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Abundance and Distribution Pattern of Macroinvertebrates at Watu Lumbung Beach, Gunungkidul, Yogyakarta

Yunita Fera Rahmawati[1*], Rizka Apriani Putri[2], Tatag Bagus Putra Prakasa[3], Chrisshinta Iris Edhiningtyas[4], Lisa Agustina Hermawan[5]

[1,2,3,4,5]Universitas Negeri Yogyakarta, Indonesia

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***Correspondence mail:**
yunita.fr@uny.ac.id

ABSTRACT

This research aimed to determine the abundance and distribution of macroinvertebrates at Watu Lumbung Beach, Gunungkidul, Yogyakarta. The study was conducted in May 2022 using the quadratic transect method with a 1x1 m plot. Sampling was carried out at two randomly selected stations. The first station was located 50 meters from the Watu Lumbung reef, while the second station was 250 meters away, resulting in a 200-meter distance between the two stations. Data analysis involved calculating the Shannon-Weiner diversity index (H'). This study identified 16 species of macroinvertebrates at Watu Lumbung Beach, classified into 13 families and nine classes: Polychaeta, Malacostraca, Anthozoa, Echinoidea, Ophiuridae, Gastropoda, Polyplacophora, Pilidiophora, and Demospongia. The family Ophiocomidae, specifically Ophiocoma erinaceus and Ophiocoma scolopendrina, was the most abundant at both stations. The diversity level was moderate, with a Shannon-Weiner index value of 1.94.

Kelimpahan dan Pola Sebaran Makroinvertebrata di Pantai Watu Lumbung, Gunungkidul, Yogyakarta

ABSTRAK: *Penelitian ini bertujuan untuk mengetahui kelimpahan dan sebaran makroinvertebrata di Pantai Watu Lumbung, Gunungkidul, Yogyakarta. Penelitian ini dilaksanakan pada bulan Mei 2022 dengan metode transek kuadrat dengan ukuran 1x1m. Pengambilan sampel dilakukan pada dua stasiun yang ditentukan secara acak. Stasiun pertama terletak di dekat karang Watu Lumbung dengan jarak 50 meter, sedangkan stasiun kedua berjarak 250 meter dari karang, sehingga jarak antar stasiun adalah 200 meter. Analisis data dilakukan dengan menghitung indeks keanekaragaman Shannon-Wiener (H'). Pada penelitian kali ini diketahui kelimpahan makroinvertebrata di Pantai Watu Lumbung berjumlah 16 spesies, dikelompokkan dalam 13 famili, dan diklasifikasikan dalam sembilan kelas (Polychaeta, Malacostraca, Anthozoa, Echinoidea, Ophiuridae, Gastropoda, Polyplacophora, Pilidiophora dan Demospongia). Famili Ophiocomidae (Ophiocoma erinaceus dan Ophiocoma scolopendrina) merupakan spesies yang paling melimpah di kedua stasiun pengamatan. Keberagaman tersebut termasuk dalam kategori sedang dengan nilai 1,94.*

INTRODUCTION

Indonesia is a maritime country that maximally utilizes its sea waters for shipping and commerce activities (Siddiq et al., 2024). This is supported by Indonesia's topography, which consists of 3.25 million km^2 of water (63% of its territory) and a coastline stretching 95,181 km, encompassing more than 17,504 islands, earning it recognition as one of the world's

largest archipelagos (Rahim et al., 2024). One region in Indonesia abundant in water zones, particularly beaches, is the Yogyakarta Special Region, especially in Gunungkidul Regency (Rahmawati et al., 2024);(Misbahuddin, 2021).

According to data from the Gunungkidul Regency Tourism Office, in 2022, 62 beaches have been developed and utilized by local managers and residents as ecotourism destinations (Rizaldi et al., 2024). One such destination is Watu Lumbung Beach in Balong Village, Girisubo District. However, it still attracts very few visitors. This low interest is partly due to the steep and challenging access caused by rocky terrain (Tuttle & Stubbins, 2023) and the lack of optimized information about the beach's rich biodiversity and its benefits to the community (Rani et al., 2023).

