

Density and Functional Role of Zooplankton in The Coastal Waters of Bahu and Meras, North Sulawesi

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ABSTRACT

The city of Manado is surrounded by waters with a long coastline. Most of the coastline is used for human activities. These activities include tourist attractions, ports, and trade centres. The sustainability of these sectors is highly dependent on the health of the marine ecosystem. One organism that plays an important role in the aquatic ecosystem is zooplankton. This study aims to calculate the density of zooplankton and analyse its functional role. The method used was exploratory descriptive, which is a research pattern that describes in detail or comprehensively the condition or status of zooplankton phenomena. This study was conducted at Bahu Beach and Meras Beach, North Sulawesi. The density value at Bahu Beach is 307.35 ind/m³ and at Meras Beach is 222.4 ind/m³. Zooplankton identified from two sampling points belonged to the phyla Arthropoda, Foraminifera, Annelida, Mollusca, and Ciliophora. The total number of genera found was 22. There were 1,032 consumer I individuals, 798 consumer II individuals, and 193 consumer III individuals.

Key words: Bahu Beach; Functional; Meras Beach; Role; Zooplankton; Density

INTRODUCTION

The western part of Manado City is bordered by waters with a long coastline. Most of the coastline is used for human activities. These activities include tourist attractions, ports, trading areas and protected areas. Areas with different purposes are Bahu Beach and Meras Beach. Bahu Beach has undergone coastal reclamation, which is the conversion of coastal land into land. Development activities in the Manado Beach area continue to increase. Reclamation, through the addition of soil from hills or mountains on land, has caused physical changes to the land, which is then used to build shops, apartments, restaurants and hotels. The consequences of this development have resulted in soil erosion through rivers, which eventually reaches Manado Bay. The development of coastal reclamation and increased activity and population in the area can result in changes to the coastline, which in turn can lead to an increase in liquid and solid waste that will pollute rivers and Manado Bay, including Bahu Beach. This can affect the existence of marine organisms such as zooplankton (Liwutang et al., 2013).

Meras Beach still has a complete aquatic ecosystem, such as mangrove ecosystems, seagrass ecosystems and coral reef ecosystems, which support the aquatic ecosystem. Meras Beach is part of the Bunaken National Park conservation area and is classified as a traditional zone. A traditional zone is part of the KPA designated as an area for traditional use by communities that have a long-standing dependence on natural resources (Bunaken National Park Office, 2018). This area can be used by local residents as a fishing ground with simple tools. A comparison of the two locations can serve as a benchmark for future aquatic conservation efforts.

The coastal areas of Bahu Manado and Meras Beach are areas with significant economic and conservation potential through the fisheries, tourism and protection

sectors. The function and condition of each beach will be reflected in the situation of the organisms living on the beach, including zooplankton.

Plankton are organisms that float in water and have very limited mobility, so their movements tend to be influenced by currents (Hendrajat & Sahrijanna, 2019). Plankton are divided into two groups, namely zooplankton (animal plankton) and phytoplankton. Zooplankton are animal organisms that float and drift in water. Zooplankton are heterotrophic organisms, which means they cannot produce their own organic matter (Imran, 2016). Zooplankton are a group of microscopic organisms that float in water. Zooplankton is also one of the components in the food chain that is measured in relation to the production value of an ecosystem. This is because zooplankton plays a role as both a primary consumer and a secondary consumer, acting as a link between phytoplankton and nekton (Odum, 1998).

Research on zooplankton in the coastal waters of Bahu and Meras has not been widely conducted to understand zooplankton and its role in these areas. Thus, this study is expected to provide further understanding of the role of zooplankton and its functional role in the aquatic food chain. The results of this study are expected to be used as a basis for the management and conservation of the aquatic ecosystems of Bahu and Meras beaches.

METHODS

Tools and Materials

The tools used in this study were a plankton net with a mesh size of 100 μm and a wire diameter of 25 centimetres, sample bottles, a Bogorov chamber, microscope slides, cover slips, a camera, a microscope, dropper pipettes, filter bottles, thermometer, refractometer and lakmus paper. The materials used in this study were plankton in seawater and 4% Lugol's solution as a preservative.

Research Method

The method used is exploratory descriptive, which is a research pattern that describes in detail or comprehensively the condition or status of the research object phenomenon (Purba & Simanjuntak, 2011). Zooplankton, as the focus of this study, will be described in detail in terms of morphology, habitat and functional role in the aquatic ecosystem.

