Size Study of Sand Grain in the Aroen Meubanja Turtle Conservation Area, Aceh Jaya

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Abstract

Due to its unique coastal characteristics, the Aroen Meubanja Turtle Conservation Area in Aceh Jaya has significant potential as a nesting site for sea turtles. This study analysed the area's sand grain size and characteristics to determine its suitability for turtle nesting. The research was conducted in March 2024, with sand samples collected from three stations using purposive random sampling. Laboratory analysis included sieving and sand grain classification based on size and shape using the Wentworth and Powers classifications. The Wentworth scale is used to classify grain size, while the Powers scale assesses the shape and roundness of the grains. The results revealed that over 70% of the sediment in the area consists of very fine sand, which is highly favourable for turtle nesting. The roundness of the sand grains indicates a long transportation process, contributing to their suitability for nesting. Fine sand allows for proper water drainage, preventing waterlogging in nests and maintaining optimal temperatures for egg incubation. Additionally, environmental factors such as beach width, slope, substrate temperature, humidity, and coastal vegetation further enhance the area's potential as a turtle conservation site. This study concludes that the Aroen Meubanja coastal area meets the criteria for an ideal turtle nesting habitat. Recommendations include habitat management, community education, and further research to ensure sustainable conservation efforts.

1. Introduction

Aceh Jaya Regency, located in the western part of Aceh Province, Indonesia, is recognised for its rich and diverse natural resources, particularly within its coastal ecosystems with varied geomorphological characteristics. Among these coastal zones, the Aroen Meubanja area has emerged as a site of ecological significance due to its potential to serve as a natural nesting habitat for sea turtles, a group of marine reptiles that play a vital role in maintaining the balance of marine ecosystems. Although sea turtles spend most of their life cycles in marine environments, they exhibit unique reproductive behaviour that requires specific coastal areas for nesting. These species are known for their long-distance migratory patterns, often travelling across vast oceanic expanses such as the Indian and Pacific Oceans, before returning to beaches to lay their eggs (Alwan et al., 2024).

The nesting behaviour of sea turtles is closely linked to the physical and ecological characteristics. One of the most critical environmental components influencing this selection is the nature and texture of beach sand. Sand is a granular material formed through weathering and sedimentation, often transported by water or wind and deposited in coastal lowlands. It consists of various mineral compositions and particle sizes that affect its temperature regulation, moisture retention, and compactness—factors crucial for the successful incubation of sea turtle eggs (Putrawiyanta, 2023). While sandy beaches are a requirement for turtle nesting, not all sandy coastlines are deemed suitable. Sea turtles are highly selective and tend to choose nesting locations that meet specific criteria, including grain size distribution, beach slope, substrate moisture, and the presence of coastal vegetation (Fardani, 2021; Alwan et al., 2024).

Coastal vegetation plays a vital role in maintaining the microhabitat conditions necessary for the survival of turtle embryos. Vegetative cover provides natural shade, which helps regulate nest temperature and prevents overheating, a condition that could otherwise be lethal to developing embryos. Moreover, vegetation acts as a natural barrier that protects nests from potential threats such as coastal erosion, wave inundation, predatory animals, and anthropogenic disturbances including human trampling or interference (Darwati et al., 2022) Research has indicated that sea turtles exhibit a preference for beaches that offer medium to fine sand texture combined with substantial vegetation cover, with approximately 90% canopy density being considered optimal for nesting activities (Hanif et al., 2024)

Despite the ecological importance of Aroen Meubanja as a potential nesting site, no comprehensive scientific study has been conducted to examine the physical properties of the beach substrate, particularly the grain size distribution of sand in this area. Such data are essential to evaluate the suitability of this location for supporting sea turtle nesting behaviour and to inform evidence-based conservation planning. Therefore, this study seeks to conduct a granulometric analysis of beach sand in the Aroen Meubanja region to provide baseline scientific data that can be used to support future conservation efforts, habitat management strategies, and policy development related to the protection of endangered sea turtle populations in Aceh Jaya and surrounding coastal regions.

2. Methodology

2.1. Time, Place, and Materials

This research was conducted in March 2024 at the Turtle Conservation Area of Aroen Meubanja, located in Keude Panga Village, Panga Subdistrict, Aceh Jaya. Observations on sand characteristics and grain size analysis were carried out at the Laboratory of Biosystematics and Genetics, Faculty of Fisheries and Marine Science, Teuku Umar University. The sampling locations are shown in Figure 1.

2.2. Method

This study employed a survey method, with sample collection conducted using purposive random sampling at three stations and three substations. The equipment used in the sand processing included a scale, mesh sieves, a microscope, and writing tools. The required materials were samples, large plastic bags, 1-kg plastic bags, name labels, and tissue.

