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Analysis of the distribution of Sea Turtle Nesting Grounds based on physical characteristics along the coast of Kretek District, Bantul Regency, Yogyakarta, Indonesia

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ABSTRACT

In the Special Region of Yogyakarta, Indonesia, the quality of its southern coastal waters has been degrading due to land-use changes, including the logging of coastal plants to provide spaces for agricultural land. It is a factor contributing to the destruction of sea turtle habitat, narrowing the potential location for landing. This study aims to analyze the distribution of sea turtle nesting grounds based on the physical characteristics of the coastal area of the Kretek District. It employed a purposive sampling technique to collect field data, particularly by determining the samples based on the updated nesting grounds. At these sites, observations and data recording were carried out according to the parameters studied, namely slope gradient, land cover/use, soil temperature, air temperature, and humidity. The results showed that the identified sea turtle nesting grounds included Pelangi, Cemara Sewu, Barchan, and Parangkusumo Beaches. The species of sea turtles found on the coastline of the district were olive ridley or gray sea turtles (*Lepidochelys olivacea*). Although generally, this coast had similar physical characteristics, there were differences in the number of nesting grounds between one beach and the others, with the highest identified on Pelangi Beach (43 locations). Most sea turtles use areas in the shade of vegetation to nest, while other nests are in vegetation-free areas or an open and long stretch of sand with gently sloping ground and far distance to built-up and agricultural land.

Key words: *Olive ridley sea turtle, Coast physical characteristics, Nesting grounds*

Introduction

Sea turtles are among the many animals targeted in global animal protection. In Indonesia, the Regulation of the Minister of Environment and Forestry No. 20 of 2018 on Protected Plant and Animal Species, gives legal protection to all species of sea turtles. Moreover, the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have included all species of sea turtles in Appendix I, which covers animals on the verge of extinction. Therefore, internationally, sea turtles are not allowed for trade or use.

Coastal areas, specifically beaches, are places that

sea turtles use to lay eggs (Nuitja and Uchida, 1983). According to the environmental and strategic study report on the Zoning Plan for Coastal Areas and Small Islands issued by the Maritime Affairs and Fisheries Office of Yogyakarta in 2018, six out of seven turtles worldwide lived in Indonesian waters. Only four frequently landed on the coast of the Special Region of Yogyakarta (SRY), which are green sea turtles (*Chelonia mydas*), hawksbill sea turtles (*Eretmochelys imbricata*), olive ridley sea turtles (*Lepidochelys olivacea*), and leatherback sea turtles (*Dermochelys coriacea*). Along this coast, there are six turtle landing sites distributed in three regencies, these are Pelangi, Samas, CemaraSewu, and Pandansimo Beaches in Bantul, Trisik Beach in Kulon Progo, and Drini Beach in Gunungkidul. When sea turtles appear on land to lay eggs, they will enter a heterogeneous and relatively vast environment and, then, choose a specific location to make the nests (Bouchard and Bjorndal, 2000). The substrate texture of their nesting habitat must be composed of no less than 90% sand (Nuitja and Uchida, 1983). Also, gently sloping beaches with gradients in the range of 3-16% are suitable for their habitat because these landforms allow sea turtles to reach their nesting grounds (Nuitja, 1992).

In the life of sea turtles, the limiting factors come from nature and humans. Potential natural harms include coastal abrasion, coastal vegetation (as barriers), and natural predators, while threats from humans are, among others, theft, illegal fishing, trades of sea turtle eggs and scales, blast fishing (bombs containing potassium), habitat pollution, and loss of nesting areas (Spotila, 2004; Lam *et al.,* 2006). The Office of Maritime Affairs and Fisheries has reported that the waters on the southern coast of SRY are experiencing a decline in quality due to the exploitation of existing natural resources, such as the logging of coastal vegetation to provide space for agricultural practices and other purposes to meet persistently increasing human demands. This practice destructs the habitats of sea turtles, i.e., sandy beaches as known nesting grounds, and reduces the potential sites for landing.

According to the data of the Natural Resources Conservation Agency (BKSDA) of Yogyakarta (2011) and the Regional Development Planning Agency (BAPPEDA) of Bantul Regency (2017), the number of sea turtle landing sites on Depok Beach showed a declining trend during these six years. There were five landing points in 2011, but only two existed in 2017. Systematic and practical efforts to save and protect these sites are therefore necessary so as to overcome this problem. However, the data and information on the distribution of sea turtle locations and habitats are limited; for instance, the latest relevant details were published by BAPPEDA in 2017.