Data collection was carried out by taking seawater samples from Bahu Beach ($1^{\circ}27'46''\text{N}$ and $124^{\circ}49'20''\text{E}$) and Meras Beach ($1^{\circ}32'57''\text{N}$ and $124^{\circ}48'50''\text{E}$) (**Figure 1**). The water samples were then identified and the data processed at the FMIPA Unsrat Biology Laboratory. This research procedure consisted of five stages, namely determining the research location, collecting plankton samples, preserving samples, identifying plankton samples, and analysing data.

1) Determination of the research location

The research location method was carried out purposively, which is a method of selecting a research location by considering known reasons for the research area (Sugiyono, 2013). Meras Beach represents an area that is rarely touched by humans. This area is also sloping with a depth of about 20-50 cm, covered with seagrass and is part of the Bunaken National Park. Bahu Beach is an area that is heavily

influenced by humans. It is located on the edge of a restaurant. The area is covered with black rocks and has a depth of more than 2 metres.

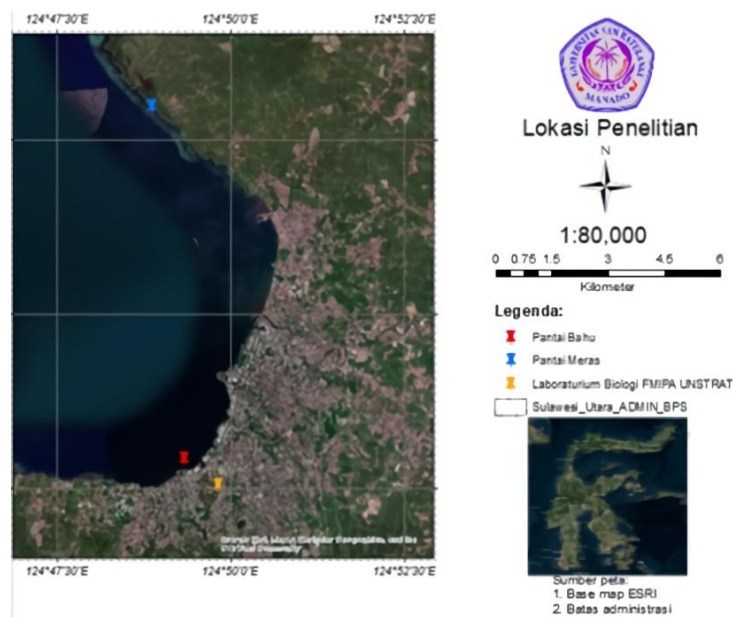


Figure 1. Research Location Map

2) *Zooplankton sampling*

Plankton samples were collected by netting water along the location. Zooplankton sampling was carried out using the sweep method. As the aim was to collect as much zooplankton as possible, the plankton net was directed along the location, starting from the water surface to above various substrates, sweeping randomly to filter as much water as possible. The screening distance is 50 metres at each station. Each station will collect one bottle of filtered plankton from the plankton net (Casas, 2017).

3) *Sample preservation*

The water samples that have been collected are then placed in 100 ml sample bottles. Three drops of 4% Lugol's solution are added to each sample bottle to preserve the samples and prevent damage to the highly vulnerable plankton (Tampubulon, 2020).

4) *Plankton sample observation*

The plankton sample observation stage for each repetition was carried out at the FMIPA UNSRAT biology laboratory. Water sample observation was carried out using a light microscope with magnifications of 40x, 100x and 400x.

5) *Identification of Zooplankton*

The samples that had been observed were then identified using plankton identification books (Hutabarat, 2001), zooplankton and phytoplankton identification books (Tamanampo, 2002) and the World Register of Marine Species. The samples were identified to the lowest possible taxon.

Data Analysis

Identified zooplankton genera will be described morphologically, in terms of habitat and functional role in the food chain and aquatic ecosystem, based on literature and sampling results.

The number of individuals observed and the density of zooplankton will be calculated for each identified genus. Based on this data, the most dominant species will be identified and comprehensive information will be provided. These results will be used as a comparison for each genus observed and the effect of its abundance on its ecological role in the aquatic ecosystem. The zooplankton density formula used in this study is as follows:

$$\text{Density (ind/m}^3\text{)} = N/V \text{ (UNESCO, 1968)}$$

The filtered water volume is calculated using the formula:

$$V = \text{Mesh mouth area} \times \text{Length travelled}$$

Explanation:

N = Number of individuals

V = Filtered water volume

RESULTS

Based on the measurement results, the physical and chemical parameters at both locations had different values. The survival of zooplankton in aquatic environments is greatly influenced by abiotic factors such as temperature, salinity, pH, light intensity, and dissolved oxygen concentration in the environment (**Table 1**). Zooplankton reproduction, metabolic activity, and gas solubility in water are influenced by temperature (Odum, 1998).

