

Invertebrate diversity in the intertidal zone of Lombang beaches, Sumenep, Madura according to area utilization

Vikry Nurul Iman^{1*}, Lise Chamisijatin¹ & Nurul Mahmudati¹

¹Program Studi Pendidikan Biologi, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Malang, Jl. Raya Tlogomas No. 246 Malang

*Corresponding author: vikryekstrada@gmail.com

ABSTRAK

Pantai Lombang telah mengalami banyak tekanan lingkungan akibat aktivitas manusia, saat ini dari kegiatan wisata, yang dapat menurunkan keanekaragaman hayati biotik pesisir, aspek penting bagi mata pencaharian penduduk setempat. Beberapa kelompok hewan dapat secara langsung terpengaruh oleh aktivitas tersebut, terutama beberapa invertebrata laut non-motil yang rentan terhadap aktivitas rekreasi dan/atau pengambilan secara tidak sengaja oleh wisatawan. Tujuan penelitian ini adalah untuk menemukan kelompok invertebrata di zona intertidal dan mendeskripsikan keanekaragaman invertebrata di zona intertidal di Pantai Lombang, Kabupaten Sumenep. Metode penelitian menggunakan transek sabuk pada tiga stasiun berbeda: area wisata, area tambak ikan, dan area yang kurang dimanfaatkan. Hasil penelitian menunjukkan bahwa invertebrata di area yang kurang dimanfaatkan memiliki indeks keanekaragaman dan keseragaman yang lebih tinggi dibandingkan dengan dua area lainnya. Area yang kurang dimanfaatkan juga dihuni oleh lebih banyak jenis dibandingkan dengan dua area lainnya. Kondisi ini mungkin berkaitan dengan DO yang lebih tinggi di area tersebut, dibandingkan dengan dua area lainnya. Hasil ini mungkin penting dalam pengelolaan keanekaragaman hayati di area pantai yang dimanfaatkan di Indonesia.

Kata kunci: *Avertebrata, Keanekaragaman, Pantai Lombang, Zona Intertidal*

ABSTRACT

Pantai Lombang had experienced many human-induced environmental pressure, presently from tourist activities, which may lower the coastal biotic biodiversity, an important aspect for the livelihood of local inhabitants. Some groups of animals may directly be influenced by the activities, especially some non motile marine invertebrates which are prone to recreational activities and/or tourist accidental picking. The purpose of this study is to find the group of invertebrates in the intertidal zone and describe the diversity of invertebrates in the intertidal zone in Lombang Beach, Sumenep Regency. The research method uses belt transect at three differing stations: the tourist area, fishpond area and a least utilized area. The result showed that the invertebrates in the least utilized area are higher in diversity and evenness index compared to two other areas. The least utilized area also inhabited with more species compared to two other area. This condition may relate to the higher DO in the area, compared to two other area. This result may be important in the management of biodiversity on utilized beaches area in Indonesia.

Keywords: *Diversity, Intertidal Zone, Invertebrates, Lombang Beach*

INTRODUCTION

Lombang Beach is a beach located in Sumenep Regency, Madura. Lombang Beach is in the eastern part of Sumenep, with coordinates 6°55'07"S and 144°03'54"E in Lombang Village, Batang-Batango District, Sumenep Regency. Its beautiful location and scenery make Lombang Beach one of the mainstay tourist destinations on Madura Island. Visitors to Lombang Beach are not limited to the beachfront; many also play in the water up to the beach area, especially the intertidal zone. Geographically, Lombang Beach is a sandy beach ecosystem. The physical structure of sandy beaches involves interactions between sand, waves, and tides that occur in the intertidal zone (Huda et al., 2017). The

intertidal zone is the area between the highest tidal zone and the lowest low tide zone, which is the transition area from ocean to land (Huda et al., 2017). Each beach has a different length of intertidal zone. Sloping beaches tend to have wider intertidal zones, ranging from 0 to 400 meters, while narrower beaches can have intertidal zones of approximately 100 to 200 meters (Yulianda, 2013). Because of its location in the transition area between ocean and land, it allows for the inhabitation of a wide group of invertebrates. According to Katili (2011; Tala et al., 2022), the intertidal zone boasts high faunal diversity due to varied environmental factors.

