The Meiofauna Abundance as an Indication of Pullution in Losari Beach, Makassar

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Abstract

The Research aimed to analyze the ecological value of meiofauna as a bioindicator of water quality in the coast of Losari Beach, Makassar. The total meiofauna abundance identified in the study was 66791 indv/m^2, composed of 12 phylum and 91 species or genera. Stations at the estuary of the Jeneberang, Tanjung Merdeka, and Tallo River estuaries are research sites with a high level of abundance, this condition allows the presence of organic contaminants produced by the surrounding anthropogenic activity which triggers the high growth of meiofauna in these locations. The ostracoda, oligochaeta, tunicata and ciliophora are phylums with a high level of abundance compared to other phylum meiofauna, because the phylum has a high adaptability to the entry of pollutant materials into the waters. The range of diversity and uniformity indices shows that the meiofauna species on the Losari Coast are categorized with high diversity. The range of the dominance index shows that there is no species was dominant, except in the research stations around the Losari Beach reclamation project.

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Keywords: Meiofauna, Abundance, diversity, dominant, Losari Coast Makassar

I. Introduction

As the result of the integration of several interconnected, dynamic, and productive ecosystems, coastal areas store an enormous amount of biodiversity and, therefore, require preservation. The aquatic resources are parts of the natural resources that are most widely used by the community. However, the exploitation remains to be neglectful of their sustainability, reducing their functions and qualities in the environment. The pollutants that directly or indirectly enter the coastal area endanger not only the lives of all biota but also the entire natural resources of coastal ecosystems, for instance, the threatsof degradations of mangroves, seagrasses, coral reefs, and aquatic animals (Elyazar *et al.*, 2007; Dahuri *et al*., 2008; Saeni, 2008).

The coastal zone of Losari Beach is one of the coastal areas in South Sulawesi that have great potential coastal and marine resources. Increased human activity or development in its surroundings deteriorates its condition to the threshold of alarming depletion of resource and ecosystem(Coremap, 2006) Some environmental parameters, e.g., physical and chemical characteristics, change slowly towards the negative category. Several studies show that the contents of dissolved heavy metals, namelylead (Pb), copper (Cu) and cadmium (Cd), have slowly exceeded the water quality standard and categorized the waters as polluted (Monoarfa, 2002; Werorilangi *et al*., 2011; Jaya *et al*, 2012; Setiawan, 2014).

In general, aquatic biota that can indicate water quality is benthic organisms, which are a community of microscopic to macroscopic invertebrates. This communitylives and remainsin seafloor environment for a long time. The use of benthic animals in water quality assessment is more effective and efficient, and it can function as a comparative data to the measurement of the physical and chemical characteristics of an aquatic environment (Arroyo *et al*., 2004; Hariyati,2007;Armenteros *et al*, 2009; Giere, 2009; Riena*et al*., 2012; Assy *et al*., 2013;Pratomo*et al*., 2013; Septiani *et al*., 2013; Anwari, 2015).

A benthic animal that can effectively indicate water pollution is meiofauna. Meiofauna defines a collection of organisms larger than microfauna but smaller than macrofauna. With a size range of 63-1,000 µm, these organisms can pass through a 1-mm mess, but they are retained by a 45-µm mesh (Moodley *et al*, 2000; Montagna*et al*., 2002; Gwyther&Fairweather, 2002; Gwyther, 2003;Zulkifli, 2008; Giere, 2009). Meiofauna is a biological component that can be used as an indicator of changes in water quality. There are some advantages of using it as a water quality bioindicator, namely: (1)this community of organisms has different sensitivity to various types of pollutants and provides a quick reaction to changes in waters; (2) due to its low mobility, it is easily influenced by the state of its surrounding environment; and (3) it is easy to capture and identify (Zulkifli, 2008; Giere, 2009; Moreno *et al*., 2011; Mirto *et al*., 2012; Alves *et al*., 2013).

