Olive ridley (*Lepidochelys olivacea*) laying eggs habitat mapping in Penimbangan Beach, Bali Island

N M N Natih*, R A Pasaribu, M A G Al Hakim, P S Budi and G F Tasirileleu

Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, IPB University, Dramaga, Bogor 16680, West Java, Indonesia

*E-mail: natih@apps.ipb.ac.id

Abstract. Penimbangan beach is one of the tourist destinations located in Buleleng Regency, Bali Province, Indonesia. This beach is also a nesting place for one of the sea turtle species in Indonesia, which is olive ridley (*Lepidochelys olivacea*). The problem that exists on the island of Bali today is most of the land in coastal areas were experienced land degradation. This land degradation occurs due to human activities or natural factors, it harms the turtle nesting habitat around the coastal area of Bali Island. Conservation of nesting turtle habitat is needed through spatial analysis using Geographic Information Systems (GIS). This study uses the parameters of sand particle, beach slope, width beach, humidity, and temperature parameter to determine the suitability of the turtle nesting habitat. Penimbangan beach area which is very suitable for turtle nesting locations has an area of 163,45 m$^2$, suitable for laying eggs 4,886,44 m$^2$, and not suitable for laying eggs 10,201,64 m$^2$. The map of the suitability for laying turtle eggs is dominated by areas that are not suitable because the width of the beach is not too long and the humidity is still relatively high.

Keywords: Bali, Buleleng, GIS, sea turtle

1. Introduction

Olive ridley (*Lepidochelys olivacea*) is one of the six species of sea turtles in Indonesia, the types of sea turtles that exist in Indonesia are green turtles (*Chelonia mydas*), loggerhead turtles (*Caretta caretta*), hawksbill turtles (*Eretmochelys imbricata*), leatherback turtles (*Dermochelys coriacea*), and flat turtles (*Natator depressus*) [1]. The sea turtle population in Indonesia is estimated to decline due to the influence of anthropogenic characteristics such as coastal and marine pollution, destruction of nesting habitats and turtle feeding areas, disruption of migration routes, consumption and trade of turtles, and conversion of habitat as tourist attractions [2].

The island of Bali is a famous tourist area for both domestic and foreign tourists because it has a beautiful natural panorama. Penimbangan Beach is one of the tourist destination located in Buleleng Regency, Bali Province, Indonesia. This beach is also a nesting place for one of the sea turtle species in Indonesia, which is olive ridley (*Lepidochelys olivacea*).

The problem that exists on the island of Bali today is most of the land in coastal areas were experienced land degradation [3]. This land degradation occurs due to human activities or natural factors, it harms the turtle nesting habitat around the coastal area of Bali Island. One of the negative effects is changed the environmental conditions that previously had the potential suitable area of the olive ridley (*Lepidochelys olivacea*) egg-laying habitat. In addition, the negative impact of tourism activities is waste, this can damage the turtle nesting habitat and threaten its population [4]. Conservation is needed for turtle habitats so that the sea turtles can lay eggs and the conservation activities can be carried out by monitoring the habitats so that the sea turtles are maintained and protected from predators [5]. The area around Penimbangan Beach, Bali Island, has a community that
helps keep sea turtles laying their eggs. Routine monitoring needs to be carried out to determine the location of turtles laying eggs and the spawning season.

Several parameters affect the suitability of the turtle habitat such as sand particle, beach slope, width beach, humidity, and temperature [4, 6, 7]. This study uses the parameters of sand particle, beach slope, width beach, humidity, and temperature parameter scoring analysis to determine the suitability of the turtle nesting habitat [8]. Geographic Information Systems (GIS) can be used to analyze the suitability of the turtle nesting habitat as were done in previous studies such as habitat suitability for aquaculture [9, 10, 11, 12]. This study aims is to analyze the suitability habitat of the olive ridley sea turtle especially in Penimbangan Beach, Bali Island.

2. Materials and methods

2.1. Time and research location
This research was conducted at Penimbangan Beach, Buleleng Province, Bali from June 15–July 15, 2021. The several parameters taken from the field are to find out the actual conditions at Penimbangan Beach, Bali Island. This study uses field data parameters (in situ) and secondary data as supporting data. (Figure 1).

