Diversity of macroalgae near sea turtle nesting in Pangandaran District, Indonesia

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Abstract. In the ecosystem, sea turtles have an important contribution to maintaining the stability of seagrass habitats and spreading nutrients in the ocean. The balance of marine ecosystems will be disrupted if sea turtle populations decline because sea turtles have an important role in maintaining coral reef ecosystems to remain productive in transferring important nutrients from the ocean to the coast. Sea turtles use significant amounts of energy during their nesting periods and promptly return to the ocean. Subsequently, they would seek out specific coastal locations as feeding habitats for recovery before embarking on their journey back to the ocean. The objective of the study was to observe the locations of macroalgae near the nesting area. The research was conducted at Karapyak and Legok Jawa Beach in Pangandaran, West Java, and used a survey method. Macroalgae data collection was based on a transect method. At Karapyak Beach Station, the macroalgae with the highest Important Value Index is *Hypnea flagelliformis* and at Legok Jawa Beach Station is *Ulva intestinalis*. Macroalgae diversity at Karapyak Beach indicated a medium category (1<H'<3) with a score of 1.94 while at Legok Jawa Beach Station indicated a low category (H'≤1) with a score of 0.68.

Key Words: conservation, sea turtles, feeding grounds, beach.

Introduction. According to Dermawan et al (2009), sea turtles are reptiles that survive in the ocean and are able to migrate over long distances across the Indian Ocean, Pacific Ocean, and Southeast Asia. Sea turtles are registered in the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) Appendix I list (Hidayat et al 2017). The Ministry of Maritime and Fisheries (MMAF) has decides that all sea turtle species in Indonesia's oceans must be protected under Government Regulation (PP) No. 7/1999 about Preservation of Plant and Animal Species (Manurung et al 2015). It means that all kinds of sea turtle trade, with either alive or dead, even with body parts, are illegal. With the decreasing population of sea turtles in the world, the marine ecosystem might become unbalanced (Ridhwan 2017). One of the things that can be done to conserve sea turtles is to protect their feeding grounds. Sea turtles have omnivorous dietary habits. According to Jiménez et al (2017), sea turtles have omnivorous feeding habits that tend to be carnivorous when juvenile. Otherwise, green turtles have a herbivorous diet (Bjorndal 1985). One of the food preferences of sea turtles is macroalgae. Macroalgae are omnipresent throughout the Indonesian marine waters, in particular 3 species: *Rhodophyta* (red algae), *Chlorophyta* (green algae), and *Phaeophyta* (brown algae) (Wiyanto & Purwanti 2020). In general, macroalgae grow on the bottom of the ocean on a substrate of sand, coral fragments, dead coral, and hard objects submerged on the seafloor (Yudasmara 2015). According to Pribadi et al (2017), the presence of macroalgae and seagrass communities is important for the ecosystem because in addition to being primary producers and food sources for herbivores, macroalgae can be a habitat for many types of marine biota.

The availability of macroalgae around turtle nesting areas will make it easier for the turtles to save energy after nesting. According to Godley et al (2002), if on the way around the coast there is no opportunity to feed, the strategy used by the turtle is to migrate directly to the last feeding site. However, in the Mediterranean, turtles do not swim directly to the last feeding site but migrate along the coastline to save energy for migration (Godley 2002). This research was conducted to identify the types of macroalgae diversity around sea turtle nesting habitat.

Material and Method. The current research used a survey method. The research was conducted at Karapyak and Legok Jawa Beach in Pangandaran, West Java. Data collection, processing and analysis were carried out in June-July 2023. Figure 1 shows the map of the research location. The selection of the location used a purposive sampling method. The macroalgae data collection method used the transect method that refers to English et al (1994), but the size of the quadrant and the distance of each interval has been modified. 10 sampling sessions were conducted using a quadrant transect (1x1 m) laid out on a 50 m transect line with 10 trials (Figure 2).