2. Research Method

2.1 Research time and location

The study was carried out in July-September 2017 on the coast of Losari Beach, which stretches from the north to the south of Makassar City, South Sulawesi. This area represents the intensive human activity and development in the surrounding environment. The sampling sites werenine (9) research stations located nearby tourist attractions, hotels, beach reclamation projects, aquaculture practices, agricultural land in the upper part of the river, hospitals, ports, industrial areas, house-scale industries, and densely populated housing. The study area is presented in Figure 1.

2.2 Sampling Method

This study employed a purposive sampling method, i.e., the selection of samples based on specific objectives, on the aquatic substrate as the habitat of meiofauna. The study area was determined based on the previous research that described the coast of Losari Beach as an areacontaminated by dangerous chemicals and metal contents.

2.3 Statistical Analysis

The density of meiofauna on the coast of Losari Beach was determined using the following formula (Eq. 1):

$$K = \frac{10{,}000 \times a}{b} \qquad \text{(Eq. 1)}$$

K : the density of macrozoobenthos (individuals/m^2),
a : the total number of macrozoobenthos (individuals),
b : the opening of Ekman Grab(22.5 cm x 22.5 cm),
10.000 : conversion factor from $cm^2$to m^2 (Krebs, 1989).

The Diversity Index is a mathematical representation of the composition, abundance, and number of individuals or species in a particular community. It can also be interpreted as an ecological index that describes the diversity of a species inhabiting a region or habitat. The diversity index in a community can be calculated using the Shannon-Wiener's Index (Odum, 1994)The formula is as follows (Eq. 2):

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where H' is the diversity index, and $p_i$is the function of (Eq. 3):

where N :the total number of meiofauna, and
n_i :the number of individuals from the i-th species.

The Diversity Index can identifythe extent of water pollution or determine the water quality of an area or region. Water quality classification based on the diversity index is summarizedin Table 1.

Table 1.The criteria for water quality based on the Shannon-Wiener’s Diversity Index (Odum, 1994)

Values	**Water Quality Index**
>2.0	High diversity
1.6-2.0	Medium diversity
1.0-1.59	Low diversity
<1.0	Very low diversity

The Dominance Index mathematically describes the level of dominance of a species within a community. In this study, it was measured with the formula of the Simpson’s Index of Dominance (Eq. 4)(Krebs, 1989).

$$D = \frac{\sum n_i (n_i - 1)}{(N - 1)}$$

(Eq. 4)

Where D : Simpson’s Index of Dominance
n_i : the number of individuals per species
N : the total number of individuals of all species

The uniformity or evenness index is an ecological index that mathematically describes the evenness of an individual or species within a community that lives in a particular habitat. It can represent the balance in the division of the number of individuals per species. In this research, it was calculated using the formula of the HilisEvenness Index (Eq. 5) (Krebs, 1989).

Where E : evenness index
H' :diversity index
S : number of species

The evenness index of a population is between 0 and 1, and the classification is as follows:
- E> 0.6 :high evenness,

- 0.4 < E < 0.6 : medium evenness, and
- E< 0.4 : low evenness.

The one-way ANOVA aimed to examinethe significant differencesin the abundance of meiofauna atthe research stations (Mirto *et al.*, 2012). A statistically significant difference between the meiofauna abundances at all stationswas indicated by a significance level (ρ-value) of <0.05. Meanwhile, the Principal Component Analysis determined the abiotic variables (i.e., physical and chemical parameters) that affected the abundance of meiofauna.

