Study of benthic foraminifera and its connection with environmental condition in Bidadari Island, Kepulauan Seribu

V Zubaida\textsuperscript{1}, A Sartimbul\textsuperscript{1}, and S M Natsir\textsuperscript{2}

\textsuperscript{1}Marine Science Department, Faculty of Fisheries and Marine Science, Brawijaya University, Malang
\textsuperscript{2}Research Center For Oceanography, Indonesian Institute For Science (LIPI)

*email: aida@ub.ac.id

Abstract. Bidadari Island is one of the tourism area, located in the southern part of Kepulauan Seribu. Tourism activities and its location that directly facing Jakarta Bay, obviously will affect the quality of the waters and ecosystems in Bidadari Island. A study of benthic foraminifera was carried out in 10 surface sediments and water quality samples, collected from the Bidadari Island, in order to determine the connection between abundance of foraminifera with the environmental conditions. Quantitative analysis, including calculation of abundance, community structure, and biplot analysis conducted to obtain this information. The results showed that there were 2473 individuals benthic foraminifera with a total of 33 species from 23 genera. The most abundant genera were \textit{Amphistegina}, \textit{Calcarina}, and \textit{Operculina}. Based on the calculation of the community structure (diversity, evenness, and dominance index), benthic foraminifera on Bidadari island are in the low to moderate category, it indicating that the environmental condition in this area has begun to declined.

1. Introduction

Kepulauan Seribu is part of Jakarta Province, consisting of 105 island groups, vertically starting from the bay of Jakarta to the north which ends on Sebira Island \cite{1}. Kepulan Seribu have an average depth of 30 meters, dominated by coral reef ecosystems, seagrass beds and mainland islands which are important habitats for marine biota \cite{2}. Bidadari Island is one of the islands located in the southern part of the Kepulauan Seribu, this group is characterized by turbid water which causes relatively low brightness \cite{3}. Bidadari Island is a tourist island so the population is not determined. Therefore, activities on this island are not based on household activities \cite{4}. Located close to the bay of Jakarta and the existence of tourism activities allows the disruption conditions on this island.

Benthic foraminifera have an important role in the food chain cycle of a waters. Foraminifera that found can describe the current ecological water conditions \cite{5}. Foraminifera has been widely used as an environmental indicator, especially among micropaleontologists. Based on its characteristics, foraminifera is a potential indicator to understand the environment because it is very sensitive to various environmental changes \cite{6}. The amount of human activity that produces waste products such as inorganic waste can change environmental conditions so that it affects the presence of benthic foraminifera \cite{5}. The purpose of this study is to find out the abundance of benthic foraminifera in Bidadari Island and its connection with environmental condition.
2. Method

2.1. Location and time
This study used 10 sediment samples that have been collected by team research from Research Center For Oceanography, Indonesian Institute of Science (LIPI) in May 2017. The survey activities included sediment sampling using Van Veen Grab, measurement of chemical parameters (salinity and pH) and physical parameters (current, temperature and clarity). Map of sampling location is shown in Figure 1.

![Figure 1](image)

**Figure 1.** Map of Jakarta Bay (insert) and sampling locations around Bidadari Island.

2.2. Sample preparation and identification
Sample preparation was conducted at Marine Geological Laboratory, Research Center For Oceanography, Indonesian Institute of Science (LIPI). One hundred gram wet weight of the sediment sample were washed while filtered using a sieve. The remaining residue is dried using an oven at 40 °C for 10-15 hours. Then named sample according to the location point. Picking and identification was carried out between February to March 2019. Sediment sample were sprinkled on the picking tray evenly with 5 repetitions. Foraminifera which had been picked and separated from other sediment was identify under binokuler microscope based on identification keys from Loeblich and Tappan [7], Yanli Lei and Tense Li [8] and Nobes and Uthicke [9].