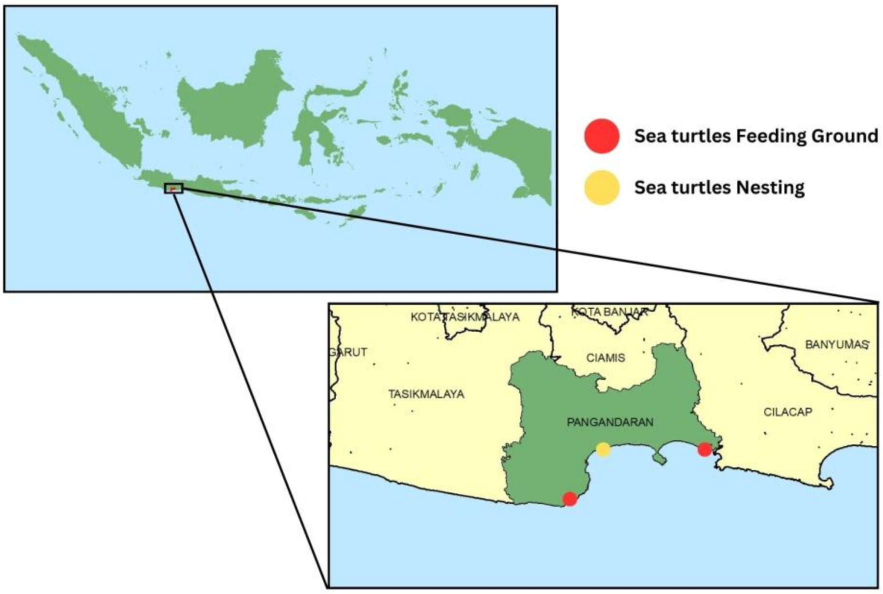

Figure 1. Research location in Pangandaran, West Java, Indonesia.

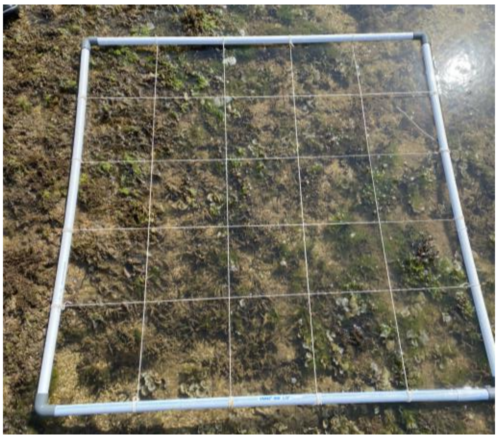

Figure 2. A quadrant transect.

Data analysis. The ecological indices (Important Value Index (IVI), relative density, frequency, and dominance), Shanon-Wiener diversity index and the dominance index by Simpson of macroalgae found in the area were determined and statistical analysis was performed to evaluate the diversity of macroalgae in Karapyak and Legok Jawa Beach. The first ecological index calculated was the Important Value Index (IVI), with the IVI formula as below (Hailu 2017; Molla et al 2023; Romoke et al 2018):

$$IVI = \text{Relative density} + \text{Relative dominance} + \text{Relative frequency}$$

Where:

Relative density: $\frac{Number\ of\ individuals\ of\ a\ species}{Number\ of\ Individuals\ of\ All\ Species}\ x\ 100$

Relative dominance: $\frac{Dominance\ of\ a\ Species}{Dominance\ of\ All\ Species}\ x\ 100$

Relative frequency: $\frac{Frequency\ of\ a\ Species}{Frequency\ of\ All\ Species}\ x\ 100$

Based on the IVI category, macroalgae with IVI 0-100% are classified in the low category, IVI 101-200% are in the medium category, and IVI 201-300% are classified in the high category (English et al 1994).

The diversity index was calculated as follows (Hailu 2017; Molla et al 2023; Romoke et al 2018):

$$H' = -\sum((pi\ x\ \ln(pi)))$$

Where:
H' - diversity index Shanon-Wiener;
Pi - ni/N;
ni - number of individual species;
N - number of individuals of all species.

The scoring criteria for the Shannon-Wiener Index are:

1. If $H' \leq 1$, the macroalgae diversity is low.
2. If $1 < H' < 3$, the macroalgae diversity is medium.
3. If $H' > 3$, the macroalgae diversity is high.

The dominance index was calculated as follows (Odum 1995; Sofiana etal 2022; Srimariana et al 2020):

$$C = \sum(Pi)^2$$

Where:
C - dominance index;
Pi - ni/N;
ni - number of individual species;
N - number of individuals of all species.