These varied environmental conditions allow the intertidal area of Lombang Beach to be a habitat for a diverse range of fauna. According to Triwahyuni (2016), the diversity of marine fauna and biota is high, from coelenterates, porifera, molluscs, crustacean, echinodermate, fishes, turtles, crocodiles, and mammals may be found in this environment, not to mention vegetation, including seaweeds (Leksono, 2011). The existence of fauna in the intertidal zone in tropical areas depends on environmental factors. The environmental conditions of the intertidal zone are very favorable for the growth of marine fauna because it is a place to live, shelter, and find food (Rumahlata, 2008). Presently, the high demand of tourist activities in Lombang Beach causing high environmental pressure on the coastal ecosystem. Tourist activities that cause environmental pressure on Lombang Beach include swimming, picnicking, camping, motorcycle racing, and the untreated discharge of shrimp farm waste into the sea. High environmental pressure in the intertidal zone can put pressure on the fauna living in this habitat (Jørgensen et al., 2019; Serena et al., 2020). Furthermore, research on the faunal diversity of Lombang Beach is limited, if not nonexistent. Furthermore, environmental pressure from tourist activities persists and can lead to habitat degradation, which in turn impacts the fauna living in the area. Environmental factors such as temperature, salinity, pH, and dissolved oxygen can also affect the diversity of invertebrates in the intertidal zone (Supratman et al., 2018). Because environmental pressure can impact invertebrates diversity in the intertidal zone, the result of this current research is important to access the biodiversity potential of the area under existing tourism activities pressure. The result may be important in promoting sustainable natural ecotourism in coastal areas, especially in small islands in Sumenep Regency.

METHODOLOGY

Research timeline and sample

This research was conducted from March 14, 2022, to October 7, 2024, at Lombang Beach, Sumenep Regency, Madura. The samples used in this study were intertidal fauna found at all stations on Lombang Beach.

Sampling technique

This study used purposive sampling. This sampling technique was used because the researchers only identified invertebrates in the intertidal zone. The sampling method used was the belt transect method. Sampling was based on differences in environmental conditions: Station 1 experienced significant human activity, Station 2 experienced shrimp ponds, and Station 3 experienced no human activity.

Research procedure

The procedure for this study included research preparation, namely preparing research tools and materials. The research implementation began with determining the research location and then determining sampling points (plots). The research site at Lombang Beach was divided into three stations: Station 1 (environmental conditions with high human activity), Station 2 (environmental conditions with shrimp ponds), and Station 3 (no human activity). Nine plots were created at each station, totaling 27 plots. The area of each observation station was 28 x 19 m². Data collection on invertebrates in the intertidal zone covered all invertebrates' species found in each plot. The samples were then cleaned with 70% alcohol, preserved with formalin, and placed in glass jars for further identification.

Abiotic data measurements were conducted at each station, representing all plots. These included temperature with a thermometer, pH with a pH meter, salinity with a refractometer, and DO with a DO test kit.

Data Analysis Techniques

The data obtained were then analyzed using the following formulas for diversity index, dominance index, and evenness index:

(1) Shannon-Wiener Diversity Index (H')

$$H' = \sum p_i \ln p_i$$

Where:

H' = Shannon-Wiener diversity index

p_i = Probability of importance of each species (n_i/N)

n_i = Number of individuals of species i

N = Total number of individuals i

The criteria for the Shannon-Wiener diversity index are as follows:

$H' < 1$ = Low diversity

$1 < H' < 3$ = Medium diversity

$H' > 3$ = High diversity

(2) Pielou's Evenness Index (E)

$$E = \frac{H'}{\ln S}$$

Where:

E = Pielou's evenness index

H' = Shannon-Wiener diversity index

S = Number of species

Determination of index criteria according to (Nurudin et al., 2013) are as follows:

$E < 0.4$ = Small population uniformity

0.4<E<0.6i = Medium population uniformity

E>0.6i = High population uniformity

(3) Importance Value Index

$$IVI = RA + RF$$

Where:

$$RA = \frac{Ai}{\sum A} \times 100\%$$

$$Ai = \frac{ni}{A}$$

Where:

RA : Relative abundance

Ai : Abundance of species-i

$\sum A$: Abundance of all species

ni : Number of individuals of species-i

A : Total area of sampling area

$$RF = \frac{Fi}{\sum F} \times 100\%$$

$$Fi = \frac{Ji}{k}$$

Where:

FR : Relative frequency

Fi : Frequency of species-i

$\sum F$: Frequency of all species

Ji : Number of plots with species-i

k : Total plot numbers

RESULTS AND DISCUSSION

We found 6 species of invertebrates, all invertebrates (**TABLE 1**): *Dardanus calidus* (Diogenidae), *Ovalipes* sp. (Ovalipidae), *Tivela stultorum* (Veneridae), *Perna viridis* (Mitilidae), *Volvarina* sp. (Marginellidae) and *Semiricinula tissoti* (Muricidae).

1. *Dardanus calidus* (Risso, 1827)

Dardanus calidus (Risso, 1827) is a solitary crustacean that is active at night and reproduces oviparously. It measures 10-12 cm in length and has three colors, dominated by pink, orange, and pink. The morphology of *Dardanus calidus* can be seen in **FIGURE 1**.



FIGURE 1. *Dardanus calidus* (Risso, 1827)

2. *Ovalipes ocellatus* (Herbst, 1799)

Ovalipes ocellatus has a transverse body shape with three pairs of walking legs and one pair of swimming legs located at the tip of the abdomen. There are six spines between the two eye stalks at the front. *Ovalipes* has a flat and slightly convex carapace with a hexagonal shape. The *Ovalipes* carapace is brownish yellow with nine sharp spines on the right and left sides of the carapace. The morphology of *Ovalipes ocellatus* can be seen in **FIGURE 2**.



FIGURE 2. *Ovalipes ocellatus* (Herbst, 1799)
(Sumber: Dokumen pribadi, 2024)

3. *Tivela stultorum* (Mawe, 1823)

Tivela stultorum (**FIGURE 3**) has a smooth shell with lines, clearly elongated ligaments, a shiny green to brownish periostracum, and a hard white to brown shell marked with brownish to purplish lines (Marquardt, 2023).



FIGURE 3 *Tivela stultorum* (Mawe, 1823)
(Sumber: Dokumen pribadi, 2024)

4. *Perna viridis* (Linnaeus, 1758)

Perna viridis (FIGURE 4) also known as the green mussel belong to bivalves' group. *Perna viridis* is 65-85 mm long, with a maximum length of 165 mm. Individuals of the Mytilidae family have a slender shell, a forward-curved umbo and a balanced shell, a brown tip (umbo), and a pale green periostracum (Fauzi et al., 2022). There are a pallial line and adductor muscles on the back that give it a kidney-like shape (Cappenberg, 2008).



FIGURE 4. *Perna viridis*

5. *Volvarina sp*

Volvarina sp. (FIGURE 5) is a small to very small sea snail. These snails can grow up to 8.8 mm in length (Zulfa, 2022).



FIGURE 5. *Volvarina sp*

6. *Semiricinula tissoti* (Petit de la Saussaye, 1852)

Semiricinula tissoti is a single-shelled mollusk. Its shell is largely composed of calcium carbonate, with the outermost layer covered by a periostracum and a horny substance. It has a hard shell, is slow-moving, and is slimy, so it rarely moves (Apriyani et al., 2022).



FIGURE 6. *Semiricinula tissoti* (Petit de la Saussaye, 1852)

Of the six species of invertebrates in Lombang Beach, only Station 3 had all 6 species, while Station 1 had only 2 species and station 2 had 4 species (**TABLE 1**). This result implies that the location with least human activity (Station 3) harbors most species, while location with most human activity, in this case tourism, has the least species. Location as fishponds (Station 2) has moderate species number, as the consequence of moderate human activity around all study areas. This is an indication that human activities may have a negative impact for the biodiversity.

Interestingly, the IVI number (**TABLE 1**) of Station 3 never the highest compared to Station 1 and 2. This is an indication that in Station 3, with the least human activity, no single species of invertebrate may dominate the area, while the reverse occur in Station 2 and 3.