3. Results and Discussion

3.1 The abundance and composition of meiofauna on the coast of Losari Beach

The total meiofauna abundance discovered during the research was 66,791 indv/m^2, consisting of 91 species or genera from 12 phyla (**Table 2**). Station I had a total meiofauna abundance of 3,209 indv/m^2, while Station II, III, and IV had 3,185 indv/m^2, 4,746 indv/m^2,and 5,100 indv/m^2, respectively. Station V had the lowest meiofauna abundance, i.e., 2,415 indv/m^2, whereas Station VI had the highest one, i.e., 16,239 indv/m^2. As for the remaining Station VII, VIII, and IX, the total meiofauna abundances were 10,909 indv/m^2, 10,118 indv/m^2,and 10,870 indv/m^2, respectively. Based on the phylum, the total meiofauna abundance was as follows: Aelosomatidae (40 indv/m^2), Ciliophora (1,902 indv/m^2), Gastrotricha (555 indv/m^2), Gnathostomulida (258 indv/m^2), Nematoda (751 indv/m^2), Nemertina (456 indv/m^2), Oligochaeta (25,562 indv/m^2), Ostracoda (31,945 indv/m^2), Polychaeta (1,286 indv/m^2), Sarcomastigophora (595 indv/m^2), Tunicata (2,905 indv/m^2), andTurbellaria (536 indv/m^2). In numerical order, the composition of the density of meiofauna was as follows: Ostracoda (47.828%), Oligochaeta (38.272%), Tunicata (4.349%), Ciliophora (2.848%), Polychaeta (1.925%), Nematoda (1.124%), Sarcomastigophora (0.891%), Gastrotricha (0.831%), Turbellaria (0.8309%), Nemertina (0.683%), Gnathostomulida (0.386%), andAelosomatidae (0.060%)(**Figure 2**).

Table 2.The Meiofauna Abundance on the Coast of Losari Beach

No	Phyla	Density (indv. m^{-2})									
		ST.I	**ST.II**	**ST.III**	**ST.IV**	**ST.V**	**ST.VI**	**ST.VII**	**ST.VIII**	**ST.IX**	**Σ**
1.	Aelosomatidae	-	-	40	-	-	-	-	-	-	40
2.	Ciliophora	238	297	159	20	99	119	120	692	158	1902
3	Gastrotricha	159	0	79	0	20	79	40	0	178	600
4.	Gnathostomulida	0	20	119	0	0	0	0	40	79	258
5.	Nematoda	20	0	79	158	178	0	0	0	316	751
6.	Nemertina	20	20	99	0	0	40	79	0	198	456
7.	Oligochaeta	218	1481	1402	1936	772	5747	4523	4583	4900	25562
8.	Ostracoda	1960	1168	1307	1840	970	9977	6007	4585	4131	31945
9.	Polychaeta	40	79	158	99	59	79	20	178	574	1286
10.	Sarcomastigophora	356	20	40	0	0	40	80	0	59	595
11.	Tunicata	0	20	1284	1047	158	79	40	0	277	2905
12.	Turbelaria	198	40	20	0	159	79	0	40	0	600
	Σ	3209	3185	4746	5100	2415	16239	10909	10118	10870	**66868**

The highest abundance was found at Stations VI, VII, and IX, while the lowest one was identified at Stations V and II. Compared with other phyla, Ostracoda, Oligochaeta, Ciliophora, and Tunicata had a high density, whereas Aelosomatidae had a low density. There was a significant difference in the average abundance of meiofauna in several research stations, as evident from F=7.584 and ρ-value=0.00 (<0.05). These results showed that the abundance of meiofauna phylum in every station was significantly different from each other or, in other words, without similarities. The Tukey's test resulted in three groups of meiofauna inhabiting the coast of Losari Beach (**Table 3**and**4**).The results of the one-way ANOVA affirmed the differences in the densities of meiofauna phylum at each station.

In general, Losari Beach is inhabited by true meiofauna, which is benthic organisms whose entire life cycle are in the form of meiofauna living at the bottom of the waters (permanent meiofauna). Ostracoda, Oligochaeta, and Ciliophoracan adapt to habitats containing the accumulation of organic and inorganic contents from the nearby land and aquatic environment. These phyla can live in a variety of habitat conditions, such as muddy environments or surfaces covered with fine sand or coarse sand. Ciliophora has cilia covering some or all parts of its body as an organ that helps its movement to find food or adapt to an unfavorable environment. In a polluted environment, Oligochaetais equipped with cysts on the walls of its body to anticipate anaerobic conditions (lack of oxygen) at the bottom of waters.Meanwhile, Ostracodahas adhesive threads to attach its body to benthic plants, sands, or other substrates (Giere and Pfannkuche, 1982; Hartmann, 1985).

