Advance Sustainable Science, Engineering and Technology (ASSET)
Vol. 6, No.4, October 2024, pp. 02404025-01 ~ 02404025-10
ISSN: 2715-4211 DOI: https://doi.org/10.26877/asset.v6i4.998

Assessment of Abiotic Factors for Sea Turtle Nesting Suitability in Coastal Bays

Chukwudi Ikegwu[1,2*], Agus Nuryanto[1], Moh. Husein Sastranegara[1]

[1]Faculty of Biology, Jenderal Soedirman University. dr. Soeparno Street no. 63 Grendeng Purwokerto 53122, Central Java, Indonesia

[2]8 Iloani Crescent Awada Obosi, Onitsha Anambra State Nigeria

* agus.nuryanto@unsoed.ac.id

Abstract. Cilacap Bays, critical nesting areas for sea turtles, face growing habitat disturbances from tourism. However, studies on nesting suitability in these regions remain scarce. This research assesses the abiotic factors influencing sea turtle nesting in Cilacap Regency, Indonesia, across eight observation stations. Key ecological parameters—land surface temperature (28°C - 36.3°C), pH (mean 6.8), sand particle size (0.212-0.500 mm), beach slope (11.50%-20.99%), and beach width (28.8m-81.8m)—were evaluated. The results highlight Sidaurip Beach as the most suitable for nesting due to optimal environmental conditions, with Station (SP1) being particularly favorable for producing male hatchlings due to its suitable 28°C temperature. These findings suggest targeted egg relocation to SP1 could help address gender imbalances, ensuring long-term population sustainability. This research provides valuable insights for sea turtle conservation and supports future policy efforts to protect nesting sites in Cilacap amidst growing environmental pressures.

Keywords: nesting-ecology, abiotic-factors, conservation, ecological-assessment, habitat-suitability.

(Received 2024-08-23, Accepted 2024-10-16, Available Online by 2024-10-26)

1. Introduction

Cilacap Bays serve as essential nesting grounds for various sea turtle species, including *Lepidochelys olivacea*, *Chelonia mydas*, *Eretmochelys imbricata*, and *Dermochelys coriacea*, all of which face significant conservation challenges due to anthropogenic pressures [1-2]. However, despite the ecological importance of these beaches, there has been little research on the specific abiotic factors influencing sea turtle nesting ecology in this region. This study addresses this gap by evaluating the suitability of Cilacap's nesting beaches, emphasizing critical abiotic factors such as land surface temperature, sand particle size, beach slope, soil humidity, beach width, and soil pH [3-5]

Abiotic factors play a crucial role in sea turtle nesting success. For example, temperature influences embryonic development and sex determination, making it a key parameter in assessing habitat suitability [6-7]. Similarly, beach slope affects nest site selection, as steep slopes increase the risk of nest inundation or erosion, which can significantly impact reproductive success [8], [3]. The width of the beach and its distance from the high tide line also contribute to nest safety, as nests too close to the shoreline are at risk of flooding, while those placed too far may face adverse conditions such as desiccation and predation [4], [9].

In addition, sand particle size influences the microenvironment required for egg incubation. Sandy beaches, as noted by [5], provide the ideal thermal and moisture conditions for embryonic development, while beaches with coarser particles may impede gas exchange and moisture retention, threatening the viability of eggs. Humidity further regulate the nest's microclimate, ensuring appropriate moisture and temperature levels for optimal development [7-10]

This study is among the first to systematically assess the abiotic factors affecting sea turtle nesting ecology in Cilacap Bay. By evaluating key parameters across multiple study sites, this research provides the foundation for evidence-based conservation strategies aimed at protecting these threatened species and ensuring the long-term sustainability of their nesting habitats [11]. Understanding how these environmental factors interact with turtle nesting behavior is vital for developing targeted management practices that can preserve Cilacap's beaches as viable nesting sites for future generations of sea turtles.

