The Ecological Analysis of Meiofauna as a Water Quality Bioindicator in the Coast of Losari Beach, Makassar

M S Yusal1,2, M A Marfai1*, S Hadisusanto4, N Khakim3
1Sekolah Tinggi Keguruan dan Ilmu Pendidikan Pembangunan Indonesia (STKIP-PI)
2Graduate School, Universitas Gadjah Mada
3Faculty of Geography, Universitas Gadjah Mada
4Faculty of Biology, Universitas Gadjah Mada
arismarfai@ugm.ac.id

Abstract. This research aimed to analyze the ecological assessment of meiofauna on the coast of Losari Beach, Makassar. Increased community activity is a trigger of the decline in the water quality surrounding the coast of Losari Beach. Meiofauna is a benthic organism can be used as an indicator of water quality. The purposive sampling is a method in this study. The stations located close to hotels and restaurants showed a high level of abundance because the anthropogenic activities occurring in them generated organic material contaminants that triggered the vast growth of meiofauna in the location. Compared to other phyla included in meiofauna, ostracoda, oligochaeta, and sarcomastigophora existed in higher abundance due to their high adaptability to any contaminating materials entering the waters. The meiofauna species in the coast of Losari Beach were highly diverse with no species prevailing in each observation station. The total meiofauna abundance identified in this study was 40,734 individuals/m2, composed of 10 phyla and 116 species. The range of the evenness index also indicated that the meiofauna species was quite even and affirmed that no species was dominant. This research found the physical and chemical parameters significantly influenced the abundance of meiofauna in the aquatic substrates.

1. Introduction
Types of pollutants that enter the coastal area endanger not only the lives of all biota but also the natural resources of coastal ecosystem both directly and indirectly, for instance, the threats of degrading mangrove, seagrass, coral reef, and benthic fauna [4, 5, 9]. Water biota that can be used as an indicator of water quality is from the groups of invertebrates. These species live most of their lifetimes in aquatic environments, and they are easily identifiable due to their microscopic-to-macroscopic size. Along with physical and chemical parameter measurements, the use of benthic organisms in water quality assessment is more effective and efficient [1, 2, 9, 18-20].

One type of benthos that can indicate water pollution effectively is meiofauna. Meiofauna is defined as a group of organisms larger than microfauna but smaller than macrofauna. This organism is 63-1000 μm in size, which can pass through a 1-mm mesh but is retained by a 45-μm mesh [7, 8, 14, 15, 22, 24]. It is a biological component that reflects changes in water quality.

The coast of Losari Beach is a valuable asset for the government of Makassar City. This zone becomes the center of attention as the local government attempts to develop it into a center for
business and tourism industry that can raise the Net Regional Revenue of the city. The water quality in this coast is, however, deteriorating due to an increase in community activities and development in the surrounding areas, which generates domestic wastes from hotels, tourism activities, aquaculture and agricultural practices, hospitals, industries, and gold crafting. These various activities have made the water quality on the coast of Losari Beach in an alarming stage [11, 13, 21]. The study assessed the ecological value of meiofauna as a bioindicator of water quality on the coast of Losari Beach, Makassar.

2. Methods
2.1. Research time and location
The research was carried out in March-April 2007 on the coast of Losari Beach, which spans from the north to the south of Makassar City. The study area depicts the substantial development activity in Makassar as the provincial capital of South Sulawesi. The sampling point consisted of nine (9) observation stations, which were located nearby the industrial sites, tourism objects, aquaculture areas, hotels, the river upstream of agricultural land, hospitals, ports, and densely populated housing. The identification of meiofauna according to book and binocular microscope [10]. The research location is presented in the following Figure 1.

![Figure 1. The map of the study area](image)

2.2. Statistical analysis
The density of meiofauna in the coast of Losari Beach was identified using the following formula (Eq. 1):

\[
K = \frac{10,000 \times a}{b}
\]

\(K\) : the density of meiofauna (individuals/m²), 
\(a\) : the number of meiofauna (individuals), 
\(b\) : the opening of Ekman Grab (22.5 cm x 22.5 cm), and 
10,000 : conversion factor from cm² to m² [12].
This research employed the Simpson’s dominance index to determine whether at least one of the species dominated the meiofauna in the study area. The equation is as follows (Eq. 2) (Krebs, 1989).