2.3. Data analysis
2.3.1. Relative abundance. Foraminifera abundance was calculated using the following equation[10].

\[
\text{Relative Abundance} = \frac{N_i}{N} \quad (1)
\]

Formula description :

- \(N_i\) = Total individu of species
- \(N\) = Total foram at one sample

2.3.2. Diversity index, evenness index, and dominance index. The Shannon-Wiener diversity index is calculated according to Odum [11].

\[
H' = -\sum P_i \ln P_i \quad (2)
\]
Formula description:
H' = Diversity index
Pi = Total foram at i sample
In Pi = Total individu of foraminifera
Index range:
- H' = 0-2 : Low diversity of foraminifera
- H' = 2-3 : Moderate diversity of foraminifera
- H' >3 : High diversity of foraminifera

2.3.3. Evenness Index
Evenness index used to find out the balance of the community. The more similar the number of individuals between species, the greater the degree of balance. This calculation uses the Buzas and Gibson formulas. The formula is:

\[ E = \frac{e^{H'}}{S} \]  

Formula description:
E : Evenness index
\( e^{H'} \) : Shannon-Weinner Index
S : Total of species
Index range:
- E' <0.4 : Low evenness of population
- 0.4< E' <0.6 : Moderate evenness of population
- E' >0.6 : High evenness of population

2.3.4. Dominance Index
Dominance index is used to determine whether there is a genus or organisms that dominate. Dominance index equation according to Simpson.

\[ D = \left( \frac{n_i}{N} \right)^2 \]  

Formula Description:
D = Dominance index
Ni = Total individu of species
N = Total foram at one sample
Index range:
- 0< D ≤0.5 : Low of dominance
- 0.5< D ≤0.75 : Moderate of dominance
- 0.75< D ≤ 1 : High of dominance

2.4. PCA (Principal Components Analysis)
Multivariate techniques which have the main goal of grouping objects to make them look more simple [12]. In this study, PCA is used to group samples based on similar oceanographic parameters (depth, pH, salinity, current, temperature and clarity) and abundance of benthic foraminifera.

3. Result and discussion
The results obtained that in 10 samples sediment from Bidadari Island found 2,473 individual foraminifera with a total 33 species from 23 genera. There are several genera found more abundant than others that is Calcarina, Amphistegina, Operculina, Elphidium and Quinqueloculina (Figure 2).
Figure 2. Relative abundance of benthic foraminifera in Bidadari Island.

Most of the calcarin genera live in waters that have a mud substrate to coral fragments and also in good coral ecosystem conditions with considerable water energy [13]. This genera is a type of algae symbiont that develops well in waters with good coral reef conditions [14]. Similar to Calcarina, genera Amphistegina and Operculina also live in coral reef ecosystems. This result, not much different from previous research conducted on Bidadari Island by Natsir and Subkhan [15], stated that in general, 68.82% of Bidadari Island waters are inhabited by benthic foraminifera associated with coral reefs, especially of the Amphistegina genera. Besides Calcarina, Amphistegina and Operculina, Elphidium is also found at all sampling locations. Whereas Quinqueloculina was found to be higher at some sample. The high abundance of Quinqueloculina genera indicate that this location starting to be ecologically depresed [13]. The Southern part of Kepulauan Seribu are still under the influence of the mainland Jakarta City which is there are 13 rivers flow. This condition can cause a decrease in the type of sediment to be smoother like mud. This type of sediment can result the low number of benthic foraminifera found at the study site [15].

Figure 3. Several benthic foraminifera found at the study site: (1) Operculina, (2-4) Calcarina, (5-6) Quinqueloculina (7) Amphistegina, (8) Elphidium, (9) Cibicides, (10). Triloculina tricarinata.

3.1. Diversity, Evenness and Dominance Index
Graph of diversity, dominance and evenness index of benthic foraminifera from Bidadari Island shows in Figure 4. The diversity index range from 0.91 – 2.19 with average 1.75. Based on these results it can be said that the diversity index of benthic foraminifera in Bidadari Island is included in the medium category. The higher diversity index value at a location indicates that the place has a good food chain so that many species are able to survive [16]. Dominance index range from 0.14 – 0.55 with average 0.28. This value indicates that the index of dominance on Bidadari Island is included in the low category [17]. This shows that at the research location no dominant species were found. The evenness index ranged
from 0.31 – 0.56 with average 0.46, it include to the low category. Based on the three index values, it indicates that Bidadari Island has begun to be threatened ecologically.