The scoring criteria for the dominance index value are as below:
1. $0.00 < C < 0.3$ = Dominance low
2. $0.31 < C < 0.6$ = Dominance medium
3. $0.61 < C < 1$ = Dominance high

Results and Discussion. The availability of macroalgae around the turtle nesting areas will make it easier for the turtles to save energy after nesting. In this research, two places were found that were thought to be turtle feeding grounds because macroalgae were found. In the research of Carrión-Cortez et al (2010), one of the macroalgae favored by sea turtles is *Ulva lactuca*. According to the data presented in Table 1, the macroalgae species *U. lactuca* and *Codium* sp. are found abundantly and distributed widely in Karapyak. Additionally, *U. lactuca* is also present at Legok Jawa. Sea turtles are likely to prefer consuming these macroalgae species, which is consistent with the findings of the Carrión-Cortez study conducted in 2010. Bugoni et al (2003) found *U. lactuca* macroalgae in the digestive tract of sea turtles in southern Brazil. In addition to green algae, according to Howell & Shaver (2021), *Sargassum* spp. is also one of the macroalgae consumed by sea turtles. In neritic habitats, the main diet of green turtles is algae and/or seaweed in a composition varying among the feeding grounds (Carrión-Cortez et al 2010).

Figure 3. Estimated migration of sea turtles to feeding grounds.

The description of Figure 3 is as follows: the red dot is the sea turtle nesting habitat at Batu Hiu Beach, the orange dot is the foraging area at Karapyak Beach, the yellow dot is the foraging area at Legok Jawa Beach, the orange line is the estimated migration path of sea turtles to Karapyak Beach, and the yellow line is the estimated migration path of sea turtles to Legok Jawa Beach. The distance traveled from the nesting habitat to the foraging area at Karapyak Beach is approximately 30.84 km and to Legok Jawa Beach is approximately 15.25 km. According to Godley et al (2002), the average distance to the feeding grounds for the was 1.776 km with a range of 274-1.730 km, while in Godley et al (2003), the distance to the feeding grounds was closer, namely 227-320 km for the loggerhead turtles. Other research studies on various loggerhead turtle nesting sites stated that the average distance traveled by loggerhead turtles to find food is between 545 to 1,000 km (Papi et al 1997). Based on these studies, both beaches could be feeding grounds for the sea turtles.

Macroalgae. At Karapyak Beach station, eight species were found in three phylae: Chlorophyta, Paeophyta, and Rhodophyta. In the Chlorophyta group, three species of macroalgae were found: *U. lactuca*, *Ulva intestinalis*, and *Codium fragile*. In the Peophyta group, three species were found: *Scytosiphon lomentaria*, *Sargassum* sp., and *Padina* sp. In the Rhodophyta group, two species were found: *Laurencia simillis* and *Hypnea flagelliformis*. At the Legok Java Beach station, only five species were found, from two groups: Chlorophyta and Rhodophyta. In the Chlorophyta group, two species were found: *U. lactuca* and *U. intestinalis*. In the Rhodophyta group, three types of species were found: *Rhodymenia skottsbergii*, *Laurencia similis*, and *Rhodymenia palmata* (Table 1). At Karapyak Beach station, a total of 552 individuals were found of the following species and distributions: *S. lomentaria* with 22 individuals, *H. flagelliformis* with 124 individuals, *U. lactuca* with 92 individuals, *Sargassum* sp. with 66 individuals, *Padina* sp. with 58 individuals, *Codium fragile* with 50 individuals, *U. intestinalis* with 113 individuals, and *Laurencia similis* with 27 individuals. At the Legok Jawa Beach station (Table 1) a total of 225 individuals were found with the following species and distributions: *U. intestinalis* 176 individuals, *U. lactuca* 2 individuals, *R. skottsbergii* 20 individuals, *L. similis* 26 individuals, and *Rhodymenia palmata* 1 individual.

According to the dietary habits of all turtle species in the world, only green turtles have herbivorous dietary habits (Bjorndal 1997). It means that green turtles prefer to consume macroalgae compared to other types of food. In research (Bugoni et al 2003; Carrión-Cortez et al 2010) stated that macroalgae were found in the digestion of green turtles, one of which is *Ulva* sp.

Table 1

Macroalgae found

No	Division	Macroalgae species	Karapyak beach station	Legok Jawa beach station
1	Chlorophyta	*Ulva lactuca*	✓	✓
2		*Ulva intentinalis*	✓	✓
3		*Codium fragile*	✓	-
4	Paeophyta	*Scytosiphon lomentaria*	✓	-
5		*Sargassum* sp.	✓	-
6		*Padina* sp.	✓	-
7	Rhodophyta	*Hypnea flagelliformis*	✓	-
8		*Laurencia similis*	✓	✓
9		*Rhodymenia skottsbergii*	-	✓
10		*Rhodymenia palmata*	-	✓

Important Value Index (IVI). Based on the results of the research, the macroalgae *H. flagelliformis* has the highest relative density, relative cover, relative frequency, and IVI compared to other macroalgae. All macroalgae in Karapyak Beach have an IVI below 100% (Table 2), which means they are included in the low IVI category. It means that all types of macroalgae found in Karapyak Beach have relatively the same role in the community.

