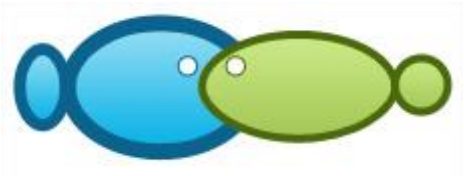

Correlation of mangrove density with fisheries commodity production on the east coast of North Sumatra

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Abstract. This study aims to analyze the correlation between mangrove density and the production of fishery commodities in the mangrove area of the east coast of North Sumatra, Indonesia. Calculation of mangrove density was conducted using the square transect method. Fisheries production data were obtained from the North Sumatra Province Marine Fisheries Office. Statistical analysis was carried out using the Pearson correlation coefficient for mangrove density and fisheries commodity production. The highest average mangrove density was in Langkat Regency (3208.33 ind ha^{-1}), and the lowest was in Deli Serdang Regency (1761.11 ind ha^{-1}). The highest average fishery commodity production was in Langkat Regency, with 18500 tonnes of shrimp, and 10529 tonnes of fish. The results of the correlation analysis showed that mangrove density was strongly correlated with the production of shrimp (0.996) and fish (0.997). This research concludes that mangrove density is strongly correlated with the production of shrimp and fish.
Key Words: fish production, marine resources, shrimp production.

Introduction. Mangrove forests play a vital role in supporting fisheries. They act as natural habitats for various species of fish, shrimps, and crabs, providing spawning, nursery, and feeding grounds. The fishery resources in mangrove forests are highly productive, both quantitatively and qualitatively (Eddy et al 2016). Mangrove forests in North Sumatra are generally distributed in coastal areas that can be found in Asahan, Batubara, Deli Serdang, Tanjung Balai, Nias, Labuhanbatu, Serdang Bedagai to Langkat. Based on data from the Sumatran Elephant Foundation, mangrove forests in North Sumatra have decreased in the area, from 96000 ha in 1989, to 36000 ha in 2014, with a reduction of 60000 ha in 25 years (Ramli et al 2017).

Degradation of coastal resources, watersheds, and upstream catchments due to climate change is important because management policies that ignore natural resource degradation will result in misleading policies (Mardiana et al 2017). The complexity of coastal resource management problems on the east coast of North Sumatra, which includes mangrove degradation, overfishing, and uncertainty of resource stocks has an impact on production uncertainty, so a holistic approach is needed in examining sustainable coastal resource management (Brown et al 2014). The destruction of mangrove forests will have an impact on the surrounding fishery commodities.

The research conducted in North Sumatra on mangroves has produced several important findings. The utilization of UAV (unmanned aerial vehicle) technology for mangrove species identification in Belawan, Medan City, North Sumatera, Indonesia, has proven to be effective in various studies. UAVs equipped with Object-Based Image Analysis (OBIA) classification have been used to analyze mangrove species in the area, identifying seven classes of mangrove species with an overall accuracy of 82.94% (Thoha

et al 2022). Additionally, a study used remote sensing, GIS, and Analytical Process Hierarchy (AHP) to map and analyze changes in mangrove cover in Medan City (Rahmawaty et al 2023). The study identified a significant decrease in mangrove forest area in Medan Labuhan Sub-district and highlighted the importance of preventing further changes in mangrove cover. Yuniastuti et al (2019) estimated the potential fisheries benefits and identified the species composition that provides maximum value for coastal fisheries. No research explains the correlation of mangrove conditions to the production of fishery commodities in North Sumatra Province. Therefore, it is important to conduct a study to determine the status of resources and the relationship between mangroves and fisheries, to support coastal management, including decisions to carry out conservation policies and habitat restoration.

Material and Method

Study sites. The research location was along the east coast of North Sumatra, including Langkat, Deli Serdang, and Serdang Bedagai Regency, with 3 observation stations in each district (Figure 1). These three districts are considered representative of the research area, because they have a larger area than the other districts and have more complex problems. The research was conducted from July to September 2023.