Figure 1. Research Location

2.3. Procedures

Sampling was carried out using a 1-meter-long PVC pipe. The pipe was cut, and the bottom end was sharpened to make it easier to insert into the sediment. The pipe was then driven into the ground by striking the top with a wooden stick until it reached a marked depth of 50 cm. The pipe was slowly pulled out to prevent the sand from falling out. A sample was then taken from the bottom section up to a depth of 10 cm. The sample was placed in a plastic bag and labelled. It was then brought to the laboratory for observation and sieving. The sample was weighed and sieved, with the resulting fractions separated and weighed according to mesh size. The percentage of each fraction was then calculated.

2.4. Data Analysis

The sand samples were observed macroscopically, focusing on their physical color. Grain shapes were classified using the Powers classification as cited in (Reynda et al., 2021) and shown in Figure 3, while grain sizes were classified using the Wentworth classification, also from Reynda et al. (2021) and shown in Figure 4. The weight of sediment per mesh size (mm) and the percentage of each sediment type were calculated in Excel using the following formula: (Weight of sieved sediment / Total sediment weight) × 100%.

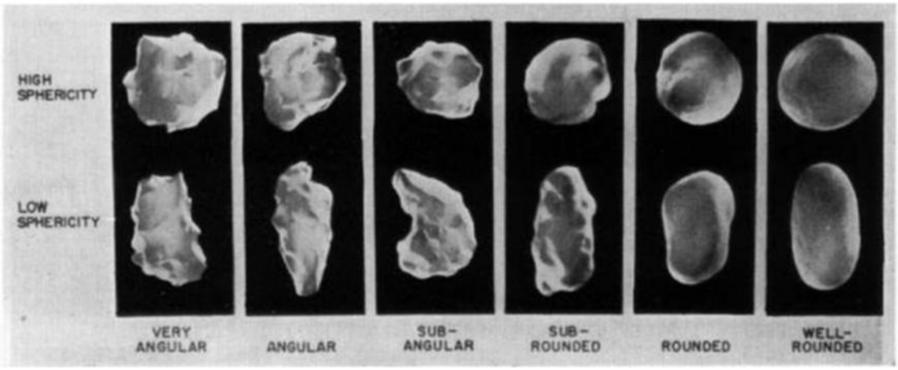


Figure 2. Classification of Mineral Grain Shape/Roundness by Powers in Reynda et al. (2021)

	U.S. standard sieve mesh	Millimeters		Phi (ϕ) units	Wentworth size class
GRAVEL		4096		−12	
		1024		−10	Boulder
		256	256	−8	
		64	64	−6	Cobble
		16		−4	Pebble
	5	4	4	−2	
	6	3.36		−1.75	
	7	2.83		−1.5	Granule
	8	2.38		−1.25	
	10	2.00	2	−1.0	
SAND	12	1.68		−0.75	
	14	1.41		−0.5	Very coarse sand
	16	1.19		−0.25	
	18	1.00	1	0.0	
	20	0.84		0.25	
	25	0.71		0.5	Coarse sand
	30	0.59		0.75	
	35	0.50	½	1.0	
	40	0.42		1.25	
	45	0.35		1.5	Medium sand
	50	0.30		1.75	
	60	0.25	¼	2.0	
	70	0.210		2.25	
	80	0.177		2.5	Fine sand
	100	0.149		2.75	
	120	0.125	⅛	3.0	
	140	0.105		3.25	
	170	0.088		3.5	Very fine sand
	200	0.074		3.75	
	230	0.0625	1/16	4.0	
MUD – SILT	270	0.053		4.25	
	325	0.044		4.5	Coarse silt
		0.037		4.75	
		0.031	1/32	5.0	
		0.0156	1/64	6.0	Medium silt
		0.0078	1/125	7.0	Fine silt
		0.0039	1/256	8.0	Very fine silt
MUD – CLAY		0.0020		9.0	
		0.00098		10.0	Clay
		0.00049		11.0	
		0.00024		12.0	
		0.00012		13.0	
		0.00006		14.0	

Figure 3. Wentworth's Classification of Mineral Grain Sizes

3. Result and Discussion

Characteristics of Sand Grains

The results of observations of sand grains obtained during the study (Table 1) generally show that sand grains between stations have similar shapes and sizes because they are still in the exact coastal location. (Saniah et al., 2014) Stated that the higher the level of a sand grain's roundness, the grain has undergone a long transportation process, which ultimately causes the grain size to become smaller or finer. The shape of the particles is formed due to abrasion during the transportation process, namely through collisions between particles or with bedrock, which changes the shape of the particles from sharp or angular to more rounded. The further the distance the particles travel, the more complex their shape tends to be, and they tend to be more rounded. Sphericity is a measure that shows how much a particle tends to approach a spherical shape.