3.2. Biozonation analysis
The abundance of benthic foraminifera can be influenced by ecological factors such as depth, temperature, clarity, salinity and pH [17]. Environmental data from Bidadari Island shows in Table 1. In total 10 sediment samples were taken from 11 - 14.5 m. At these depths Amphistegina lessonii species are good enough to live and reproduce [15]. This is one reason why Amphistegina is found abundant compared to other genera. According to Phleger [18] states that Amphistegina lessonii, A. Radiata, and Calcarina spengleri characteristic of the depositional environment of the middle to outer neritic regions (20 - 200 m). The temperature range from 29 – 30 °C, foraminifera can live well in temperatures around 21-26 °C, so the temperature conditions at this location have exceeded the quality standard. The clarity ranges from 4-5 m, low clarity will reduce the amount of oxygen resulting in reduced benthic foraminifera populations [15]. The average of pH on Bidadari Island is 7.6 while the standard pH of sea water for biota is 7 - 8.5 so it can be said that Bidadari Island are still within the existing quality standards.

Table 1. Environmental data.

| No sample | Depth (m) | pH   | Clarity (m) | Temperature (°C) | Salinity | Current (m/s) |
|-----------|-----------|------|-------------|------------------|----------|---------------|
| 1         | 11.00     | 7.80 | 5           | 30.08            | 32.61    | 0.141         |
| 2         | 10.58     | 7.79 | 5           | 30.11            | 32.60    | 0.145         |
| 3         | 11.00     | 7.60 | 5           | 30.05            | 32.57    | 0.133         |
| 4         | 14.50     | 7.86 | 5           | 30.00            | 31.70    | 0.370         |
| 5         | 13.59     | 7.81 | 4           | 30.01            | 31.71    | 0.350         |
| 6         | 11.50     | 7.50 | 4           | 29.99            | 31.48    | 0.320         |
| 7         | 12.00     | 7.44 | 4           | 30.50            | 31.43    | 0.320         |
| 8         | 12.06     | 7.61 | 5           | 29.98            | 32.69    | 0.320         |
| 9         | 11.80     | 7.70 | 4           | 29.11            | 32.50    | 0.330         |
| 10        | 12.33     | 7.61 | 5           | 30.05            | 32.12    | 0.310         |
3.3. PCA (Principal Components Analysis)
PCA-Biplot shows in Figure 5. The results of biplot analysis showed that from 10 sediment samples divided into 4 quadrants based on oceanographic parameters and abundance of benthic foraminifera. Quadrant 1 consists of stations 4 and 7 influenced by depth and pH factors. Quadrant 2 consists of stations 10, 9, 3 and 1 affected by the abundance of benthic foraminifera and brightness. Quadrant 3 consists of stations 2 and 6 which are affected by salinity, quadrant 4 consists of stations 5 and 8 which is affected by current and temperature.

![Figure 5. PCA-biplot.](image)

4. Conclusion
Foraminifera that were found in the Tambelan Islands very abundant, dominated by algal symbiont bearing larger benthic foraminifera such as *Amphistegina* and *Operculina* genera. It was observed that the abundance of foraminifera in Tambelan Islands is not only influenced by water depth factors, but also influenced by more complex factors such as sediment type and the influence from the mainland around the Tambelan Islands. FORAM Index analysis indicated that Tambelan Islands waters are naturally conducive to coral reef growth. However, the possibility in water quality degradation might be occurred confirmed by the low FORAM Index values in 2 locations associated with decrease in *Amphistegina* and *Operculina* abundance, that need to be concerned.

Appendix A. Diversity, Evenness and Dominance Index Value

| No. Sample | Diversity (H') | Dominance (D) | Evenness (E) |
|------------|----------------|---------------|--------------|
| 1          | 1.93           | 0.21          | 0.49         |
| 2          | 1.47           | 0.36          | 0.36         |
| 3          | 2.04           | 0.18          | 0.51         |
| 4          | 2.19           | 0.14          | 0.56         |
| 5          | 1.65           | 0.29          | 0.47         |
| 6          | 1.32           | 0.45          | 0.31         |
| 7          | 2.01           | 0.19          | 0.53         |
| 8          | 0.91           | 0.55          | 0.31         |
| 9          | 1.85           | 0.23          | 0.42         |
| 10         | 2.10           | 0.17          | 0.51         |
Appendix B. The results of identification benthic foraminifera in Bidadari Island.