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

(2)

As for the evenness index, the researchers used the Hills Evenness Index with the following formula (Eq. 3) [12].

\[ E = \frac{H'}{\ln S} \]  

(3)

The evenness index of a population ranges from 0 to 1 with the following criteria:
- E> 0.6 : high evenness,
- 0.4 < E < 0.6 : medium evenness, and
- E< 0.4 : low evenness.

In addition to dominance and evenness indices, the research also relied on the Shannon-Wiener index to assess species diversity (Eq. 4) [16].

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

(4)

where \( H' \) is diversity index and \( p_i \) is calculated as (Eq. 5):

\[ p_i = \frac{n_i}{N} \]  

(5)

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

Diversity index can indicate as to what extent the water has been polluted. In other words, it determines the water quality of an area or region. The basis of water quality assessment is the value of the diversity index, which is presented in the following Table 1.

| Diversity Index | Water Quality Criteria |
|-----------------|------------------------|
| >2.0            | High diversity         |
| 1.6-2.0         | Medium diversity       |
| 1.0 - 1.59      | Low diversity          |
| <1.0            | Very low diversity     |

The Analysis of Variance (ANOVA) examined the differences in the abundance of meiofauna at each observation station. A significant difference was considered when the significance probability value was less than 0.05 (\( p < 0.05 \)).

3. Result and Discussion

3.1. The Density and Composition of Meiofauna in the Coast of Losari Beach

The total abundance of meiofauna identified during the research was 40,734 individuals/m², which comprised 10 phyla and 116 species and genera. As presented in the lowermost row in Table 2, the abundance of meiofauna identified in the nine stations varies between 2,476 indv/m² and 11,063
indv/m². The meiofauna phyla identified in this research were aelosomatidae (99 indv/m²), ciliophora (3,030 indv/m²), gastrotricha (179 indv/m²), gnathostomulida (140 indv/m²), nematoda (2,036 indv/m²), oligochaeta (12,505 indv/m²), ostracoda (20,010 indv/m²), polychaeta (3,542 indv/m²), sarcomastigophora (6,308 indv/m²), dan turbellaria (2397 indv/m²). The composition of the density of meiofauna from the highest to the lowest was as follows: ostracoda (39.714%), oligochaeta (24.819%), sarcomastigophora (15.520%), polychaeta (7.030%), ciliophora (6.014%), turbellaria (4.757%), nematoda (4.041%), gastrotricha (0.355%), gnathostomulida (0.278%), and aelosomatidae (0.196%) (Figure 2).

Table 2. The abundance of meiofauna in the coast of Losari Beach.

| No | Phyla                  | ST.1 | ST.2 | ST.3 | ST.4 | ST.5 | ST.6 | ST.7 | ST.8 | ST.9 | ∑    |
|----|------------------------|------|------|------|------|------|------|------|------|------|------|
| 1  | Aelosomatidae          |     | 99   |     |     |     |     |     |     |     | 99   |
| 2  | Ciliophora             | 375 | 356 | 119 | 673 | 179 | 218 | 257 | 60   | 793  | 3030 |
| 3  | Gastrotricha           |     | 99  |     |     |     |     |     | 40   | 40   | 179  |
| 4  | Gnathostomulida        |     |     |     |     |     |     | 20  | 40   | 80   | 140  |
| 5  | Nematoda               | 889 | 771 | 218 |     |     |     |     |     | 158  | 2036 |
| 6  | Oligochaeta            | 514 | 673 | 2844| 1344| 593 | 1560| 987 | 1238 | 2252 | 12505|
| 7  | Ostracoda              | 729 | 2887| 40  | 1425| 813 | 755 | 4329| 849  | 1643 | 20010|
| 8  | Polychaeta             | 514 | 1068| 258 | 198 | 613 | 40  | 692 | 80   | 3542 |      |
| 9  | Sarcomastigophora      | 1383| 1384| 1147| 278 | 633 | 178 | 671 | 317  | 317  | 6308 |
| 10 | Turbellaria            | 119 | 1462| 40  | 40  | 60  | 80  | 178 | 338  | 80   | 2397 |
|    | ∑                      | 11063| 6762| 6227| 4236| 2476| 3424| 6502| 4034 | 5522 | 40734|