Sea turtles have a strong homing instinct, that is, migration between feeding and breeding grounds (McConnauhey, 1974; Mortimer and Carr, 1987). With such strong instincts, they will return to the same location to lay their eggs; therefore, monitoring or protection of their nesting grounds are necessary to prevent any damages. Moreover, sea turtles are naturally shy, tend to be vigilant and avoid direct encounters with humans (Mortimer and Carr, 1987). Nest-site selection is a key component of habitat selection (Jones, 2001; Morris, 2011), with nest position often resulting from trade-offs that are made by adults to maximize their own survivorship and optimize the fitness of their offspring (Fuentes *et al.,* 2011). They will not lay eggs in damaged or changed nesting grounds, which then disrupts their overall life cycle. This study set out to analyze the distribution of turtle nesting grounds based on the physical characteristics of the coast of Kretek District, Bantul Regency, SRY.

Materials and Methods

Research Location

The research site was along the coast of Kretek District, Bantul Regency, SRY, Indonesia, particularly between 110º16’30" - 110º20’30" E and 8º00’30"-8º02’00" S. This coast, lying from Depok, Pelangi, Cemara Sewu, Barchan, to Parangkusumo Beaches, was selected because it is part of coastal conservation areas under the Local Regulation No. 9 of 2018 on Zoning Plans for Coastal Areas and Small Islands in SRY. Also, according to the Office of Maritime Affairs and Fisheries for SRY, it is a known sea turtle nesting ground location.

Based on measurements in the field, this coast had nearly flat to moderately sloping relief, with slope gradients in the range of 0-14%. Part of the coastal areas that were closer to inland had nearly flat slope (0-3%) and was covered with sand and used for agricultural and built-up areas, while gently (3-8%) to moderately sloping reliefs (8-14%) were common in shoals along the beach and dunes.

In addition to the stretch of sand, vegetation, dune, and river covered the coast observed, and the community utilized these land covers for buildings, ponds, roads, and as vacant land.

Regosols, the dominant soil type in the study area, are derived from volcanic materials and have a coarse-grain texture mixed with sand, thick solum, and low fertility rate. Table 1 shows that throughout 2019, the highest rainfall and longest rainy days occurred in January (427 mm; 22 days). According to Nuitja (1992), low rainfall causes sand conditions, surface temperature, and wind to be more stable, creating a suitable environment for sea turtles to lay eggs.

Table 1. Average rainfall and the number of rainy days by month in Bantul Regency in 2010

Months	Average rainfall (mm)		Rainy Days (days)	
	2018	2019	2018	2019
January	556	427	24	22
February	362	226	21	20
March	395	511	16	20
April	227	89	14	7
May	20	8	4	1
June	14	0	1	0
July	0	0	0	0
August	0	2	0	1
September	7	0	1	0
October	5	0	1	0
November	217	99	12	8
December	210	270	16	17

Source: Meteorology, Climatology, and Geophysics Agency (BMKG) for SRY, SDA Dlingo Station (2019)

Data Collection on the Presence of Sea Turtles

The data collection in the field was conducted in March 2020 and divided into two steps: (1) recording the coordinates of the nesting grounds and observing their physical characteristics and (2) filling in a checklist of land cover/use information. Coastal physical data characteristics required for identifying sea turtle nesting grounds are temperature and humidity (Hays *et al.*, 1995; Wood *et al.*, 2000), slope gradient (Garmestani *et al.*, 2000; Wood *et al.*, 2000; Spanier, 2010), and landcover/landuse (Hays *et al.*, 1995; Huijbers *et al.*, 2015). For the first step, it employed a purposive sampling technique where the samples were determined based on research objectives and related to the updating of data on nesting grounds. An unstructured interview with the chief manager of the sea turtle conservation zone on Pelangi Beach (a selected respondent) and field observation aimed to gather the physical characteristics of areas where sea turtles usually laid eggs. The equipment used consisted of Global Positioning System (GPS) to plot the coordinates of the nesting ground locations, soil survey kit to record soil temperature, thermo-hygrometer to measure temperature and humidity, and laser range finder (LRF) to measure the slope gradient. Meanwhile, the second step employed random sampling, where the points were selected randomly based on land cover/use class.