2. Methods

2.1. Research time and site

The research was conducted at Turtle Bay of Cilacap, Central Java, Indonesia, at eight observation stations during the new moon (July 3, 2023; August 16, 2023) and full moon (July 18, 2023; August 2, 2023) conditions. The study covered a distance of approximately 16 km from Sodong Beach (SP 1) to Pagubugan Beach (SP 8). The stations' geographic coordinates were determined using a Global Positioning System (GPS), providing precise locations for data collection. Both in-situ (on-site) and ex-situ (laboratory) parameters were measured, with in-situ data including land surface temperature, pH, humidity, soil particle size, beach slope, and beach width. The ex-situ analysis focused on soil particle separation, conducted at Universitas Jenderal Soedirman, Indonesia.

Table 1. Sampling sites with its geographic position

No	Code	Sampling Site	Coordinate
1	SP1	Sodong	7.69195˚S, 109.181622˚E
2	SP2	Srandil	7.69195˚S, 109.191656˚E
3	SP3	Welahan Wetan	7.696132˚S, 109.231723˚E
4	SP4	Widarapayung Kulon	7.692683˚S, 109.244497˚E
5	SP5	Sidayu	7.698763˚S, 109.260091˚E
6	SP6	Widarapayung Wetan	7.698754S, 109.261489E
7	SP7	Sidaurip	7.700976˚S, 109.292523˚E
8	SP8	Pagubugan	7.700794˚S, 109.287625˚E

2.2. Ecological parameters measurement

Measurements were taken at a depth of 18 cm, allowing for a more accurate representation of the environment in which sea turtle eggs are incubated. The temperature, pH, and humidity were recorded after the probe stabilized, with values noted and compared to classifications established by [10], [12] for sea turtle nesting suitability (Tables 2 and 3).

Table 2. Habitats' temperature, pH, and humidity classification for turtles' nesting

No	Temperature Natih *et al*. (2021)	pH Ngabito *et al*. (2021)	Category
1	29°C – 32.5°C	7.0 – 8.0	Very suitable
2	26°C - 29°C	6.0 – 6.9	Suitable
3	<26°C or >35°C	1.0 – 5.55	Not suitable

Humidity of soil has an essential effect on egg hatching rates. The suitability of soil humidity for turtles' nesting habitat is classified as presented in Table 3 [10].

Table 3. Soil humidity classification

Humidity Natih *et al*. (2021)	Classification	Category
<20%	Dry+	Not suitable
20% - 29%	Dry	Suitable
30% - 40%or	Wet	Very suitable
>40%	Wet+	Not suitable

Sand particle sizes were determined by collecting approximately 100 g of sand at each sampling site. At the laboratory, the sand samples were separated using a sieve shaker. The sieve shaker was calibrated as 0.150 mm, 0.212 mm, 0.500 mm, and 0.100 mm. The sand textures obtained were converted using a percentage scale for easy analysis and comparison to existing data. Sand particle classification has been made by [10] as summarized in Table 4.

Table 4. Sand particle size classification

No	Diameter (mm)	Category
1	0.150 – 0.212	Fine
2	0.212 – 0.500	Medium
3	0.500 – 1.000	Coarse

The beach slope was determined by placing a 50-inch board on the ground, with the length going up and down the slope being measured. A waterpas was set on the lower end of the board. The lower end of the board was lifted until the liquid in the waterpas settled in the middle. A measuring tape was used to measure the distance in inches from the raised board to the ground. The slope was determined according to the formula from [10]. The category of the beach slope is presented in Table 5.

$$\text{Slope} = (\text{rise} / \text{run})\ \text{cm} \times 100\% \tag{1}$$

Table 5. Beach slope classification [10]

No	Slope (%)	Class	Category
1	3 – 8	Slope slightly	Very suitable
2	8 – 16	Sideway	Suitable
3	>16	Steep	Not suitable

Beach width measurement was carried out by placing a scale on the vegetation boundary. The rope was pulled perpendicular to the shoreline, and the length was noted. The suitability of beach width for turtles' nesting has been determined by [13] as summarized in Table 6.