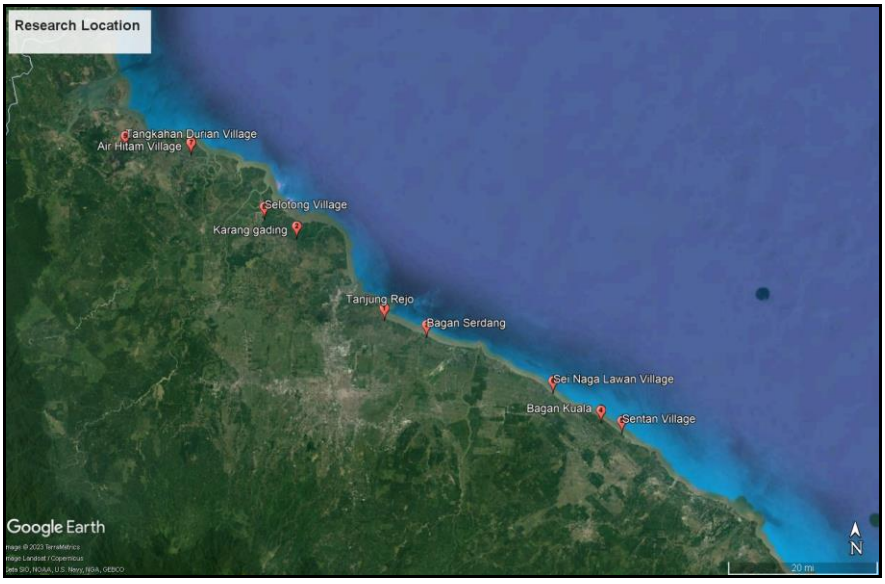

Figure 1. Research location on the east coast of North Sumatra.

Mangrove density. The method used in this study was the quadrat transect method. Mangrove data were collected by counting the number and species of mangroves in each sample plot measuring 10x10 m^2 with a distance of 20 m between transects (Figure 2). The number of transects at each location was 20 transects. Mangrove identification was conducted by referring to the guidebook of mangrove introduction in Indonesia (Noor et al 2006).

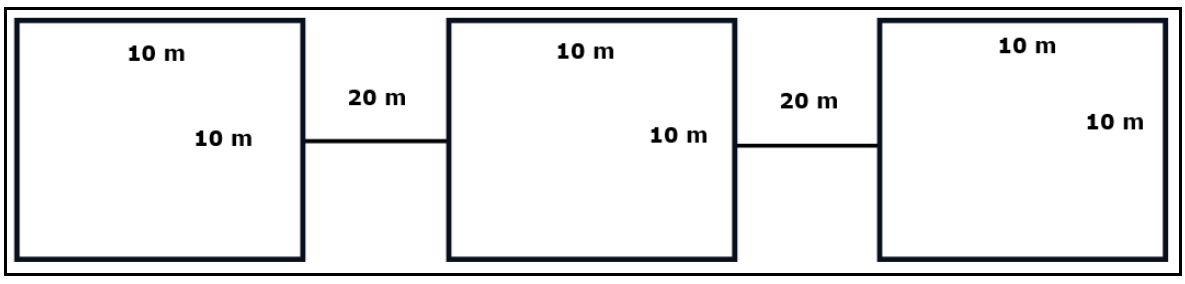

Figure 2. Illustration of mangrove observation plots.

Mangrove species density was calculated using the following formula (English et al 1994):

$Di = Ni/A$

Where: D_i - density of the i-th species; N_i - total number of individuals of the i-th species; A - total sampling area.

Mangrove density criteria are determined based on the Decree of the Minister of Environment of the Republic of Indonesia No. 201 of 2004 (Table 1).

Table 1

Criteria for mangrove density

Criteria	*Coverage (%)*	*Density (ind ha^{-1})*
High	≥75	≥1500
Medium	≥50, <75	≥1000, <1500
Low	<50	<1000

Fishery resource utilisation. Data on fisheries resource production was secondary data sourced from the North Sumatra Provincial Marine and Fisheries Office. Fisheries resource production data was analyzed descriptively, then in relationship with mangrove density.