In addition to primary data, this research also drew on secondary data to support the distribution analysis of the nesting grounds. The secondary data comprised the coordinates of the nesting ground sites in October-November, 2011 (obtained from the Natural Resources Conservation Agency for Yogyakarta) and in August 2017 (from the Regional Development Planning Agency of Bantul Regency). Also, remote sensing data were used to support the spatial analysis involving land cover/use and slope gradient. These data were selected because they provide continuously updated information on land-use changes. The study used the Planet Scope's Level 3A Ortho Tile Product picturing part of Kretek Districton May 22, 2018, with a spatial resolution of 3.125 m, and ALOS PALSAR Digital Elevation Model (DEM) (Scene: AP_07425_FBS_F3780_RT1) with a spatial resolution of 12.5 m.

Data Analysis

The data analysis contains stages used to analyze the research results, which in this study included spatial, descriptive, and quantitative descriptive analyses. The spatial analysis provided information on the spatial distribution of sea turtle nesting ground locations by displaying the plotted sites based on the primary (field) and secondary data in the ArcGIS 10.4 program. The quantitative descriptive analysis produced details on the average distance of the nesting grounds to land cover/use by first manually or visually classifying the land cover/use and then drawing on the Euclidean distance algorithm in the ArcGIS 10.4 program. Nine elements of interpretation (i.e., hue/color, size, shape, pattern, texture, shadow, height, site, and association) were used to recognize and classify ev-

ery object of land cover/use (Lillesand *et al.*, 2004). As for the descriptive analysis, it described the physical characteristics of the location that sea turtles used to deposit their eggs by presenting the analyzed primary data in tabular form.

Results and Discussion

Spatial Distribution of Sea Turtle Nesting Grounds

Interviews with the manager of the sea turtle conservation area on Pelangi Beach, document reviews, and field surveys revealed 89 nesting ground locations in the district, as presented in detail in Table 2. The secondary data comprised the coordinates of these locations in October-November 2011 (obtained from the Natural Resources Conservation Agency for Yogyakarta) and in August 2017 (from the Regional Development Planning Agency of Bantul Regency). Therefore, this research updated these data based on the observation in March 2020.

Table 2 describes that from October 2011 until August 2017, the nesting grounds only existed on three beaches, namely Depok, Pelangi, and Cemara Sewu. In 2011, sea turtles frequented to lay eggs at 13 landing sites on these beaches, whereas six years later, or in 2017, 14 sites were found. Pelangi Beach had the greatest number of landing sites frequented by sea turtles. From 2017 until 2020, the number of nesting grounds on Depok Beach has become lower because it accommodates the most intensive human activities compared to three other beaches. Depok is the central beach for the local fish trade market and has been actively growing into one of the tourist attractions in the district. Due to the intensity and high presence of human activities, sea turtles are likely to feel threatened and, therefore, will not land on places where they normally would. As evidence, the field survey in March 2020 did not find any nesting grounds of sea turtles on Depok Beach.

This 2020 study also updated the data on nesting ground locations. In the last five years, sea turtles have been depositing their eggs from April until August or even longer. Based on the field survey results, there were 62 nesting grounds, 43 of which were on Pelangi Beach. In this study, sea turtle nesting grounds were found in four beaches, namely Pelangi, Cemara Sewu, Barchan, and Parangkusumo.

Parangtritis, of all the other beaches on the ob-

Table 2. List of beaches and their respective number of sea turtle nesting grounds in three different times

Beach Names	Number of Nesting Grounds			
	Oct-Nov 2011	August 2017	March 2020	Total
Depok	5	2	0	7
Pelangi	4	8	43	55
CemaraSewu	4	4	7	15
Barchan	0	0	8	8
Parangkusumo	0	0	4	4
Parangtritis	0	0	0	0
Total	13	14	62	89

Source: Document Review and Field Survey (2020)