Table 6. Beach width classification

No	Width (m)	Category
1	20 – 40	Very suitable
2	40 – 80	Suitable
3	<20 or >80	Not suitable

2.3. *Data analysis*

The data collected from the eight stations were analyzed descriptively by comparing the field parameters; land surface temperature, pH, humidity, soil particle size, beach slope, and beach width, with established benchmarks for suitable sea turtle nesting habitats [10], [12-13]. Each parameter was systematically categorized based on suitability, and the results were presented in tables. The descriptive approach focused on comparing the current field data with previously published standards, ensuring an interpretation aligned with existing research.

2.4. *Descriptive Comparison*

For each station, abiotic factors such as temperature, pH, humidity, and soil particle size were compared to the classification schemes outlined by [10] and other relevant literature. For instance, land surface temperatures between 29°C and 32.5°C were considered very suitable for nesting, while values outside this range were deemed less favorable. Similar classifications were applied to other parameters like pH and humidity. The comparison allowed us to identify which stations provided the most favorable conditions for sea turtle nesting without requiring inferential statistical testing.

2.5. *Bias and Data Processing*

Potential biases in the data were mitigated by performing measurements under both new moon and full moon conditions to account for tidal variations. GPS devices were used to ensure consistency in station positioning. Any environmental interference from nearby human activity was noted and considered in the analysis. The descriptive data were then compared with findings from previous research to establish the relative suitability of each station for sea turtle nesting.

3. Results and Discussion

3.1. *Land surface temperature*

Land surface temperature at turtles' bay Cilacap varied from 26°C to 39°C, with the average temperature ranged of 28.0°C and 36.3°C. The sampled beach with the highest temperature was station 4, Widarapayung Kulon Beach with an average mean temperature of 36.3°C. Details of land surface temperatures and mean temperatures at each sampling site are presented in Table 7.

Table 7. Land surface temperature at each sampling site in the Cilacap turtles' bay

No	Code	Sampling Site	Temperature ranges (°C)
1	SP1	Sodong	26 – 29
2	SP2	Srandil	31 – 36
3	SP3	Welahan Wetan	28 – 31
4	SP4	Widarapayung Kulon	31 – 39
5	SP5	Sidayu	30 – 38
6	SP6	Widarapayung Wetan	30 – 36
7	SP7	Sidaurip	29 – 36
8	SP8	Pagubugan	30 – 36

3.2. *Soil acidity (pH)*

Soil acidity was assessed using pH values, with measurements taken in Turtle Bay ranging from 6 to 7. The specific soil pH recorded during each sampling event conducted on the field trips is detailed in Table 8.

Table 8. Soil pH at each sampling in Cilcap Turtle Bay

No	Code	Sampling Site	Soil pH
1	SP1	Sodong	6.0 – 7.0
2	SP2	Srandil	6.5 – 7.0
3	SP3	Welahan Wetan	6.0 – 7.0
4	SP4	Widarapayung Kulon	7.0
5	SP5	Sidayu	7.0
6	SP6	Widarapayung Wetan	6.5 – 7.0
7	SP7	Sidaurip	6.0 – 7.0
8	SP8	Pagubugan	6.5 – 7.0

3.3. Soil humidity

The humidity value kept fluctuating in each of the stations except in SP5 and SP8 where it was Dry+ all through (Table 9). This could be interpreted as Dry+ signifies extremely dry moisture content, Dry indicates the availability of moderate humidity, which is very suitable for nesting, Wet+ implies that the sampled area was extremely wet and Wet simply showed that the humidity was still high although can still support nesting.

Table 9. Humidity values across sampling stations

No	Code	Sampling Site	Humidity
1	SP1	Sodong	Wet – Dry+
2	SP2	Srandil	Wet – Dry+
3	SP3	Welahan Wetan	Dry – Dry+
4	SP4	Widarapayung Kulon	Wet – Dry+
5	SP5	Sidayu	Dry+
6	SP6	Widarapayung Wetan	Wet – Dry+
7	SP7	Sidaurip	Dry – Dry+
8	SP8	Pagubugan	Dry+

3.4. Soil particle size (texture)

The texture of the sand for sea turtle species to land and lay their eggs is very important. The Sand particles analyzed contained fine sand, medium sand, and coarse sand in the proportion of 0.150-0.212mm, 0.212-0.500mm, and 0.500-1.00mm, respectively (Table 10), with varying soil content percentages.