Figure 2. The phylum composition of meiofauna in the coast of Losari Beach

The highest abundance was found in Station 1, while the lowest one was in Stations 5, 6, and 8. Among the phyla identified in this research, ostracoda, oligochaeta, sarcomastigophora, dan ciliophora had the highest density, whereas aelosomatidae had the lowest one. There was a significant difference in the abundance of meiofauna in several observation stations, as evidenced by F-value= 7.584 (p=0.00<0.05). These results showed that the abundance of each meiofauna phylum in every station had no similarity and that they were significantly different. Furthermore, the Tukey’s test revealed that three groups of meiofauna inhabited the coast of Losari Beach (Table 3). The ANOVA results were also supported by the different densities of the meiofauna phyla existing in each observation station.

Located nearby the hotels in Losari Beach, Station 1 had a high level of meiofauna abundance. The organic waste generated by the surrounding hotels and restaurants induced the vast growth of
meiofauna at this station. Station 5 had very low abundance. It was located close to the Soekarno-Hatta Port, the largest port in eastern Indonesia. This site was surrounded by intensive development activities, busy traffic in the harbor, and the intensive port renovation to welcome the Indonesian government’s Sea Toll Road program.

Table 3. The results of the Analysis of Variance (ANOVA) on the abundance of meiofauna in the coast of Losari Beach

| Phyla                  | N   | Subset for alpha = 0.05 |
|------------------------|-----|------------------------|
|                        |     | 1         | 2   | 3     |
| Tukey HSD             |     |           |     |       |
| Aeolosomatidae        | 9   | 11.00     |     |       |
| Gnathostomulida       | 9   | 15.56     |     |       |
| Gastrotricha          | 9   | 19.89     |     |       |
| Nematoda              | 9   | 226.22    | 226.22 |     |
| Turbellaria           | 9   | 266.33    | 266.33 |     |
| Ciliophora            | 9   | 336.67    | 336.67 |     |
| Polychaeta            | 9   | 393.56    | 393.56 |     |
| Sarcomastigophora     | 9   | 700.89    | 700.89 |     |
| Oligochaeta           | 9   | 1389.44   | 1389.44 |     |
| Ostracoda             | 9   | 2223.33   |     |       |
| Sig.                  |     | .699      | .056 | .433  |

Station 6 also showed a low abundance of meiofauna. It was located at the mouth of Jeneberang River that flanked the coast of Makassar City on the south. This river flows directly out to the coast of Losari Beach. The low abundance at the station was caused by Jeneberang River and rainwater that carried organic and inorganic pollutants in the downstream area to the river mouth. This finding is in line with [23], which state that anthropogenic activity is also a contributor to the hazardous pollutants in the northern and southern parts of Makassar City because it can create bioavailable fractions in the bottom sediment, i.e., the habitat of various marine organisms. The contaminants may come in the forms of household wastes, detergents, pesticide residues, livestock manure, the refuse from the upstream agriculture and fishery practices, and metal content that are harmful to aquatic organisms [11, 13, 21].