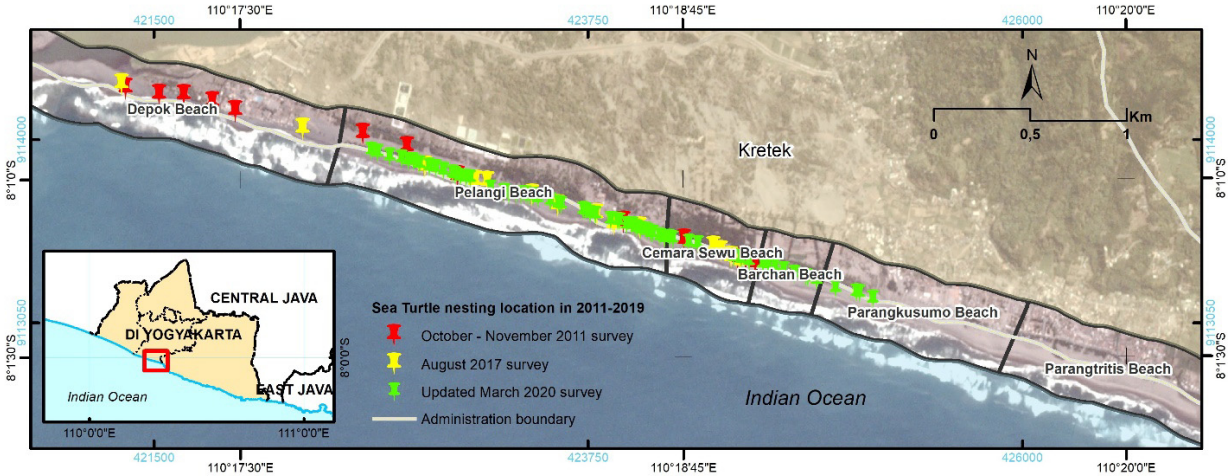

Fig. 1. The distribution map of sea turtle nesting grounds along the coast of Kretek District (Background: Planet Scope image (321 color composite) recorded on May 22, 2018)

served stretch of sand, remained the only beach where no nesting grounds were found. This finding reflects the condition of Parangtritis as a primary tourist attraction on the southern coast, triggering more physical development, human occupation, and land-use conversion than on other beaches. Figure 1 shows the spatial distribution of the nesting grounds in the study area. Sea turtles tend to nest rather far from the coastline up to the outer borders of the terrestrial zone, namely areas that are covered with trees and still allow sea turtles to dig their nests.

The Physical Characteristics of Sea Turtle Nesting Ground Locations

According to the information provided by the manager of the sea turtle conservation area at Pelangi Beach, sea turtles that most often landed at some points in this location were of olive ridleyor gray sea turtle species (*Lepidochelys olivacea*). Their identifiers include external carapace shape (morphology), trails, nest size, and the physical characteristics of the habitat. *L. olivacea* has a high dome-like dark green carapace (consisting of five pairs of costal scutes), with yellow plastron and relatively large head. It leaves a trail of approximately 80 cm wide, with shallow shortcuts and asymmetrical diagonal markings left by its front limbs.

The female sea turtles land ashore, whereas the males stay in subtidal areas. Every species of turtle has different nesting timings. *L. olivacea* lays its eggs from around 20:00 to 24:00, but it does not exclude the possibility of nesting outside this time. It shows that for this purpose, sea turtles require a place that is suitable and safe from various kinds of disturbances.

The availability of suitable biotic and abiotic environmental carrying capacity is likely to affect the location of the nesting grounds. Humans can be a supporting biotic factor as long as they do not excessively utilize the coast and disturb the nesting habitat. For instance, on Pelangi, Cemara Sewu, Barchan, and Parangkusumo Beaches, human activities were rare compared to other beaches that had developed into tourist attractions, such as Depok and Parangtritis. The activities of sea turtles are dependent upon the state of land cover/use: the farther the nesting grounds to built-up land (e.g., settlements), the more secure the sea turtle will feel; and vice versa, if the nesting grounds are closer to roads or buildings where lots of human activities exist, the more threatened they will feel and the less likely they will deposit eggs in them.