Statistical analysis. The relationship between mangrove density and fisheries production was calculated using a Pearson correlation coefficient analysis. If the correlation coefficient is 0 then there is no correlation between the two parameters; if it is below 0.25, there is a very weak correlation; if it is between 0.25 and 0.5, there is a moderate correlation; if it is between 0.5 and 0.75, there is a strong correlation; if it is between 0.75 and 0.99, there is a very strong correlation; a value of 1 for the correlation coefficient shows a perfect correlation (Sarwono 2006).

Results and Discussion

Mangrove composition. 7 species of mangroves were found: *Avicennia alba*, *Avicennia marina*, *Bruguiera gymnorhiza*, *Bruguiera cylindrica*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Sonneratia alba*. The composition of mangrove species at each research station can be seen in Table 2.

Table 2

Composition of mangrove species found at each station

Species	*Deli Serdang*			*Serdang Bedagai*			*Langkat*		
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Rhizophora apiculata	√	-	√	√	√	√	-	√	√
Rhizophora mucronata	√	-	√	√	√	√	-	√	√
Avicennia alba	-	√	√	√	-	-	√	-	-
Avicennia marina	-	√	√	√	-	-	√	√	-
Bruguiera gymnorhiza	-	-	-	√	-	-	-	-	-
Bruguiera cylindrica	-	-	-	√	-	-	-	-	-
Sonneratia alba	-	-	-	-	√	-	-	-	-

Note: √ - found; - - absent.

The mangroves in North Sumatra, Indonesia consist of various species. Some of the mangrove species found in this region include *Acanthus ilicifolius, R. apiculata, A. marina, Soneratia caseolaris, Acrostichum aureum, A. alba, Avicennia lanata, Avicennia officinalis, Bruguiera parviflora, B. gymnorhiza, Ceriops tagal, Nypa fruticans, R. mucronata, Aegiceras corniculatum, Acanthus ilicifolius, B. cylindrica, Sonneratia alba*, and *Xylocarpus granatum* (Basyuni et al 2021; Nawar et al 2022; Purwoko et al 2023). These mangrove species have been studied for various purposes such as assessing their

capacity as culinary products, their characteristics and nutrient content, and investigating their antimicrobial activity (Basyuni et al 2017; Sumardi et al 2018). The diversity of mangrove species in North Sumatra highlights the importance of mangrove conservation and restoration efforts to protect these valuable ecosystems and their associated benefits.

The average mangrove density level is highest in Langkat Regency, with 3208.33 ind ha^{-1}, followed by that in Serdang Bedagai Regency, with 2300 ind ha^{-1}, and the lowest was in Deli Serdang Regency, with 1761.11 ind ha^{-1} (Table 3).

Table 3

Average density values for each research station

Regency	*Station*	*Mangrove density (ind ha^{-1})*	*Criteria*
Langkat	1	2650.00	High
	2	3741.67	High
	3	3233.33	High
	Total	9625.00	
	Average	3208.33	High
Deli Serdang	1	1541.66	High
	2	1050.00	Medium
	3	2691.67	High
	Total	5283.33	
	Average	1761.11	High
Serdang Bedagai	1	1900.00	High
	2	2433.34	High
	3	2566.67	High
	Total	6900.01	
	Average	2300.00	High