Table 10. Particle size percentage at each sampling site in Cilacap Bay

No	Code	Sampling Site	Particle Size Category (%)		
			Fine	Medium	Coarse
1	SP1	Sodong	39.00	56.38	4.26
2	SP2	Srandil	48.42	49.47	2.11
3	SP3	Welahan Wetan	38.78	55.10	6.12
4	SP4	Widarapayung Kulon	55.1	44.90	0
5	SP5	Sidayu	44.89	55.10	0
6	SP6	Widarapayung Wetan	38.78	59.18	2.04
7	SP7	Sidaurip	68.32	31.63	0
8	SP8	Pagubugan	62.88	37.11	0

3.5. Beach slope

The average beach slopes for each sampling station are presented in Table 11. Slopes ranged from 11.50% to 20.99%, with station 2 exhibiting a particularly high average slope. This data will be instrumental in assessing the range of suitable slopes for nesting, aligning with established parameters by previous researchers. The findings will identify beaches conducive to sea turtle nesting.

Table 11. The observed beach slope at each sampling site during the field trips

No	Code	Sampling Site	Slope (%)	Mean value
1	SP1	Sodong	11.99 – 31.91	17.20 ± 1
2	SP2	Srandil	11.99 – 36.00	20.99 ± 1
3	SP3	Welahan Wetan	11.99 – 31.91	18.50 ± 1
4	SP4	Widarapayung Kulon	10.00 – 19.98	12.99 ± 1
5	SP5	Sidayu	7.99 – 19.98	14.50 ± 1
6	SP6	Widarapayung Wetan	10.00 – 11.99	11.50 ± 1
7	SP7	Sidaurip	11.99 – 16.00	13.99 ± 1
8	SP8	Pagubugan	10.00 – 17.99	12.50 ± 1

3.6. *Beach width*

Beach width plays a crucial role in studying the environmental cues influencing sea turtle nesting. The proximity of a beach significantly impacts turtle nesting activities and how other environmental factors affect the laid eggs. The beach width data (Table 12) indicates a range from 28.8m to 81.8m, with SP5 recording the highest measurement. Understanding these variations in beach width is essential for comprehending the nesting dynamics and its interaction with other environmental parameters.

Table 12. Beach width in Cilacap bays

No	Code	Sampling Site	Width (m)	Mean value
1	SP1	Sodong	2 – 42	29.30 ± 1
2	SP2	Srandil	2 – 40	28.80 ± 1
3	SP3	Welahan Wetan	2 – 45	31.50 ± 1
4	SP4	Widarapayung Kulon	65 – 80	79.30 ± 1
5	SP5	Sidayu	73 – 90	81.80 ± 1
6	SP6	Widarapayung Wetan	79 – 85	81.50 ± 1
7	SP7	Sidaurip	50 – 80	63.80 ± 1
8	SP8	Pagubugan	52 - 90	68.00 ± 1

3.7. *Impact of Land Surface Temperature on Sea Turtle Nesting*:

The land surface temperature at Turtles' Bay Cilacap ranged between 26-39°C, with an average temperature of 28.0-36.3°C. The sampled beach with the highest temperature was Station 4, Widarapayung Kulon Beach, with an average mean temperature of 36.3°C. Detailed land surface temperatures and mean temperatures at each sampling site are presented in Table 7.

Temperature is a critical environmental factor influencing sea turtle nesting ecology. [14] noted that temperature fluctuations occur at a depth of 15 cm, while our environmental data were collected at a depth of 18 cm. The mean-average temperatures across the study locations (SP1-SP8) ranged from 28-36.3°C (Table 7). According to [15], a gradual and consistent temperature range of 25-35°C is optimal for sea turtle nesting, leading to good hatching rates and shorter incubation times.