The size of sediment grains at the study site is influenced by the environmental conditions that play a role in the formation process. One of the main factors is the source of sediment material originating from land, such as due to abrasion or erosion, which is then carried by river flows. These results can be seen in Table 2.

Table 1. Morphology of Sand Grains found during the study (with 40x Magnification)

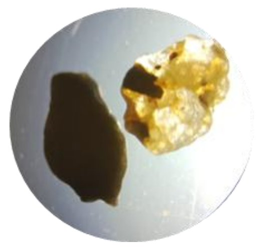
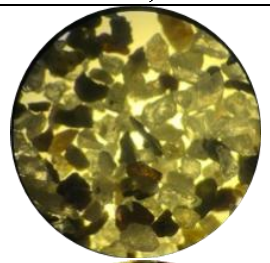
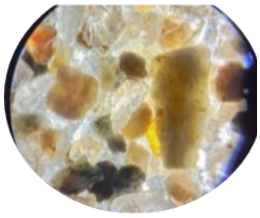
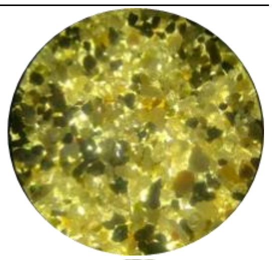
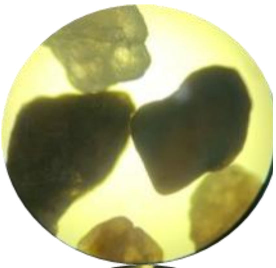
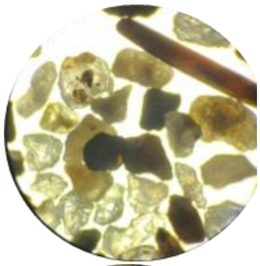
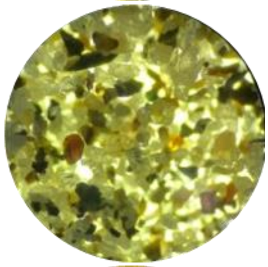
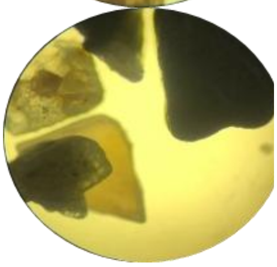
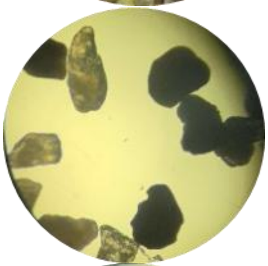
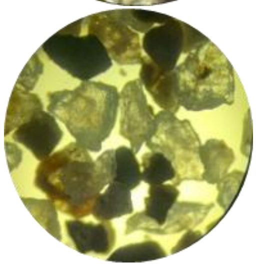
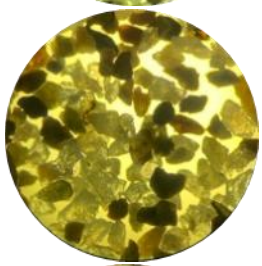
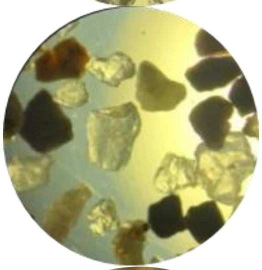
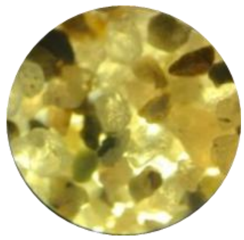
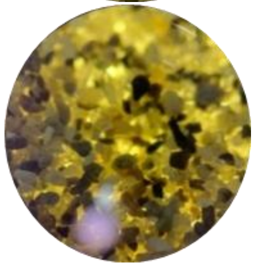
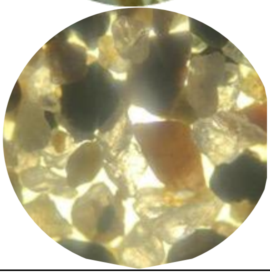
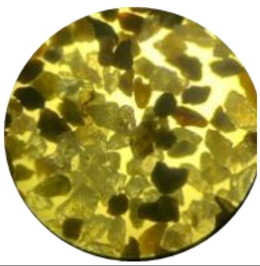
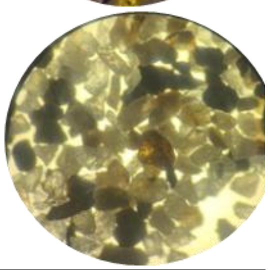
	Per-size Mesh 18/1	Per-size Mesh 60/0,3	Per-size Mesh 40/0,45	Clean sieve
station 1				
station 2				
station 3				
station 4				
station 5				