Watu Lumbung Beach is situated between Wediombo Beach and Gunung Batur Beach. It juts into the sea, separated from the mainland, surrounded by karst hills. The beach is characterized by coral rocks scattered along the shore. According to residents, these rocks originated from Mount Batur, a nature reserve featuring terraces and green areas inhabited by long-tailed macaques. Another distinctive feature of the beach is the presence of two large rocks (Watu Lumbung) and a smaller one (Watu Semar) in the middle.

The coral ecosystem at Watu Lumbung Beach provides a habitat for various marine species. Similar studies in the Gunungkidul area, including Nglambor Beach, have identified species such as Mollusca (Monetaria sp., Conus sp., Nerita sp.), Arthropoda (Episesarma sp., Tiarinia sp.), Echinodermata (Ophiocoma sp., Echinometra sp., Holothuria sp.), Nemertea (Baseodiscus sp.), and Annelida (Nereis sp., Perinereis sp., Sabella sp.) (Nurcahyo et al., 2024);(Rahmawati et al., 2021). A study conducted by (Wulandari et al., 2022) at Krakal and Kukup Beaches revealed species from the phylum Coelenterata (Anthopleura xanthogrammica), Echinodermata (Echinometra lucunter, Echinometra mathaei), Arthropoda (Brachyura pilumnus, Ophiocoma erinaceus), and Mollusca (Melanoides tuberculata, Conus textile). Additionally, studies at Pok Tunggal Beach identified species from the echinodermata phylum, including two from the class Ophiuroidea (Ophiocoma erinaceus, Ophiocoma dentata) and three from the class Echinoidea (Echinometra oblonga, Echinometra mathaei, Echinothrix diadema) (Azizah et al., 2022). Rahmawati (2021), in Sepanjang Beach, Gunungkidul, several macroinvertebrate species were found, namely *Scylla serrata*, *Nereis virens*, *Ophioderma longicauda*, *Echinus esculentus*, and *Ophiopholis aculeata*. The findings of aquatic biota from various studies show that this beach in Gunungkidul has a high abundance.

Macroinvertebrates are animals that do not have a spinal structure and live naturally in the bottom substrate of seawater (indigenous residence). They can be seen directly without the help of special tools with a size <0.1 mm, while mature animals are about 3-5 cm (Budijastuti et al., 2023). Their diversity and presence are significantly influenced by habitat conditions, including current speed, turbidity, and vegetation within the substrate (Lemma et al., 2024). On rocky beaches like Watu Lumbung, physicochemical factors greatly impact macroinvertebrates, as they are sensitive to environmental changes such as tides, temperature, salinity, pH, and oxygen levels (Dodiya & Poriya, 2024). Therefore, macroinvertebrates indicate aquatic ecological health, with species abundance reflecting water quality (Leeuwis & Gamperl, 2022). Measuring macroinvertebrate abundance and diversity is essential for developing strategies to conserve aquatic biodiversity and ensure

sustainable distribution. This research assesses the abundance of macroinvertebrates at Watu Lumbung Beach, Gunungkidul.

METHOD

This study was conducted in May 2022 at Watu Lumbung Beach, Gunungkidul, Yogyakarta, at coordinates 8°11'9 "S 110°42'1 "E (Figure. 1).

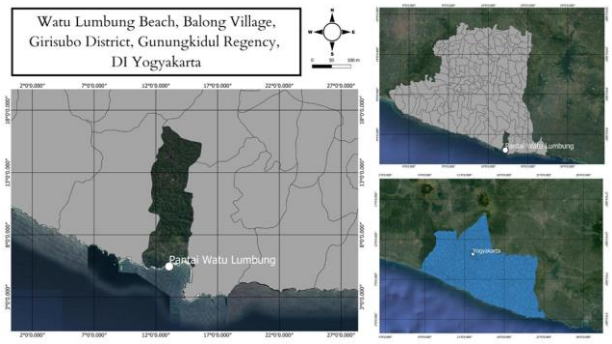

Figure. 1. Study Sites at Watu Lumbung Beach

Sampling was conducted in May 2022 from 12:00 to 16:00 WIB, coinciding with low tide conditions at the beach. Identification, description, and other data analyses took place in June 2022. Sampling occurred at two randomly selected stations: the first was 50 meters from the Watu Lumbung reef, and the second was 250 meters away, creating a 200-meter distance between the two stations. The tools and materials used in this study included shovels, tweezers, trays, cameras, stationery, and 70% alcohol.