Table B1. Foraminifera found at the study site.

| No. | Species                  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | Total | Average Abundance (%) |
|-----|--------------------------|----|----|----|----|----|----|----|----|----|----|-------|------------------------|
| 1   | Ammonia beccari          | 21 | 0  | 12 | 21 | 0  | 0  | 0  | 3  | 58 |   |       | 2.35                   |
| 2   | Ammonia tepida           | 6  | 0  | 0  | 0  | 0  | 5  | 13 | 0  | 24 |   |       | 0.97                   |
| 3   | Amphistegina lessoni     | 11 | 11 | 40 | 7  | 75 | 211| 15 | 183| 45 | 592|       | 23.94                  |
| 4   | Anomalina semipunctata   | 0  | 0  | 0  | 0  | 0  | 0  | 3  | 0  | 3  |   |       | 0.12                   |
| 5   | Asterorotalia trispinosa | 79 | 0  | 0  | 0  | 12 | 0  | 18 | 0  | 1  | 111|       | 4.49                   |
| 6   | Calcarina calcara        | 0  | 5  | 61 | 29 | 30 | 0  | 22 | 3  | 125| 6  | 281   | 11.36                  |
| 7   | Calcarina majori         | 1  | 152| 14 | 5  | 75 | 211| 15 | 183| 4  | 45 | 592   | 23.94                  |
| 8   | Calcarina spangleri      | 0  | 47 | 1  | 6  | 4  | 0  | 6  | 0  | 39 | 2  | 105   | 4.25                   |
| 9   | Cibicides subhaedingerii | 71 | 0  | 0  | 0  | 9  | 0  | 2  | 13 | 95 |   |       | 3.84                   |
| 10  | Cornuspiroides foliaceus | 0  | 0  | 3  | 1  | 0  | 0  | 0  | 0  | 4  |   |       | 0.16                   |
| 11  | Elphidium crispum        | 7  | 26 | 41 | 60 | 18 | 13 | 50 | 3  | 21 | 17 | 256   | 10.35                  |
| 12  | Epinooides berthelatus    | 0  | 3  | 0  | 0  | 1  | 3  | 0  | 0  | 0  | 7  |       | 0.28                   |
| 13  | Hauerinella inconstant   | 0  | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 1  |   |       | 0.04                   |
| 14  | Miliolinella circularis  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 2  |       | 0.08                   |
| 15  | Nanionella decora       | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  | 2  |       | 0.08                   |
| 16  | Operculina ammonoides    | 2  | 9  | 6  | 75 | 8  | 44 | 66 | 50 | 6  | 28 | 294   | 11.89                  |
| 17  | Peneroplis planatus      | 0  | 0  | 8  | 0  | 3  | 0  | 1  | 0  | 4  | 1  | 17    | 0.69                   |
| 18  | Pseudorotalia indopasifica | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 8  | 0  | 8     | 0.32                   |
| 19  | Pyrgo denticulata        | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 8  | 0  | 8  |       | 0.32                   |
| 20  | Quinqueloculina bicornis | 1  | 7  | 6  | 0  | 3  | 11 | 0  | 0  | 9  | 37 |       | 1.50                   |
| 21  | Quinqueloculina bouena    | 18 | 0  | 36 | 7  | 11 | 0  | 0  | 0  | 72 |   |       | 2.91                   |
| 22  | Quinqueloculina pseudoreticulata | 14 | 5  | 0  | 43 | 6  | 5  | 13 | 0  | 21 | 6  | 113   | 4.57                   |
| 23  | Quinqueloculina reticulata | 0  | 0  | 4  | 0  | 0  | 0  | 0  | 0  | 4  |   |       | 0.16                   |
| 24  | Quinqueloculina tikutoensis | 4  | 1  | 0  | 1  | 0  | 0  | 0  | 0  | 13 |   |       | 0.53                   |
| 25  | Sorites orbiculosis      | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 1  | 3  |       | 0.12                   |
| No. | Species                | No. Sample | Total | Average Abundance (%) |
|-----|-----------------------|------------|-------|-----------------------|
| 26  | *Spirolina arietina*  | 3          | 5     | 0.20                  |
| 27  | *Spiroloculina angulata* | 1         | 4     | 0.16                  |
| 28  | *Spiroloculina communis*  | 8          | 28    | 1.13                  |
| 29  | *Spiroptalmidium pusillum* | 0         | 1     | 0.04                  |
| 30  | *Streblus botavus*     | 1          | 1     | 0.04                  |
| 31  | *Triloculina rupertiana* | 0         | 5     | 0.20                  |
| 32  | *Triloculina tricarinata* | 5         | 21    | 0.85                  |
| 33  | *Triloculina trigonula* | 4          | 4     | 0.16                  |
|     | **Total:**            | **247 269**| **2473**| **100.00**            |
References