Table 3.The Results of the One-way ANOVA of the Meiofauna Abundance along the Coast of Losari Beach

Abundance	Sum of Squares	Df	Main Square	F	Sig.
Between Groups	4.630E7	11	4209146.891	**7.584**	**.000**
Within Groups	5.328E7	96	555031.012		
Total	9.958E7	107			

Table 4.The Results of the Tukey's Test of the Meiofauna Abundance along the Coast of Losari Beach

	Phyla	N	Subset for alpha= 0.05		
			1	2	3
Tukey HSD[a]	Aelosomatidae	9	2.22		
	Gnathostomulida	9	11.00		
	Nemertina	9	13.22		
	Turbellaria	9	15.56		
	Gastrotricha	9	19.89		
	Sarcomastigophora	9	226.22	226.22	
	Nematoda	9	266.33	266.33	
	Polychaeta	9	336.67	336.67	
	Ciliophora	9	393.56	393.56	
	Tunicata	9	700.89	700.89	
	Oligochaeta	9		1389.44	1389.44
	Ostracoda	9			2223.33
	Sig.		.699	.056	.433

Some of the meiofauna have slender bodies and adhesive glands. Oligochaeta can even adapt to oxygen-deficient habitats using its rigid body shape with a few but large setae. The reproduction rates of Ostracoda, Oligochaeta, and Ciliophora are also high even in unfavorable environmental conditions. They can anticipate such adversities because they are hermaphrodite, bisexual, and even parthenogenic, i.e., asexual reproduction without the fertilization of two different sexes. Ciliophora can also regenerate by binary fission, i.e., the direct division of the nucleic cells of the body to giverise to two cells without the fertilization of two entities with different sexes (Corliss, 1972; Fenchel, 1987; Higgins and Thiel, 1988). Tunicata can adapt to an unfavorable environment by simplifying its internal organs to a very small shape and hermaphroditic form (i.e., having multiple sex cells for reproduction). The small gonadal sex is always carried on the lower side of the body until it becomes mature and develops into new individuals at any time (Higgins and Thiel, 1988).

Stations VI, VII, and IX represent the conditions in Jeneberang and Tallo Riversestuaries thatflow directly to the coast of Losari Beach. Stations VI and IX have a high abundance of meiofauna because organic pollutants, which trigger the high growth rate of meiofauna, are transported by both rivers and washed out by rainwater from the low-lying areas to the river mouth. The same case applies to Station VII, which illustrates the condition of Tanjung Merdeka Beach as the tourist attractions in Makassar City. This area is crowded with local tourists duringthe holidays and even on weekdays. The constructions of tourist-supporting facilities on and around the beach, such as villas, lodges with simple to luxurious amenities, semi-permanent buildings for recreation or rest, and cafes and food stalls, have started. The development at the tourism sites also plays a major role in the entry of organicwastes into the surrounding waters. These particles can cause a high abundance of meiofauna in this region.

Station V has a very low level of abundance. It illustrates the areas around Soekarno-Hatta Port, Makassar, which is the largest port in the eastern part of Indonesia. It is characterized by intensive development activities, busy maritime traffic, and port renovation to welcome the Indonesian government's Sea Toll Road Program. Station II also has a low abundance of meiofauna. It typifies the conditions nearby the hotels, restaurants, cafes, hospitals, house-scale industries, and handicraft and gold-crafting industries. These anthropogenic activities introduce inorganic wastes, e.g., hazardous metals, to the surrounding waters and cause a fatal impact on the growth of meiofauna (Monoarfa, 2002; Werorilangi *et al*., 2011; Jaya *et al*., 2012; Setiawan, 2014).