Figure 2 shows that parts of the beach that were close to settlements and agricultural areas had a lower frequency of sea turtle landing, including on Depok and Parangkusumo Beaches, and even no presence was identified on Parangtritis Beach. As for Pelangi, Cemara Sewu, and Barchan, these beaches are located far from built-up and agricultural land. In the coastal area of the district, the physical structures included settlements, markets, and trade and service centers, while the local people made use of the agricultural land to grow rice and other seasonal crops. The map also shows coastal vegetation within the vicinity of the identified nesting grounds along Pelangi, Cemara Sewu, and Barchan Beaches; these plants were Pandanus and

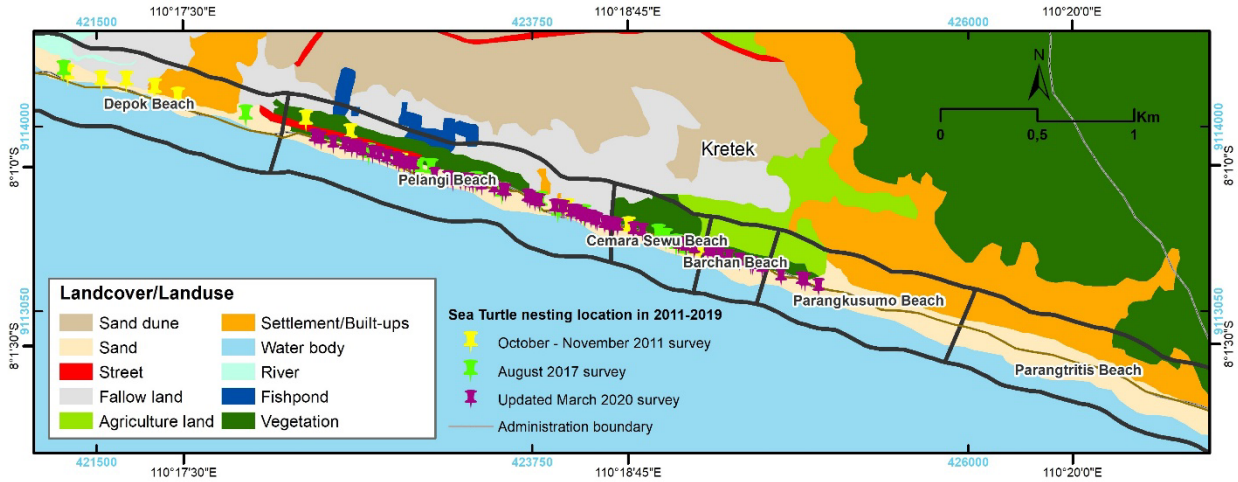

Fig. 2. Landcover/use map of the coastal region of Kretek District

creepers like bay hops (*Ipomoea pescaprae*) and grasses of the Spinifex genus. Vegetation-covered areas can help sea turtles to balance soil surface temperatures.

Table 3 shows that the location used by sea turtles to lay eggs had a distance of averagely more than 100 m from built-up areas. The closer the beach to buildings, the fewer the number of sea turtles nesting there; Depok and Parangkusumo Beaches are the examples of this location (see Table 2). In addition to built-up areas, human activities are relatively high in agricultural land, fishponds, and roads. Land covers like the sea, vegetation, and sand provide different environments that affect the frequency of nesting: the closer the beach to these land covers, the more suitable it is for nesting grounds. This statement is attributable to the fact that after landing and depositing eggs, sea turtles return to the sea. A broad stretch of sand is a condition of a nesting location because sea turtle eggs will be placed at a certain depth under the sand. Some species, however, require the presence of vegetation, including olive ridley, green, and leatherback sea turtles, because they like to make nests in the shade of thatch screwpine (*Pandanus tectorius*). Moreover, the roots of this plant increase moisture, provide stability to the sand, and allow sea turtles to dig holes for their nest more easily. Accordingly, not all vegetation species are suitable for their nesting grounds.

The distance of the nesting grounds on Barchan and Parangkusumo Beaches to the stretch of sand (land cover) was, on average, 0 m, meaning that they are located right on the sand without any obstacles like vegetation or other land covers/uses. Meanwhile, on Pelangi and Cemara Sewu Beaches, several nesting grounds were in the shade of vegetation, with a distance of 0.4-2.1 meters to the stretch of sand. Although the surface material was still sand, these areas, in terms of land use, were included in the vegetation category. When discovered in 2011, the nesting sites were generally near the vegetation-covered areas that, in 2020, had been converted into buildings. For this reason, there was no nesting ground found on Depok Beach during the data updating process. On Pelangi and Cemara Sewu Beaches, sea turtle landing sites were also found right on the sand (mean distance to the sand= 0 m). Based on land cover/use analysis and the average distance of nesting grounds to every land cover/use category (Figure 3), Pelangi, Cemara Sewu, and Barchan Beaches are ideal for sea turtle nesting. These beaches are not only far from buildings and agricultural areas but also quiet and close to coastal vegetation, increasing the frequency of landing.