Table 1. Results of physical and chemical parameter measurements

Physical and Chemical Parameters		
Parameters	Meras Beach	Bahu Beach
Temperature	31°C	29°C
pH	6	7
saline	33‰	32‰

Zooplankton found at Meras Beach and Bahu Beach are generally divided into five phyla, namely Arthropoda, Foraminifera, Annelida, Mollusca and Cilliophora (**Table 2**). The most commonly identified zooplankton species belong to the Arthropoda phylum.

Table 2. Identified zooplankton species and their density

Phylum	Class	Order/Genus	Number	Density (ind/m ³)	Relative density (%)
Bahu beach					
Arthropoda	Copepoda	<i>Hastigerella</i>	71	29.9	9.43
		<i>Acartia</i>	56	22.8	7.44
		<i>Calanus</i>	97	39.5	12.88
		<i>Harpacticus</i>	132	53.8	17.53
	Malacostraca	<i>Mysis</i>	55	22.4	7.30
		Nauplius (Larvae)	74	30.2	9.83
		Branchiopoda	<i>Daphnia</i>	157	64.1

Phylum	Class	Order/Genus	Number	Density (ind/m ³)	Relative density (%)		
Foraminifera	Globothalamea	<i>Bolivina</i>	17	6.9	12.9		
		<i>Ammonia</i>	38	15,5	28,8		
		<i>Elphidium</i>	12	4,9	9,1		
Mollusca	Gastropoda		44	17,9	5,84		
<i>11</i>			753	307.35	100		
Meras beach							
Arthropoda	Copepoda	<i>Harpacticus</i>	17	6.9	3.12		
		<i>Calanus</i>	54	22.0	9.91		
		<i>Acartia</i>	26	10.6	4.77		
	Malacostraca	<i>Mysis</i>	23	9.4	4.22		
		Nauplius (larvae)	33	13.5	6.06		
		<i>Daphnia</i>	30	12.2	5.50		
Foraminifera	Tubothalamea	<i>Peneroplis</i>	16	6.5	2.94		
		<i>Sorites</i>	23	9.4	4.22		
		Globothalamea	<i>Bolivina</i>	17	6.9	3.12	
<i>Ammonia</i>	37		15.1	6.79			
<i>Elphidium</i>	32		13.1	5.87			
		<i>Planulina</i>	11	4.5	2.02		
		<i>Calcarina</i>	15	6.1	2.75		
		<i>Ammonia</i> (2)	8	3.3	1.47		
Annelida	Polychaeta	<i>Nereis</i>	18	7.3	3.30		
		<i>Platynereis</i>	17	6.9	3.12		
		Phyllodocida*	30	12.2	5.50		
		Phyllodocida (2)*	21	8.6	3.85		
		Mollusca	Gastropoda		53	21.6	9.72
				Bivalvia	44	18.0	8.07
Ciliophora	Spirotrichea	<i>Euplotes</i>	20	8.2	3.67		
<i>21</i>			545	222.4	100		

The asterisk (*) indicates that some samples could not be identified to the genus level.

Based on the density values obtained, Bahu Beach has a relatively higher density than Meras Beach due to different location characteristics. The density value at Meras Beach is 222.4 individuals/m³ and the density value at Bahu Beach is 307.35 individuals/m³ (Table 2). Bahu Beach has a higher density than Meras Beach due to two dominant types of zooplankton, namely *Daphnia* sp and *Harpacticus* sp.

Bahu Beach is a coastal area with high anthropogenic activity, particularly restaurants that discharge organic waste directly into the sea. This organic waste triggers eutrophication, characterised by an increase in bacterial biomass, phytoplankton, and the accumulation of fine detritus. These conditions provide an abundant food source for certain zooplankton, such as Harpacticoida (benthic copepods) and *Daphnia* (filter-feeding cladocerans), causing both to have high densities and dominate the zooplankton community at this location. Low salinity, abundant nutrients and phytoplankton, as well as tidal dynamics also have an impact on the life cycles of these two plankton (Belkahia et al., 2021). Harpacticoida are benthic copepods that are detritivorous-omnivorous, consuming organic detritus, biofilm, bacteria, and microalgae on substrates. Harpacticoida selectively graze on bacteria, diatoms, and ciliates, thus playing an important role in the utilisation of

biofilms in eutrophic waters (Wiackowski et al., 2017). Detritus is only highly nutritious for harpacticoids if it is enriched by microorganisms that generally thrive on organic waste (Anderson, 2017). The availability of restaurant waste on Bahu Beach makes the benthic substrate rich in detritus and biofilm, creating optimal conditions for the growth of the Harpacticoida population.