![Figure 1. Research location at Penimbangan Beach Bali.](image)

2.2. Data and tools
Tools used include ASUS X407UB Core i5 Laptop hardware equipped with ArcGIS 10.8, Microsoft Excel 2019, and Microsoft Word 2019. Tools used during field surveys include the Garmin 64s Global Positioning System (GPS), Digital thermometer hygrometer, and camera. Materials used include data Digital Elevation Model (DEM) National, Image Satellite Landsat 8, and Tidal (Geospatial Information Agency/BIG). The sources and information about the data used can be seen in Table 1.
### Table 1. Data source of turtle laying eggs habitat.

| Parameter                          | Data             | Resolution | Source |
|------------------------------------|------------------|------------|--------|
| Land Surface Temperature (LST)     | Landsat 8        | 100 m      | NOAA   |
| Beach Slope                        | DEMNAS           | 30 meter   | BIG    |
| Width beach                        | Sentinel 2       | 10 meter   |        |
| The size of sand (0.25 mm)         | Insitu           |            |        |
| Sand humidity                      | Insitu           |            |        |
| Nesting Location                   | GPS Insitu       |            |        |

2.3. Survey method
Data retrieval in this study used a field survey for the environmental parameters data and also interviews. The field data survey was used to determine the criteria for suitable environmental characteristics for sea turtles laying eggs habitat at Penimbangan Beach, Bali Island, supported by secondary data. A survey using the interview method was conducted to obtain testimonies from residents and collect information about the area of sea turtles laying eggs at Penimbangan Beach, Bali Island.

2.4. Data processing and analysis
Field data were taken at the Bali Turtle Conservation Center. These field parameters are used to determine the conditions of suitable parameters for turtle nesting sites, some of the parameters analyzed are sand particle, slope, beach width, humidity, temperature.

2.4.1. Sand
The size of the sand particle affects the turtle's ability to dig a nest. When the turtle digs it is not too hard and also does not slip easily. The size of sand particles suitable for laying turtle eggs is as follows in Table 2 [5].

### Table 2. Sand classification.

| Sand diameter (mm) | Classification | Skor |
|--------------------|----------------|------|
| 0,10-0,20          | Fine sand      | 2    |
| 0,21-0,50          | Medium         | 3    |
| 0,51-1,00          | Rough sand     | 1    |

2.4.2. Slope
The slope of the coast of 3–8% makes it easier for turtles to find a place to lay their eggs because it is not too steep to find a place to lay their eggs. Some turtle nests are located on a slope that is too low, this can cause sea air infiltration which will affect the air content in the nest. As a result, it will affect the humidity and temperature of the turtle nest in the turtle nest [9]. The results of the beach slope are adjusted to the classification of the beach slope and the right scoring for turtle nests (Table 3).

### Table 3. Slope classification.

| Beach slope (%) | Class        | Statement   | Score |
|-----------------|--------------|-------------|-------|
| 3-8             | Slope slightly | Suitable   | 2     |
| 8-16            | Sideway      | Very suitable | 3     |
| >16             | Steep        | Not suitable | 1     |
2.4.3. Beach width

The nesting beach area greatly affects the turtle's accessibility to reach areas suitable for making nests. The supratidal area is dry and is not affected by tides, making it easier for turtles to make nests. The width of the beach that is used as a turtle nesting place is between 20–80 m [10]. This data is taken from the tides using the Mean Sea Level method to get the lowest and highest tides so that the width of the beach is obtained [11].

2.4.4 Humidity

Humidity is a parameter that plays a role in the incubation period or hatching of turtle eggs, while sand media can store 20%–40% water with an effective water storage capacity of 20% [13]. The higher the humidity (> 40%) will cause the eggs to rot and if less (< 20%) the eggs will wrinkle (Table 4).

| Humidity | Category     | Score |
|----------|--------------|-------|
| 20-29 °C | Very Suitable| 3     |
| 30-40 °C | Suitable     | 2     |
| <20 atau >40 | Not Suitable | 1     |

2.4.5. Temperature

The high temperature causes the hatching results to be less than optimal because the optimal temperature of the turtle nest during incubation is 28°C–32°C. In addition, the relatively high temperature can cause the turtle eggs to dry out. There is temperature classification (Table 5) [7].

| Temperature | Category     | Score |
|-------------|--------------|-------|
| 29-32 °C    | Very Suitable| 3     |
| 26-29 °C    | Suitable     | 2     |
| <26 °C or >32 °C | Not Suitable | 1     |

Temperature data retrieved from satellite Landsat 8 OLI using Split Windows Algorithm. Landsat 8 OLI is equipped with Thermal Infrared Sensor (TIRS) attached in Bands 10 and 11. L8 level 1T data is data in the form of Digital Number (DN) to obtain Brightness Temperature (BT) radiometric correction must be carried out using the gain offset method to obtain Spectral data Light (Lλ) [14].

\[ L_\lambda = M_\lambda \times Q_{\text{Cal}} + A_\lambda \]  
\[ T = K2 (1 L_\lambda + 1) \]

\( L_\lambda \) is radian sensor (ToA) (W/(m².sr.μm)), \( M_\lambda \) is radiance_mult_band_n, QCal is DN value, and \( A_\lambda \) is radiance_add_band_n, where n is band number. \( M_\lambda, A_\lambda \) data contained in L8 metadata. Then, \( L_\lambda \) data is converted into BT data using the following equation. T is BT (Celvin), \( K1 \) and \( K2 \) is conversion constant a (contain in metadata L8) [14].

