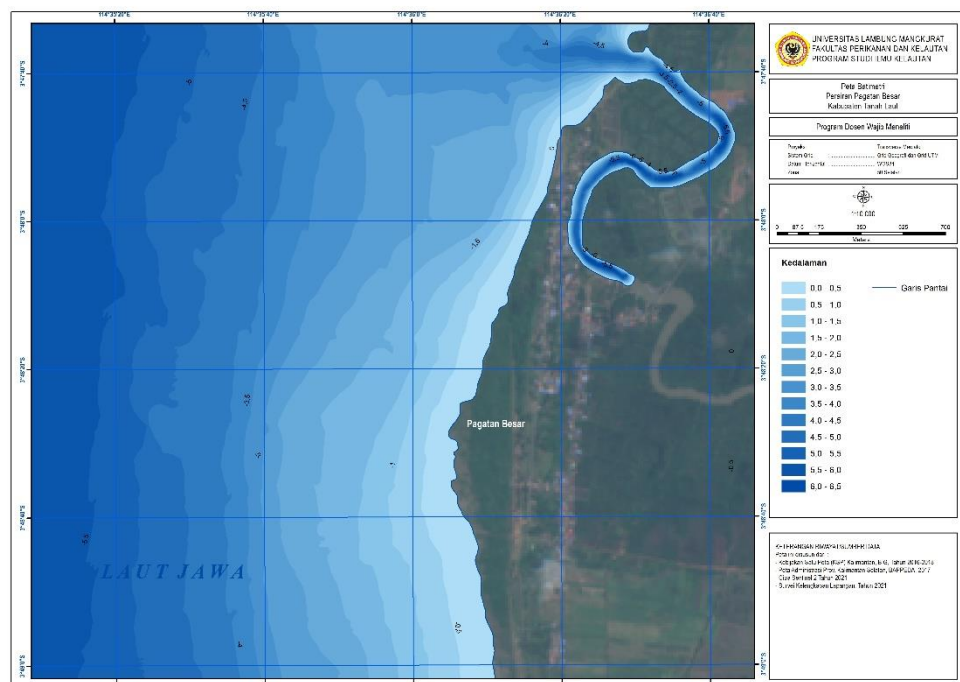


Figure 5. Contours of Bathymetry of Waters

Waves that propagate from the deep sea to the coast undergo a change in shape caused by transformation processes such as refraction and shoaling due to changes in sea depth, diffraction, and reflection. The decrease in sea depth causes a decrease in the length and speed of waves and an increase in wave height. When the wave taper (steepnes) reaches its maximum limit, the wave will break at a certain angle to the shoreline.

Wave Condition

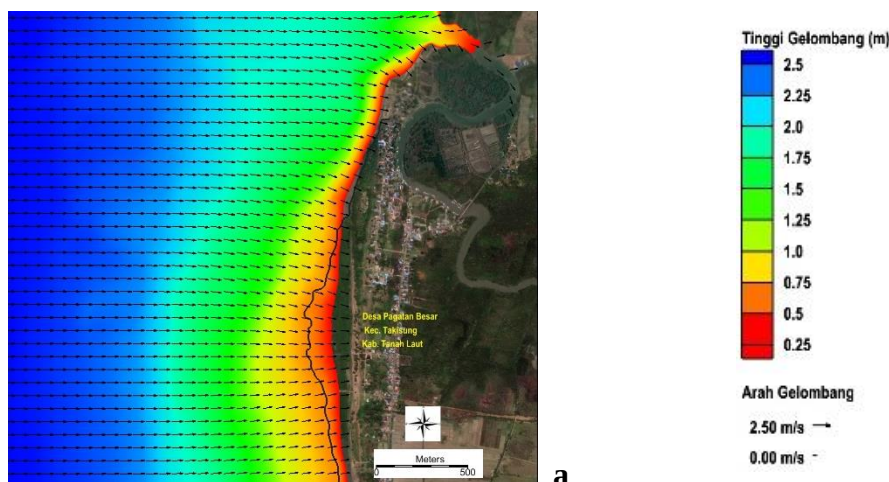
Based on the results of the analysis of monthly maximum wind data for 21 years (1999 – 2020) that can generate waves in the study area are from the southwest, west, and southeast while from other directions are not used, because the wind is considered from land which cannot be detected. generate waves. Based on this, a wave prediction is obtained every season from the direction of the wind that generates waves, namely during the West season the