Abiotic factors refer to the physical characteristics of the coast, which had a gently sloping relief. The field survey also re-checked the results of the image data processing (DEM ALOS PALSAR), and this process revealed that the beaches of Kretek District had slope gradients in the range of less than 10° or 17%. According to Nuitja (1992), gently or moder-

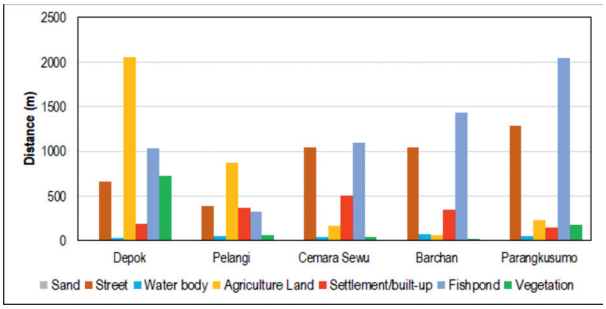

Fig. 3. Comparison of the average distance between nesting grounds and land cover/use

Table 3. The average distance of nesting grounds to land cover/use

Average Distance of Nesting Grounds to Land Cover/Use (m)	Beach Names				
	Depok.	Pelangi	Cemara Sewu	Barchan	Parangkusumo
Sand	3.8	2.1	0.4	0.0	0.0
Roads	665.5	384.5	1040.3	1045.2	1288.8
Sea	33.3	50.6	44.4	76.6	52.4
Agricultural Land	2055.3	876.5	165.6	65.0	228.1
Built-up Land	187.0	367.1	504.6	349.0	149.8
Fishponds	1035.2	322.5	1099.0	1437.1	2045.5
Vegetation	729.7	65.4	39.7	18.4	179.3

Source: Data Analysis (2020)

ately sloping beaches (3-8% or 8-16%) create habitats that can facilitate sea turtles to reach the nesting grounds easily. Table 4 shows that the beaches observed are suitable for nesting.

Table 4. Slope gradients along the coast of Kretek District

Beach Names	Slope Gradient (%)	
	ALOS PALSAR	Field Data
Depok	0 - 7.21	2 - 10
Pelangi	0 - 9.37	1 - 10
CemaraSewu	0 - 6.3	1 - 8
Barchan	0 - 6.84	4
Parangkusumo	0 - 4.04	2 - 8
Parangtritis	0.0	0 - 5

Source: Image processing and field survey

Physical conditions are among the factors that are likely to affect the location of the nesting ground. In this context, they comprise soil temperature, air temperature, and humidity. This research observed the physical conditions directly in the field at two times of the day: morning and evening. Table 5 shows that a difference in observation time is in line with a variety of physical conditions. According to Silalahi (1990), the embryonic development of sea turtle eggs requires temperatures in the range of 25-32 °C. Also, Nuitja (1992) has confirmed that temperature fluctuates at a depth of 15 cm below the surface but becomes more stable as the depth increases. Olive ridley sea turtles make nests at a depth of up to 37-38 cm.

Here, the soil temperature is the average of soil temperatures above the surface of the sand (the location of sea turtle landings). Both soil and air temperatures exceeding the threshold represent an environment that does not support the embryonic development of sea turtle eggs during the daytime. Meanwhile, at night, a supporting environment occurs if both temperatures are close to the standard threshold. During the field survey in the afternoon (11.00 to 13.00), the temperature measured was relatively high due to sun exposure. However, within 24 hours, the temperature range was categorically suitable for the embryonic development, mainly because the temperature of the sand can change with depth. Physical conditions, such as temperature and humidity, are very volatile and sensitive to seasonal change. The data collected during the wet month were most likely to differ from the ones taken during the dry month. Figure 4 compares the