[16] highlighted that temperatures ranging between 33.4-35.7°C can cause uncertainty in egg development, while temperatures above 36-37.5°C can inhibit hatching. From the data in Table 7, it is evident that all stations except Station 4 support sea turtle nesting activities. Specifically, SP4, with a mean average temperature of 36.3°C, presents a high risk of eggs drying out and failing to hatch, as indicated by [10].

[17] reported that the incubation temperature for Olive ridley turtles ranges from 28.5-32.2°C, while [10] suggested a range of 24-33°C as suitable. [18] further noted that temperatures exceeding normal limits can lead to embryo mortality and affect hatchling sex ratios. Temperature-dependent sex determination in turtles means higher temperatures result in female embryos, while lower temperatures produce a mix of male and female hatchlings. [19-20] confirmed that elevated temperatures predominantly produce female hatchlings, and [21] added that temperatures above 28°C result in females. [22] observed that incubation temperatures between 28-29°C favor male hatchlings, whereas temperatures above 30°C tend to favor females.

Based on the data in Table 7, SP1, with an average mean temperature of 28°C, supports male hatchlings. Stations 1, 3, and 7 are suitable for female hatchlings, while SP 2, 5, 6, and 8 also support female hatchlings. SP4, however, is unsuitable for nesting due to its high temperature. Therefore, transferring eggs from SP4 to SP7 or SP1, with close monitoring, is advisable to ensure successful hatching and balance hatchling sex ratios.

3.8. Soil pH and Its Influence on Nesting Success:

The pH levels recorded across Turtle Bay ranged from 6.0 to 7.0 (Table 8), indicating a generally neutral to slightly alkaline environment. This is consistent with [12], who identified pH levels between 7 and 8 as ideal for turtle nesting. Our results support this, as no station recorded a pH value below the critical threshold of 5.5 established by [5]. Low pH levels, which are strongly acidic, have been shown to inhibit embryo growth and hatching, highlighting the importance of maintaining neutral pH conditions for successful nesting.

Stations 5 and 6, which consistently recorded a pH of 7.0, are particularly notable as they fall within the ideal range for nesting, ensuring minimal risk of bacterial infections and promoting healthy embryo development. Therefore, the neutral pH levels at all study sites suggest that pH is not a limiting factor for nesting success in the Turtle Bay.

3.9. Humidity and Its Effects on Egg Viability:

Our study recorded humidity levels varying from 'Dry+' to 'Wet+', with extremes observed at SP5 and SP8 (Table 9) where conditions remained extremely dry. According to [10], and [23], very high humidity (>40%) can lead to egg rot, while very low humidity (<20%) can cause desiccation. The fluctuating humidity conditions across stations underscore the importance of moderate humidity levels for successful incubation.

SP7, with a balanced humidity level of 'Dry', aligns well with the recommended range of 20-29% as per [13] and [24], making it highly suitable for nesting. Conversely, SP5 and SP8's 'Dry+' conditions could potentially lead to desiccation, indicating less suitability for nesting. This variability highlights the need for precise monitoring and management to ensure optimal humidity conditions for sea turtle egg incubation.

3.10. Particle Size and Its Role in Nesting Site Selection:

The particle size of beach sand plays a critical role in sea turtle nesting site selection, influencing the ease with which turtles can dig nests and the stability of the eggs. Our study found that SP7 and SP8, with high percentages of fine sand (68.32% and 62.88%, respectively) (as in Table 10), are particularly favorable for nesting. This finding aligns with [25], who reported that green turtles exhibit a preference for fine sand beaches due to the ease of excavation and egg placement.

The presence of fine sand is crucial for successful nesting because it allows for easier digging and reduces the likelihood of mechanical resistance during nesting. Conversely, the study found significant levels of coarse sand at other stations, such as SP3, with up to 6.12% coarse sand, potentially making it more challenging for turtles to dig their nests. [26] supports this by noting that larger sand particles can hinder nesting activities, as they require more energy for digging and can lead to nest instability.

Moreover, the absence of coarse sand at SP7 and SP8 corroborates [14], who emphasized the importance of fine and medium sand in facilitating effective nesting. The high proportion of fine sand at these stations ensures that nesting is less labor-intensive and more secure, reducing the risk of eggs being disturbed or dislodged.