waves propagate towards the southeast with a wave height range of 0.31 - 2.96 meters for maximum waves. Transitional Season I (March - May) waves propagate towards the Southeast in March, ranging from 0.27 - 1.92 meters. The waves during the East monsoon (June-August) dominantly propagate towards the Northwest. The maximum wave height ranges from 0.49 - 2.56 meters. The waves during the Transition II season (September - November) in September and October propagate to the Northwest and West, while in November the direction of wave propagation is to the Southwest. The maximum wave height in Transitional Season II ranges from 0.33 - 2.46 meters.

Wave Transformation Modeling

In this study, the wave transformations presented are only those from the West with wave height data input of 2.5; 1.5; and 1 m while the wave period is 6.5; 5.5; and 5 s (Figure 6).

The results of the wave transformation show changes in the height and direction of the waves. In the estuary area, the waves tend to spread towards the nearest land. The waves tend to converge on the coastal area in the form of a headland and divergence in the area that is shaped like a bay. The higher the wave that propagates from the open sea to the beach, the stronger the energy and the closer the wave is to the shore. Thus, the higher the potential for damage caused if the wave blows its energy on a beach that is not overgrown with mangrove vegetation.



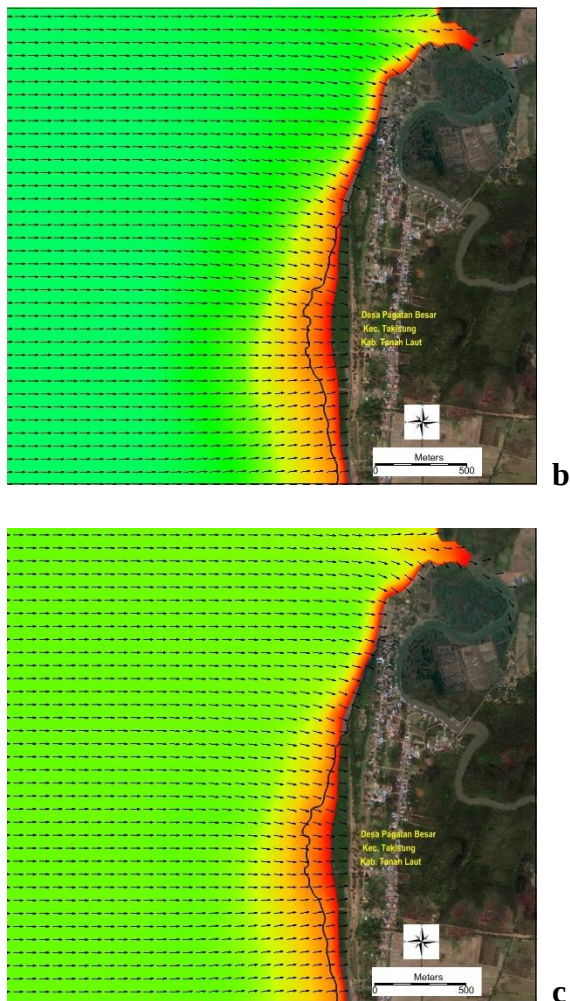


Figure 6. Pattern of wave transformation of Pagatan Besar waters during HAT from the west ((a) $H = 2.5$ m; $T = 6.5$ s (b) $H = 1.5$ m; $T = 5.5$ s (c) $H = 1.0$ m; $T = 5.0$ s)

The Effectiveness of Wave Attenuation by Mangrove Vegetation

The level of effectiveness of wave attenuation by mangrove vegetated beaches based on the results of model analysis is shown in Table 5. below.