Data collection involved sweeping both stations using a 1 × 1 m cylindrical pipe set and the quadratic transect method (Hauri et al., 2024). Quadrats were placed every 10 meters along the transect to collect macroinvertebrate samples. Preliminary data were gathered by observing and documenting macroinvertebrate fauna encountered during the sweep (Simaika et al., 2024).

The macroinvertebrate fauna observed were invertebrates larger than 0.5 mm (Koperski, 2023). Additionally, 2–3 individuals of each species were collected using hand sampling for further analysis. Based on the initial data, the species were identified, classified, and described according to their morphological characteristics.

During sample collection, pH and water temperature were measured at both stations. A thermometer was used to measure the temperature by immersing it in the water for approximately 5–10 seconds, while a pH meter, calibrated with a pH buffer, was used to measure the pH. The data collected through these methods were used to estimate species abundance (Rahmawati et al., 2024):

$$Magdalef\ Index\ (D) = S\text{-}1/LogN$$
$$Shannon\text{-}Wiener\ Index\ (H') = -\sum Pi \ln Pi$$
$$Pielou\ Index\ (e) = H'\ lnS$$

Annotation(s):
S : Total Number of Species
N : Total Number of Observed Individuals
ni : The Number of i individuals
Pi : ni/N

The proportion of the total number of individuals that a given number of individuals represents can be calculated using the following formula:

$$RA = ni/\mathrm{N} \times 100\%$$

Annotation(s):
RA : Relative Abundance
N : Total Number of Observed Individuals
ni : The Number of I individuals

Using the following formula, the distribution pattern of macroinvertebrate species can be established by estimating the mean value and standard deviation.

$$\mathrm{V} = \sqrt{2/n-1}$$

To calculate the mean value, the following formula can be used:

$$\mathrm{m} = \mathrm{n}/\mathrm{N}$$

Annotation(s):
V : Variant Value
n : Number of Individuals
m : Mean
N : Total Number of Individuals

According to Janah et al. (2021), there are three distribution patterns for individual organisms in nature: random, uniform, and clumped. These patterns provide the following outcomes:

v = m; the pattern of distribution random
v > m; the pattern of distribution clumped
v < m; the pattern of distribution uniform

Relative abundance determines the proportion of individuals to the total numbers. The following formula can calculate it.

RESULTS AND DISCUSSION

Observation Results

The current study identified a total of 118 species, with 16 species belonging to 13 families and nine classes, including Polychaeta, Malacostraca, Anthozoa, Echinoidea, Ophiuridae, Gastropoda, Polyplacophora, Pilidiophora, and Demospongia. The highest diversity of Echinodermata was observed in the family Ophiocomidae, specifically Ophiocoma erinaceus and Ophiocoma scolopendrina, at Watu Lumbung Beach. In contrast, the least abundant macroinvertebrate species were Portunus pelagicus (Portunidae), Drupella margariticola (Muricidae), Tonicella lineata (Tonicellidae), and Baseodiscus hemprichii (Valenciniidae). No previous records exist on the macroinvertebrate species found at Watu Lumbung Beach. The functional groups of macroinvertebrates identified at the beach are presented in Table 1.

Table 1. Functional Groups of Macroinvertebrates Found at Watu Lumbung Beach

Phylum	Class	Family	Species	Σ Individual
Annelida	Polychaeta	Nereidae	*Nereis virens*	3
Arthropods	Malacostraca	Coenobitidae	*Coenobita* sp.	5
Arthropods	Malacostraca	Portunidae	*Portunus pelagicus*	1
Cnidaria	Anthozoa	Poritidae	*Porites murrayensis*	2
Echinodermata	Echinoidea	Arbaciidae	*Arbacia lixula*	6
Echinodermata	Echinoidea	Arbaciidae	*Arbacia punctulata*	2
Echinodermata	Ophiuridae	Ophiocomidae	*Ophiocoma erinaceus*	42
Echinodermata	Ophiuridae	Ophiocomidae	*Ophiocoma scolopendrina*	35
Mollusca	Gastropods	Columbellidae	*Pardanilops testudinaria*	2
Mollusca	Gastropods	Conidae	*Conus coronatus*	6
Mollusca	Gastropods	Cypraeidae	*Monetaria annulus*	3
Mollusca	Gastropods	Muricidae	*Drupella margariticola*	1
Mollusca	Gastropods	Muricidae	*Semiricinula turbinoides*	3
Mollusca	Polyplacophora	Tonicellidae	*Tonicella lineata*	1
Nemertea	Pilidiophora	Valenciniidae	*Baseodiscus hemprichii*	1
Porifera	Demospongiae	Chalinidae	*Haliclona caerulea*	5