3.11. Beach Slope and Its Suitability for Nesting:

The beach slope is another crucial factor influencing sea turtle nesting. Our study's results indicate that the average beach slopes ranged from 11.50% to 20.99%, with SP6, SP4, SP8, SP7, and SP5 (Table 11) exhibiting slopes within the optimal range for nesting. [27] argue that moderate beach slopes are favorable for nesting, as they facilitate easier access and reduced energy expenditure for turtles.

Specifically, the slopes at SP6 (11.50%) and SP5 (14.50%) are well-suited for nesting, as they fall within the range identified by [10] as ideal for successful nesting. In contrast, the steeper slopes at SP1 (17.20%), SP2 (20.99%), and SP3 (18.50%) may pose challenges for turtles, making it more difficult to locate appropriate nesting sites and potentially leading to increased energy expenditure and lower nesting success. [24] reinforce this by noting that turtles prefer gentle slopes, which make nesting and subsequent movement away from the surf easier.

The data thus support the findings of [5], who noted that a gentler slope facilitates turtle landing and nesting, while steeper slopes could impede these activities. The optimal slope range identified in our study is consistent with these findings, underscoring the importance of slope in selecting suitable nesting beaches.

3.12. Beach Width and Its Influence on Nesting:

Beach width is a critical factor in studying environmental cues for sea turtle nesting, influencing both nesting activity and the impact of other environmental parameters on the eggs. As shown in Table 12, beach widths ranged from 28.80 to 81.80 meters, with SP5 having the widest beach.

Beach width is as significant as beach slope in determining the suitability of nesting sites. According to [27], a sandy beach's width is often correlated with its slope, with sloping beaches typically having a wider expanse than steeper ones. Our data (Table 12) support this observation.

For SP1, SP2, and SP3, which have steeper slopes, the beach widths were measured at 28.8 meters, 29.3 meters, and 31.5 meters, respectively. Although these widths fall within the range considered suitable for sea turtle nesting—20 to 80 meters as indicated by [13] fluctuations in width observed at these stations could disrupt the nesting process and affect other critical environmental parameters. Additionally, unstable beach widths may increase the risk of eggs being displaced by water currents.

In contrast, SP7 and SP8, with average beach widths below 80 meters, are well-suited for nesting. However, SP5 and SP6, with average widths exceeding 80 meters, are less suitable due to their wider expanse.

4. Conclusion

This study investigated the diverse abiotic conditions across eight sampling sites along the coastline of Cilacap, Central Java, Indonesia; a notable nesting habitat for various sea turtle species. Our findings revealed significant variations in environmental parameters, which have direct implications for sea turtle nesting and conservation. Sidaurip Beach (SP7) emerged as the most suitable habitat for sea turtle nesting, demonstrating optimal conditions in terms of humidity, particle size, and beach slope. Conversely, SP1 was identified as the only site supporting male hatchlings due to its favorable temperature of 28°C. Given the temperature-dependent sex determination in sea turtles, it is crucial to address gender balance in nesting sites. To promote gender balance and support the sustainability of sea turtle populations, it is recommended to transfer some eggs from beaches with less suitable conditions to SP1. However, such transfers should be conducted with close monitoring to ensure hatchling survival and adaptation. Effective management of these environmental parameters will be vital in conserving the sea turtle species in Turtle Bay of Cilacap and enhancing the overall success of nesting and hatching processes. Again, implementing these recommendations will not only aid in achieving a balanced sex ratio among hatchlings but also contribute to the long-term conservation and sustainability of sea turtle populations in the region.

Acknowledgement

We want to thank the Directorate of Research and Community Services, Ministry of Education, Culture, Research and Technology of Indonesia for funding this study through the Undergradute Research Program for Master Thesis (Contract: 3.64/UN23.35.5/PT.01/VII/2023) Research grant. The authors are also grateful to the Research and Society Service Institute of the University of Jenderal Soedirman for providing administrative support. The authors also thank all parties who contributed to the fieldwork and collectors from all sampling sites for the assistance rendered, especially Mr. Juwana.