3.2 The Dominance, Diversity (Shannon-Wiener's), and Evenness Index

The dominance index of meiofauna in all stations ranged from 0.0507 to 0.1178 with an average of 0.0746±0.0217 (**Figure 3**and **4**). This range is close to 0, indicating the absence of dominant meiofauna species at each station. As for the diversity index, it ranged from 2.2653 to 3.0992 with an average of 2.8824±0.2009 (**Figure 3** and **4**). These figures represent the high diversity of the community of meiofauna inhabiting the research stations (Odum, 1994). A high diversity meansthat the meiofauna can adapt to disturbed and polluted environments caused by the entry of contaminants from the surrounding land or environment (Coull *et al*., 1992; Albuquerque *et al*., 2007).The evenness index varied between 0.7860 and 0.9459 with an average of 0.8673±0.0439 (**Figure 3** and **4**). These index values are close to 1, which indicates that the meiofauna species are diverse and evenly distributed, or in other words, there are no dominant species at the research stations(Krebs, 1989). However, Station III is an exception. It has a low evenness index due to the presence ofdominant meiofauna species.

3.3 The relationship between the physical-chemical parameters and the abundance of meiofauna on the coast of Losari Beach

According to the Decree of the Indonesian Ministry of Environment No. 51/2004, some of the physical-chemical parameters do not meet the standards for water quality. The Dissolved Oxygen (DO) is below its supposed level in waters. Meanwhile, the acidity (pH) and the phosphate and nitrate content at some of the research stations exceedt he threshold of their allowed presence in waters (**Table 5**).

Table 5.The Physical-Chemical Characteristics of Waters at the Research Stations

Parameters	Research Stations									Max. Limit*
	St. I	St. II	St. III	St. IV	St. V	St. VI	St. VII	St. VIII	St. IX	
Salinity	25	30	29	26	26	20	27	20	25	Natural
pH	9.98	7.52	7.48	7.8	7.42	7.15	7.7	7.78	7.98	7-8.5
Temp. (ºC)	30	28	31	28	32	33	30	32	33	Natural
Depth (m)	3.2	2.4	6	2	3	4	2.6	4	2	-
Current velocity(m s^{-1})	0.032	0.08	0.4	0.1	0.59	0.68	0.35	0.42	0.67	-
Brightness (m)	2	2	3	1	1.5	3.5	2.5	3.4	1.5	-
DO	4	3.4	5	3.2	5	5	5	3	5	>5 mgL^{-1}
Phosphate-seawater	0.03	0.12	0.0002	0.18	0.0003	0.005	0.0004	0.64	0.0024	0.015 mgL^{-1}
Phosphate-sediment	0.02	0.025	0.019	0.015	0.018	0.017	0.013	0.023	0.023	-
Nitrate-seawater	0.0006	0.02	0.0003	0.51	0.00021	0.09	0.0002	0.78	0.00023	0.008 mgL^{-1}
Nitrate-sediment	0.0014	0.001	0.0005	0.0006	0.0012	0.001	0.0006	0.0006	0.0006	-
Max. Limit*: Based on the Decree of the Indonesian Ministry of Environment No. 51/2004										

4. Conclusions

Ostracoda, Oligochaeta, Tunicata, and Ciliophorahave a high level of abundance on the coast of Losari Beach. These phyla are classified as true meiofauna, and they have high adaptability to water conditions that contain organic and inorganic contaminants generated by the anthropogenic activities on the surrounding lands.

The meiofauna species on the coast of Losari Beach are highly diverse, as evidenced by the diversity index (i.e., >2). The range of the evenness index of all stations is close to 1, indicating that the meiofauna species in the study area are very even. Meanwhile, the dominance index reveals the absence of dominant meiofauna species in the study area, except for the stations located in the reclamation area of Losari Beach. However, the high diversity index is not a guarantee of good water quality. It represents an alarming condition of water quality because most of the study area is only inhabited by meiofauna species that can adaptto seafloor environments that are contaminated by organic and inorganic materials.

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