Table 2

Important value index of macroalgae at Karapyak Beach

No	Macroalgae species	Di (%)	Rci (%)	Fi (%)	IVI (%)
1	*Scytosiphon lomentaria*	3.99	4.47	4.10	12.56
2	*Hypnea flagelliformis*	22.46	22.12	18.21	62.79
3	*Ulva lactuca*	16.67	18.35	16.14	51.16
4	*Sargassum* sp	11.96	10.82	16.37	39.15
5	*Padina* sp	10.51	8.47	4.36	23.34
6	*Codium fragile*	9.06	10.12	10.02	29.19
7	*Ulva intentinalis*	20.47	20.24	16.15	56.85
8	*Laurencia similis*	4.89	5.41	14.65	24.95

At Legok Jawa Beach Station, the macroalgae that has the highest relative density, relative cover, relative frequency and IVI values is *U. intestinalis*. Based on the IVI category, this macroalgae is included in the high IVI category (Table 3). It means that *U. intestinalis* species has a high contribution to the community. According to Aziz & Chasani (2020), the Important Value Index (IVI) describes the role of an algal species against other species in an algal community. The higher the IVI score of a species relatively to other species, the higher the contribution of that species to the community.

Table 3

Important value index of macroalgae at Legok Jawa Beach

No	Macroalgae species	Di (%)	Rci (%)	Fi (%)	IVI (%)
1	*Ulva intestinalis*	80.22	78.22	94.95	253.40
2	*Ulva lactuca*	0.75	0.89	0.02	1.66
3	*Rhodymenia skottsbergi*	8.21	8.89	2.04	19.14
4	*Laurencia similis*	10.45	11.56	2.89	24.89
5	*Rhodymenia palmata*	0.37	0.44	0.10	0.91

Diversity index. Diversity reflects the number of macroalgal species and the distribution of macroalgal individuals within each species. The diversity index can describe the level of stability of a community. The value of this index is influenced by the number of individuals of each macroalgae species and the total number of individuals of all macroalgae species (Zamani 2017). This index can also be used to identify water quality in an area (Aziz & Chasani 2020). The diversity index is presented in Table 4.

Table 4

Diversity index score

Station	*Diversity index*	*Criteria*
Karapyak Beach	1.94	Medium
Legok Jawa Beach	0.68	Low

Based on the results of the research, the diversity index score obtained for Karapyak Beach station is 1.94, in the category 2, which means a medium macroalgae diversity; the diversity index score obtained for Legok Jawa Beach station is 0.6, in the category 1, which means a low macroalgae diversity. This can be due to the small percentage of species and individuals found. According to Wilhm et al (2012), the highest diversity occurs when each individual comes from a different species.

Dominance index. The dominance score of a species in a community can be identified by the dominance index. A lower dominance score in a community can be interpreted by a low number of species that dominate, so that the community can become balanced (Aziz & Chasani 2020). The macroalgae dominance is presented in Table 5.

Table 5

Macroalgae dominance

Station	*Dominance index*	*Category*
Karapyak Beach	0.16	Low
Legok Jawa Beach	0.66	High

Based on the results of the research, the Karapyak Beach station has a dominance index score of 0.16 with a category of 1 that means the dominance at the station is in the low category. At Legok Jawa Beach station has a dominance index value of 0.66 that means the dominance of macroalgae at the station falls into the high category. At the station there is one macroalgae that really dominates, *U. intestinalis*.

Conclusions. Macroalgae diversity in Karapyak Beach represents a medium category ($1<H'<3$), with a value of 1.94. *H. flagelliformis* is a macroalgae frequently found on Karapyak Beach. Macroalgae diversity at Legok Jawa Beach represents a low category ($H'\leq 1$) with a value of 0.68. *U. intestinalis* is a macroalgae frequently found in Legok Jawa Beach. The occurrence and abundance of macroalgae in Pangandaran will have an impact on the conservation efforts of sea turtles. The macroalgae ecosystem will provide sustenance for the sea turtles during their post-nesting periods. All parties must prioritize the preservation of the macroalgae habitat and ecosystem.

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Conflict of interest. The authors declare no conflicts of interest.

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