Based on observations, the bottom substrate in each plot of the research location is predominantly craggy, with some areas featuring seagrass substrates. Citraningrum et al. (2022) state that the type of bottom substrate is a significant factor influencing and indicating the presence of various macroinvertebrate species, as their adaptations to rigid substrates differ from those to softer ones. The craggy bottom substrate enables aquatic macroinvertebrate species to bury themselves by digging into the substrate, exhibiting sedentary behavior (Nugraha et al., 2023). This is evident from the identification of macroinvertebrate functional groups at Watu Lumbung Beach, where many macroinvertebrates from the phyla Arthropoda, Mollusca, and Annelida can burrow into the substrate, including the craggy areas. Kesuma et al. (2022) support this finding, noting that macroinvertebrates incapable of free swimming, such as species from the phyla Annelida, Mollusca, Platyhelminthes,

Nematoda, and Arthropoda, generally dig into bottom substrates.

Ophiocoma erinaceus was the most abundant species at collection stations 1 and 2. This species is often observed in coral crowns in deeper waters (Lesti et al., 2021). O. erinaceus typically inhabits coral heads, while other species are found among coral fragments and green alga Halimeda colonies. O. erinaceus can change its color (Afshar et al., 2023). It is generally black with an elongated body, thick and short arm spines, and cream-colored tube feet (Lawere et al., 2023).

It is the holotype species with a body diameter of about 17 mm, arm lengths up to 12 cm, and a disc diameter of 20 mm, characterized by a pentagonal shape with slight interradial notches. The dorsal disc is covered with granules measuring 0.15 mm in diameter. As a nocturnal and benthic species, O. erinaceus inhabits coral reef flats, sand-substrate seagrass areas, and coral fragments in shallow and sublittoral zones, including reefs, shoals, crevices, pits, and dead corals (Rostikawati et al., 2023).

Another species identified in this study was Ophiocoma scolopendrina, recognizable by its lighter and more varied ventral disc coloration. Its coloration is generally lighter underneath, with patchy or occasionally dark areas on top. This species has arm lengths reaching 13 cm and a disc diameter of 20 mm. With five arms, O. scolopendrina captures food particles from the water's surface during tidal movements (Mufida et al., 2023). It occupies benthic and littoral zones, often hiding in crevices of large rocks. As a member of the genus Ophiocoma, this species is distributed throughout the Indo-Pacific, commonly inhabiting intertidal rock pools and areas beneath boulders. Adapted to extreme conditions, O. scolopendrina tolerates temperatures up to 40°C and significant salinity fluctuations. This adaptability contributes to the widespread presence of both O. erinaceus and O. scolopendrina on Gunung Kidul's beaches, including Watu Lumbung Beach.

The high abundance of these species may result from the availability of their primary food sources, including suspended particles, organic material in the water, and bacteria attached to sediments. Consequently, these species play a crucial role in coral reef tropodynamics by linking decomposers, primary producers, and upper-level consumers.

The results of the calculations and analyses are presented in Table 2 below.

Table 2. Diversity, Evenness, and Abundance Index in the Watu Lumbung Beach.

Parameters	Value
Total number of individuals	118
Total number of species	16
Diversity index (H')	1.94
Evenness index (e)	0.70
Richness index (D)	0.21

Based on the diversity index calculation, the macroinvertebrates found on Watu Lumbung Beach have a diversity index value (H') of 1.94, which falls into the medium category. Diversity systematically describes the community's structure and helps interpret data on the quantity and types of organisms (Rahmawati, 2021). The number of species within a community affects the diversity and uniformity of the biota. This diversity value depends on the number of individuals of each species (Wilkaniec et al., 2021). Therefore, a greater number of species leads to higher diversity. The diversity index of aquatic macroinvertebrate species can serve as a benchmark for assessing the condition of marine ecosystems, as these species have a certain tolerance threshold for environmental changes and rely on the quality of their habitat to maintain body metabolism (Schultz, 2020).