The survey was conducted to collect data on turtle nest points, it is used the purposive sampling method with consideration of sea turtle landing sites to lay eggs on the coast of the study area. The data collection technique used the interview method with the selected respondent, namely the Kelompok Masyarakat Pengawas (Pokmasw – environmental care community) in Penimbangan Beach, Bali Island. Meanwhile, secondary data was used to obtain some field parameter values that were used to analyze the effect of environmental factors on sea turtle nesting areas. Coastal slope data was obtained by extracting DEM data. Sand particle size data were obtained by taking a sample of sand and then sifting and measuring the sand particle using a sieve shaker. Land surface temperature data was obtained by extracting Landsat 8 OLI images using the Split Window Algorithm. Land use data were obtained...
from the interpretation of Landsat 8 OLI imagery. Data analysis was carried out using descriptive qualitative analysis and arranged in the form of scientific sentences systematically [15]. The data that was analyzed after carrying out the research was the characteristics of the turtle nesting habitat at the study site. The suitable predicted area of sea turtle habitat lying eggs was analyzed using a scoring method based on the weighting and scoring values for each biological and physical parameter, as shown in Table 6 below.

![Table 6. Parameter nesting olive ridley sea turtle.](image)

The suitability of the location of the turtle nesting habitat is determined by the formula proposed by [16, 17] as follows:

\[
\text{Interval} = \frac{\text{Max} - \text{Min}}{3} \tag{3}
\]

The criteria for the suitability of turtle nesting locations are as follows: (3) A score of >=1.6 (very suitable), (2) 1.5-0.5 (suitable), and (1) < 60% (not suitable; stations have severe limitations).

3. Results and discussion

3.1. Sand
Penimbangan Beach sand has a type of black sand. The substrate texture of olive ridley sea turtle nest at Penimbangan Beach is dominated by sand, which is more than 90% is gravel and silt with very small amounts. The average size of sand at Penimbangan Beach ranges from 0.1-0.5 mm (Table 7). The characteristics of the beach chosen by the turtle (L. olivacea) as a nesting site are fine sandy beaches with wide and gently sloping expanses and dark sand substrate [3].

![Table 7. Sand result.](image)
3.2. **Humidity**

Based on Pokmaswas data at Penimbangan Beach, humidity at Penimbangan Beach, Bali ranges from 60%–75% (Table 8). Turtle eggs are sensitive to dry environments, but high humidity is prone to fungal growth on eggshells. High humidity can be caused by high water content in the nest [10].

**Table 8. Humidity result.**

| Parameter | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 |
|-----------|---------|---------|---------|---------|---------|
| Humidity %| 60-70   | 60-70   | 60-70   | 60-70   | 60-70   |

3.3. **Slope**

Coastal slope data is obtained from DEM data which can be downloaded for free on the United States Geological Survey (USGS) website. This data is used to see the slope of the coast around the Penimbangan Beach. The results obtained at 5 sampling station points are at station point 1 the slope obtained is 7%, station point 2 is 2%, station point 3 is 8%, station point 4 is 10%, station point 5 is 5%. The following is the result of the slope map of Penimbangan Beach (Table 9).

**Table 9. Slope result.**

| Parameter | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 |
|-----------|---------|---------|---------|---------|---------|
| Slope (%) (3) | 7       | 2       | 8       | 10      | 5       |

The slope of the coast of 3–8% makes it easier for turtles to find a place to lay their eggs because it is not too steep to find a place to lay their eggs. Some turtle nests are located on a slope that is too low. This can cause sea air infiltration which will affect the air content in the nest. As a result, it will affect the humidity and temperature of the turtle nest in the turtle nest [7]. A beach slope is a favorite place by turtles as a gentle beach because it greatly affects the turtle’s accessibility to reach areas suitable for laying eggs. The steeper the beach, the greater the energy needed to get to the supratidal to lay eggs, and the more difficult it is for the turtle to see objects in front of it because the turtle’s eyes are only able to see well with an angle below 150° [18].

3.4. **Land surface temperature (LST)**

Land surface temperature data is obtained from data from the application of the Split Window Algorithm on band 10 Thermal Infrared (TIR) Landsat 8 OLI satellite imagery. This data is used to see the soil surface temperature around the Penimbangan Beach area. The results were obtained at 5 sampling station points. Station point 1 the ground surface temperature obtained is 26.61°C, station point 2 is 26.94°C, station point 3 is 27.92°C, station point 4 is 27.63°C, station 5 points is 26.95°C. The following is the result of the map of the ground surface temperature at Penimbangan Beach (Table 10).