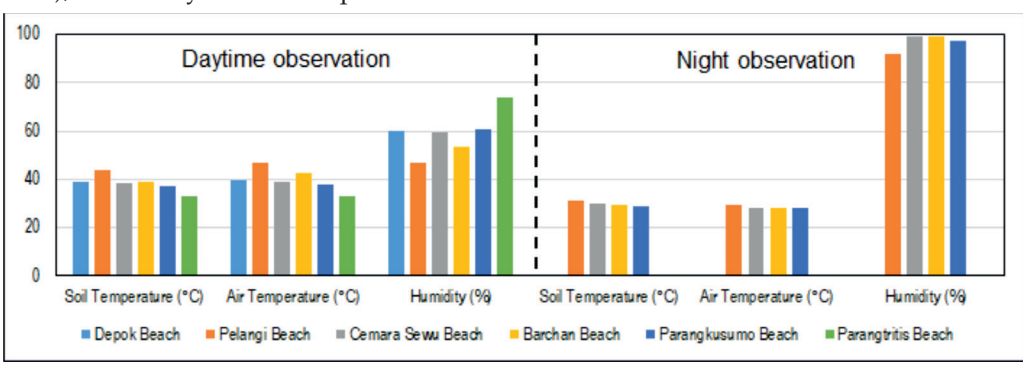

Fig. 4. Soil temperature, air temperature, and humidity at daytime and night observations.

Table 5. Soil temperature, air temperature, and humidity along the coast of Kretek District

Beach Names	Soil Temp. (°C)	Air Temp. (°C)	Air Humidity (%)	Data Collection Time	Soil Temp. (°C)	Air Temp. (°C)	Air Humidity (%)	Data Collection Time
	Daytime				Nighttime			
Depok Beach	33 - 50	32 - 51	47 - 80	11.52 - 12.59	No data			
Pelangi Beach	32 - 50	31 - 60	33 - 57	10.00 - 13.25	30 - 39	27 - 39	77 - 99	21.00 - 00.16
Cemara Sewu Beach	39 - 43	41 - 50	42 - 54	09.33 - 09.53	29 - 31	27 - 28	99.0	00.20 - 00.45
Barchan Beach	38 - 42	41 - 52	45 - 54	09.08 - 09.29	29 - 30	27 - 29	99.0	00.49 - 01.07
Parangkusumo Beach	37 - 39	36 - 46	51 - 60	08.53 - 09.04	28 - 30	27 - 28	99.0	01.11 - 01.20
Parangtritis Beach	31 - 34	31 - 35	65 - 84	16.45 - 17.09	No data			

Source: Field Survey (2020)

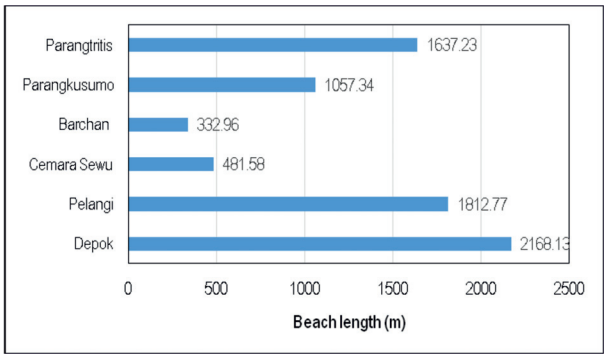

Fig. 5. The lengths of every beach in the coastal area of Kretek District

average soil temperature, air temperature, and humidity in the study area.

Based on the above analysis, it shows that every beach in the coastal area of Kretek District has relatively similar physical characteristics, although there is a significant difference in the number of nesting grounds due to the different length of the beach. For instance, Pelangi is 1812.77 m in length, which is significantly longer than Cemara Sewu (481.58 m) and Barchan (332.96 m). In other words, Pelangi Beach can accommodate more nesting grounds, i.e., up to 43 nesting grounds. Figure 5 shows that although Parangtritis has a long stretch of sand (1637.23 m), there was no nesting ground. This finding is the product of other physical conditions that make this beach unsuitable for nesting grounds, as evident from its land cover/use (Figure 2).

Conclusion

Although generally the beaches along the coast of Kretek District have similar physical characteristics, there are differences in the number of sea turtle nesting grounds between one and the others, mainly due to biotic factors, i.e., humans.Humans, with their various activities, create a barrier for sea turtles to deposit their eggs—the more intensive the human activity, the less the number of nesting grounds in this location. The examples include Depok and Parangtritis Beaches. On the contrary, Pelangi Beach has the highest number of nesting grounds (43 points). Most sea turtles make nests in the shade of vegetation, while the other nests are in vegetation-free areas or open sand, gently sloping grounds, and long beaches far from built-up land.

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