References

[1] Abreu-Grobois, A. and Plotkin, P. (IUCN SSC Marine Turtle Specialist Group). 2008. *Lepidochelys olivacea*. *The IUCN Red List of Threatened Species* 2008: e.T11534A3292503. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T11534A3292503.en. *Accessed on 07 September 2024*.

[2] Dharmawan, L., 2020. *The story of a young man who is struggling to "save turtles" in Cilaca p - starting from spending his own money, "hiding" eggs, to making captives*. Jakarta: BBC NEWS Indonesia.

[3] Wood, D. W. & Bjorndal, K.A. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. *Copeia* 2000(1): 119-128. doi:10.1371/journal.pone.0015465

[4] Kamel, S.J. & Mrosovsky, N. 2004. Nest site selection in leatherbacks, Dermochelys coriacea: Individual patterns and their consequences. Anim. Behav. 68(2): 357-366. doi:10.1016/j.anbehav.2003.07.021

[5] Budiantoro, A., Retnaningdyan, C., Hakim, L. & Leksono, A.S. 2019. Characteristics of olive ridley (*Lepidochely olivacea*) nesting beaches and hatcheries in Bantul, Yogyakarta, Indonesia. *Biodiversitas* 20 (11): 3119-3125. https://doi.org/10.13057/biodiv/d201103

[6] Ewert, M.A. and Nelson, C.E. 1997. Sex determination in turtles: diverse patterns and some possible adaptive values. *Copeia,* 1991, pp.50-69.

[7] Hamann, M., Godfrey, M., Seminoff, J., Arthur, K., Barata, P., Bjorndal, K. and Godley, B.J. 2010. Global research priorities for sea turtles: Informing management and conservation in the 21st Century. *Endangered Species Res*., 11(3), pp.245-269.

[8] Kamel, S.J. & Mrosovsky, N. 2005. Repeatability of nesting preferences in the hawksbill sea turtles, *Eretmochelys imbricata*, and their fitness consequences. Anim. Behav. 70(4): 819-828. doi:10.1016/j.anbehav.2005.01.006.

[9] Tripathy, B. & Rajasekhar, P.S. 2009. Natural and anthropogenic threats to olive ridley sea turtles (*Lepidochelys olivacea*) at the Rushikulya rookery of Orissa coast, India. Indian J Mar. Sci. 38 (4): 439-443.

[10] Natih, N.M., Pasaribu, R.A., Hakim, M.A., Budi, P.S. & Tasirileleu, G.F., 2021. Olive ridley (*Lepidochelys olivacea*) laying eggs habitat mapping in Penimbangan Beach, Bali Island. Earth Environ. Sci., 944(01): 20-38. DOI: 10.1088/1755-1315/944/1/012038

[11] Peričić, T.P. and Tanveer, S., 2019. Why systematic reviews matter. www.elsevier.com/connect/authors-update/whysystematic-reviews-matter (accessed February 2023).

[12] Ngabito, M., Fahrizal, A., Umsini, M.Y., Polimango, E. A. & Ningsi, A., 2021. The biophysical characteristics of Sea Turtles Spawning Beaches: a study in Mas Popaya Raja Nature Reserve. The International Journal Journal of Social Sciences World 3(1): 210-217. DOI: https://doi.org/10.5281/zenodo.5032478

[13] Mathenge, S.M., Mwasi, B.N. & Mwasi, S.M. (2012). Effects of anthropogenic activities on seaturtle nesting beaches along the Mombasa-Kilifi Shoreline Kenya. Marine Turtle Newsletter 135: 14-18. http://www.seaturtle.org/mtn/archives/mtn135/mtn135p14.shtml?nocount

[14] Nuitja, I.N.S. 1992. *Biologi dan Ekologi Pelestarian Penyu Laut.* Buku: Institut Pertanian Bogor Press, Bogor