3.2. The Dominance, Shannon-Wiener (diversity) and Uniformity Indices

The Simpson’s Dominance Index of the observation stations was averagely 0.0663 with a standard deviation of 0.0168 (Figure 3). The range of this index in all stations was between 0.0416 and 0.0952 (Figure 4). Its mean value was close to 0, which indicated that none of the meiofauna species dominated the stations. As for the Shannon-Wiener (Diversity) Index, it was averagely 3.0248 with a standard deviation of 0.2337 (Figure 3). The nine observation stations had a diversity index ranging from 2.6183 to 3.3641 (Figure 4). This finding showed that the meiofauna inhabiting the observation stations had high levels of diversity [16]. Meiofauna can adapt to disturbed and polluted environments caused by the introduction of contaminants from the surrounding lands to the waters [3]. The evenness index was in the range of 0.8238-0.9316 (Figure 4) with an average of 0.8813±0.0393 (Figure 3). These figures showed that the meiofauna species among the observation stations were dissimilar and very even and that no meiofauna dominated each station because the range of the evenness index was close to 1 [12].
3.3. The Influence of Environmental Parameters on The Abundance of Meiofauna in the Coast of Losari Beach

This research found that the environmental parameters controlled the abundance of meiofauna in the coast of Losari Beach, Makassar. Based on Figure 5 and Table 4, temperature, current velocity, depth, salinity, brightness, and pH are the environmental parameters that have a considerable influence on the abundance of meiofauna. Some of them significantly affect the growth and development of meiofauna at the bottom of the waters, including how meiofauna find food, adapt, and breed [6, 17].
Table 4. The contributions of the research variables

| F1       | F2       | F3       | F4       |
|----------|----------|----------|----------|
| Abundance| 9.3351   | 0.3204   | 11.0283  | 0.5926   |
| Dominance| 15.5018  | 1.2818   | 0.2574   | 2.2129   |
| Uniformity| 12.9428  | 2.4495   | 0.7741   | 6.7369   |
| Diversity| 10.8347  | 0.9757   | 6.8906   | 6.1825   |
| Phosphate*| 0.1568   | 25.1152  | 1.6087   | 0.2906   |
| Phosphate**| 0.0429   | 6.1403   | 1.7934   | 12.2964  |
| Nitrate*| 1.4470   | 21.5619  | 0.0239   | 4.6404   |
| Nitrate**| 0.0551   | 0.3321   | 0.0091   | 58.1719  |
| Salinity| 7.4806   | 3.8605   | 11.0559  | 2.1631   |
| pH| 4.3253   | 6.5400   | 6.0891   | 0.5108   |
| Temperature| 11.7814  | 2.1903   | 6.5276   | 1.9727   |
| Depth| 8.2246   | 0.0313   | 25.6541  | 0.0261   |
| Brightness| 6.4216   | 0.0115   | 17.9144  | 2.8752   |
| DO| 0.5742   | 25.2823  | 0.1408   | 0.8765   |
| Current velocity| 10.8760  | 3.9073   | 10.2326  | 0.4512   |

Notes: *presence in seawater; ** presence in sediment

4. Conclusions

Ostracoda, oligochaeta, sarcomastigophora, and ciliophora were the meiofauna phyla with a high level of abundance in the coast of Losari Beach. These true meiofaunas are highly adaptable to waters containing organic and inorganic contaminants generated by the anthropogenic activities in the surrounding land.

The observation stations situated nearby the hotels and restaurants along the edge of Losari Beach had a high abundance of meiofauna because the activities taking place in these buildings supplied both organic and inorganic materials, i.e., the primary food of meiofauna, to the surrounding waters. Meanwhile, the stations located close to the Soekarno-Hatta International Port, Paotere Harbor, and the mouth of Jeneberang River had a low abundance of meiofauna on account of the direct physical disturbances from the diverse anthropogenic activities to the habitat of meiofauna.

The meiofauna in the coast of Losari Beach was highly diverse with no species dominating the stations, as evidenced by the Shannon-Wiener Index (>2) and the Simpson’s Index (approximately 0). The evenness index was close to 1, indicating that the meiofauna in the coast of Losari Beach was very even or that no species were dominant in each station. The physical and chemical environmental parameters, such as temperature, current velocity, depth, salinity, brightness, and pH, significantly influenced the abundance of meiofauna on the bottom substrate of aquatic environments.

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