Mangrove density in northern Sumatra varies across different locations. In Medan Labuhan Sub-district, the mangrove forest area has decreased by 111.25 ha over the years (Rahmawaty et al 2023). Sembilan Island has a mangrove density ranging from 333 to 4601 ind ha^{-1} (Muhtadi et al 2016). The coastal forests of northern Sumatra, including mangroves, have an overall density of 54871 standing trees in 16 sites, with *R. apiculata* and *R. mucronata* being widely distributed and dominant (Onrizal & Mansor 2016). In terms of management, mangrove restoration enhances tree density, while mangrove conservation maintains species diversity (Hanggara et al 2021). Sebatik Island has a mangrove density ranging from 500 to 2000 ind ha^{-1}, with *S. alba* being the dominant species (Ardiansyah et al 2012). The density of mangroves is influenced by various factors. Physical factors such as temperature, coastal typology, ocean currents, land barriers, wave action, sediment supply, river catchment discharge, tidal range and inundation frequencies play a role in determining the lateral extent of mangroves and their accretion rates over time (Ellison 2021). Climate change, including sea level rise, acidifying oceans, and oscillating weather patterns, poses a significant threat to mangrove ecosystems and can lead to their depletion (Khumari & Pathak 2023). Human activities such as aquaculture, tourism, over-exploitation of forests, and land conversion for agriculture and urbanization also contribute to the reduction of mangrove density (Rasyid et al 2016; Setiawan et al 2019). Additionally, the dispersal and establishment success of mangrove species, as well as their tolerance limits and growth responses, are factors that affect their distribution and density (Duke et al 1998).

Fishery resource production. The production of fishery commodities around mangroves in each research location is presented in Table 4. The highest fisheries production was in Langkat regency with 55499 tonnes of shrimp and 9608 tonnes of fish during the 2019-2021 period. Serdang Bedagai Regency had a total production of shrimp of 7226 tonnes, and 29269 tonnes of fish. The lowest total production of fishery resources was in Deli Serdang Regency with a total of 29108 tonnes for shrimp and 6232 tonnes for fish.

Table 4

Production of fisheries around mangroves at each research location

Regency	Fisheries resource production around mangroves (tonnes)							
	Shrimp				Fish			
	2019	2020	2021	Average	2019	2020	2021	Average
Langkat	17477	17310	20712	18500	2006	26820	2762	10529
Deli Serdang	1255	3363	2608	209	2031	2168	2033	2077
Serdang Bedagai	9696	9716	9696	9703	5846	4041	3961	4616

Note: source: North Sumatra Provincial Marine and Fisheries Office (2022).

Shrimp and fish production in mangrove forest areas is affected by several factors. Fishery production in mangrove forest areas is influenced by various factors. The degradation of mangrove ecosystems leads to a decline in fishery outputs, impacting the income of fishery households (Yamamoto 2023). Mangrove forests with larger areas, more waterways, and longer mangrove-river interfaces provide greater nursery grounds for economically important fish and shrimp species (Jamizan & Chong 2017). The physicochemical parameters, nutrients, and primary production of mangrove litter also play a role in fish production, with different mangrove species contributing to litter production and nutrient availability (Alam et al 2022). Overall, understanding these factors can aid in better management practices for shrimp and fish production in mangrove forest areas.

Correlation between mangrove density and fisheries production. The results of the correlation analysis between mangrove density, shrimp, and fish production are presented in Table 5. Mangrove density is strongly correlated with shrimp and fish production with correlation values of 0.996 and 0.997, respectively.

Table 5

Correlation between mangrove density, shrimp, and fish production

Parameters	Correlation coefficient (r^2)	Criteria
Mangrove density with shrimp production	0.996	Very strong
Mangrove density with fish production	0.997	Very strong

Mangrove density has a positive correlation with fishery production. Studies showed that mangroves provide critical habitats for fish and crustaceans, functioning as nurseries, food sources, and reproduction areas (Carrasquilla-Henao et al 2019; Londoño et al 2020). The presence of mangroves has been correlated with increased fish species richness and catch per unit effort (CPUE) in various locations (Hutchison et al 2015; Carrasquilla-Henao & Juanes 2017). Mangrove area and zooplankton biovolume were found to be the main factors influencing fish species richness (Jamizan & Chong 2017). Mangrove area was also positively correlated with catches of common fish species in local artisanal fisheries. Additionally, the hydrogeomorphological metrics of mangrove forests, including mangrove areas, waterways, and creeks, have been found to influence the diversity and abundance of fish and shrimps. These findings highlight the importance of conserving mangroves to sustain fishery resources and support small-scale fisheries in coastal areas.