TABLE 1. The survey results from 3 stations; Station 1 (high human activity), Station 2 (Fishponds) and Station 3 (no human activities)

Variables		Station 1	Station 2	Station 3
Water quality	Temperature (°C)	30.7	30.6	30.4
	Salinity (ppm)	31	30	31
	pH	8	8	8
	DO mg/L	4.5	4.3	6
Population	H'	0.23	1.09	1.45
	E	0.13	0.61	0.81
Importance Value Index	<i>Dardanus calidus</i>	0	521.7	439.2
	<i>Ovalipes</i> sp.	156.3	144.9	122.3
	<i>Tivela stultorum</i>	7031.3	1689.4	928.4
	<i>Perna viridis</i>	0	0	166.8
	<i>Volvarina</i> sp.	0	0	55.6
	<i>Semiricinula tissoti</i>	0	314.7	111.9

Shannon's index showed that Station 3 are more diverse compared to Station 2 and Station 1 (**TABLE 1**). This is a clear indication that area with least human activity is the best area for biodiversity, and conversely, area with high tourist activity harbors less biodiversity. This is similar to a study in Italy where high tourist and recreational activity have direct impact to biodiversity (Marzetti Dall'aste Brandolini, 2006).

Station 1 showed low evenness (Pielou's E = 0.13, **TABLE 1**). This means that the invertebrate community in high tourism activity is unbalanced and likely dominated by one or a few opportunistic species that have high abundances compared to others. It is seen that *Ovalipes* and *Tivela* are the only two invertebrates encountered in the Station 1 in high individual number. Station 2, where the fishponds are, representing moderate human activity shows moderate evenness (Pielou's E = 0.61; **TABLE 1**). The invertebrate community is somewhat unbalanced, but the individuals are more equitably distributed among species compared to the place with the 0.13 index. There is a less pronounced dominance by a single species. Station 3 showed high evenness (Pielou's E = 0.81). This is a well-balanced community where the relative abundances of the different species are very similar. No single species overwhelmingly dominates the others. Pielou's E confirms

the Shannon's H' , where area with low human activity has better population structure, where no species act as a sole dominants.

The diversity and evenness indices may be related to the environmental variables of the differing area. In **TABLE 1** we see that the temperature, salinity and pH are rather similar in three area. This is logical as these three variables are very much prone to water stirring by waves and current. However, it is most interesting that the dissolved oxygen (DO) in Station 3 is highest compared to lower Station 1 and 2. It is logical to say that the high IVI, high Pielou's E and Shannon's H' as the result of higher DO in Station 3. Or is it vice versa? The healthy invertebrate population in Station 3 leads to the healthier abiotic indices in that location. Should we measure the plant diversity (macroalgae, or seagrasses), we believe that the higher DO will correspond to higher plant biodiversity on the least human activity area. This is in accordance with another research that explicitly revealed that in coastal area, benthic infaunal functional diversity in regulating the biogeochemistry of nearshore sediments, including dissolved oxygen (Waldbusser et al, 2004).

Beach tourism growth has led to environmental issues like overcrowding, sand loss, and pollution, requiring sustainable policies. Nature-based recreation can harm biodiversity through vegetation trampling and disturbances, Management strategies like beach zoning could help limit visitor impacts and protect biodiversity (Chen & Teng, 2016). There is also a need for supporting participative and sustainable beach management (Coombes, Jones & Sutherland, 2008) to implement more sustainable beach utilization and biodiversity management. Lombang Beaches in Sumenep may be an ideal study site for the sustainable beach management study and implementation.

CONCLUSIONS

There are 6 species of invertebrates found in Lombang Beaches, Sumenep, Madura with the highest Shannon's H' and Pielou's E at the least human activity area. The Importance Value Index of species in Station 3 never the highest compared to the other Station, signifying there is no dominant species in the least human activity area. The high diversity and evenness of the least human activity area correlates with higher DO. This signifies the importance to manage biodiversity in the high demand of beaches as recreational and other purpose area.

AUTHOR CONTRIBUTIONS

V.N.I.: project conception; V.N.I., L.C., N.M.: methodology; V.N.I.: data analyses; V.N.I.: original manuscript draft; V.N.I., L.C., N.M.: manuscript review and editing. All author members must be named individually.

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CONFLICTS OF INTEREST STATEMENT

There are no conflicts to declare.

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