[1] Estradivari, Setyawan E and Yusri S 2007 Terumbu Karang Jakarta 112
[2] Rositasari R 2011 Karakteristik Komunitas Foraminifera di Perairan Teluk Jakarta 12
[3] Sachoemar S I 2008 Karakteristik Lingkungan Perairan Kepulauan Seribu 6
[4] Rusdiyanto E, Pratomo H and Winarni I. 2001 Studi Komparatif Kualitas Biofisik Lingkungan Antara Daratan Pulau Pramuka Dengan Pulau Bidadari, Kepulauan Seribu [Laporan Penelitian] Universitas Terbuka
[5] Pranajaya R 2015 Struktur Komunitas Foraminifera Bentik Di Perairan Desa Teluk Bakau Kabupaten Bintan. 2015
[6] Nurdin J and Afrizal S 2013 Kepadatan dan Keanekaragaman Foraminifera di Perairan Laut Teluk Bayur Padang Sumatera Barat
[7] Loeblich A R and Tappan H 1998 Foraminifera of The Sahul Shelf and Timor Sea 31-661: Cushman Foundation for Foraminifera Research Special Publication
[8] Lei Y and Li T 2017 Atlas of Benthic Foraminifera from China Seas New York, Ny: Springer Berlin Heidelberg
[9] Nobes K and Uthicke S 2008 Marine and Tropical Sciences Research Facility (Qld.), Australian Institute of Marine Science, Reef and Rainforest Research Centre. Benthic Foraminifera of the Great Barrier Reef: A Guide to Species Potentially Useful as Water Quality Indicators. Reef and Rainforest Research Centre
[10] Noortiningsih I and Handayani S 2008 Keanekaragaman Makrozoobenthos, Meiofauna dan Foraminifera di Pantai Pasir Putih Barat dan Muara Sungai Cikamal Pangandaran, Jawa Barat Vis Vitalis 134–42
[11] Odum E P 1993 Dasar-Dasar Ekologi. Yogyakarta: Gajah Mada University Press; 1993
[12] Ramdani J 2017 Analisis Statistik Multivariat Pada Batuan Beku, Sedimen, dan Metamorf Dengan Metode PCA (Principal Component Analysis)
[13] Toruan L N L, Soedharma D and Dewi K T. 2013 Komposisi Dan Distribusi Foraminifera Bentik di Ekosistem Terumbu Karang Pada Kepulauan Seribu. Jurnal Ilmu dan Teknologi Kelautan Tropis 5 1-17
[14] Hallock P, Lidz B H, Cockey-Burkhard E M and Donnelly K B 2003 Foraminifera as Bioindicators in Coral Reef Assessment and Monitoring: The Foram Index. In: Melzian Bd, Engle V, Mcalister M, Sandhu S, Eads Lk, Editors. Coastal Monitoring Through Partnerships [Internet]. Dordrecht: Springer Netherlands
[15] Natsir S M and Subkhan M 2011 Benthic Foraminifera as Indicators for Water Quality of Coral Reefs Ecosystem in Bidadari and Ringit Islands, Thousand Islands. Journal of Coastal Development 15 1-8
[16] Zallesa S 2012 Korelasi Karakteristik Sedimen Permukaan Dasar Laut Terhadap Struktur Komunitas Foraminifera Bentik Di Perairan Selat Selat Makassar (Jatinangor: University of Padjadjaran)
[17] Natsir S M and Dewi K T 2015 Foraminifera Bentik Terkait Dengan Kondisi Lingkungan Perairan Sekitar Pulau Damar, Kepulauan Seribu. Jurnal Geologi Kelautan 13 165-170
[18] Phleger F B 1960 Ecology and Distribution of Recent Foraminifera. Baltimore. Maryland: The John Hopkins Press 297
Acknowledgement
The authors would like to thank Research Center for Oceanography, Indonesian Institute of Science (LIPI) which has allowed the author to conduct research and use sediment samples as analytical material.