The ecosystem of Watu Lumbung Beach appears relatively stable, which can be attributed to adequate food sources, suitable substrate conditions, and other environmental factors. The moderate diversity of macroinvertebrates at Watu Lumbung Beach also reflects a moderate level of productivity. According to Krebs, the beach's evenness (e) value is 0.70, indicating a well-distributed community. Overall, there is no dominant species at the research site, likely because several species were found with only one individual, resulting in a low dominance value.

Ophiocoma erinaceus was the most frequently observed species, with a relative abundance of 35.59%. Its high abundance is influenced by its compatibility with the ecosystem. Ophiocoma erinaceus primarily feeds on algae and typically inhabits rough or rocky terrains (Kundariati et al., 2020), which aligns with the research area's stony substrates covered in algae.

Figure 2 displays the results of the relative abundance calculations, revealing that a clumped distribution pattern is the most common. Populations are likelier to form clusters of various sizes to promote individual interaction. Local habitat factors also contribute to this pattern, causing organisms to cluster as a survival strategy in response to changes in food availability, climate, habitat, and reproduction (Regehr et al., 2021). However, the distribution patterns of four species—Baseodiscus hemprichii, Drupella margariticola, Portunus pelagicus, and Tonicella lineata—could not be evaluated due to the discovery of only one specimen each during sampling. Attempts to analyze their distribution returned a variance value of zero, making analysis impossible.

The relative abundance of a species is calculated by comparing the number of individuals of that species to the total number of individuals observed (Pangestu et al., 2023). Relative abundance and species richness are key to measuring the species diversity index. This measure is particularly useful in marine biota diversity studies because it estimates species abundance while reducing sampling effort, especially for species that are difficult to monitor or capture. Additionally, different indicators may show varying sensitivities to the same ecological parameters (Lanlan et al., 2024).

At the Watu Lumbung Gunungkidul Beach research site, the relative abundance calculation revealed the highest percentage, 35.59%, and the lowest, 0.85%. Temperature, food availability, biotic interactions, and environmental conditions influence these variations. Paquette & Hargreaves (2021) emphasized that relative abundance is closely related to habitat conditions. Moreover, relative abundance is significantly affected by the sampling techniques and the specific relative abundance index applied, as the effectiveness and performance of each model can vary.

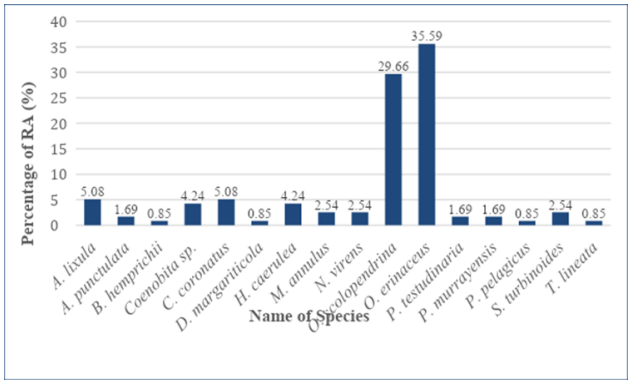

Figure 2. Relative Abundance of Macroinvertebrates Species from the Watu Lumbung Beach

Table 3 presents the findings of the distribution pattern.

Table 3. Macroinvertebrate Distribution Patterns in Watu Lumbung Beach

Species	V	M	Distribution pattern
Arbacia lixula	0.63	0.050	Clumped
Arbacia punctulata	1.41	0.016	Clumped
Baseodiscus hemprichii	0.00	0.008	-
Coenobita sp.	0.70	0.042	Clumped
Conus Coronatus	0.63	0.050	Clumped
Drupella margariticola	0.00	0.008	-
Haliclona caerulea	0.70	0.042	Clumped
Monetaria annulus	1.00	0.025	Clumped
Nereis virens	1.00	0.025	Clumped
Ophiocoma scolopendrina	0.24	0.296	Uniform
Ophiocoma erinaceus	0.22	0.355	Uniform
Pardanilops testudinaria	1.41	0.016	Clumped
Porites murrayensis	1.41	0.016	Clumped
Portunus pelagicus	0.00	0.008	-
Semiricinula turbinoides	1.00	0.025	Clumped
Tonicella lineata	0.00	0.008	-