Table 5. Comparison of wave heights at several monitoring stations

Wave Dirrection	Station	Wave Height (m)	Depth (m)
Northwest	1	0,951	0,95
	2	0,164	0,27
	3	0,038	0,08
	4	0,048	0,09
West	1	0,693	0,95
	2	0,163	0,27
	3	0,058	0,08
	4	0,048	0,09

Southwest	1	0,691	0,95
	2	0,163	0,27
	3	0,058	0,08
	4	0,048	0,09
South	1	0,160	0,95
	2	0,164	0,27
	3	0,042	0,08
	4	0,052	0,09
North	1	0,682	0,95
	2	0,197	0,27
	3	0,061	0,08
	4	0,050	0,09

Description: Station 1: Beach without mangroves;
 Stations 2 and 4: Beaches with thin mangroves;
 Station 3: Beach with dense mangrove
 authority: Analysis results (2021)

To see the difference in the decrease in wave height at several monitoring stations, observations were made at stations with different conditions. Profile 1 is a beach that does not have mangroves, Profile 2 is a beach with dense mangroves, while Profile 3 is a beach with thin mangroves (Figure 7 and Table 6).

The results showed that at stations overgrown with mangroves, the waves tended to be high when they approached the mainland. This is different from Stations 2 and 3 which are overgrown with mangroves. The waves tend to have decreased before approaching land (Figure 8).