Table 2. Sediment Size Percentage

Stasion	Sediment Size Percentage (%)				
	Fine Gravel	Very Coarse	Medium Sand	Very Fine Sand	Description
I	0	2,39	23,75	73,86	VFS
II	0,50	11,80	26,10	58,80	VFS
III	0,00	4,02	16,97	79,02	VFS
IV	0,42	3,75	13,00	82,08	VFS
V	0,44	3,10	13,33	83,13	VFS

Note: VFS (Very Fine Sand)

The size and characteristics of beach sediment grains play a crucial role in supporting the success of sea turtle nests. This measured: Dissolving, and these are influenced by material transport mechanisms that can modify sediment patterns and distribution along the coast.

Sediment transport occurs through the interaction of ocean currents, waves, and tides, each of which influences the size and type of deposited sediment. The farther sediment particles are transported, the finer the grain size becomes. This aligns with the findings of (Saniah et al., 2014), who noted that finer sediments are typically deposited in low-energy environments such as coastal areas. Therefore, understanding sediment transport mechanisms is essential for assessing the suitability of an area as a sea turtle nesting habitat.

In this study, using a sieve shaker, sediment sieving provided precise data on sediment size distribution along the Aroen Meubanja coastline. The analysis revealed that very fine sand dominates more than 70% of the coastal environment, supporting optimal nest temperature and humidity for turtle egg incubation. This indicates that Aroen Meubanja possesses physical characteristics conducive to successful hatching, with sand that drains well, prevents waterlogging, and maintains a warm nest temperature consistent with the findings of (Abelino et al., 2022) The presence of such fine sand also provides an advantage in maintaining ideal thermal conditions for turtle embryo development, which is highly influenced by environmental factors (Benni et al., 2017).

However, when compared to other areas such as Ujong Pancu Beach in Aceh Besar, which has coarser sediment than Aroen Meubanja (Maula et al., 2016), the dominance of fine sand in Aroen Meubanja offers more stable conditions for egg incubation. (Stewart et al., 2019) At the Chagar Hutang Turtle Sanctuary, Redang Island, Malaysia, a study was conducted to examine the influence of sand grain size on nest temperature, oxygen pressure, hatching success, hatchling morphology, and locomotion performance. The results showed that sand grain size had minimal impact on hatching success and other related parameters. However, nests with medium-grained sand exhibited higher temperatures, and hatchlings from these nests demonstrated better self-righting ability, although their crawling and swimming performances were lower.

On the other hand, in some areas, such as the Seribu Islands Marine National Park in Jakarta, the grain size at Peteloran Timur Island is dominated by coarse sand, reaching up to 48.55% (Rachman et al., 2019). With larger grain fractions and less fine sand content, this site faces challenges in maintaining optimal nest humidity. These differences are important to consider when designing effective conservation strategies, as each coastal site has unique characteristics that influence sea turtle reproduction.

In addition to sediment factors, other environmental characteristics such as beach width and slope, substrate temperature, humidity, and vegetation presence also contribute to the suitability of a nesting habitat (Santoso et al., 2023). Wider and gently sloping beaches provide advantages for turtles by offering safer nesting sites, away from tidal disturbances and human interference. Coastal vegetation also plays a critical role by protecting from wind and predators and helping maintain substrate moisture and stability.

These environmental factors are particularly relevant in the face of climate change and anthropogenic pressures. As seen in several other regions, the degradation of coastal habitat due to uncontrolled coastal development or the destruction of natural habitats can exacerbate the challenges of turtle nesting. For example, in some beaches in Thailand, high erosion rates and habitat damage caused by mass tourism have significantly reduced the number of turtles returning to nest (Piboon et al., 2025). This underscores the importance of data-driven conservation efforts and sustainable management practices to maintain the stability of sea turtle habitats, as exemplified by the case of Aroen Meubanja.

4. Conclusion

Findings from the Aroen Meubanja Turtle Conservation Area in Aceh Jaya reveal that the beach sand offers ideal conditions for sea turtle nesting. More than 70% of the sediment comprises very fine sand, which helps regulate water flow and maintain stable nest temperatures, key factors in successful egg incubation. The rounded shape of the sand grains also suggests long-term natural transport processes, further supporting the area's suitability as a nesting site. This detailed understanding of beach sediment highlights the ecological value of Aroen Meubanja and provides a valuable reference for future conservation work, habitat management, and policy-making to protect endangered sea turtles along the coast.

Further research is recommended on other factors that influence the success of turtle conservation, such as the effect of substrate temperature on embryonic development or the impact of climate change on coastal habitats.

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