Macroinvertebrates in the area exhibit clumped distribution patterns, as shown by the analysis of species such as Arbacia lixula, Arbacia punctulata, Coenobita sp., Conus coronatus, Haliclona caerulea, Monetaria annulus, Nereis virens, Pardanilops testudinaria, and Porites murrayensis. However, some species, like Ophiocoma scolopendrina and Ophiocoma erinaceus, display a uniform distribution pattern. Clumped or clustered distribution is the most common pattern because macroinvertebrates tend to settle in more favorable areas to sustain their existence (Chakraborty et al., 2022).

The spacing between individuals within a population is influenced by the need to avoid competition for natural resources. Environmental and social factors significantly affect distribution patterns, with clumped distribution being the most prevalent. Resource availability, dispersal, disturbances, and population dynamics shape species distribution. During high tide, the sampling of clumped distribution reflects the expanded seawater discharge and a broader sea surface, resulting in wider and higher sampling plots (Santos et al., 2021);(Zhang et al., 2024).

The observed distribution patterns reveal both clustering and uniformity. According to Bastille-Rousseau & Wittemyer (2022), individual clustering occurs due to habitat uniformity, leading to groupings in areas with abundant food. Generally, animals form groups to protect themselves from predators and other environmental threats. In aquatic ecosystems, the type of substrate at the bottom influences species distribution, as it provides food sources. Dewi et al. (2024) explain that differences in intertidal organism distribution patterns are often due to variations in the substrate of the waters they inhabit.

The environment is crucial in biological studies because it directly affects macroinvertebrate growth. During sample collection, pH and water temperature were measured to assess environmental conditions (Table 4).

The water temperature at Watu Lumbung Beach ranged from 31–36°C

during the study, which is unfavorable for supporting the existence of macroinvertebrates. This condition contributes to the low species abundance observed at the study site. Most invertebrates can tolerate water temperatures between 26–30°C (Bonacina et al., 2023). Temperature variations beyond this optimal range can negatively impact an organism's ability to grow and reproduce (Verberk et al., 2021). The water's pH was alkaline (>7), indicating acceptable water quality. Biological processes such as photosynthesis, temperature fluctuations, and oxygen levels influence water acidity. Changes in pH disrupt the balance of carbon dioxide, bicarbonate, and carbonate levels in the water. Waters with pH values between 6.6 and 8.5 are most productive and ideal for marine life (Arofah et al., 2021). This suggests that pH variations caused by chemical and biological processes, including the production of acidic and alkaline compounds and the influx of acidic waste from land, can impact water quality (Teng et al., 2021). The pH measured at Watu Lumbung Beach was classified as suitable for the survival of marine invertebrates.

Table 4. Habitat Parameters of Watu Lumbung Beach

Parameters	Range	Optimum
Water temperature (° C)	31.3 - 36.4	26 - 30
pH	7.7 - 8.4	6.6 -8.5

Physicochemical factors such as temperature, pH, and salinity significantly influence macroinvertebrates' distribution patterns and abundance. The correlation between environmental stress and fertility outcomes indicates that these chemical and physical factors affect organisms' development, metabolic activity, and immune responses (Chen et al., 2021). Further investigation is needed to understand the biodiversity of macroinvertebrates at Watu Lumbung, especially due to the site's limited accessibility. Additional research on other invertebrate species and their populations at the molecular genetic level would contribute to conservation efforts and biodiversity preservation in this area.

CONCLUSIONS AND SUGGESTIONS

This study identified 16 species of macroinvertebrates at Watu Lumbung Beach, belonging to 13 families and nine classes (Polychaeta, Malacostraca, Anthozoa, Echinoidea, Ophiuridae, Gastropoda, Polyplacophora, Pilidiophora, and Demospongia), with a diversity level categorized as moderate. Future research should be conducted repeatedly and over longer periods to obtain more comprehensive data. Repeated and extended data collection is necessary to accurately determine macroinvertebrates' abundance and distribution patterns in this area.

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