**Table 10. Temperature result.**

| Parameter | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 |
|-----------|---------|---------|---------|---------|---------|
| Temperature (°C) | 26.61   | 26.94   | 27.92   | 27.63   | 26.95   |

The nest temperature suitable for hatching turtle eggs is 25°C–33°C, while others argue that the lowest and highest temperatures that give good hatching percentages are 28.5°C and 32.2°C [19]. A suitable temperature for the development of turtle egg embryos is between 24-33°C. The temperature will also determine the sex ratio of young turtles, turtles born from nests whose incubation temperature is between 28-29°C will most likely produce male turtles while the incubation temperature is between 30-31°C most likely will produce a female turtle [20].
3.5. **Width beach**

Width beach data retrieve from lowest tide and highest tide data using Mean Sea Level method. The results obtained at 5 sampling at station point 1 the width beach obtained is 19.04 m, station point 2 is 6.28 m, station point 3 is 15.61 m, station point 4 is 11.02 m, station 5 points is 12.28 m Table 11 below is the result of the map of the width beach at Penimbangan Beach.

| Parameter                  | Station 1 | Station 2 | Station 3 | Station 4 | Station 5 |
|----------------------------|-----------|-----------|-----------|-----------|-----------|
| Width beach (m)            | 19.04     | 6.28      | 15.61     | 11.02     | 12.28     |

3.6. **Suitable area**

Based on the suitability matrix data for turtle nesting parameters, it was found that the area along the coast of Penimbangan Beach is a suitable area for laying turtle eggs. This area is above the Mean Sea Level (MSL) area with a beach width ranging from 10-20 meters. Areas that are far from settlements have larger areas and are suitable for turtle nesting places.

The humidity of the turtle nest is relatively low during the day compared to the morning and evening. Nests located on slopes less than or equal to 3-8% tend to contain high humidity compared to nests located on slopes above 8%. It is suspected that nests located on a slope of less than 3% experience seawater intrusion because on a beach that is too slope there will be puddles of seawater due to the waves crashing on the beach. The humidity level of the sand in the turtle nest has a relationship with the conditions at high tide, this is related to the selection of laying places [21].

The following table (Table 12) results from the tabulation of data based on several parameters used to determine the suitability of environmental parameters as turtle nesting locations at the five points sampling location in Penimbangan Beach.

| Parameter                  | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 |
|----------------------------|---------|---------|---------|---------|---------|
| The size of sand (0.25 mm) | 0.1-0.5 | 0.1-0.6 | 0.1-0.7 | 0.1-0.8 | 0.1-0.9 |
| Slope (%)                  | 7       | 2       | 8       | 10      | 5       |
| Width beach (m)            | 19.04   | 6.28    | 15.61   | 11.02   | 12.28   |
| Temperature (°C)           | 26.61   | 26.94   | 27.92   | 27.63   | 26.95   |
| Humidity %                 | 60-70   | 60-70   | 60-70   | 60-70   | 60-70   |

Based on Figure 2 the results of the weighting and scoring of the turtle nesting suitability map, it was found that there were three categories of suitability, namely very suitable, suitable, and not suitable. In Penimbangan Beach, the area is very suitable for the turtle laying eggs is 163.45 m², the suitable area is 4,886.44 m², and the unsuitable area is 10,201.64 m². The map of the suitability for laying turtle eggs is dominated by areas that are not suitable because the width of the beach is not too long and the humidity is still relatively high. However, based on the available data, it shows that there is a suitable area for laying turtle eggs at Penimbangan Beach covering an area of 4,886.44 m² so that the turtles are found to lay eggs. Based on the results of interviews with Pokmaswas, it was found that the nesting location of the olive ridley turtles at Penimbangan Beach is in an area suitable for laying eggs from the turtles based on the map that has been made.
4. Conclusion

Penimbangan beach is one of the tourist destinations located in Buleleng Regency, Bali Island. This beach is also a nesting place for one of the sea turtle species in Indonesia, which is olive ridley (Lepidochelys olivacea). Several parameters that affect the nesting location of the sea turtle are sand grain size, slope, beach width, humidity, temperature. Penimbangan beach area which is very suitable for turtle nesting locations has an area of 163.45 m$^2$, suitable for laying eggs 4,886.44 m$^2$, and not suitable for laying eggs 10,201.64 m$^2$. The map of the suitability for laying turtle eggs is dominated by areas that are not suitable because the width of the beach is not too long and the humidity is still relatively high.

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