Daphnia are filter-feeding zooplankton that effectively filter phytoplankton, bacteria, and fine organic particles in the water column. Organic waste input from restaurants increases water fertility (eutrophication), leading to an increase in the population of bacteria and phytoplankton, which are the main food sources for *Daphnia*. *Daphnia* can function as a biological polishing unit in wastewater treatment because it can reduce turbidity, bacteria, and micro-particles (Serra et al., 2022). Several studies have shown that some *Daphnia* species are tolerant to brackish water conditions with low salinity, allowing *Daphnia* to survive in estuaries that are still dominated by fresh water before mixing completely with seawater. The presence of *Daphnia* in these estuarine areas is usually temporary and highly influenced by salinity fluctuations (García-Rodríguez, 2023).

The zooplankton density in the waters of Meras Beach is 222.4 ind/m³. This value reflects a fairly productive but stable environmental condition. Zooplankton is an important component in the marine food chain because it acts as a primary consumer that connects phytoplankton with higher trophic level organisms such as small pelagic fish. According to Sari et al. (2020), zooplankton density in Indonesian coastal waters generally varies between 150–400 ind/m³ depending on organic input and the physical-chemical conditions of the water. This is consistent with the results at Meras Beach, which show a value of 222.4 ind/m³, which is still within the normal range for a healthy tropical coastal ecosystem. The waters of North Sulawesi also have a zooplankton density range of 200–300 ind/m³ in areas with good environmental conditions (Yuliana et al., 2017).

The density value at Meras Beach can be explained by the existence of a complete coastal ecosystem consisting of mangroves, seagrass beds, and coral reefs. The mangrove ecosystem contributes organic detritus that serves as a source of nutrients, seagrass functions as a protective habitat and spawning ground for small biota, while coral reefs play a role in recycling nutrients through complex ecological processes. The stable availability of nutrients from these ecosystems encourages sufficient phytoplankton growth to support a balanced zooplankton population.

Functional Role

Based on the data obtained, the composition of the zooplankton community at both observation sites, namely Bahu Beach and Meras Beach, was classified according to consumer level or functional role in the aquatic food chain. This classification aims to analyse the trophic structure and understand the distribution of biomass at various energy levels. Zooplankton is divided into three main groups, namely Consumer I, Consumer II, and Consumer III (Table 3).

Table 3. Classification of zooplankton and their functional roles

Consumer Level	Amount
Bahu Beach	
Consumer I	642
Consumer II	439
Consumer III	99
Meras Beach	
Consumer I	390
Consumer II	359
Consumer III	94

1) Phylum Arthropoda

Genera in the phylum Arthropoda Most belong to the holoplankton group, such as *Harpacticus*, *Acartia*, *Daphnia*, *Hastigerella*, and *Calanus*. The genera *Daphnia* and *Hastigerella* are herbivorous zooplankton that consume phytoplankton as their main food source. These genera are categorised as primary consumers. In an aquatic ecosystem, their role is very important in connecting energy from the producer level to higher consumer levels (Sun *et al.*, 2023). The genera *Acartia* and *Calanus* are copepods that can eat phytoplankton, microzooplankton, and other organic particles. These two genera are often classified as level I–II consumers depending on their food composition (Svensen *et al.*, 2011). The genus *Harpacticus*, a copepod from the harpacticoid group, is commonly found in the benthic zone and feeds on detritus and algae. Due to its varied food sources, this zooplankton is categorised as a primary–secondary consumer (**Table 3**).

Nauplius is the early stage of many herbivorous crustaceans that feed on phytoplankton. Nauplii are classified as primary consumers. The genus *Mysis* undergoes a meroplanktonic phase before becoming a benthic organism. As omnivorous and carnivorous organisms, *Mysis* occupy a higher trophic level (II–III), preying on small zooplankton and other microscopic organisms (Svensen *et al.*, 2011).

This distribution of tropical roles illustrates the complexity of aquatic food webs. Genera such as *Daphnia* and *Nauplius* play an important role as primary consumers that transfer energy from phytoplankton to higher consumer levels. The genera *Acartia*, *Calanus*, and *Mysis* serve as connectors to larger predators such as fish and shrimp. These interactions between zooplankton are greatly influenced by environmental changes such as temperature, salinity, pH, and nutrient availability, which can affect the stability of the ecosystem as a whole (Serra *et al.*, 2022).

2) Phylum Foraminifera

Phylum Foraminifera consists of shelled protist organisms (test) that are mostly benthic, but some are meroplankton. Genera such as *Peneroplis*, *Sorites*, *Bolivina*, *Ammonia*, *Elphidium*, *Planulina*, and *Calcarina* are foraminifera that often act as meroplankton, especially in coastal habitats, estuaries, and tidal zones. Foraminifera are a food source for small invertebrates, fish larvae, and other benthic animals.