[15] Damanhuri, H., Dahemi, Syandri, H. & Bengen, D.G. 2019. Biophysical Characteristics of Nesting Habitat of Green Turtle Chelonia Mydas in the Coastal Zone of Kasiak, Bindalang, and Karabak Ketek Island of West Sumatra, Indonesia. *Int'l J. of Agric. Sci.* 3(2): 44-49. DOI: 10.25077/ijasc.3.2.44-49.2019

[16] Drake, D.L. and Spotila, J.R. 2002. Thermal Tolerances and The Timing of Sea Turtle Hatchling Emergence. *Journal of Thermal Biology* 27(1) 71 - 81. DOI: 10.1016/S0306-4565(01)00017-1

[17] Agus, D.I., Nyoman, S.N., Dedi, S., Matheus, H.H., Mirza, D. K., Syamsul, B. L., Rofi, A.M., Khazali.Mimi, M., Poppi, L.W., Setiabudiningsih, and Ali, M. 2009. *Pedoman teknis pengelolaan konservasi penyu*. Direktorat Konservasi dan Taman Nasional Laut, Direktorat Jenderal Kelautan, Pesisir dan Pulau-Pulau Kecil, Departemen Kelautan dan Perikanan RI.

[18] Hawkes, L.A., Broderick, A.C., Godfrey, M.H., Godley, B.J. & Witt. M.J. 2014. Coastal Conservation. Cambridge University Press, Cambridge: 310 hlm.
[19] Kawagoshi, T., Uno, Y., Nishida, C. & Matsudaa, Y. 2014. The *Staurotypus* Turtles and Aves Share the Same Origin of Sex Chromosomes but Evolved Different Types of Heterogametic Sex Determination. PLoS ONE 9(8): e105315. *https://doi.org/10.1371/journal.pone.0105315*
[20] Laloë, J.O., Cozens, J., Renom, B., Taxonera, A. and Hays, G.C. 2014. Effects of rising temperature on the viability of an important sea turtle rookery. *Nat. Clim. Change* 4: 513-518. DOI: 10.1038/nclimate2236
[21] Lutz, P.L., Musick, J.A. & Wynekken, J. 2003. *The Biology of Sea Turtles Volume II* (Florida: CRC Press).
[22] Colin, J. L. 2009. A Biological Review of Australian Marine Turtles. EnvironmentalProtection Agency Queensland Government.
[23] Segara, A.R. 2008. Studi Karakteristik Biofisik Habitat Peneluran Penyu hijau (*Chelonia mydas*) di Pangumbahan Sukabumi, Jawa Barat, *Bachelor Thesis*, Faculty of Fisheriesand Marine Science, IPB University.
[24] Pertiwi, M.P. & Lathifah, S.S. 2018. Conditions of hilling habitat of *Chelonia mydas* (Green Turtle) in Pangumbahan Beach Ujung Genteng, Sukabumi Selatan. Journal of Sci. Innovare 1(2): 2615-3769. DOI: 10.33751/jsi.v1i02.1003
[25] Panjaitan, R.A.and Iskandar, S.A.H. 2012. Hubugan Perubahan garis pantai terhadap habitat bertelur *penyu hijau* (*Chelonia mydas*) di pantai Pangumbahan Ujung Genteng, Kabupaten Sukabumi. Jurnal Perikanan dan Kelautan 3(3): 311-320
[26] Ekanayake, E.M.I., Rajakaruna, R.S., Kapurusinghe, T., Saman, M.M., Rathnakumara, D.S., Samaraweera, P. & Ranawana, K.B. 2010. Nesting behaviour of the green turtle at Kosgoda Rookery, Srilanka. Cey. *Journal Science (Biological Science)* 39(2): 109—120. doi:10.4038/cjsbs.v39i2.2997
[27] Anshary, M., Setyawati, T.R. & Yanti, A.H. 2014. Karakteristik pendaratan penyu hijau (*Chelonia mydas*, Linnaeus 1758) di pesisir pantai Tanjung Kemuning Tanjung Api dan Pantai Belacan Kecamatan Paloh Kabupaten Sambas. *Protobiont* 3(2): 232-239. DOI: https://doi.org/10.18343/jipi.28.2.192