Conclusions. Based on the results of this study, it can be concluded that mangrove forest density is strongly correlated with the production of fishery commodities, both shrimp and fish.

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Conflict of Interest. The authors declare that there is no conflict of interest.

References

Alam M. I., Rahman M. S., Ahmed M. U., Debrot A. O., Ahsan M. N., Verdegem M. C. J., 2022 Mangrove forest conservation vs shrimp production: Uncovering a sustainable co-management model and policy solution for mangrove greenbelt development in coastal Bangladesh. Forest Policy and Economics 144:102824.

Ardiansyah W. I., Pribadi R., Soenardjo N., 2012 [Structure and composition of mangrove vegetation in the coastal area of Sebatik Island, Nunukan Regency, East Kalimantan]. Journal of Marine Research 1(2):203-215. [In Indonesian].

Basyuni M., Sagami H., Baba S., Oku H., 2017 Distribution, occurrence, and cluster analysis of new polyprenyl acetones and other polyisoprenoids from North Sumatran mangroves. Dendrobiology 78:18-31.

Basyuni M., Slamet B., Sulistiyono N., Munir E., Alejandra G., Vovides, Bunting P., 2021 Physicochemical characteristics, nutrients, and fish production in different types of mangrove forests in North Sumatra and the Aceh Provinces of Indonesia. Kuwait Journal of Science 48(3):1-14.

Brown B., Fadillah R., Nurdin Y., Soulsby I., Ahmad R., 2014 Case study: Community based ecological mangrove rehabilitation (CBEMR) in Indonesia. Sapiens 7(2).

Carrasquilla-Henao M., Juanes F., 2017 Mangroves enhance local fisheries catches: a global meta-analysis. Fish and Fisheries 18(1):79-93.

Carrasquilla-Henao M., Ban N., Rueda M., Juanes F., 2019 The mangrove-fishery relationship: A local ecological knowledge perspective. Marine Policy 108:103656.

Duke N. C., Ball M. C., Ellison J. C., 1998 Factors influencing biodiversity and distributional gradients in mangroves. Global Ecology and Biogeography Letters 7(1):27-47.Eddy S., Ridho R.M., Iskandar I., Mulyana A., 2016 Community-based mangrove forests conservation for sustainable fisheries. Jurnal Silvikultur Tropika 7(3):S42-S47.

Ellison J. C., 2021 Factors influencing mangrove ecosystems. In: Mangroves: Ecology, biodiversity and management. Rastogi R. P., Phulwaria M., Gupta D. K. (eds), Springer, Singapore, pp. 97-115.

English S., Wilkinson C., Baker V., 1994 Survey manual for tropical marine resources. Australian Institute of Marine Science, Townville, pp. 34-49.

Hanggara B. B., Murdiyarso D., Ginting Y. R. S., Widha Y. L., Panjaitan G. Y., Lubis A. A., 2021 Effects of diverse mangrove management practices on forest structure, carbon dynamics and sedimentation in North Sumatra, Indonesia. Estuarine, Coastal and Shelf Science 259:107467.

Hutchison J., Philipp D. P., Claussen J. E., Aburto-Oropeza O., Carrasquilla-Henao M., Castellanos-Galindo G. A., Costa M. T., Daneshgar P. D., Hartmann H. J., Juanes F., Khan M. N., Knowles L., Knudsen E., Lee S. Y., Murchie K. J., Tiedemann J., Ermgassen P. Z., Spalding M., 2015 Building an expert-judgment-based model of mangrove fisheries. American Fisheries Society Symposium 83:17-42.

Jamizan A. R., Chong V. C., 2017 Demersal fish and shrimp abundance in relation to mangrove hydrogeomorphological metrics. Sains Malaysiana 46(1):9-19.

Kumari P., Pathak, B., 2023 Effect of climate change and urbanization on mangrove ecosystem. In: Climate change and urban environment sustainability. Disaster resilience and green growth. Pathak B., Dubey R. S. (eds), Springer, pp. 293-301.