The genera *Peneroplis*, *Sorites*, *Elphidium*, and *Calcarina* fall into the category of primary consumers, indicating that they utilise low-level primary

food sources such as microalgae, diatoms, or fine organic detritus. *Peneroplis* and *Sorites* are miliolids commonly found in intertidal and lagoon habitats, feeding on phytodetritus and benthic microflora (Gupta, 1999). *Elphidium* and *Calcarina* are also dominant in shallow tidal or mangrove habitats and utilise microalgae and decomposed organic matter in surface sediments (Sariaslan, 2021).

The genera *Bolivina*, *Ammonia*, and *Planulina* are categorised as consumers I–II, meaning that these genera have a more flexible feeding strategy, consuming anything from phytodetritus to small microzooplankton or bacteria. This strategy allows for low-level adaptation to tropical–intermediate conditions, especially in tidal environments or environments with high detritus activity (Haynert et al., 2020).

3) Phylum Annelida

The phylum Annelida plays a very important ecological role in the structure and dynamics of food webs. Polychaeta exhibit a wide variety of feeding strategies, occupying various trophic levels. Some polychaete species act as filter feeders by filtering phytoplankton, organic detritus, and suspended particles from the water column, thereby connecting primary producers with higher-level consumers. Other species are deposit feeders, consuming organic particles from the seabed sediment, playing a role in nutrient recycling and maintaining substrate quality. Some polychaetes are predators that prey on small invertebrates, while a small number are parasites on other marine organisms (Kristian & Peters A, 1979). Genera such as *Nereis*, *Phyllodoce*, and *Platynereis* are classified as meroplankton, which are the larval phase of benthic organisms (Polychaeta) that are temporarily planktonic. These zooplankton play an important role as intermediate to high-level consumers in marine food webs, particularly in coastal and estuarine areas.

Nereis sp. is known as an omnivorous polychaete and actively feeds on various types of organic matter in estuaries. Research on its diet shows that it feeds on plankton, bacteria, and detritus, as well as small macrofauna such as amphipods. This highly varied diet pattern places *Nereis* as a medium to high level consumer (II–III) due to the presence of carnivorous components in their diet, such as protozoa or small zoobenthos (Jumars, 2015).

4) Phylum Mollusca

Gastropod larvae are known as veligers, which belong to the meroplankton group. These larvae swim freely and actively feed on planktonic microorganisms during this phase. Gastropod larvae are omnivorous and sometimes carnivorous. These larvae are categorised as secondary to tertiary consumers. Gastropod veligers feed on various particles, including phytoplankton and protozoa, making this class an important part of energy transfer to higher trophic levels (McEdward, 1997).

Bivalve larvae also include veligers, but have a different feeding method. Bivalves are filter feeders that actively filter phytoplankton from the water column, especially diatoms and nanoeukaryotes. Bivalve larvae filter about 75% of the plankton community from small phytoplankton groups, making Bivalvia an important component in phytoplankton population control (Lindeque et al.,

2015). Gastropod larvae are known as veligers, which belong to the meroplankton group. These larvae swim freely and actively feed on planktonic microorganisms during this phase. Gastropod larvae are omnivorous and sometimes carnivorous. These larvae are categorised as secondary to tertiary consumers. Gastropod veligers feed on various particles, including phytoplankton and protozoa, making this class an important part of energy transfer to higher trophic levels (McEdward, 1997).

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5) *Phylum Ciliophora*

Euplotes plays an important role in the microbial food chain and acts as a primary–secondary consumer. This zooplankton feeds on bacteria, detritus, and small microalgae (as a primary consumer) and can prey on other microorganisms such as small flagellates (secondary consumer). This zooplankton also serves as food for larger microscopic predators such as rotifers, small copepods, and nematodes (Serra et al., 2020). Euplotes sp. plays an important role in regulating the dynamics of the microbial food web through its control of phytoplankton and bacterial biomass, while also contributing to the regeneration of nutrients (C, N, P) into the water column (Li et al., 2024).

CONCLUSION

Zooplankton density at Bahu Beach was 307.35 ind/m³ and at Meras Beach was 222.4 ind/m³. *Daphnia* and *Harpacticus* were the dominant species in the waters of Bahu Beach, while no species dominated at Meras Beach. A total of 22 zooplankton genera were found, with 1,032 individuals classified as consumers I, 798 individuals as consumers II, and 193 individuals as consumers III.

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