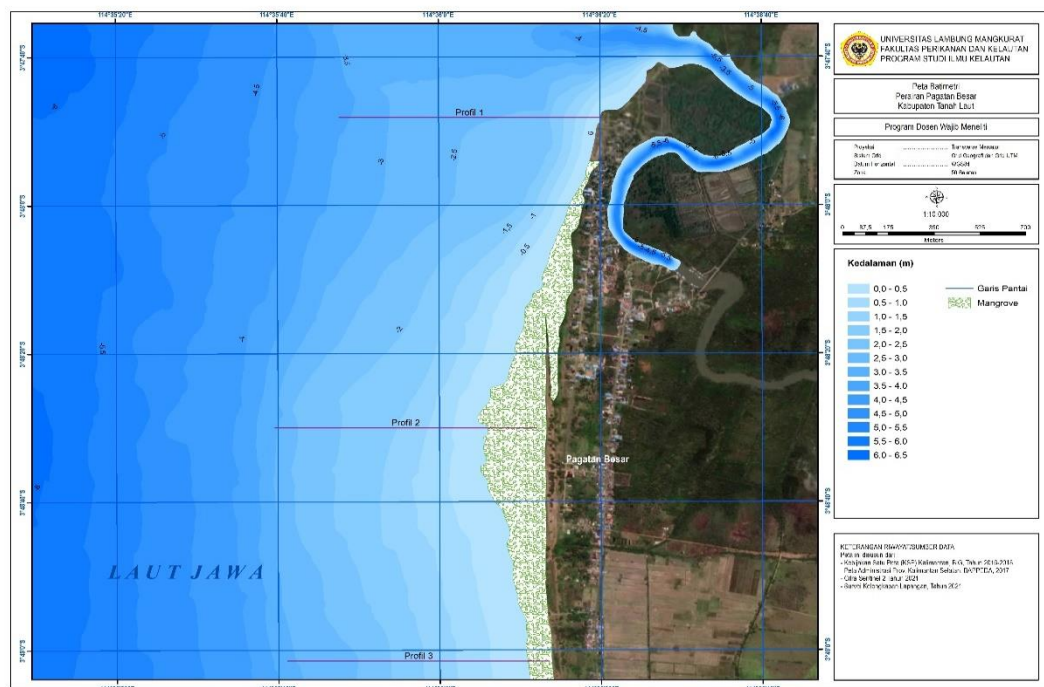


Figure 7. Division of beach segments Profiles 1, 2, and 3

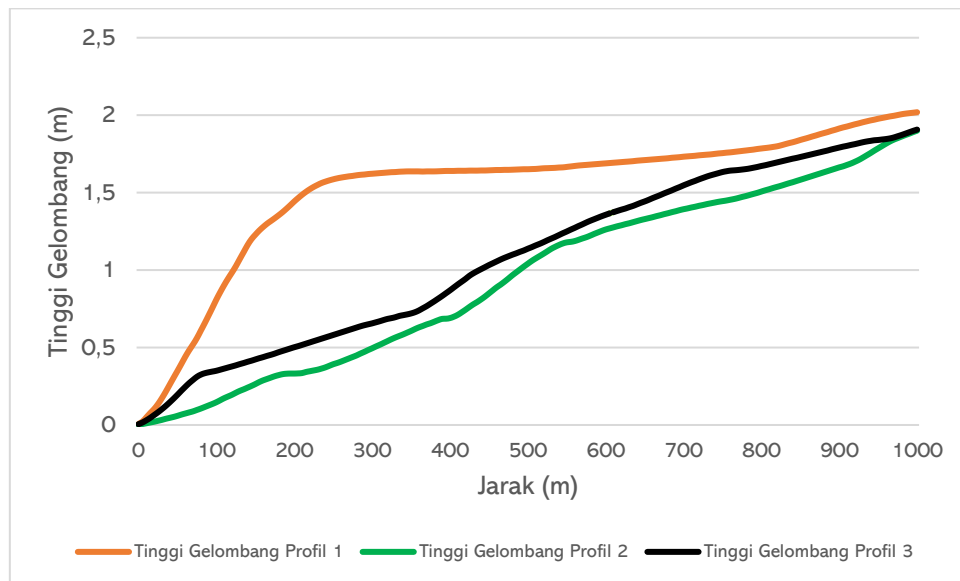


Figure 8. Changes in wave height in profiles 1, 2, and 3 (Profile 1: Area without mangrove; Profile 2: Area with dense mangrove; Profile 3: Area with thin mangrove)

Table 6. Comparison of the profile of changes in wave height in several coastal segments

Distance (m)	Wave Condition (m)		
	Wave Height Profil 1	Wave Height Profil 2	Wave Height Profil 3
1000	2,02	1,90	1,91
750	1,76	1,45	1,63
500	1,65	1,04	1,14
250	1,59	0,39	0,58
150	1,23	0,26 (in front of mangrove)	0,42
100	0,81	0,15	0,35
75	0,56	0,10	0,31 (in front of mangrove)
50	0,35	0,06	0,20
25	0,14	0,03	0,08
10	0,05	0,01	0,03
0	0,01 (shore)	0,00 (back mangrove)	0,01 (back mangrove)

authority: Analysis results (2021)

CONCLUSION

Based on the results of the study, the following conclusions can be drawn:
Beaches with thick mangrove vegetation are more effective in reducing wave heights that reach the coast than beaches without mangrove vegetation.

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REFERENCES

- Dewi, I.P. 2014. Oceanographic Characteristics to Support Agroecosystems in East Kutai Waters, East Kalimantan Province. *Journal of Torani Fisheries and Marine Science*. 24(3), 10 – 18 Vol 1.
- _____. 2014. Prediction of High Seas Wave Height Using Average Wind Data (2003 - 2012) on East Kutai Beach. *Music Journal*. Vol 1 No. 1.
- Dewi, I.P., Nursalam. 2020. Vulnerability of the Wetland Ecosystem to the Threat of Extreme Waves/abrasion in the mangrove ecotourism area of Pagatan Besar Village. *PWDM Research Report*. LPPM ULM. Banjarmasin
- Nursalam, Syahdan, M. and Akbar, Z. 2019. Biomass Content in Mangrove Stand Structure of *Avicennia marina* in Pagatan Besar Village. Paper of the VI National Seminar on Fisheries and Marine Affairs. Banjarbaru.
- Ponaru, A.S., Syahdan, M., and Nursalam. 2017. Monitoring the Distribution and Area of Mangrove Vegetation Using Landsat Imagery on the Coast of Tanah Laut Regency. *MCSIJ Journal*. new Vol. 1. No. 1