Mardiana S., Kuswardani R. A., Usman M., 2017 Management policy for organic waste from plantation and plantation production factory in North Sumatra. International Journal of Management Science and Business Administration 3(5):21-29.
Muhtadi A., Siregar R. H., Leidonald R., Harahap Z. A., 2016 [Ecological status of mangrove of Sembilan Island, Langkat Regency, North Sumatra Province]. Depik 5(3):151-163. [In Indonesian].
Nawar M. K., Basyuni M., Hanum C., Siregar E. S., 2022 Bioprospecting opportunities of mangrove fruits for the coastal community in Lubuk Kertang and Pulau Sembilan, North Sumatra, Indonesia. Asian Journal of Plant Science 21(1):145-153.
Noor Y. R., Khazali M., Suryadiputra I. N. N., 2006 [A guide to mangroves in Indonesia]. Ditjen PHKA/WI-IP, Bogor, 227 p. [In Indonesian].
Onrizal, Mansor M., 2016 Status of coastal forests of the Northern Sumatra in 2005 (after 2004's tsunami catastrophe). Biodiversitas 17(1):44-54.
Purwoko A., Susilawati A., Situmorang A. I., 2023 Assessing the carrying capacity of mangroves as raw materials for culinary products: Case study in Serdang Bedagai, North Sumatra, Indonesia. Biodiversitas 24(1):250-257.
Rahmawaty, Nuryawan A., Harahap M. M., Ismail M. H., Rauf A., Kurniawan H., Gandaseca S., Karuniasa M., 2023 Mangrove cover change (2005-2019) in the Northern of Medan City, North Sumatra, Indonesia. Geocarto International 38(1):2228742.
Ramli F., Samdin Z., Ghani A. N. A., 2017 Willingness to pay for conservation fee using contingent valuation method: The case of Matang Mangrove Forest Reserve, Perak, Malaysia. Malaysian Forester 80(1):99-110.
Rasyid A., Akbar M. A. S., Nurdin N., Jaya I., Ibrahim, 2016 Impact of human interventions on mangrove ecosystem in spatial perspective. IOP Conference Series: Earth and Environmental Science 47:012041.
Londoño L. A. S., Leal-Flórez J., Blanco-Libreros J. F., 2020 Linking mangroves and fish catch: a correlational study in the southern Caribbean Sea (Colombia). Bulletin of Marine Science 96(3):415-429.
Sarwono J., 2006 [Quantitative and qualitative research methods]. Graha Ilmu Publisher, Yogyakarta, Indonesia, 286 p. [In Indonesian].
Setiawan A., Realino B., Triyulianti I., Hamzah F., Murdimanto A., Putri M. R., Nugroho D., 2019 Using WorldView-2 imagery to estimate mangroves density in the Porong Estuary. In: Remote sensing of the Asian seas. Barale V., Gade M. (eds), Springer, pp. 377-393.
Sumardi S., Basyuni M., Wati R., 2018 Antimicrobial activity of polyisoprenoids of sixteen mangrove species from North Sumatra, Indonesia. Biodiversitas 19(4):1243-1248.
Thoha A. S., Lubis O. A., Hulu D. L. N., Sari T. Y., Ulfa M., Mardiyadi Z., 2022 Utilization of UAV (unmanned aerial vehicle) technology for mangrove species identification in Belawan, Medan City, North Sumatera, Indonesia. IOP Conference Series: Earth and Environmental Science 1115:012074.
Yamamoto Y., 2023 Living under ecosystem degradation: Evidence from the mangrove–fishery linkage in Indonesia. Journal of Environmental Economics and Management 118:102788.
Yuniastuti E., Astuti A. J. D., Simanungkalit N., 2019 Identification of the physical characteristics of mangrove ecosystems in the coastal area of Pantai Labu Subdistrict, Deli Serdang Regency, North Sumatra. Advances in Social Science, Education and Humanities Research 208:381-387.
*** Decree of the Minister of Environment of the Republic of Indonesia No. 201 of 2004
*** North Sumatra Provincial Marine and Fisheries Office, 2022 Annual report on fisheries and marine resources of North Sumatra.

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